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Development Prospects of Technological Integration: Regional Perspective

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Abstract—Technological integration is considered as an effective measure to increase the technological performance of Russian industrial companies and improve their adaptation to a system of industrial and economic relations based on digital technology. Common issues related to integration of new technologies are identified for Russian regions, emphasizing the importance of cluster-type economic relations. A current state evaluation and a development forecast are given for petrochemical clusters. To improve technological performance, it is proposed to use technological integration as a process of transforming production resource flows into new technologies. The experience in technology advancement accumulated by world science has been investigated and summarized. It is shown that the Russian economy is on the right path to a new technological paradigm.

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Introduction to the problem. Technological integration is a phenomenon that can transform the external and internal relations of business entities that are integrated into each other or closely interact for the period of performing certain tasks. First of all, we are talking about the development of technologies focused on process innovations, including the production of high-tech products with a deep degree of processing, as well as technologies for managing industrial complexes at the regional level. The ultimate goal of such changes is to obtain added value along the production chain and digitalization of the economy.

The study of the problems and prospects for the development of technological integration is due to the global challenges of the economic crisis in the oil sector of the world economy, a sharp deterioration in the environmental situation on a planetary scale, as well as restrictions and barriers to the free circulation of innovative ideas, technologies and developments in relation to individual countries.

How ready are we for the Fourth Industrial Revolution? The process of transition to the Industry 4.0 format implies the acquisition of research activities at almost all levels of management. An analysis of the dynamics of gross domestic expenditure on R&D in Russia shows a certain static nature of this indicator; its share in the country's GDP ranges from 1.13% in 2010 to 1.10% in 2016 [1]. The main reason can be called the conservative policy of financing scientific activities that has developed for decades, while the European states purposefully maintained a high level of spending on testing and developing the latest technologies: USA, 2015 - 2.79%; Japan, 2015 - 3.29%; South Korea, 2015 - 4.23%; EU, 2015 - 2.03% of the GDP of the respective states (Fig. 1).

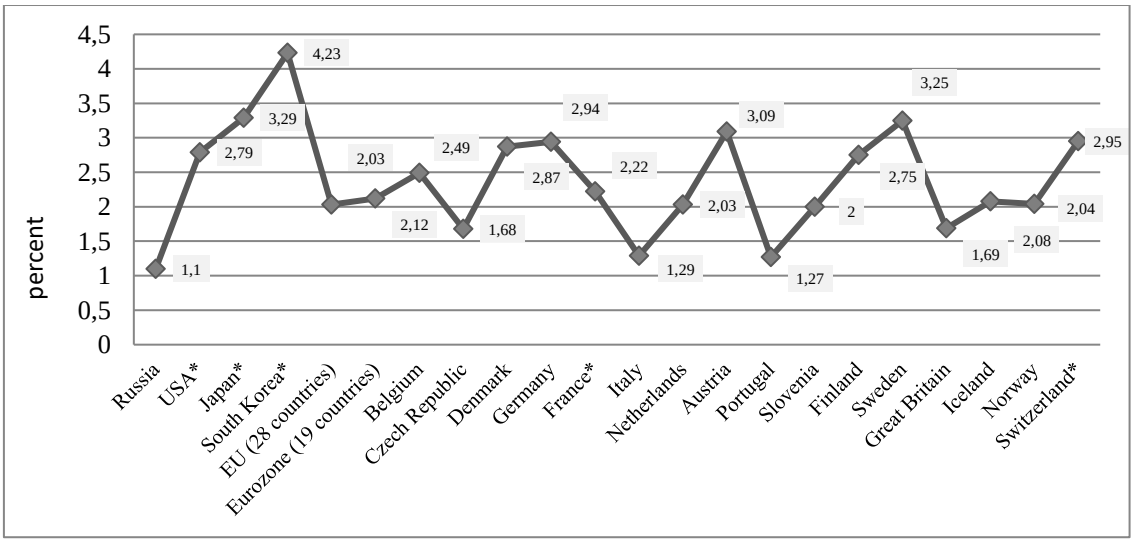

Figure 1. Volume of gross domestic expenditure on R&D in 2016* (or nearest years for which data are available), in % of GDP [1, 2]

According to the structure of research expenditures in 2016, investments in the Volga Federal District dominated - almost 16% of all expenditures in the country, as well as the North-Western Federal District - 4% of all expenditures (Fig. 2).

