Interrelation of technological, ecological and economic aspects of industrial development of Arctic mineral resources

V S Zharov$^1$ and V A Tsukerman$^2$

$^1$Department of Economics, Management and Sociology, Murmansk Arctic State University, Apatity Branch, Russia
$^2$Department of Industrial and Innovation Policy, Luzin Institute of Economic Problems KSC RAS, Apatity, Russia

E-mail: zharov_vs@mail.ru

Abstract. The article studies the directions for expanding the innovative activity of the enterprises working with Arctic minerals and raw materials. It is shown that the influence of the scientific and technological progress on the efficiency of material usage, labour resources and other economic factors, as well as physical capital (fixed assets) of manufacturing enterprises may be reflected in the technological production coefficient. Based on the developed matrix of possible directions for enterprises’ technological development and the graphic model of the technological development life cycle, the foundations of a new direction in the economic analysis - the investment and innovation analysis - are formulated. Prospects of using the technological production coefficient have been identified and the main factors influencing the change in its values have been highlighted. It is shown that the influence of technological development on the enterprises’ activities efficiency is caused not only by objective, but also by subjective factors. The procedure for implementing the retrospective investment and innovation analysis is considered. Requirements for the economic efficiency assessment during the implementation of investment projects at Arctic enterprises working with the extraction and processing of mineral resources are formulated.

1. Introduction

The North and the Arctic now and in the future are and will remain the main source of mineral resources and raw materials, as well as fuel and energy [1, 2]. Up to 80% of Russian gas and a significant part of world’s diamonds are produced in the Arctic. Production facilities of nickel, cobalt, copper, precious metals and other valuable minerals are concentrated in this region. At the same time, the total cost of both minerals, raw materials, fuel and energy resources exceeds 30 trillion dollars, of which 20 trillion dollars account for fuel and energy resources [3]. Over the past years, the Arctic has developed a powerful industrial complex that provides more than 20% of the export earnings of the Russian Federation [4], but the industry is characterized by increased capital intensity and capital efficiency associated with conducting economic activities in extreme natural conditions. Although labor productivity exceeds the average Russian level, it several times lags behind the level of Scandinavian countries. For example, labor productivity in the Russian JSC Vorkutaugol is four times lower than in the Norwegian company SNSG mining coal on Svalbard [4]. In addition, northern and especially Arctic industrial enterprises operate in conditions of reduced production waste assimilation by the natural environment [5, 6]. These factors point to the need for priority production modernization and use of innovations.
It should be noted that the innovative potential of the North and the Arctic is used insufficiently as noted in a number of publications [7, 8]. In [9] we showed that the indicator reflecting the influence of the scientific and technological progress (STP) on the economic efficiency of resources used by enterprises - material, labor and physical capital in the form of fixed assets - can be called the technological production coefficient (k) which is defined as the ratio of the enterprise’s production capital intensity (CI) to the material intensity (MI) or as the ratio of the material efficiency (ME) to the capital efficiency (CE). The quantitative coefficient value for each enterprise may increase or decrease. Obviously, it is preferable to increase the “k” value and correspondingly decrease the production material intensity. It enhances the enterprise’s contribution to the gross regional product (GRP) growth in the regions of the Russian Federation and the country’s gross domestic product (GDP) growth, as the added value share in the volume of the enterprise’s product sales increases, as well as the total volume of gross value added (GVA) of the Arctic regions and the country as a whole. Accordingly, the volume of production waste emitted into the environment reduces. However, the question arises: when and in what cases MI, k and CE values, being opposite to CI, change, the increase in which causes labor productivity (LP) growth at the enterprise.

The purpose of the study is to show the possibility of using the investment and innovation analysis to improve the management process efficiency in the sphere of the innovative technological development of the Arctic industrial enterprises and reduce environmental pollution.

