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Optimization of Energy-Efficient Functioning of the Oil and Gas Sector of the Economy through Digitalization and Resource Conservation

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ABSTRACT

This study is aimed at identifying the best values for the parameters of energy efficient digital development of the petroleum and gas sector. Research methods - construction of a production function, regression analysis and linear programming. Based on the production function of Cobb-Douglas, the dependence of the sales volumes of the petroleum and gas sector of the economy on the costs of digitalization and labor costs was revealed; the regression analysis method provided the construction of a set of equations describing the impact of the costs of energy resources of petroleum and gas enterprises and the costs of digitalization on the total costs of enterprises for production and sales, the efficiency of using by-products from petroleum production and labor capital; the optimal values of energy-efficient digital resource-saving development of the petroleum and gas sector of the economy have been determined, the achievement of which will ensure a decrease in the energy consumption of processes at the enterprises of the petroleum and gas complex. Thus, connections have been established and the trajectories of energy efficient functioning of the petroleum and gas sector of the economy have been determined. The research results can be applied within the framework of strategies for socio-economic development, sustainable development, as well as digitalization of the petroleum and gas complex and industrial enterprises.

Keywords: Regression Analysis, Digitalization, Resource Conservation, Energy Efficiency, Petroleum and Gas Sector
JEL Classifications: O14, D24, C41

1. INTRODUCTION

The global economic fluctuations caused by the pandemic, the reduction in petroleum production, which determine the decline in the economic activity of the industry, exacerbate the problem of resource-saving development of the petroleum and gas sector of the economy. Industrial enterprises are faced with an acute issue of resource optimization, in particular, energy resources, as well as informatization and digitalization (Zaitseva et al., 2018). At the same time, the problems of depletion of natural resources are still of great importance from the point of view of sustainable development, encompassing the harmonization of the interests of the economic, ecological and social systems (Kvon et al., 2018; Nizamutdinova et al., 2019; Khairullina et al., 2020; Begishev et al., 2021). The American Council for an Energy Efficient Economy annually presents a ranking of 25 developed countries for energy efficiency. According to the results of research at the end of 2018, the Russian economy ranked 21st in the rating with a score of 34.5 out of 100 possible (The American Council for an Energy-Efficient Economy, 2021). Energy efficiency in construction (9 points out of 25 possible), industry (10 out of 25) and transportation (9.5 out of 25) were noted at a relatively low level in Russia. The top countries include Germany (1st place, 75.5 points), Italy (2nd place; 75.5) and France (3rd place; 73.5). Russia occupies such positions, being the world's largest supplier of energy resources – coal, petroleum and natural gas (European Commission, 2021). The presented statistics allow us to summarize the significant gap between the Russian economy and developed countries.

In terms of digitalization, Russia also lags behind many countries in terms of the level of information and communication technologies development. According to the latest data published by the International Telecommunication Union - in the ICT Development Index (2017) Report (International Telecommunication Union, from: https://www.itu.int/), Russia ranks 45th (index value - 7.07) from 176 countries represented in the ranking. The leading positions were occupied by Iceland (8.98), Korea (8.85) and Switzerland (8.74).

Thus, to the Russian economy, in particular industry, requires the search and implementation of opportunities to rationalize resource consumption by concentrating efforts on one of the priority development tasks - automation and digitalization of industrial production. It is necessary to optimize the costs of energy and digital resources while simultaneously reducing the energy intensity of industrial production, including the petroleum and gas complex, which plays a key role in Russia in ensuring competitive exports.

2. LITERATURE REVIEW

Resource-saving development has become one of the key studies of many Russian and foreign scientists. The dynamically developing world economy is accompanied by qualitative changes, which requires from science and practice new approaches to the management of technological processes, industrial enterprises, and complexes. The works of foreign researchers are devoted to the issues of energy efficiency, reflecting the investment aspect of rationalizing energy consumption (Ayres et al., 2013), modeling the dependence of energy efficiency on external factors, impact assessment based on the Efficient reliability index (Barzegar et al., 2020), "Rebound effect" in ensuring energy efficient industrial production (Bongers, 2020), social aspect of energy saving development (Dunlop, 2019), solutions to optimize production to minimize energy costs (Gong et al., 2015), directions for improving energy efficiency and decarbonization of the machine-building industry (Kanchiralla et al., 2020), a systematic approach to energy efficiency and organizational culture of the enterprise (Koenig, 2020), energy management of buildings and structures (Marinakis, 2020). The works of Russian scientists have also made a significant contribution to solving the issues of increasing the energy efficiency of industrial enterprises. The influence of structural changes in industry on energy efficient development has been investigated (Malysheva et al., 2016; Razumovskaya et al., 2018), the dependence of energy consumption costs on external factors is formalized (Mokhov and Demyanenko, 2019); energy efficiency optimization models are built (Meshalkin et al., 2017; Dovì and Meshalkin, 2017); the trends and prospects of reducing the specific energy consumption of enterprises and industrial clusters have been identified (Dyrdonova and Lin'kova, 2019).