It is these regions that differ from others in the predominance of innovative enterprises (Fig. 3). If the overall level of innovative activity of organizations in 2016 was 8.4% (against 9.3% in 2015 and 9.9% in 2014), then in the Volga Federal District it reached 9.4% (against 10 .6% in 2015, 11.4% in 2014).

Higher recent rates in the Central Federal District: 10.3% in 2016, 10.9% in 2014-2015 [3]. The general downward trend is caused by the stagnation of innovative processes in medium-tech industries, such as metallurgy, the production of electrical machinery and equipment. In this regard, the search for internal sources of technological growth is one of the top priorities for the formation of a competitive industrial complex in Russia. Domestic enterprises have opportunities to accelerate the technologization of production through the development and implementation of intelligent systems, and the digitalization of the economy acts as a lever for precise impact on production and economic relations between industrial enterprises, research centers and laboratories.

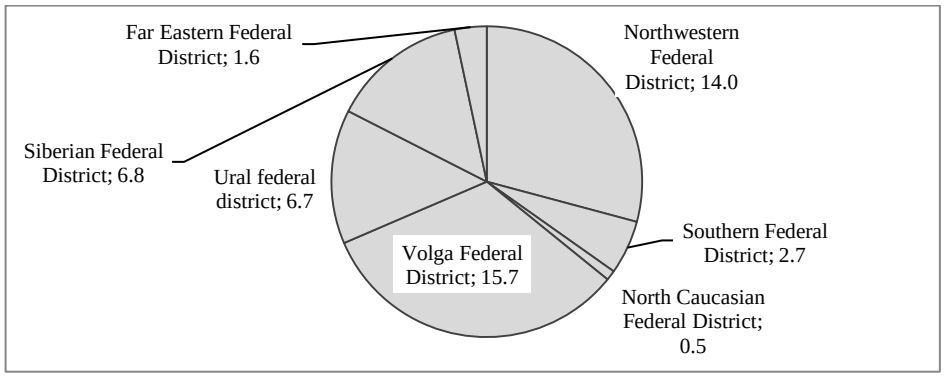

Figure 2. Regional structure of R&D expenditures in 2016, in % of expenditures in the Russian Federation [1]

Cluster model for the purpose of technological integration. The cluster model of inter-farm relations can definitely be called as a factor contributing to enhanced innovative development. This type of combination of industrial and research capital compares favorably with "the effective organization of domestic markets with a low degree of monopolization, a high level of competition and a strict sequence of the supply chain" [4]. According to the Association of Clusters, there are currently 137 clusters operating and being formed in 52 regions in the country, and 25 of them are industrial clusters included in the register of the Ministry of Industry and Trade of the Russian Federation. More than 400 industrial enterprises operate within the clusters, of which 75% are small and medium-sized businesses [5].

