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Methodical Approach to Energy-Economic Evaluation of Industrial Production

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***Abstract*—In this article, the theoretical bases of the methodical approach to the energy-economic evaluation of industrial production and the regulation of its energy efficiency are considered. The prerequisites, categories, and principles of the energy-economic approach, which is initially based on the ideas of the energy analysis of economic activity, proposed by national and foreign researchers, are determined. In the energy analysis, the state of microeconomic systems is estimated based on the real costs of energy carriers used for a given technology, which makes it possible to determine the factors of production energy saving and energy-efficient development. While constructing an energy-economic model of the production and economic system, the authors based themselves on the thermodynamic point of view, according to which the energy flow is the main factor of production, which forms the value, and labor determines the measure of efforts to create it. As a tool for studying the economic factors of industrial development, the Cobb-Douglas production function in the labor-energy system was adopted, as well as R. Solow's model of economic growth, modified from the energy standpoint. Advantages of the proposed methodical approach are the visibility of the graphic model, in which the generalized indicator of the technical equipment and innovation, and, consequently, the economic development of material production is the energy-to-labor ratio. According to the dynamics and correlation of this indicator and labor productivity, it is possible to analyze the energy efficiency of production and to plan an energy saving or labor-saving direction of production development. The approbation of the methodic approach to the energy-economic evaluation of the production and economic system was made using the example of the Russian extractive industry.**

Keywords*—industrial production, production function, energy saving, energy efficiency, energy-economic model, labor productivity, power-to-weight ratio of labor.

I. Introduction

Energy resources are the basis of any production activity. Consequently, the management of energy-efficient development of industrial production becomes effective with the obligatory consideration of energy flows not only in the production process, but also in the operation of any production and economic system.

The transfer of all spheres of the national economy to an energy-efficient development path necessitated the development of a methodical approach to assessing and regulating the energy-economic situation in the industry. According to specialists' estimates [1], the energy saving potential in industry reaches 20-25% of annual energy consumption, the share of energy costs in the cost of industrial output is 15-40%.

II. Theoretical Bases of the Energy-Economic Approach to the Assessment and Regulation of Production Activities

A. *Prerequisites for the Formation of the Energy-Economic Approach*

The fundamentals of applying energy indicators for the analysis of production and economic activity were first formulated in 1880 [2]. Two main ideas of S.A. Podolinsky's theory can be singled out: 1) the measure of production capacities of an economic system is its energy potential, concluded in the form of ordered structures - structures, machines, information, technological processes, production skills; 2) to obtain sound results on production activities, financial statistics should prefer "accurate and conscientious" energy statistics.

The interrelation of energy, economics, ecology and the role of energy saving in this relationship have been reflected and further developed in the works of domestic and foreign researchers [3; 4; 5; 6; 7]. However, proposed scientific ideas are practically not applied in production activities in the context of implementing energy conservation policies.

An attempt is made to disclose certain aspects of the methodology of energy-economic evaluation and regulation of the ratio of labor and energy costs in the industry from the standpoint of choosing an energy-saving or labor-saving direction of its development [8, 9].

B. *Main Principles of the Methodical Approach*

The main factors of production are traditionally considered to be labor and capital. Moreover, the increase in labor productivity, as the basis for economic growth, has been associated for a long time with the increase in capital (machinery, mechanisms and equipment) [10]. However, this process is accompanied by a parallel increase in energy consumption, which goes into the category of important production factors [3]. The functional role of the equipment in this case, is the replacement of the human force by the forces of nature (the expenditure of human energy by external energy expenditure) [7]. Labor is enhanced by external energy supplied by machinery and equipment, and, in accordance with the natural-science point of view, produces no substance, but adds the converted energy to the substance, while consuming the mechanical energy stored in the body [2].

Proceeding from these postulates in scientific research, two points of view on the role of energy resources in the increase of value were formed. The first is the neo-energy theory of value, in which energy flows are identified with product flows [6]. In the second point of view, thermodynamic one, it is assumed that energy is the main factor of production, creating value, but the measure of efforts to create it determines labor [7; 11; 12]. In connection with the noted, it seems justified, along with labor *L*, to allocate the energy *E* to an independent production factor.

Rational economic behavior of an economic entity in a market economy implies a reduction in production costs in accordance with the principle of substitution of production factors. With a different combination of factors, the same volume of output *Y* is provided [15]. The idea of such alternatives with a certain technology is characterized by the production function [13; 14], whose modification from the energetic positions takes the form:

$$Y = f(L, E) \text{ or } Y_t = L_t^{1-\alpha} \cdot E_t^{\alpha}. \qquad (1)$$

At the same time, one of the directions of saving individual resources and accelerating the development of the production system is a rational combination of key factors of production through their addition or substitution.