2. Method
In [10] based on the analysis of the dynamics of the main economic development indicators of 12 northern regions of the Russian Federation, a matrix of possible directions for innovative development depending on the efficiency of the used economic resources has been worked out for three separate types of industrial activities and leading Arctic corporations. The matrix defines four possible directions of the investment and innovation analysis of the industrial development of the Arctic mineral resources. Their interrelation has allowed developing a graphic model of the life cycle of the enterprises’ technological development [11], which includes six stages reflecting possible development directions.

The technological development life cycle applied to a particular enterprise allows us to determine the stage of its development in the relevant period of time and on this basis to formulate ideas about its possible future development. Accordingly, it becomes possible to form a new type of economic analysis: the investment and innovation analysis.

3. Results and discussion
Like other types of traditional economic analysis of enterprises (managerial, financial), the investment and innovation analysis can also be retrospective and prospective. In this case, the main analyzable indicator is the technological production coefficient. Firstly, it allows performing easy calculations based on the information available at the enterprises. Secondly, this indicator can be calculated for different production branches, production activities, regions and the country on the basis of statistical and financial reports from enterprises, which are processed by Gosstat. The proposed indicator can be considered universal as it can be calculated for individual types of products, technological processes, individual structural subdivisions of the enterprise, and, if necessary, even for individual sections and brigades. The considered indicator allows comparing the level of technological production of different enterprises within one industry.

This coefficient is of particular importance when assessing the integrity of the use of the Arctic mineral resources. Firstly, the growth in the number of extracted valuable components should generally lead to the rise in their value due to the increased production costs. However, in this case, investments in the enterprise’s basic capital can be substantially increased, and the value of the capital productivity index may reduce, that is, the enterprise will not develop in the most efficient way. Secondly, increasing the value of the recovery factor of useful components is of great importance for improving the efficiency of mineral raw materials extraction and processing, since, for example, in
Norway oil recovery reaches 70%, whereas in Russia it is maximum 35 %. At the same time, it is obvious that new technologies should be applied to significantly increase the recovery, so the value of the technological production efficiency coefficient should also grow, but the question is to what cost-effective limits this growth should continue. To answer it, it is necessary to calculate the value of the technological production coefficient based on the production cost for different variants of technological improvement, even at the stage of scientific research. Accordingly, it is possible to replace the original formula - C1 to MI ratio - with the amount of accrued depreciation of fixed assets cost to the total material costs, that is, the cost of raw materials, fuel and energy. As a result of the calculations, depending on the changes in the volume of depreciation and material costs, that is, their decrease or increase, the stage of the production technology life cycle is determined and the conclusion on the need for further technological change is formed.

Despite the simplicity of calculating the technological development coefficient, the change in its values depends on many factors that determine the level of both the material intensity and the capital intensity, respectively the material efficiency and capital efficiency. In our opinion, the main factors can be:

1. Inflation.
2. Type of activity of the enterprise.
3. Depreciation of fixed assets.
4. Structure of the enterprise’s fixed assets (ratio of active and passive parts).
5. Rate of fixed assets upgrading.
6. Enterprise management level.

As it turned out, the main influence on the change in the “k” coefficient values is associated with the rate of fixed assets upgrading, that is, in fact, with the rate of improvement of the applied production technology or the introduction of a new one which is more preferable. The introduction of new funds causes an increase in capital efficiency, although not always, and this, in turn, can lead to a decrease in the production material intensity.

One may wonder why the capital efficiency does not always increase and the material intensity does not always decrease. In our opinion, this circumstance stems from the theory of endogenous economic growth and its various branches [12, 13], which in general shows that the influence of technical progress on the economic development of various countries is multifaceted. At the microeconomic level of individual enterprises it means that in addition to the main objective factor of the technological progress - introduction of technological innovations - there is also the main subjective factor - the management of such innovations - that is, the level of experience, knowledge and skills not only of qualified employees, but of workers as well. It should be noted that lack of competence, for example, in the field of investment and innovation analysis can lead to the fact that this is not always the case and not all technological innovations will result in the increase in capital efficiency and the decrease in the material efficiency.