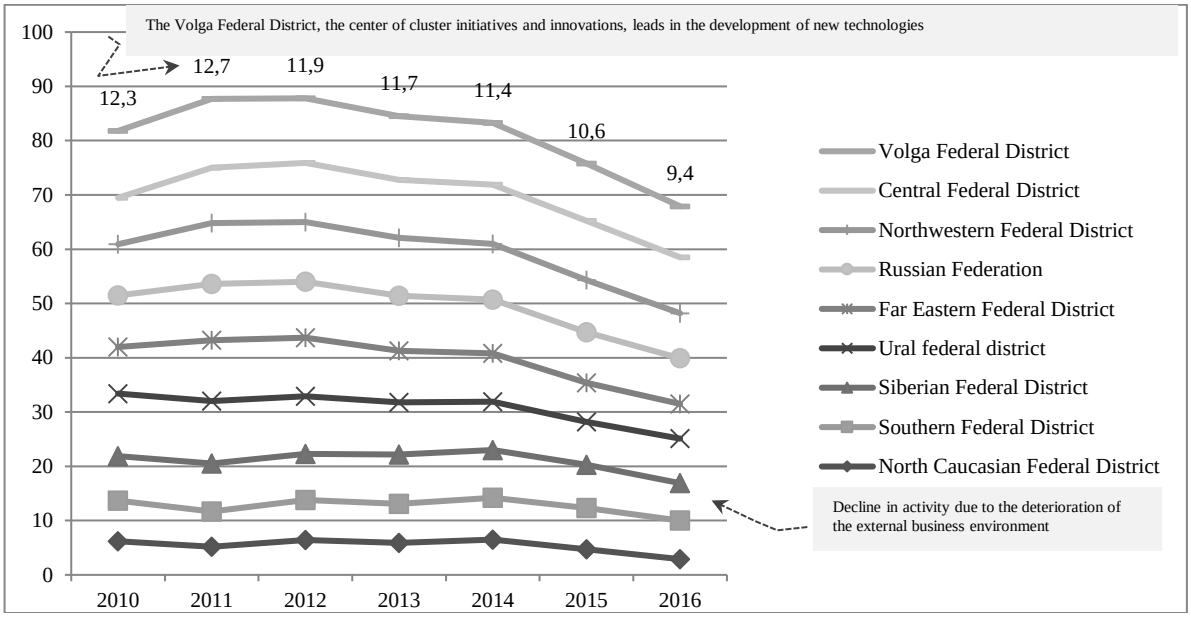

Figure 3. Dynamics of innovative activity of organizations (share of organizations that carried out technological, organizational, marketing innovations in the reporting year, in the total number of surveyed organizations), by constituent entities of the Russian Federation, in % [3]

International practice suggests adapting positive experience, which, in particular, comes down to recommendations on the number of participants in a cluster of more than "50" entities, which should include industrial enterprises, educational institutions, research institutes and laboratories. The fundamental basis for the development of technological integration within the framework of the cluster model is industrial cooperation and the condition that at least 30% of the products of each participant are used in the technological stages of other participants (with the exception of final products). Russian clusters operate within this framework.

Taking the level of organizational development as a base, it is possible to carry out a gradation into three groups*: 1) the initial level; 2) average level; 3) high level [6]. As of the beginning of 2018, the first group included the Troitsk Innovation Territorial Cluster "New Materials, Laser and Radiation Technologies" (53 participants), the Machine-Building Cluster of the Republic of Tatarstan (126 participants), the Information Technology Cluster of the Republic of Tatarstan (70 participants), the Innovation Territorial Cluster medical pharmaceutical technologies of the Samara region (55 participants), Innovative territorial cluster of mechanical engineering and metalworking of the Lipetsk region "Valley of mechanical engineering" (118 participants), Innovative territorial cluster "Cluster of nuclear physics and nanotechnologies in Dubna" (80 participants), Association of enterprises mechanical engineering "Cluster of the automotive industry of the Samara region" (59 participants). The second group includes two clusters: Pushchino Biotechnological Innovative Territorial Cluster (68 participants), Zelenograd Innovative Territorial Cluster (53 participants). The third group is the most numerous, it includes nine clusters: Petrochemical Territorial Cluster of the Republic of Bashkortostan (187 participants), Pharmaceutics, Biotechnology and Medicine, Kaluga Region (54 participants), Development of Information Technologies, Radio Electronics, Instrument Engineering, Communications and Information and Telecommunications of St. Petersburg, direction "Information technologies" (66 participants), Kama innovative territorial production cluster (213 participants), Innovation cluster of information and biopharmaceutical technologies of the Novosibirsk region (60 participants), Consortium "Scientific - educational - production cluster "Ulyanovsk-Avia" (77 participants), St. Petersburg Cluster of Clean Technologies for the Urban Environment (57 participants), Udmurt Machine-Building Cluster (61 participants), Nuclear Innovation Cluster of the city of Dimitrovgrad, Ulyanovsk Region (54 participants). The clusters maintain a high level of competition, and the core is made up of industrial enterprises, research centers and laboratories. These factors contribute to the development and advancement of technology.*