The significance and trends of digitalization, its possibilities in order to optimize costs in industry, in particular in the petroleum and gas sector of the economy, are also the object of close attention and research of scientists. Thus, the scientific literature contains provisions describing ways to modernize the assets of the petroleum and gas sector through the implementation of the capabilities of Industry 4.0 (Wassink et al., 2020), digital possibilities of designing closed systems of the petroleum and gas industry (Hause and Ashfield, 2018), synthesis of sustainable development, relevant for the petroleum and gas industry, and Big Data in order to ensure sustainable intelligent production (Ren et al., 2019), rational management of information flows from petroleum fields through cloud data analytics (McCarthy, 2018), etc. In Russia, studies of digitalization of the petroleum and gas sector of the economy touch upon the specifics of digitalization of exploration, drilling and production (Dmitrievsky et al., 2019), automation of the work of pipelines of industrial enterprises (Meshalkin and Moshev, 2015; Larionova et al., 2018). A number of works are devoted to the study of the features of the development and technological modernization of enterprises in the petroleum and gas sector of the economy (Lyashenko et al., 2018; Frolov et al., 2017; Shinkevich et al., 2020).

The analysis of published scientific research allows us to emphasize the relevance of the topic under study, the high interest of the scientific community in digitalization and energy efficiency, including in the petroleum and gas industry. We propose to develop the presented tools for improving the energy consumption system of petroleum and gas enterprises by optimizing costs accompanying the processes of digital transformation and energy consumption of industrial enterprises, as well as taking into account the labor factor.

3. DESCRIPTION OF DATA

The dynamic analysis of energy consumption by the petroleum and gas sector of the economy reflects an obvious increase in the consumption of energy resources (natural fuel, electricity, heat, etc.) - by 9.3% and a decrease in the specific consumption of equivalent fuel for petroleum refining - by 8.5% (Figure 1).

Undoubtedly, we are talking about the expansion of the scale of activities, the desire of the business sector to increase revenue from sales and net profit by increasing the volume of petroleum and gas production. We can observe the wavelike dynamics of the industry's profitability in the period 2008–2018, which is explained by fluctuations in the ratio of the growth rates of costs and proceeds from sales, changes in demand for the industry's products (Figure 2).

However, not all the volume of extraction of natural resources is required by the market in the short term, as a result of which the costs of storing resource reserves increase. So, the problem is to achieve a balance between supply and demand, the extraction

Figure 1: Trends in energy consumption in the petroleum and gas sector of the Russian economy (compiled by the authors based on Federal State Statistics Service (Rosstat, 2020)).

