Efficiency management of technological renewal of production enterprises in the Arctic under conditions of economy digitalization

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Abstract. Three main problems have been formulated and their solution will make it possible to ensure the maximum efficiency in the use of production resources - material, labor and fixed capital due to the digitalization of managing technological renewal of production enterprises in the Arctic. It is shown that these problems can be solved by using a new direction of economic analysis of production systems—the investment- and innovation analysis. It is proposed to use the coefficient of technological effectiveness level, defined by the ratio of capital intensity of production to its material intensity of product or by the ratio of material productivity to capital productivity, as well as the level of material productivity as targets of technological renewal. It is established that the simultaneous increase in the values of the coefficient of technological effectiveness level, material and capital productivity is possible only at one of six possible stages of the life cycle of technological development of enterprises. An algorithm of enterprises’ actions in making management decisions on technological renewal of production has been developed. It is proposed to supplement the methodology for assessing the effectiveness of investment projects in their implementation at existing enterprises by calculating the damage from the reduction of material productivity, capital productivity and labor productivity in case of delay in the technological renewal of production.

1. Introduction

In [1], [2], we have shown that it is in the Arctic regions that it is urgent to implement technological modernization of industrial production, that is, the introduction of new production technologies that can significantly increase labor productivity, reduce material intensity of product and the level of environmental pollution. However, unfortunately, over previous years the innovation activity of industrial production in the Arctic regions was insignificant [3], thus the process of introducing technological innovation must be managed. In addition, it should be borne in mind that the future development of the world’s economy, including the Russian economy, will be associated with its gradual digitalization [4], [3], [4], [5], [6], [7], with the most important part being the digitalization of managing economic development [8], which should ensure the maximum possible economic efficiency of the resources used - material, labor and fixed capital [9], [10], [11], [12]. To do this, in our opinion, it is necessary first of all to solve three main tasks. Firstly, we need to determine the development targets that should be linked to the effectiveness indicators of the resources used. Secondly, it is necessary to be able to determine their real achievable values for the future. Thirdly, an
algorithm should be formulated for enterprises’ actions to achieve the target values for the corresponding period of time. Thus, the purpose of the work is to solve the above tasks.

2. Materials and methods
All the tasks mentioned above are successfully solved due to a new direction of economic analysis of production system activity that we are dealing with, namely, the investment- and innovation analysis [1], [2]. Its essence is as follows. We have established that there is a proportional relationship between the capital intensity and the material intensity of production systems (enterprises and industries), which is reflected by the proportionality coefficient $k$:

$$k = \frac{CI}{MI} = \frac{MP}{CP},$$

where CI and MI are capital intensity and material intensity of product and MP and CP are material productivity and capital productivity, respectively.

We have shown that the numerical value of this coefficient can change in any direction depending mainly on the degree of renewal of fixed assets. Thus, the implementation of technological progress in the field of technological renewal of production determines the growth of its values, so it can be the main target indicator of technological modernization. Accordingly, it was referred to as the coefficient of technological effectiveness level. However, as for increasing the economic efficiency of using production resources, the MP and CP values should also grow simultaneously with the increase in the value of k coefficient. In this case, the level of labor productivity will also increase due to the growth of the capital productivity, that is, the efficiency of all the main types of production resources will increase simultaneously. From the point of view of the interests of the regions and the state as a whole, the most important thing is to increase the MP level, that is, to reduce material intensity level, as it leads to an increase in the share of value added in the unit cost of production of enterprises, and thus to the growth of gross regional product in the regions-subjects of the Federation and GDP growth of the country. Accordingly, the MP level can be the second target indicator of technological modernization. However, as we have shown in [1], [2], the simultaneous growth of k, MP and CP values in enterprises can only occur if they develop technology in accordance with one of six possible stages of technological development life cycle of production systems.

3. Results
In [13] we defined the conditions and opportunities for enterprises to move to this best stage if their development corresponded to other stages based on the results of the retrospective investment- and innovation analysis. However, it should be noted that even if the company's activity is in accordance with the best stage, firstly, it cannot continue for a long period of time without improving the existing production technology. Such an activity is to result in a further increase in the coefficient of technological effectiveness level, but if the increase stops, it means reaching the economic limit of technology improvement and a need to introduce a new technology. Secondly, the enterprise may not be a leader in its industry by the value of the coefficient of technological effectiveness level, thus, if the goal is to provide leadership or to pursue a leader, it is necessary to introduce a new technology. These considerations are the basis for the preliminary determination of the target values (k and MP) for the corresponding future period of time. However, one should realize that the prolongation of this period will first lead to a decrease in MP level and then in CP level, which will result in the increase in production cost and therefore in the reduction of profits.