Technological integration in cluster formations of domestic petrochemistry. Oil refining and petrochemical production are strategic objects for the development of the country. The favorable location of production facilities within petrochemical clusters combines the advantages of the availability of raw materials, the availability of transport infrastructure, the concentration of research institutes, and the proximity of consumers. According to these principles, the West Siberian, Volga, Caspian, East Siberian, Northwest and Far East oil and gas chemical clusters have been created and are functioning. The strategy for the development of the chemical and petrochemical complex for the period up to 2030 sets a goal to increase the share of the chemical complex in Russia's GDP to 2.1%, including by reducing the share of imports of plastic products for industrial purposes from 20% in 2014 to 15% in 2025 year and stimulate domestic demand [7]. In the period 2015 - 2030, the goal of active construction and expansion of pyrolysis capacities is being realized (Table 1).

Table 1

Forecast dynamics of development of pyrolysis capacities at petrochemical enterprises of the Russian Federation

Index	2017	2018	2019	2020	2025	2030
Output volume, million tons	3660	3680	3760	5860	9914	9914

***Source**: [7].*

The achievement of such parameters largely depends on solving the problems of technological backwardness, insufficient disclosure of the scientific and technological potential of the industry, the difficulty of expanding the transport and logistics infrastructure, the underdevelopment of the technical regulation system, industry standards and quality control systems for petrochemical and chemical products.

Import dependence is reduced due to the development of domestic production. To reach the forecast indicators, unique projects were launched, in particular, the project of the West Siberian Petrochemical Cluster with the participation of PJSC SIBUR Holding - the construction of a pyrolysis plant in Tobolsk with a capacity of 1.2 million tons of ethylene per year (the Zap-Sib-2 "), which is designed to provide an annual contribution to the country's GDP of more than 130 billion rubles, as well as annual budget revenues of more than 10 billion rubles, while creating 9,000 new jobs. The joint project of the Volga Petrochemical Cluster with the participation of TAIF-NK OJSC, Gazprom Neftekhim Salavat LLC will increase the production of ethylene and propylene derivatives by 2.9 and 1.2 million tons per year with an annual contribution to GDP of more than 240 billion rubles , as well as annual budget revenues in the amount of more than 10 billion rubles and the creation of approximately 14,000 new jobs [7]. The essence of all new projects is the organization of production on the principle of "smart technologies".

Stimulation of domestic demand for products of domestic manufacturers is planned to be carried out through a loyal pricing policy and through the introduction of innovative technologies. According to statistics for 2010 - 2016. only a small part of industrial enterprises used new or radically improved marketing methods of sales, their presentation and promotion to sales markets, the formation of new pricing strategies (Fig. 4).