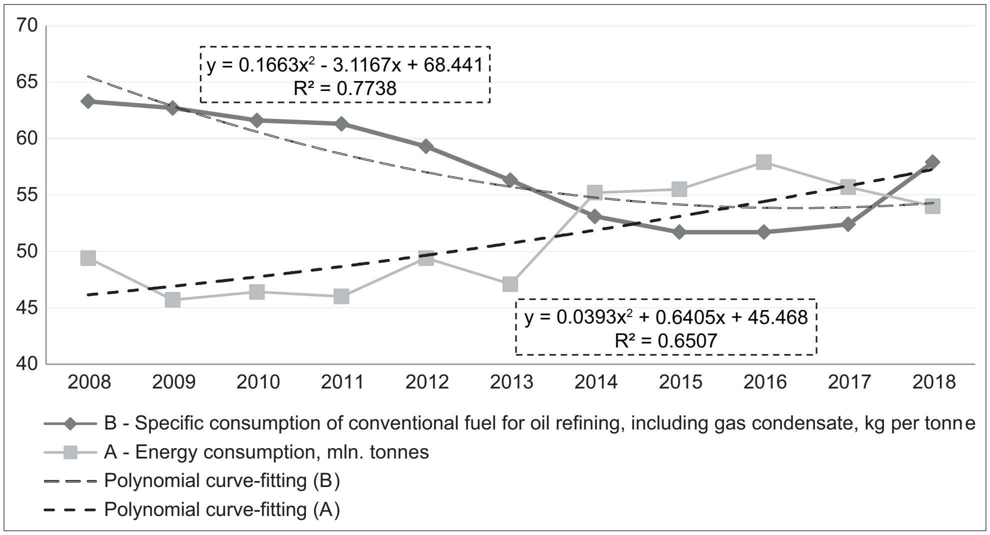
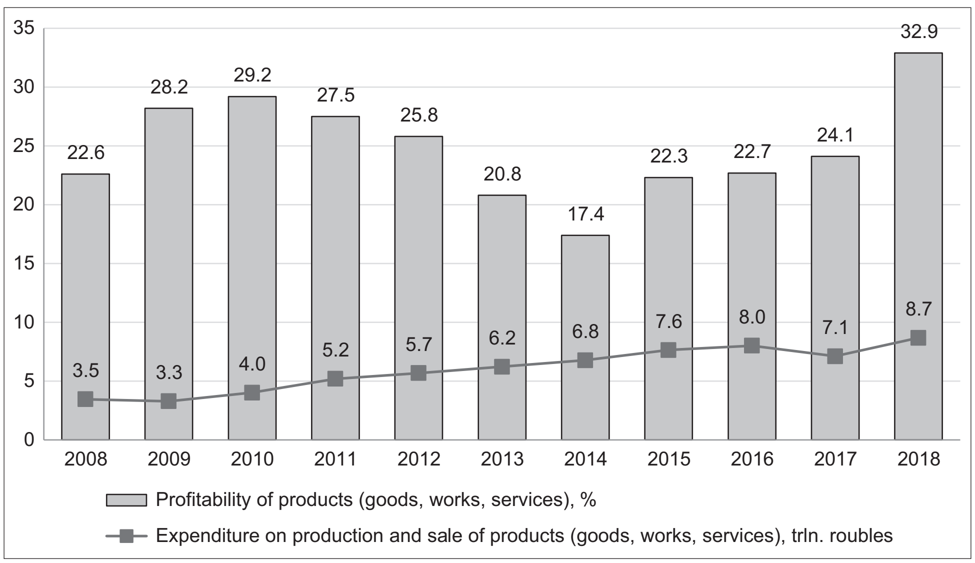


Figure 2: Trends in economic indicators of the functioning of the petroleum and gas sector of the Russian economy (compiled by the authors based on Federal State Statistics Service (Rosstat, 2020))



of such a volume of natural resources that will be sold without additional storage costs. It can be argued that a pushing material flow management system has emerged in the Russian petroleum and gas market, which determines the need to optimize not so much the increase in revenue and profits, but rather to reduce the costs of producing and selling the industry's products, which is especially important in the current economic crisis.

Figure 2 demonstrates, that total costs for the type of activity "Extraction of crude petroleum and natural gas" are growing, which is natural due to objective reasons (reduction of production in other countries), as well as the desire of the Russian economy to overtake competitors in the production market and subsequent sale at favorable prices.

It should be noted that there are positive dynamics in terms of energy intensity. So, for the studied 10 years, there has been a twofold reduction in energy consumption attributable to the total costs of the production and sale of petroleum and natural gas (Figure 3). Also, the share of energy costs in the extractive sector decreased by 26%. Thus, in general, the development of the oil and gas sector of the economy is observed along the resource-saving vector.

At the same time, the specificity of the industry is the separation of a by-product during petroleum production - a mixture of gaseous components. Increase in oil production contributes to the growth of produced associated petroleum gas. The problem of its utilization is one of the key problems of sustainable industrial development, since the consequence of associated gas emissions is environmental pollution, the formation of a greenhouse effect, a negative impact on public health, as well as a negative economic effect in the form of lost profits from the sale of a valuable energy resource. The introduction of modern technological solutions ensures an increase in the level of associated gas utilization, but in dynamics in recent years, the percentage of rational utilization of associated petroleum gas has been decreasing relative to the extremum reached in 2008–2018 of 88% (Figure 4). Thus, with an overall increase in the level of efficient use of associated gas (by the end of 2018 - by 9.6% or 7.4% points), a relative decrease in the environmental responsibility of industrial enterprises has been observed since 2015.

The next important aspect of this study is the study of the progress of the petroleum and gas production sector of the Russian economy within the framework of digital transformation. The costs for the development of information and communication technologies at the enterprises of the industry have significantly increased (3 times over the reporting period), the intensity of interaction with counterparties based on information technology has increased (more than 2 times) (Figure 5).