Thus, the considered factors that have the greatest impact on the change in the technological production coefficient values, confirm the conclusion of Academician Trapeznikov A.N. of the USSR Academy of Sciences, who formulated in the 1980s that the rate of the scientific and technical progress reflects the “knowledge and skills indicator” [14], meaning that it is important not only to know which innovations to use, but also to possess managerial ability that will allow using them with the greatest possible economic efficiency.

In the process of the retrospective investment and innovation analysis it is necessary to determine the changing trends in the technological production coefficient value. To do this, the annual data for a period of 5-10 years should be analyzed. The annual growth or decline rates are calculated, as well as the average annual rate over the analyzed period of time. If a favourable trend for the “k” coefficient value growth is revealed, a comparison should be made with a similar trend at other manufacturing enterprises in order to determine the degree of implementation of scientific and technical progress achievements at the analyzed enterprise. Then a detailed analysis of the enterprise’s activity for the latest reporting period (a month, a quarter, a year) can be performed. If a negative trend of the “k”
Coefficient is revealed as a result of the retrospective analysis, a more detailed analysis for the past three years is needed. The same should be done if there is no stable trend.

If the enterprise uses economic resources in the most effective way for a long time, that is, the development is carried out according to the first variant of the first direction, it is obvious that further technological upgrade should take place. In this case, the investment and innovation analysis will have a predictive nature. Its basis lies in the determination of the values of target development indicators for each year of the forecast period and further calculations of the attainability of these values depending on the financial capabilities of the enterprise, that is, the possibilities of attracting borrowed capital, primarily in the form of commercial bank loans, without losing financial stability. To ensure intensive economic growth and environmental pollution reduction, the added value share in the enterprise’s product sales which essentially reflects the magnitude of production material intensity should be the most important target indicator.

For the initial determination of the target values of these interrelated indicators, their values at the best enterprises in the relevant production sector and in developed countries can be taken. The same approach can also be applied for the initial determination of another coefficient – the technological production coefficient (k). The third most important indicator - the necessary level of capital efficiency - is determined as the ratio of ME to k coefficient. Next, the imitation dynamic model developed by the authors [15] is used, as well as its subsequent modifications for application of the values of added value share and capital efficiency. It will allow calculating any financial and economic indicators, and, if necessary, technical and economic indicators of the company's innovative development for any forecast period of time. In the process of calculations, it is possible to check whether the target values of the above-mentioned indicators can be achieved with the forecasted sales volumes in order to ensure a normal level of financial stability. If stability is not ensured, the target values are adjusted accordingly.

Thus, it becomes possible to fully formalize the procedure of the investment and innovation analysis combining its retrospective and forecasting types, which means the possibility of digitization of the technological development managing process of manufacturing enterprises. Besides, the investment and innovation analysis is especially important for determining the technological development prospects of mining, metallurgical and chemical enterprises in the Arctic zone of the Russian Federation since they differ from the processing industry enterprises by the primary need to upgrade production technology in order to prevent the production costs increase due to worse quality of the used mineral resources and deterioration of mining, geological and technical conditions of the mineral deposits development. This leads to the increase in production waste emissions into the environment.

4. Summary
1. The use of the investment and innovation analysis will make it possible to foster upgrading of the Arctic enterprises working with extraction and processing of mineral resources and reduce environmental pollution.
2. The prospects of the proposed indicator application - the technological production coefficient for the innovative development of Arctic enterprises - are presented. The main factors affecting the change in its values are considered.
3. The procedure for retrospective investment and innovation analysis is considered. Requirements for technological upgrade of production facilities in the form of the stages of the technological development life cycle of Arctic enterprises are formulated.
4. The necessity of priority use of investment and innovation analysis for justifying the development prospects of industrial enterprises operating in the Arctic is determined.