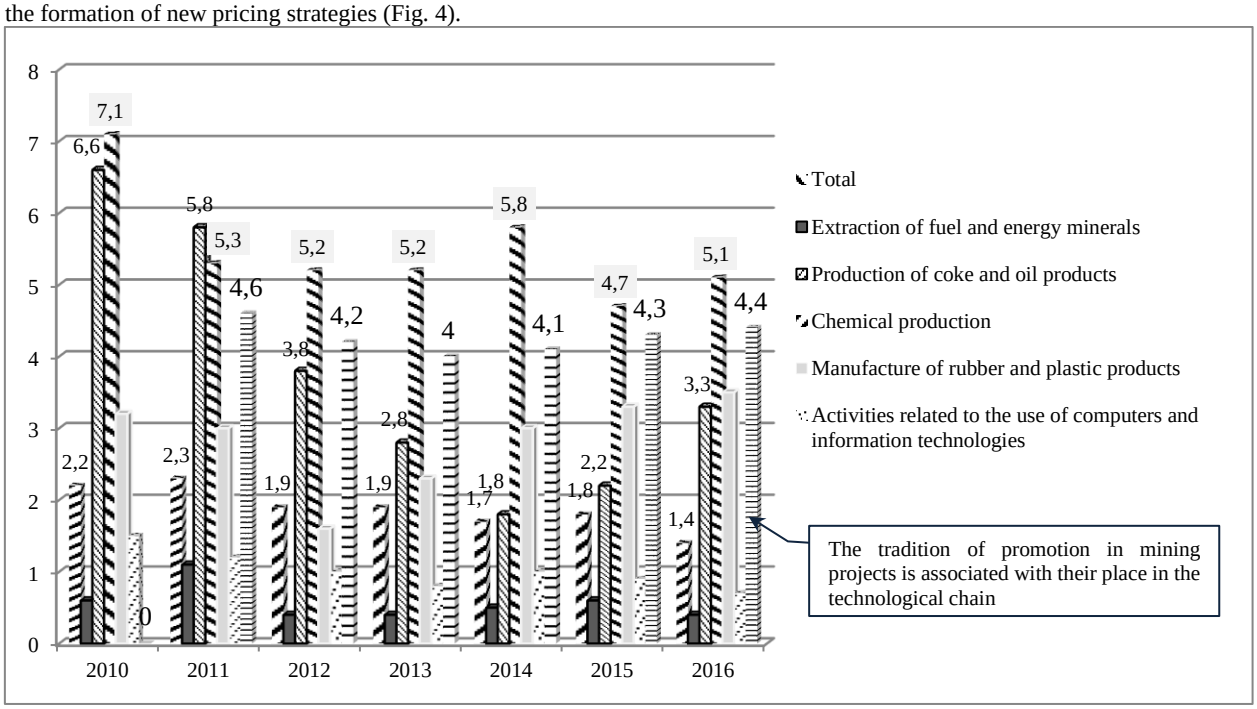

Figure 4. The share of organizations that carried out marketing innovations in the Russian Federation for the period 2010 - 2016, in% [8]

In our opinion, this may become a threat in the context of the formation of a new market within the framework of the Eurasian partnership, as well as the prospects for participation in the global project of the Silk Road Economic Belt. Completion of projects for the modernization of production facilities will require an increase in the flow of investment in research and development, which, under favorable conditions, will contribute to an increase in the production and consumption of high-tech chemical products by almost two times by 2030 (Table 2).

Table 2

Forecast dynamics of individual target indicators for the development of the petrochemical industry in Russia

Target indicator	2014	2015	2020	2025	2030
Share of investments in research and development (R&D) in total revenue in the chemical complex, %	0,09	0,11	0,23	0,48	1,00
The share of output volumes of deep processing products in the structure of output of the chemical complex (in physical terms), %	12,5	13,5	15,3	17,4	19,7
Consumption of products of the chemical complex per capita, kg / person.	223,6	228,7	283,0	355,9	460,0

***Source**: [1].*

In order to implement the set plans, enterprises are pursuing a policy of active interaction with other economic structures within clusters, with government agencies, research centers and experimental design laboratories. In our opinion, the complexity of implementing the strategy of transition to a new technological level is seen in the absence of effective management mechanisms. For this purpose, the best practices of world companies, research institutes in the field of development and promotion of technologies have been studied and structured.

Landmarks of the world scientific school of technological development. Objective studies show that technological integration can develop only in a favorable innovation environment, in which prerequisites and conditions are formed for the development and implementation of related complex technologies (Fig. 5).