The experience of "Gazprom Neft" can be cited as an example of the successful implementation of digital solutions. In a pandemic, digital projects provide the ability to carry out installation work remotely through the implementation of virtual reality technologies: a factory engineer equipped with a helmet and VR devices, being in the factory in front of the object, transmits data to the maintenance equipment specialist, regardless of the location of the latter. VR technologies and cameras, therefore, reflect the image of the equipment to the specialist and allow the engineer to consult on the adjustment of the new installed equipment ("Gazprom Neft", 2021). The undoubted advantage of this approach is the cost savings on attracting a foreign specialist, his secondment to an industrial facility, reducing the downtime of work and equipment while waiting for the end of the isolation period. In addition, digital technologies, in particular Big Data, provide opportunities for attracting new customers based on the analysis of an array of data generated by retail chains; improving drilling efficiency (digital drilling); making optimal decisions through the implementation of intelligent fields, and others (Gazprom Neft, 2021). However, the presented example is one of the most successful in the petroleum and gas sector of the Russian economy, and it should be borne in mind that opportunities for such intensive digital development are not available to the entire business sector, which determines the importance of optimizing digitalization costs.

Thus, the dynamic analysis of economic indicators of petroleum and gas sector development, energy consumption of industrial

Figure 3: Indicators of the energy intensity of the petroleum and gas sector of the Russian economy (compiled by the authors based on Federal State Statistics Service (Rosstat, 2020))

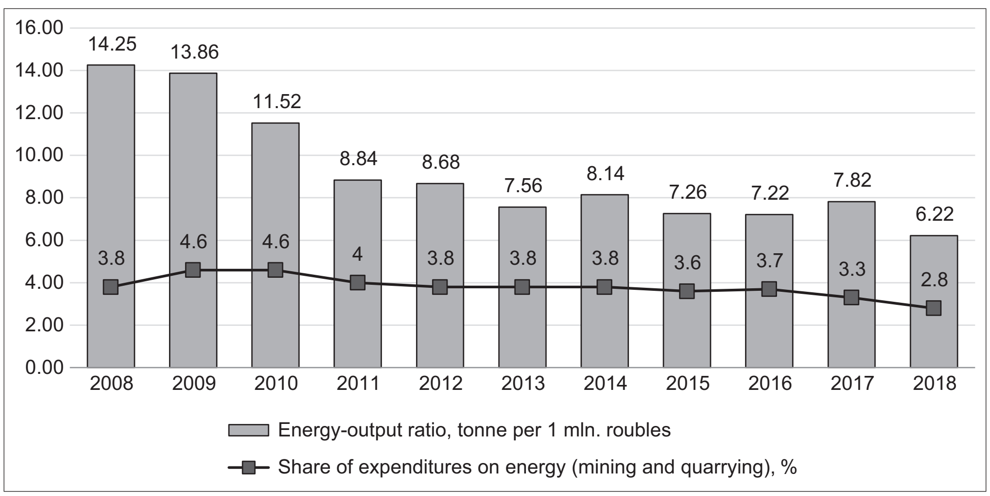


Figure 4: Usage level of petroleum (associated) gas, as a percentage of the total resources of petroleum (associated) gas (compiled by the authors based on Federal State Statistics Service (Rosstat, 2020))