C. Production Function in the System "Productivity and Power-to-Labor Ratio"

To determine the limits of energy conservation and the parameter of regulation of the energy-economic level of production, we use the modified production function (1). Its important property is the constant return on the scale of production, which allows us to multiply both sides of the equation by *1 / L*. We get a function in which output per worker - labor productivity *q* - is functionally dependent on the amount of energy per unit of labor - the energy-to-weight ratio of labor *e* –

$$\frac{Y}{L} = q = f\left(\frac{E}{L}, 1\right) = f(e, 1). \qquad (2)$$

This expression represents a modified function of R. Solow [16; 17; 18]. In the energy-economic model, labor productivity is traditionally the condition for intensifying the economic development of production, and the only parameter that ensures the energy-efficient development of production is the power-to-weight ratio of labor that is characteristic of a certain technological method. It is the power-to-weight ratio of labor e, in the opinion of Academician T.S. Khachaturov [19], which is a generalizing indicator of technological progress in material production and the technical equipment of labor. This indicator can be represented as the product of the capital-labor ratio Ψ and the energy intensity of the EC fixed assets (capital) E_K

$$e = \frac{\sum E}{L} = \frac{\sum E \cdot K}{L \cdot K} = \frac{K}{L} \cdot \frac{\sum E}{K} = \psi \cdot E_K. \qquad (3)$$

In the joint solution of expressions (1) and (2), the energy-economic function takes the form:

$$q_t = f(e, 1) = \frac{Y_t}{L_t} = \frac{E_t^{\alpha} \cdot L_t^{1-\alpha}}{L_t} = \left(\frac{E_t}{L_t}\right)^{\alpha} = e_t^{\alpha}, \qquad (4)$$

where *α* is the coefficient of elasticity, which characterizes the relative change in the level of labor productivity in comparison with the change in its energy intensity. The coefficient is calculated by the method of least squares from expression (4), represented in logarithmic form.

A local measure of the effectiveness of a possible economic substitution between two factors of production is the marginal rate of technical substitution of *MRTS* [16; 18; 20]. By the value of this indicator, it is possible to analyze and regulate the energy-economic indicators of production and the level of industrial energy-saving.

Depending on the value of the marginal rate of technical substitution of labor, the energy $MRTS_{Le}$ for a specific energy-economic function can be divided into three boundary conditions. The first, if $MRTS_{Le}$ = 1, then this indicates an optimal combination of factors of production and maximization of the profit of the business entity. The second condition, if $MRTS_{Le}$> 1, the price of labor is higher than the tariffs for energy. Therefore, it is economically advantageous to increase the energy content of labor and to reduce the number of people employed in production. The third condition, when $MRTS_{Le}$> 1, then it is advisable to lower the power consumption of labor, using energy-saving technologies in production.

III. Assessment of the Energy-Economic Situation in the Russian Extractive Industry

Consider the behavior of the energy-economic function in relation to the activities of the Russian extractive industry during the period 2010-2016 [21; 22]. In the structure of energy resources used in this sector of the economy, the major share is accounted for by the electric energy *El*. Therefore, we construct a model of the production function, in which the output per worker *q* is functionally dependent on the electrified labor *el* (see Fig. 1). In determining the parameters of the energy-economic production function and $MRTS_{Lel}$, the index method was used.

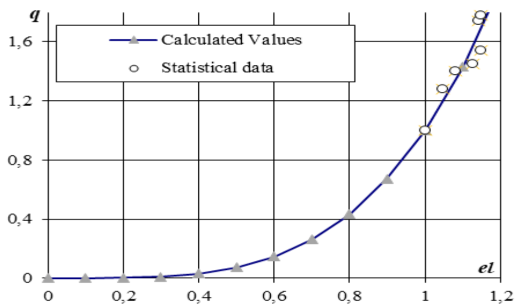

Fig. 1. Functional dependence of labor productivity and its power in Russia's mining industry.

From the form of the production function it can be seen that in the second part of the model, in which the points of statistical data characterizing real technological production methods in the extractive industry of Russia for the analyzed period are concentrated, the productivity of labor increases more than its electric capacity. This indicates the use of energy-saving technologies in the industry and trends in the growth of energy efficiency of production.

It was in the latter area that the data on productivity and the electric power of labor, which characterize the real technological methods of production in the extractive industry of Russia for the analyzed period, were concentrated. The productivity of labor of workers actually increased at a faster rate than in the growth of its possible electric capacity. This situation is explained by the replacement of production equipment and equipment in earlier periods by more energy-efficient ones.

The obtained conclusions about the energy-economic situation in the country's extracting industry are confirmed by the graph of chain indices of productivity and electric capacity of labor (see Fig. 2a). In the period 2010-2016. Outperformed growth in labor productivity was noted in comparison with the growth of its electrification. However, the marginal rate of technical replacement of labor by $\boldsymbol{MRTS_{Lel}}$ electricity in the country's mining industry was in the negative quadrant of the schedule (see Fig. 2b). The trend of the indicator had a downward slope, which indicates higher tariffs for electricity compared to the labor price in the industry.