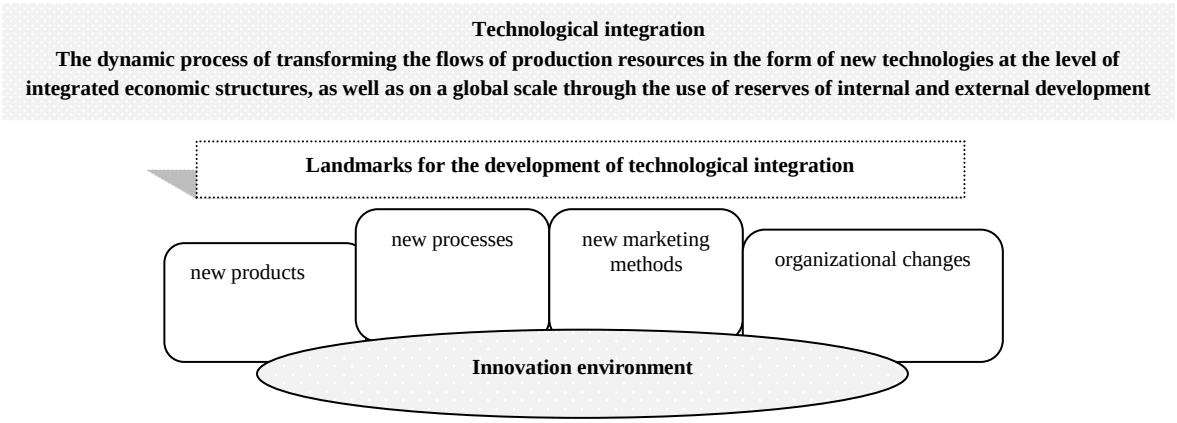

Figure 5. Objectives for the development of technological integration in an innovative environment (using [9 - 11])

In the last three to five years, scientists have paid special attention to finding solutions related to the formation of an innovative strategy focused on the use of R&D results. Researchers from China, New Zealand, and the United States have established a link between strategy formation and resource support for research and development work. Observation of Chinese industrial enterprises in the period 2008 - 2014 established a direct dependence of the strategy on the introduction of improving, modifying, incremental innovations; at the same time, “radical” innovations go in the opposite direction from the planned development options [12]. This conclusion confirms Joseph Schumpeter's conclusions about the "destructive" power of basic innovations that fundamentally transform the existing production system. Researchers note that R&D resources strengthen the link between improving innovations and enterprise strategy and weaken this link in cases of fundamentally new discoveries.

We consider it expedient to join the opinion of American and European researchers on the leading role of technological integration in choosing directions and participants in the innovation process, especially at the R&D stage. Russian practice demonstrates a close connection in the development and promotion of technologies with innovative processes, whether it is an increase in the depth of oil refining in integrated industrial complexes, as well as the organization of its own production of catalysts or the construction of an interaction scheme within the framework of projects for the digitalization of logistics systems. In all of these trajectories of strategic vision, there is a multiplier effect of synergies, which will have a long-term character for decades to come, despite the pessimistic scenarios associated with the future of the oil sector [13].

In support of this argument, we present the results of the joint work of Elias G. Karayiannis, professor at the School of Business at the George Washington University, and Dirk Meissner, an employee of the Institute for Statistical Research and Economics of Knowledge at the Higher School of Economics (Moscow), who came to the conclusion that technological integration should be based on to a long-term and holistic approach to knowledge sharing [14]. In particular, for the contact audience, depending on the interests of the participants in the integration process, the exchange of knowledge will have specifics, namely:

- enterprises of the same group - due to the unification of innovative technologies;
- enterprises of unrelated groups - mutually beneficial exchange of industrial technologies and the latest designs;
- research institutes - creation of joint experimental design production sites;
- authorities - by strengthening public-private partnerships.

In order to practically adapt research in the field of technological development to building a new type of production system that meets the challenges of global digitalization, we propose to synthesize concepts and approaches based on the principle of influencing the system through economic levers (Table 3).

