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Innovative and Technological Development of the Russian Arctic

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Abstract. The article presents an analysis of the innovative and technological development of the Russian Arctic. Innovative development has a great significance for the economy of the country. Economic development of territories should be based on new knowledge and innovation. The purpose of the study is to assess the innovative and technological development of the Russian Arctic in order to forecast and create a strategy for the Russian Arctic based on knowledge and innovation. The author issues theoretical approaches to the problem of innovative and technological development of countries. The author suggests a methodology for innovative analysis and assesses the innovative and technological index of the Russian Arctic regions using the index method based on integrated index calculation. The analysis is based on the official data of the Federal State Statistics Service of the Russian Federation of 2015. The results of the study show that Arctic regions can be divided into three groups, namely: 1) regions with a high level of innovative and technological development (Krasnoyarsk region); 2) regions with a medium level of innovative and technological development (Arkhangelsk region, Komi Republic, Yamalo-Nenets and Chukotka Autonomous Areas); 3) the least developed regions (Nenets Autonomous Area). The results of the study can be used to create a strategy of innovative and technological development for each group of Russian Arctic regions.

1. Introduction

Development of the Arctic regions is one of the priority objectives of Russia's government policy. It is an economic necessity since the Arctic territories are a major source that provides the country with mineral, fuel, energy, and biological resources. Economic development of countries and regions should be based on new knowledge and technology. In the 21st century, the innovative component plays a vital role in the socio-economic development of countries across the world. The innovative vector of development creates an environment where many scientific and technological problems (generation of innovations, formation of high-tech industries, production of innovative goods) can be solved to improve the well-being of nations and countries.

Innovative and technological development serves as a foundation for socio-economic development aimed at improving the quality of life of the population. Such development helps preserve and enhance moral and cultural values, promotes civic engagement and patriotism. Sustainable socio-economic development should be accompanied by the intensification of innovative processes and technological modernization of economic sectors.

Modern economic literature generally defines innovative and technological development as a process of creating new technologies based on scientific knowledge [1]. The term "Technology" is represented as a complex structure consisting of four elements: technology itself (as a transition from



the initial to the final state); machinery and equipment used to implement this transition (embodiment of labor); organized labor and adequately skilled workers (human labor); management mechanism and qualified managers.

Technology implies new ways of transferring the product from the initial to the final state through a full technological cycle, including the extraction and processing of resources, consumption and recycling of the manufactured products [2].

At each stage of the technological cycle, technologies are implemented by skilled workers using new machinery and equipment on the basis of managerial decisions. Innovative and technological development involves the interaction between research and development, the technology itself and its implementation.

Thus, a high level of innovative and technological regional development (including the Russian Arctic regions) can be achieved through research and development, advanced technology, high-tech equipment, highly skilled workforce and efficient management of technological development.

2. Literature review

For a long time, the issues of technological development have not been the focus of global economic science. It wasn't until the beginning of the 21st century that economic literature began to address the problem of the impact of technology on economic development. By that time it was clear that statistical models dominating in the neoclassical economic theory were becoming increasingly less relevant in the way they reflected the economic reality.

One of the first economists to propose a theory of innovative economic development was *Joseph Schumpeter*. He outlined the fundamental concepts of his theory in *Theory of Economic Development* (1912) [3]. Schumpeter believed human creativity (new ideas) to be the main driving force behind economic development. He defined economic agents capable of efficiently turning a new idea into an economic solution as entrepreneurs. Entrepreneurs create "new combinations", thus disturbing the balance of the economic system for a long time. By "new combinations" Schumpeter meant production of new goods, implementation of new production methods, development of new markets or sources of raw material, and transformation of the industry structure. According to Schumpeter, the process of innovation continues until "new combinations" become commonplace for all economic actors.

By the beginning of the 20th century, the scientific community has realized the importance of scientific and technological progress for economic development. In economic literature, there was a perception that scientific and technological progress facilitates evolutionary economic development based on periodic economic recessions and upturns, forming economic cycles that could last up to 50-60 years. This period saw the formation of the concept of long economic fluctuations, with a significant contribution from Russian economist *N.D. Kondratiev*, who laid the foundations for the long wave theory. Having analyzed selected economic parameters, Kondratiev developed the idea of repeating development cycles consisting of an upward and a downward stage within a 50- to 60-year period [4]. Kondratiev found that the upward stage is 20-30 years long and is characterized by an active market with possible minor short-term recessions in the global economy. During the downward stage, there is a slack economy accompanied by depression, low business activity, and major economic crises. The duration of the downward stage is about 20 years. The transition from crises and depressions to the upward stage of the economic cycle is accompanied by technological changes, destruction of the existing capital values, and replacement of infrastructure.