Thus, when forming an algorithm for the company’s actions in the field of technological renewal of production at the initial stage, it is necessary to determine the stage of technological development at which the development can be provided for a certain period of time.

To do this, the annual values of material productivity, capital productivity and the coefficient of technological effectiveness level of production are calculated based on enterprises’ financial
statements for three to five years of the retrospective period and the stage of technological development cycle is determined for each year. Then, first, the trend to changing the values of the coefficient of technological effectiveness level of production is analyzed as follows.

If these values have a steady upward trend, it is obvious that the company is actively engaged in technological renewal of production. However, this raises two questions. The first question is related to the efficiency of the production resources used. The fact is that the value of the coefficient of technological effectiveness level of production can increase at three of six possible stages of the life cycle of technological development. Therefore, it is worth considering the trend to changes in the stages of this cycle. If the development is ensured mainly at the best stage with maximum efficiency use of all major productive resources, then you need to answer the second question - is the company a leader in technological development in its field (within the region, country or the world depending on the scale of activity of the particular enterprise) and then determine the target values of the coefficient of technological effectiveness level for the future. In cases where the best stage is provided not in each year of the time period under analysis, you need to pay attention to the quality of human capital of enterprises [14], [15], [16], [17], i.e. knowledge, experience and qualification of management personnel not only at the highest level of management (top management), but the mean (management of structural divisions of the enterprise) and even lower (sections, brigades).

If there is a tendency to decrease the values of the coefficient of technological effectiveness level of production, which means that there is no technological renewal, then special attention should be paid to the analysis of changes in the stages of the life cycle of technological development. However, the most negative situation for an enterprise occurs when there is a tendency to simultaneously reduce the values of material productivity, capital productivity and labor productivity. In this case, it is obvious that the company is going to face bankruptcy, thus it is urgent to take measures - if it is not too late- to its financial recovery. If the company has reduced the rate of technological renewal, which shows a trend to a slight decrease in the values of the coefficient of technological effectiveness level of production, these rates must be accelerated again to reach at least the previous highest values of this coefficient. There may also be a situation when the values of coefficient now increase now decrease. This shows that the company does not have a targeted policy of technological renewal and consequently the poor quality of its human capital at all levels of management hierarchy.

Then, at the next stage, some ideas arise concerning the form of technological renewal of production, i.e. there is the answer to the question “What to do?”– either to modernize the technology available or to introduce a new one (depending on the fact whether the enterprise is a leader and what particular stage of technological development it is at ). At the same time, the implementation terms of the new technology depend on the particular stage. In the worst case, when the k, MP and CP values reduce simultaneously, the delay in implementation of a new technology can result in bankruptcy of the enterprise.

At the final stage of forming the algorithm for making management decisions on technological modernization the problem of the terms of introducing the new technology as well as the target values that the company is expected to achieve should be solved. The main limitation to both the terms and the values is the opportunity for the enterprises to attract investments for implementing a relevant investment project at the expense of their own and borrowed capital without losing their financial stability.

In our opinion, however, the methodology for evaluating the efficiency of the investment projects being used abroad and in Russia [18], [19], [20], [21], which is followed in business planning should be supplemented by calculating the damage to the enterprise from the loss of a part or all of its profit as a result of reducing the efficiency in using production resources – material, labor and fixed capital.

This calculation should be performed taking into account compounding, that is, increasing the cost in the future period covering the entire period of time from the beginning of calculations to the beginning of the project implementation. On the one hand, it should allow the management of enterprises to realize that slowing down the process of technological renewal will reduce the profitability of the business and may lead to a loss of its competitiveness. On the other hand, this
calculation allows one to determine the specific terms of the investment project implementation but only by taking into account the subsequent assessment of the financial stability of the enterprise’s future activity under conditions of its technological renewal. Thus, accepted for implementation should be only such an investment option, which will allow the company to achieve pre-determined target values (k and MP as well as CP) on time, taking into account a loss of future profit and ensure a proper level of financial stability. It is natural that all these requirements will be met only when iterative calculations are performed; thus, the full algorithm for making management decisions on technological modernization of production enterprises must include many feedbacks.

4. Conclusions
Three main problems have been formulated and their solution will make it possible to ensure the maximum efficiency in the use of production resources - material, labor and fixed capital due to the digitalization of managing technological renewal of production enterprises in the Arctic. It is shown that these problems can be solved by using a new direction of economic analysis of production systems—the investment- and- innovation analysis.

The stages of the algorithm for enterprises’ actions in making management decisions on technological renewal of production have been developed. It is proposed to supplement the methodology for evaluating the effectiveness of investment projects when they are implemented at existing enterprises by calculating the damage caused by a decrease in material productivity, capital productivity and labor productivity in case of a delay in the technological renewal of production...

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