Table 3

Conceptual approaches to the development of technological integration

Research area	Direction of research	Researchers
Solving the problems of technological backwardness of the industrial economy	Development of special tools for assessing technological progress and productivity, including by building an input-output balance based on the experience of the European economy for the period from 1995-2011. [fifteen]. Experience of the EU countries.	Zambelli S., Fredholm T., Venkatachalam R. [15]
	Development of technological integration using scenario modeling based on economic and mathematical balance models [16].	Duchin F., Levine St.H. [16]
	Studying the phenomenon of the knowledge economy based on the experience of companies in Germany, Austria and Switzerland, identifying the benefits of digitalization of the economy, consisting in the possibility of free exchange of information in direct mode and modeling of production business processes, as well as the creation of innovative start-ups. It turned out that this advantage is used by companies that develop according to the strategy of horizontal and vertical growth in the global market [17].	Richter C., Kraus S., Brem A., Durst S., Giselbrecht C. [17]
Continuity of levers of regional integration for resource support of the process of promoting high technologies	Building structures to coordinate the distribution of resources (including for technological development), programs for the elimination of trade barriers in the EU [18].	Boglioni M., Zambelli S. [18]
	Options for building an innovation ecosystem with the participation of industry, educational institutions, technology centers of the EU [19].	Benedetti Fasil C., Biagi F., Boden J.M. [19]
	Sectoral interaction of industrial enterprises, universities and research institutes (abbr. Research Institute) through regional resources and spatial development of an innovative cooperative network - "Chinese Silicon Valley", Zhongguancun IUR technology center [20].	Lyu Lachang, Wu Weiping, Hu Haipeng, Ru Huang [20]
Formation of industrial policy	Factor assessment of increasing the competitiveness of European enterprises and labor productivity with a parallel decrease in prices for manufacturing products [21].	Peneder M., Streicher G. [21]
Deepening industry specialization	Fragmentation of production processes into "modular processes of the second order" through outsourcing and offshoring. Measures of intensive use of R&D (R&D costs per unit of output) by industry, determining the dependence of industries on acquired technologies [22].	Boundi Chraki F. [22]
	The exclusivity of cluster interaction for the development of technological integration based on twenty years of experience in the interaction of over 20,000 high-tech enterprises embedded in industrial clusters of digital technologies and the information industry, innovative materials, energy, energy transport and the environment, as well as other advanced industries [23].	Zhongguancun Science Park [23]
Development of forms of public-private partnership	Evaluation of the activities of clusters with the participation of the government in the period 1998 - 2012. testifies to the prospects of this cooperation scheme, as evidenced by economic indicators of the growth in the share of income of public clusters in the volume of gross regional product, an increase in labor productivity, the development of an innovation system and the knowledge economy [24].	Lehmann Erik E., Menter Matthias [24]

Immediate prospects. The introduction of new technologies that create completely new ways of serving existing needs and significantly disrupt existing production chains is what new generation production systems will breathe [24]. In order to survive in the face of global competition, it is very important to find the use of digital platforms in the field of research, development, marketing, sales and distribution of high-tech products. The state of the economy of the EAEU countries shows that all the prerequisites have developed for the transition to a new technological order.

The quality of integration interaction will be a guarantee of success in the development of digital technologies, such as EAEU DataX (a single subsystem for the transmission and exchange of data in electronic form), EAEU ID (a single electronic trust space based on identification, authentication, authorization digital archive services) and "EAEU Geo" (geoinformation system and services of the cartographic basis for managing transport and logistics flows) [26]. At the same time, the management of the technological development process should be based on total monitoring, evaluation and forecasting of innovations, which form a continuous closed cycle of analytical work.***

In conclusion, we can summarize that technological integration will allow domestic enterprises to reach the forefront of the global economy. This should happen in the coming years, because. the level of manufacturability of production is affected by the compression of the innovation cycle from the period of the birth of an idea to its implementation in practice. The digital economy, modern methods of information processing demonstrate the results of an effective combination of industrial and intellectual resources. In this regard, enterprises should form a value chain with synergy from the technological integration of related industries.

****Notes***

Technological integration is a dynamic process of transforming production resource flows in the form of new technologies at the level of integrated business structures, as well as on a global scale, using the reserves of internal and external development.

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