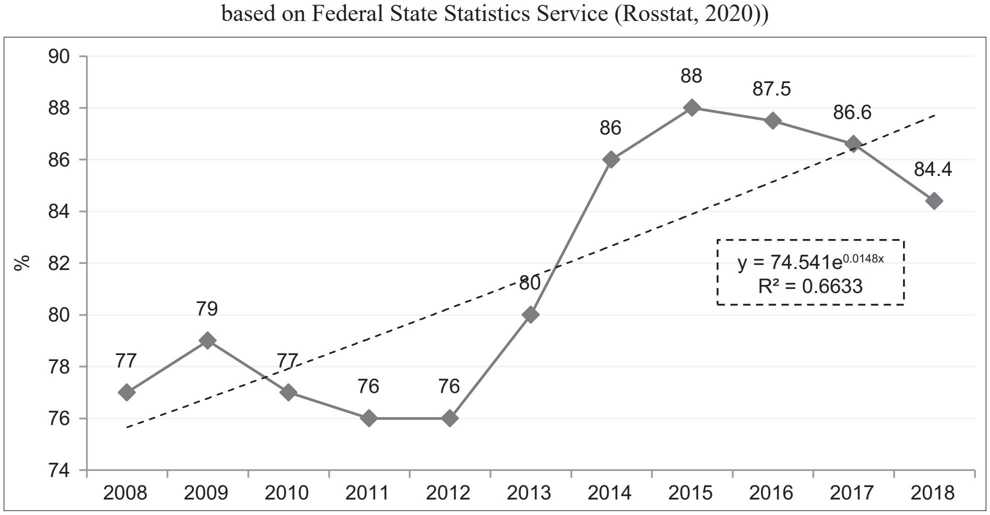
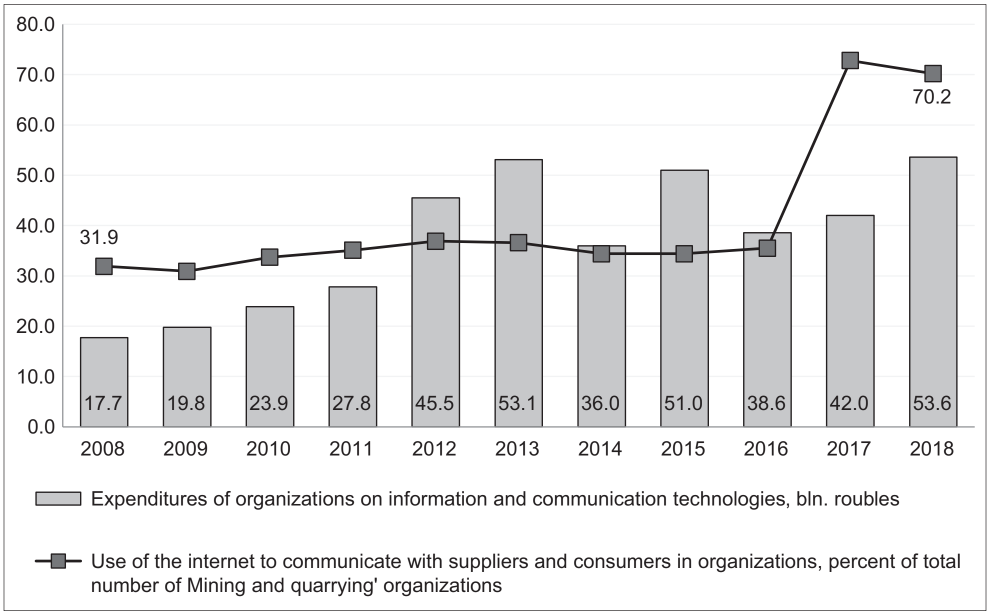


Figure 5: Digitalization trends of enterprises in the extractive industry (compiled by the authors based on Federal State Statistics Service (Rosstat, 2020))



enterprises of the industry, the level of rational use of associated petroleum gas and the digital transformation of the oil and gas sector allows us to assert positive trends in the framework of sustainable resource-saving development, as well as the presence of unrealized potential, to determine which this study is aimed.

4. METHODS AND MODELS

Optimization process of energy efficient functioning of the petroleum and gas sector of the economy through digitalization and resource conservation covers a number of methods aimed at identifying the dependencies between the economic efficiency of the industry and the factors of digitalization and energy efficiency. For this purpose, modeling methods are applied in the work:

1. Cobb-Douglas production function, the classical model of which is the dependence of the activity result of the petroleum and gas sector of the economy on capital investment and labor;
2. Correlation and regression analysis aimed at formalizing the mathematical relationships between the investigated resource saving tools;
3. the solving a linear programming problem that allows to determine the optimal levels of energy consumption and costs for the digital transformation of enterprises in the industry.

The modeling tools are based on an array of data (economic, digital, energy) characterizing the development of the oil and gas sector of the Russian economy in 2008-2018 (table 1). These are indicators:

Y_C – costs of enterprises producing crude petroleum and natural gas for the production and sale of products (goods, works and services) (trillion rubles);

Y_Q – volume of shipped goods and rendered services by mining industry enterprises (trillion rubles);

Y_{PAG} – usage level of petroleum (associated) gas (percentage of the total resources of petroleum (associated) gas);

Y_{LC} – the share of labor costs incurred by enterprises in the extractive sector (%);

x_1 – consumed energy resources by enterprises producing crude petroleum and natural gas (million tons of conventional fuel);

x_2 – the costs of extractive industry enterprises for information and communication technologies, i.e., for digitalization (billion rubles).