5. Direction for further research
Determining the possibility of managing the cost formation process of certain types of products manufactures by the Arctic enterprises, reducing the level of material consumption and production waste emissions into the environment.

References
[1] Zharov V S 2017 Influence of technological innovations on productivity growth Industrial policy in the digital economy: problems and prospects: proceedings of the scientific-practical conference with international participation ed A V Babkin (Saint Petersburg: Publishing house of St. Petersburg State Polytechnical University) pp 101-108 DOI: 10.18720/IEP/2017.5/15.
[2] State program of the Russian Federation" Socio-economic development of the Arctic zone of the Russian Federation for the period up to 2020 " (approved by the Government of the Russian Federation on April 21 2014 No 366
[3] 2016 Arctic Space of Russia in the XXI Century: Factors of Development, Organization of Management ed. W W Ivanter (Saint Petersburg: Publishing house of St. Petersburg State Polytechnical University Peter the Great; Science) p. 1016
[4] Selin V S, Larichkin F D, Tsukerman V A and Goryachevskaya E S 2016 Challenges of the national industrial development and policy of mineral mining companies in the Arctic Region of the Russian Federation Gorny Zhurnal 10 pp 25-33 DOI 10.17580/gzh.2016.10.04
[5] Kozlov A V, Fedoseev S V, Cherepovizyn A E, Gutman S S, Zaychenko I M, Marinina O A, Rytova E V, Tzvetkov P S, Tochilo M V 2016 Integrated Development of Economic Space of the Arctic Zone of the Russian Federation (Saint Petersburg: Publishing house of St. Petersburg State Polytechnical University) p 315
[6] Englington A, Israel R and Vartanov R 1998 Towards sustainable development for the Murmansk region Ocean and Coastal Management 41 (2-3) pp 257-271
[7] Kozlov A, Gutman S, Zaychenko I, Rytova E and Nijinskaya P 2015 Environmental management on the basis of complex regional indicators concept: case of the Murmansk region. IOP Conference Series: Materials Science and Engineering 6. Cep. “6th International Scientific Practical Conference on Innovative Technologies and Economics in Engineering” pp 012073
[8] Tsukerman V, Ivanova L and Selin V 2016 System of State Regulation of Sustainable Ore Processing and Production Waste Treatment in the Russian Arctic Rewas 2016: Towards Materials Resource Sustainability. February 14-18, 2016, Nashville, Tennessee, USA (John Wiley & Sons, Inc., Hoboken, NJ) doi: 10.1002/9781119275039.ch31. pp 215-231 DOI 10.1007/978-3-319-48768-7_31
[9] Komkov N I, Selin V S, Tsukerman V A and Goryachevskaya E S 2017 Problems and perspectives of innovative development of the industrial system in Russian Arctic regions Studies on Russian Economic Development 28 (1) pp 31-38 DOI 10.1134/S1075700717010051
[10] Zharov V S 2017 Trends and prospects of innovative industrial development of the regions of the North and the Arctic Trends in the development of economy and industry under the conditions of digitalization ed.A V Babkin (Saint Petersburg: Publishing house of St. Petersburg State Polytechnical University) pp 374-397 DOI: 10.18720/IEP/2017.6 / 15
[11] Zharov V S 2018 The interrelation technological and economic development of production systems St. Petersburg State Polytechnical University Journal. Economics 11(3) pp 32-44 DOI: 10.18721 / JE.11303
[12] Romer P 1986 Increasing Returns and Long-Run Growth Journal of Political Economy vol 94 (5)
[13] Barro R and Sala-i-Martin X 1995 Economic Growth (N. Y.: McGraw-Hill)
[14] Kuchin B L and Yakusheva E V 1990 Management of Economic Systems Development,
[15] Zharov V S and Tsukerman V A 2006 Modeling imitation system for development strategy for beneficiation plants Abstracts XXIII International Mineral Proc. Congress, 3-8 September 2006, Istanbul, Turkey (Istanbul) pp 20-26