German economist *Gerhard Mensch* has made a significant contribution to the innovative theory of economic development. In his book *Stalemate in Technology* published in 1973, Mensch proposed the concept of basic and improvement innovations. Mensch believed that these innovations are in constant competition. In a market economy, improvement technologies are more popular as they are less risky and more cost-effective. However, technologies cannot be improved infinitely, being limited by demand, and then supply. This situation, being the top turning point of the large Kondratiev wave, instigates an economic recession. Mensch introduces the concept of a technological stalemate,

i.e. a period when old (improvement) technologies are no longer able to sustain a high development rate, and new technologies cannot ensure economic growth yet. According to Mensch, the technological stalemate is what causes economic growth, recession and the subsequent depression, when the so-called business innovation clusters are forming, starting the innovation process. Thus, Mensch has described a mechanism for the economy to overcome a crisis through innovation [5].

English economist *Christopher Freeman* paid special attention to diffusion processes in the technological system, assuming that it is the diffusion of technologies that drives the long-term economic growth. Freeman also believed that technological systems have their own life cycles, on which the dynamics of the long wave depends. Another proponent of the theory of innovative economic development, *Jacob van Duijn*, devoted special attention to infrastructure development in his studies. He attached particular importance to the relationship between such units as innovation, life cycle and infrastructure investment.

In the late 1980s, Russian economist *S.Y. Glaziev* proposed the concept of technological waves in his book *Economic Theory of Technological Development* (1990). According to this concept, at the heart of the technological and economic evolution lies the "technological complex", i.e. a complex of technologically related industries combined into technological production chains. The technological complex launches the evolutionary process simultaneously across all related industries and serves as a foundation for cyclical fluctuations. Glaziev claimed that technological development of the economy involves one technological wave making way for another.

The problems of innovative and technological development are widely discussed in economic literature. Theoretical and methodological aspects of the innovation economy and the impact of the innovative and technological factor on regional socio-economic development can be found in the works of Skripnuk, D., Ulitin, V.V. [6], Atroshenko, S.A., Korolyov, I.A., Didenko, N.[7], Kulik, S., Samylovskaya[8], Kikkas, K., Romashkina, E.[9], Kireev, K.V., Ermakov, V.V. [10].

3. Methodology and procedure for estimating the model

The proposed method of assessing the level of innovative and technological development of the Russian Arctic regions consists of the following stages:

The first stage involves the substantiation of indicators for calculating the integrated index of innovative and technological development of the Russian Arctic regions. Indicators for calculating the integrated index of innovative and technological development characterize such elements as technology itself, production means, employee qualification, and management quality.

At the second stage, we shall create databases on the analyzed objects: technology itself (technological process), production means, workforce, technology management system.

At the second stage, we shall develop matrices (X, Y, Z, K) describing regional innovative and technological development based on specific indicators: technology itself, production means, workforce, technology management system (formulas 1,2,3,4).

$$X = \parallel X_{ij} \parallel \quad i = 1 \dots, n; j = 1 \dots, m \quad (1)$$

Where X_{ij} is the value of the j indicator that assesses the level of development of technology itself in the i region;

n is the number of analyzed regions;

m is the number of indicators that assess the level of development of technology itself.

$$Y = \parallel Y_{ij} \parallel \quad i = 1 \dots, n; j = 1 \dots, m \quad (2)$$

Where Y_{ij} is the value of the j indicator that assesses the level of development of production means in the i region;

n is the number of analyzed regions;

m is the number of indicators that assess the level of development of production means in the region.

$$Z = \parallel Z_{ij} \parallel \quad i = 1 \dots, n; j = 1 \dots, m \quad (3)$$

Where Z_{ij} is the value of the j indicator that assesses the quality of workforce in the i region;
 n is the number of analyzed regions;
 m is the number of indicators that assess the quality of workforce in the region.

$$K = \parallel \kappa_{ij} \parallel \quad i = 1 \dots, n; j = 1 \dots, m \quad (4)$$

Where K_{ij} is the value of the j indicator that assesses the level of the technology management system in the i region;
 n is the number of analyzed regions;
 m is the number of indicators that assess the level of the technology management system in the region.