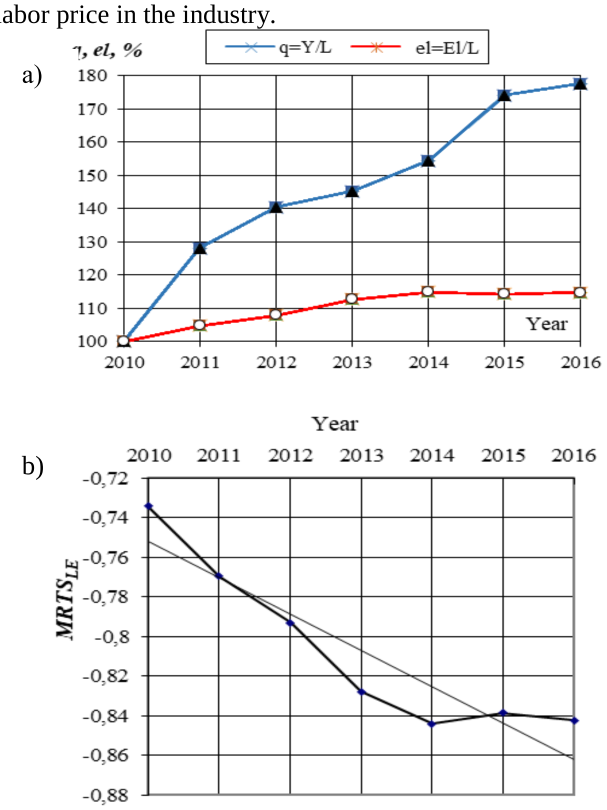

Fig. 2. Dynamics of energy-economic indicators of the manufacturing industry in Russia: a) $MRTS_{LE}$; b) chain indices of productivity and power-to-weight ratio of labor.

In order to improve the production of energy efficiency and profitability, it is advisable to continue reducing the electric power in the extractive industry.

REFERENCES

[1] Zavadsky, V.G., Sargsyan, L.G.: Energy saving in industry. Rational use of energy resources. ESCO Homepage, http://esco-ecosys.narod.ru, last accessed 2018/05/20.

[2] Podolinsky, S.A.: Human work and its relation to the distribution of energy. Noosfera, Moscow (1991).

[3] Anchishkin, A.I.: The science of technology is economics. Economica, Moscow (1986).

[4] Bushuev, V.V.: Sustainability of energy-ecological development. Energeticheskaya politika 6, 2-4 (1998).

[5] Sinyak, V.I.: Energy-saving and economic growth. Problemy prognozirovaniya 3, 49-62 (1999).

[6] Odum, H., Odum, E.: Energy Basis for Man and Nature, McGraw-Hill Book Company, New York (1981).

[7] Pokrovsky, V.N.: Energy, technological progress and economic growth. Printsipy ekodinamiki. Tradition, Moscow (1993).

[8] Golovanova, L.A., Ivanchenko, O.G.: Energy-economic approach to the regulation of the development of industrial production. Vestnik Tikhookeanskogo gosudarstvennogo universiteta 1(16), 109-118 (2010).

[9] Golovanova, L.A.: Methodical foundations of energy-economic analysis and regulation of development of production and economic systems. Vestnik Tikhookeanskogo gosudarstvennogo universiteta 3(46), 151-160 (2017).

[10] Smith, A.: An inquiry into the nature and causes of the wealth of nations. Strand, London (1786).

[11] Georgescu-Roegen, N.: The Entropy Law and the Economic Process. Harvard University Press, Cambridge (1971).

[12] Prigogine, I., Stengers, I.: Order out of Chaos: Man's New Dialogue with Nature. Bantam Books, New York (1984).

[13] Cobb, C., Douglas, P.: Theory of Production. American Economic Review 18(1), 139-165 (1928).

[14] Douglas, P.: The Cobb-Douglas Production Function Once Again: Its History, Its Testing, and Some New Empirical Values. The Journal of Political Economy 84(5), 903-915 (1976).

[15] Brown, M.: On the theory and measurement of technological change. Cambridge U.P., Cambridge (1966).

[16] Galperin, V.M., Ignatiev, S.M., Morgunov, V.I.: Microeconomics. Ekonomicheskaya shkola, St. Petersburg (2002).

[17] Solow, R.: Technical Change and the Aggregate Production Function. The Review of Economics and Statistics 39(3), 312-320 (1957).

[18] Samuelson, P.A., Nordhaus, V.D.: Economics. McGraw-Hill Book Company, New York (1992).

[19] Khachaturov, T.S.: Economics of nature management. Efficiency of capital investments. Vol'noye ekonomicheskoye obshchestvo Rossii, Moscow (1996).

[20] Mankju, N.G.: Principi ekonomije. Centar za izdavacku delatnost, Belgrad (2008).

[21] Regions of Russia. Social and economic indicators 2017. GKS Homepage, http://www.gks.ru/free_doc/doc_2017/region/reg_sub17.pdf, last accessed 2018/05/20.

[22] Technological development of economic sectors 2017. GKS Homepage, http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/economydevelopment/, last accessed 2018/05/20.