The study uses the classic Cobb-Douglas production function model, which reflects the dependence of the sales volume (Y_Q) on the costs of digitalization and labor costs of personnel, which ensures the reliability of the production process and the digitalization of technological and organizational processes:

$$Y_Q = a_{01} * K^{a11} * L^{a21} \quad (1)$$

where K – the costs of extractive industry enterprises for information and communication technologies, i.e., for digitalization, billion rubles;

L – share of labor costs in the extractive sector, %;

a_{01} – coefficient of neutral technical progress;

a_{11}, a_{21} – elasticity coefficients of factors K and L.

The model's adequacy to the initial data is checked on the basis of Fisher's F-criterion. Comparison of the tabular and calculated values of the criterion allows to determine the quality of the equation of the production function, which is recognized as high in the case:

$$F_{calculated} > F_{tabular} \quad (2)$$

where $F_{calculated}$ is determined as:

$$F_{calculated} = (\Sigma(Y_i - Y_{average})^2/m)((n - m - 1)/\Sigma(Y_i - Y_{icalculated})^2), \quad (3)$$

Table 1: An array of data for economic and mathematical modeling of the energy efficient functioning of the petroleum and gas sector of the Russian economy (Rosstat, 2020)

Symbols	Year										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Y_C	3,47	3,30	4,03	5,21	5,69	6,23	6,78	7,65	8,02	7,12	8,69
Y_Q	4,65	4,54	5,47	7,03	7,92	8,16	8,56	9,90	10,17	9,38	13,21
Y_{PAG}	77,00	79,00	77,00	76,00	76,00	80,00	86,00	88,00	87,50	86,60	84,40
x_1	49,40	45,70	46,40	46,00	49,40	47,10	55,20	55,50	57,90	55,70	54,00
K/x_2	17,70	19,80	23,90	27,84	45,51	53,08	35,98	51,00	38,60	42,00	53,60
L/Y_{LC}	10,30	10,80	9,70	8,80	8,90	8,80	8,80	8,80	9,20	8,30	7,50

where m – number of factors,
n – number of observations,
Yi – the actual value of Y_Q for the i-th period,
$Y_{average}$ – average Y,
$Y_{icalculated}$ – Y_Q value for the i-th period, calculated on the basis of the constructed production function.
F_{table} is defined by using Microsoft Excel function:

$$F_{tabular} = F.INV\ (0{,}99;\ m;\ (n - m - 1)) \quad (4)$$

In this case, the confidence level is taken equal to 99%.

Correlation-regression analysis serves to form a formalized foundation for optimizing the energy efficient functioning of the petroleum and gas sector of the economy. A multiple linear regression model of the type is applied:

$$Y = a_0 + a_1 * x_1 + a_2 * x_2 \quad (5)$$

where a_0 – free term of the regression equation,
a_1, a_2 – slopes at x_1, x_2.

Each equation assumes an assessment according to three criteria: the coefficient of determination, which in our case should exceed 0.7 and thus reflect the high accuracy of the selection of variables; Fisher's F-criterion, which must also meet the requirements of inequality (2); Student's t-test, which is evaluated on the basis of a similar inequality:

$$t_{calculated} > t_{tabular} \quad (6)$$

Within the framework of the study, equations were constructed for the dependence on independent variables of such effective indicators as Y_C, Y_{PAG}, Y_{LC}. The indicators of digitalization and energy consumption were selected as independent variables: x_1 and x_2.

Based on the obtained equations of dependence, it is proposed to construct an economic and mathematical model in the form of a linear programming problem, where the objective function is Y_C, focused on the minimum possible value, and restrictions on the level of use of petroleum (associated) gas and labor costs are set. The general view of the model takes the form as:

$$\text{Objective function: } Y_C = a_0 + a_1 * x_1 + a_2 * x_2 \rightarrow \min, \quad (7)$$

and restrictions:

$$\begin{cases} Y_{PAG}: b_1 \le a_3 + 0_4 * x_1 + 0_5 * x_2 \le b_2 \\ Y_{LC}: b_3 \le a_6 + 0_7 * x_1 + 0_8 * x_2 \le b_4 \end{cases} \quad (8)$$

$x_i \ge 1$,
$x_1 \le x_{1\ (ind)}$,
where $x_{1\ (ind)}$ – consumed energy resources by enterprises of the extractive industries as a whole (million tons of conventional fuel).

Thus, the objective function and constraints are multiple regression equations, and the model as a whole is aimed at determining the best values of the independent variables - energy consumption and digitalization costs - within the framework of energy-efficient and resource-saving development.