The fourth step is to standardize indicators included in matrices (X , Y , Z , K). Standardization serves to convert indicators into a comparable form, since indicators included in matrices (X , Y , Z , K) have different units of measurement. This conversion is performed according to formulas 5,6,7,8:

$$X'_{ij} = \frac{X_{ij} - \min_j(X_{ij})}{\max_j(X_{ij}) - \min_j(X_{ij})} \quad (5)$$

Where X'_{ij} is the standardized value of the j indicator that assesses the level of development of technology itself in the i region;

X_{ij} is the value of the j indicator that assesses the level of development of technology itself in the i region;

$\max_j(X_{ij})$ is the maximum value of the j indicator;

$\min_j(X_{ij})$ is the minimum value of the j indicator;

$$Y'_{ij} = \frac{Y_{ij} - \min_j(Y_{ij})}{\max_j(Y_{ij}) - \min_j(Y_{ij})} \quad (6)$$

Where Y'_{ij} is the standardized value of the j indicator that assesses the level of development of production means in the i region;

Y_{ij} is the value of the j indicator that assesses the level of development of production means in the i region;

$\max_j(Y_{ij})$ is the maximum value of the j indicator;

$\min_j(Y_{ij})$ is the minimum value of the j indicator;

$$Z'_{ij} = \frac{Z_{ij} - \min_j(Z_{ij})}{\max_j(Z_{ij}) - \min_j(Z_{ij})} \quad (7)$$

Where Z'_{ij} is the standardized value of the j indicator that assesses the quality of workforce in the i region;

Z_{ij} is the value of the j indicator that assesses the quality of workforce in the i region;

$\max_j(Z_{ij})$ is the maximum value of the j indicator;

$\min_j(Z_{ij})$ is the minimum value of the j indicator;

$$K'_{ij} = \frac{K_{ij} - \min_j(K_{ij})}{\max_j(K_{ij}) - \min_j(K_{ij})} \quad (8)$$

Where K'_{ij} is the standardized value of the j indicator that assesses the level of the technology management system in the i region;

K_{ij} is the value of the j indicator that assesses the level of the technology management system in the i region;

$\max_j(K_{ij})$ is the maximum value of the j indicator;

$\min_j(K_{ij})$ is the minimum value of the j indicator;

The fourth stage results in matrices X', Y', Z', K'

Following the construction of standardized matrices, let us calculate the *technology development index* (I_t), the *production means development index* (I_{eq}), the *workforce quality index* (I_l), and the *technology management system index* (I_m) for the i Arctic region (fifth stage). The indices represent the arithmetic average of the specific indicators that characterize each of the above areas (formulas 9,10,11,12).

$$I_t = \frac{\sum_j^m X'_{ij}}{m} \quad (9)$$

Where I_t is the technology development index for the i region;

X'_{ij} is the standardized value of the j indicator that assesses the level of development of technology itself in the i region;

m is the number of indicators that assess the level of development of technology itself in the i region;

$$I_{eq} = \frac{\sum_j^m Y'_{ij}}{m} \quad (10)$$

Where I_{eq} is the production means development index for the i region;

$Y_{ij}^/$ is the standardized value of the j indicator that assesses the level of development of production means in the i region;

m is the number of indicators that assess the level of development of production means in the i region;

$$I_l = \frac{\sum_j^m Z_{ij}^/}{m} \quad (11)$$

Where I_l is the workforce quality index for the i region;

$Z_{ij}^/$ is the standardized value of the j indicator that assesses the quality of workforce in the i region;

m is the number of indicators that assess the quality of workforce in the i region.

$$I_M = \frac{\sum_j^m K_{ij}^/}{m} \quad (12)$$

Where I_M is the technology management system index for the i region;

$K_{ij}^/$ is the standardized value of the j indicator that assesses the level of the technology management system in the i region;

M is the number of indicators that assess the level of the technology management system in the i region;

At the sixth stage, we shall calculate the innovative and technological development index for the i Russian Arctic region I_{TD} , which is an integrated index comprising a set of specific indicators (formula 13):

$$I_{TD} = \frac{I_t + I_{eq} + I_l + I_M}{4} \quad (13)$$

Where I_{TD} is the innovative and technological development index for the i Arctic region;

I_t is the technology development index for the i region;

I_{eq} is the production means development index for the i region;

I_l is the workforce quality index for the i region;

I_M is the technology management system index for the i region;

The innovative and technological development index for the i Arctic region changes from 1 to 0, where 1 is the maximum value of I_{TD} , and 0 is the minimum value of I_{TD} . The closer the index is to 1, the higher the level of innovative and technological development of the i Arctic region of the Russian Federation.

4. Empirical analysis of the model

For the purposes of this study, we have selected eight Arctic regions included in the Arctic zone of the Russian Federation: Murmansk region, Arkhangelsk region, Nenets Autonomous Area, Komi

Republic, Yamalo-Nenets Autonomous Area, Krasnoyarsk region, Sakha Republic, Chukotka Autonomous Area [11].

Let us now calculate the innovative and technological development index for the Russian Arctic regions using the proposed methodology.

4.1. Substantiation of the indicators of innovative and technological development of the Russian Arctic regions: the level of development of technology itself, the level of development of production means, the quality of workforce, the level of the technology management system.

We shall determine the level of development of technology itself (technological process) using indicators that reflect the potential of technological innovations in the production process:

X_1 — expenditure on technological innovations in the i region, millions of rubles;

X_2 — payment of patents in the i region, units;

X_3 — import of technologies and technical services in the i region, thousands of US dollars.

The level of development of production means in the Arctic regions is characterized by the following indicators:

Y_1 — fixed assets value, millions of rubles;

Y_2 — advanced production technologies used, units;

Y_3 — advanced production technologies developed, units;

The quality of workforce is represented by the following indicators:

Z_1 — economically active population, thousands of people;

Z_2 — production of skilled workers and employees with basic vocational education, thousands of people.

The technology management system in the region is determined by indicators that reflect the availability of qualified managers and the performance of the technology management methods used in the region.

K_1 — innovation activity of organizations, percents;

K_2 — the volume of innovative goods, works, services, millions of rubles;

K_3 — production of specialists with higher professional education, thousands of people.

4.2. Collection of baseline data for the study

Let us summarize the proposed indicators for assessing the level of innovative and technological development of the Russian Arctic regions in the tables of baseline indicators. Indicators for assessing the level of innovative and technological development pertain to the year 2015 [12].

We shall draw up a table of baseline indicators for calculating the integrated technology development index for the Russian Arctic regions (Table 1).

Table 1 - Indicators of development of technology itself (technological processes) in the Russian Arctic regions

No.	Arctic regions	X_1	X_2	X_3
1.	Murmansk region	787.7	65.0	2192.1
2.	Arkhangelsk region	6833.7	84	21608.6
3.	Nenets Autonomous Area	1457.4	1.0	0
4.	Komi Republic	2942.7	47.0	56764.8
5.	Yamalo-Nenets Autonomous Area	8139.5	36.0	36938.4
		24979.	529.	144216.
6.	Krasnoyarsk region	5	0	9
7.	Republic Of Sakha (Yakutia)	2378.9	90.0	140

8. Chukotka Autonomous Area 58.2 0 0

Source: compiled by the author based on the data of the Federal State Statistics Service.

Let us draw up a table of indicators that characterize the level of development of production means in the Russian Arctic regions (Table 2).

Table 2 – Indicators that characterize the production means in the Russian Arctic regions

No.	Arctic regions	Y_1	Y_2	Y_3
1.	Murmansk region	1298653	1154	0
2.	Arkhangelsk region	849713	1342	20
3.	Nenets Autonomous Area	409702	25	1
4.	Komi Republic	1717183	491	3
5.	Yamalo-Nenets Autonomous Area	6737214	3920	1
6.	Krasnoyarsk region	2070838	2261	38
7.	Republic Of Sakha (Yakutia)	1194724	880	2
8.	Chukotka Autonomous Area	89475	0	0

Source: compiled by the author based on the data of the Federal State Statistics Service.

Let us draw up a summary table of baseline indicators that characterize the quality of workforce in the Russian Arctic regions (Table 3).