5. RESULTS AND DISCUSSIONS

The mathematical dependence of the sales volumes of the extractive sector of the economy on capital expenditures for digitalization and labor in the form of the Cobb-Douglas production function equation is revealed.

Earlier, we identified the task of harmonizing supply and demand in the oil and gas market, which determined the need to build the dependence of sales volumes on the digitalization factor, presented as the cost of informatization of industrial enterprises, and on human resources, estimated as the share of labor costs in the total costs of enterprises in the mining sector. Despite the extensive automation of production processes, human potential remains a key source, generating innovative ideas or ensuring the reliable operation of automated systems, as well as the maintenance of equipment and technological chains.

According to the formula (1), the production function is obtained:

$$Y_Q = 84{,}86 * K^{0{,}4} * L^{(-1{,}73)}, \quad (9)$$

where Y_Q – volume of shipped goods and rendered services by mining industry enterprises (trillion rubles);
K – the costs of extractive industry enterprises for information and communication technologies, i.e., for digitalization, trillion. rub.;
L – the share of labor costs in the extractive sector.

The resulting equation allows us to summarize the direct relationship between investment in digitalization and the results of sales activities of industrial enterprises, which confirms the effectiveness and feasibility of the further process of transforming the industry and approaching the moment of integration of individual enterprises into a single digital platform, which, through the development of cooperative ties, will provide a synergistic effect in terms of cost optimization. In accordance with the elasticity coefficient a_{11}, it can be argued that with an increase in the cost of digitalization by 1%, the volume of shipped products will increase by 0.4%.

As for the labor factor, we observe an inverse relationship, that is, an increase in the share of labor costs by 1% will contribute to a decrease in the volume of sales of enterprises in the extractive industry by 1.73%. In this regard, we believe that, on the one hand, the work of qualified personnel requires decent wages, on the other hand, according to the revealed connection, it is not recommended to exceed the achieved level of the share of labor costs for personnel (which will be incorporated as a limitation in the linear programming problem).

It is also possible to judge the labor-saving growth of sales volumes, since the elasticity coefficient of factor K exceeds that of factor L. The sum of the elasticity coefficients in modulus exceeds 1, which indicates an excess of the growth rates of the volumes of shipped goods and services over the growth rates of the variables K and L.

In order to visualize the deviations of the calculated Y_Q data from the actual ones, graphs are built that reflect the approximate values (Figure 6).

The quality of the model is assessed by comparing the calculated and tabular values of the F-criterion according to formulas (3) and (4) with m = 2 and n = 11:

$F_{calculated} = (\Sigma(Yi\text{-}Y_{average})^2/2)\ (8/\Sigma(Yi\text{-}Yi_{calculated})^2) = 28{,}86;$
$F_{tabular} = \text{F.INV}\ (0{,}99;\ 2;\ 8) = 8{,}65;$
$F_{calculated} > F_{tabular}$

Thus, with a probability of 99%, it can be argued that the constructed model is adequate to the actual data characterizing the growth of the extractive sector of the economy against the background of digital transformation and optimization of labor costs.

A complex of economic and mathematical models is proposed, reflecting the relationship between the investigated tools of resource conservation: the performance of petroleum and gas production enterprises, energy efficiency, rational use of oil by-products, and digitalization.

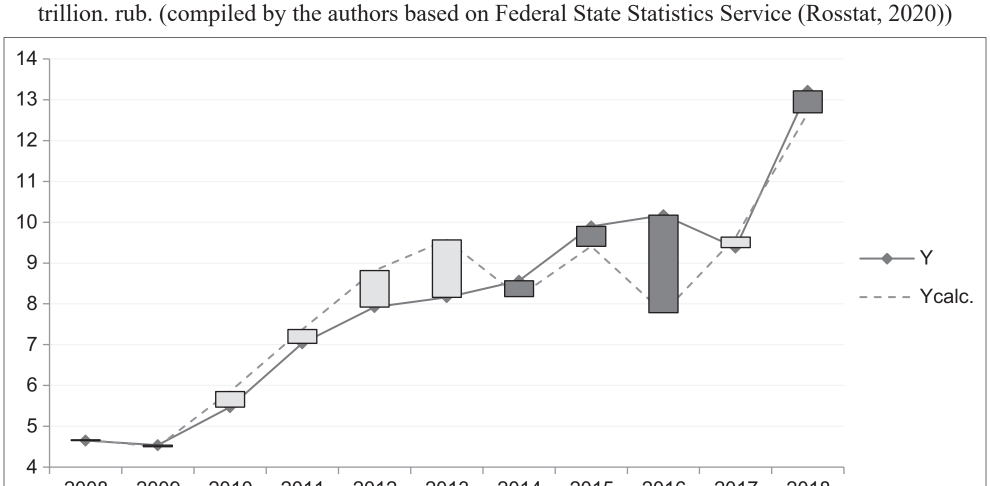
As a result of using Microsoft Excel tools and building models in the format (5), a number of dependencies were obtained, the quality and adequacy of which were assessed at a high level (Table 2).