Table 3 – Indicators that characterize the quality of workforce in the Russian Arctic regions

No.	Arctic regions	Z_1	Z_2
1.	Murmansk region	471	3.0
2.	Arkhangelsk region	613	5.6
3.	Nenets Autonomous Area	23	0.1
4.	Komi Republic	492	6.8
5.	Yamalo-Nenets Autonomous Area	333	1.4
6.	Krasnoyarsk region	1513	13.6
7.	Republic Of Sakha (Yakutia)	500	5.5
8.	Chukotka Autonomous Area	33	0.5

Source: compiled by the author based on the data of the Federal State Statistics Service.

Let us draw up a summary table of baseline indicators that characterize the level of the technology management system in the Russian Arctic regions (Table 4).

Table 4 – Indicators that characterize the technology management system in the Russian Arctic regions

No.	Arctic regions	K_1	K_2	K_3
1.	Murmansk region	9.0	251.0	6.1
2.	Arkhangelsk region	8.2	22569.7	8.0
3.	Nenets Autonomous Area	10.5		
4.	Komi Republic	7.6	24165.9	5.8
5.	Yamalo-Nenets Autonomous Area	7.6	11785.7	0.9
6.	Krasnoyarsk region	9.5	35800.1	20.9
7.	Republic Of Sakha (Yakutia)	6.7		7.9
8.	Chukotka Autonomous Area	17.9	488.6	

Source: compiled by the author based on the data of the Federal State Statistics Service, www.gks.ru

4.3. Construction of matrices that characterize regional innovative and technological development through the values of specific indicators

Let us construct matrices (X, Y, Z, K) that characterize regional innovative and technological development (the level of development of technology itself, the level of development of production means, the quality of workforce, and the level of the technology management system) through the values of specific indicators.

4.4. Standardization of matrix indicators

We shall standardize the indicators of matrices (X, Y, Z, K) based on formulas 5, 6, 7, 8.

4.5. Calculation of the technology development index, the production means development index, the workforce quality index, and the technology management system index for the Arctic regions of the Russian Federation

Using formulas 9,10,11,12, let us calculate the technology development index, the production means development index, the workforce quality index, and the technology management system index for the Russian Arctic regions. The calculation data are presented in Table 5.

Table 5 - Technology development, production means development, workforce quality, and technology management system indices for the Russian Arctic regions

No.	Arctic regions	I_{ti}	I_{eqi}	I_{li}	I_{Mi}
1.	Murmansk region	0.05	0.16	0.26	0.16
2.	Arkhangelsk region	0.19	0.32	0.40	0.37
3.	Nenets Autonomous Area	0.02	0.02	0.00	0.11
4.	Komi Republic	0.20	0.14	0.41	0.33
5.	Yamalo-Nenets Autonomous Area	0.22	0.67	0.15	0.13
6.	Krasnoyarsk region	1.00	0.62	1.00	0.75
7.	Republic Of Sakha (Yakutia)	0.09	0.14	0.36	0.12
8.	Chukotka Autonomous Area	0.00	0.00	0.02	0.34

Source: compiled by the author

4.6. Calculation of the innovative and technological development indices for the Russian Arctic regions

The calculation is based on formula 17. The calculation data are summarized in Table 6.

Table 6 - Innovative and technological development indices for the Russian Arctic regions

No.	Arctic regions	I_{TD}
1.	Krasnoyarsk region	0.84
2.	Arkhangelsk region	0.32
3.	Yamalo-Nenets Autonomous Area	0.29
4.	Komi Republic	0.27
5.	Republic Of Sakha (Yakutia)	0.18
6.	Murmansk region	0.16
7.	Chukotka Autonomous Area	0.09
8.	Nenets Autonomous Area	0.04

Source: compiled by the author

5. Conclusions

The conducted comparative analysis of the innovative and technological development of the Arctic regions using the proposed methodology makes it possible to conclude that only the Krasnoyarsk

region has a high innovative and technological development index (0.84), while the other Arctic regions remain at a rather low level of innovative and technological development. The second place is occupied by the Arkhangelsk region (0.32), the third – by the Yamalo-Nenets Autonomous Area (0.29); the Nenets Autonomous Area has the minimum value (0.04).

The prospects of the innovative and technological development of the Arctic regions should involve accumulating knowledge, improving the level of education of the working age population, creating an innovation infrastructure that would facilitate the development of new ideas, "know-hows", high-tech products, advanced production and promotion technologies.

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