In the first case, the economic meaning of the equation boils down to an increase in the costs of production and sale of crude petroleum and natural gas enterprises as a result of increased energy consumption and investments in the development of information and communication technologies at industrial enterprises. We observe the predominant influence of energy consumption on the resulting indicator.

Also, the change in independent variables is directly proportional to the efficiency of by-products of petroleum production, which should be interpreted as rationalization of the use of petroleum (associated) gas as a result of additional costs for digitalization (in this case, they can be considered effective), but at the same time attracting additional energy for the installation and operation of petroleum (associated) gas collection systems.

The process of automation and digitalization is associated with a reduction in human resources, which is due to the replacement of manual labor with robotic and automated. This process explains the dependence identified in the third case. The model describing the feedback of independent variables and the share of labor costs in the extractive sector confirms the nature of the changes revealed as a result of constructing the Cobb-Douglas production function (9): rising costs of digitalization contributes to a reduction in the share

Figure 6: Comparison of the actual (y) and calculated (Y') values of the volume of shipped goods and rendered services by mining enterprises, trillion. rub. (compiled by the authors based on Federal State Statistics Service (Rosstat, 2020))



of labor costs. At the same time, digitalization is accompanied by an increase in energy costs due to the replacement of manual (energy-saving) labor with automated (energy-intensive) labor.

The resulting dependencies determine the need to determine the optimal values of energy consumption and investments in digital transformation in the form of costs for the development of information and communication technologies at enterprises of the oil and gas sector of the Russian economy.

An optimization model has been built for the energy efficient functioning of the petroleum and gas sector of the economy through digitalization and resource conservation.

As the target function, the indicator of costs for the production and sale of petroleum and gas was selected, which is determined by the desire of business structures not so much to increase production volumes, creating unprofitable reserves and unclaimed supply, but to increase cost efficiency. In this research the energy consumption and digitalization costs were used as tools for increasing cost efficiency.

According to the formulas (7) and (8), and to the set of the obtained economic and mathematical models, a linear programming problem is built:

Objective function: $Y_C = -7{,}93 + 0{,}21*x_1 + 0{,}08*x_2 \rightarrow \min$,

restrictions:

$$\begin{cases} Y_{PAG}: 88 \le 33{,}13 + 0{,}92*x_1 + 0{,}038*x_2 \le 100, \\ Y_{LC}: 5 \le 12{,}46 - 0{,}029*x_1 - 0{,}051*x_2 \le 7{,}5 \end{cases}$$

$x_i \ge 1$,
$x_1 \le 79{,}9_{(ind)}$.

Limitations on the usage level of petroleum (associated) gas at Y_{PAG} are determined by the maximum achieved value of the indicator for 2008–2018 (88%) and the maximum level of the indicator (100%), and despite the stable decline in the indicator by the end of 2018, we can judge the presence of unrealized potential in terms of the effective use of petroleum by-products.

Limitations on the share of labor costs incurred by enterprises in the extractive sector are due to the results obtained above, reflecting the negative economic effect in the event of an increase in the share of labor costs.

As a result of the search for the optimal solution from the set of possible options, the optimal values of the studied indicators were obtained:

$x_1^* = 56{,}94$ million tons conv.fuel;
$x_2^* = 64{,}81$ billion rubles.

At the same time, the usage level of petroleum (associated) gas will be 88%, the share of labor costs will remain at the level of 7.5% (since it is necessary to take into account the provision of employment for the population), and the costs of enterprises in the petroleum and gas sector of the economy for production and sales will increase to 9.5 trillion rubles (table 3).

As a result of achieving optimal values, the effect will be expressed in a reduction in the energy consumption of processes at the enterprises of the petroleum and gas complex by 0.22 tons, which are attributable to 1 million rubles of costs of petroleum and gas companies for production and sale.

6. FINDINGS AND DISCUSSION

A dynamic analysis of the socio-economic indicators of the petroleum and gas complex of the Russian economy, the growth rate of energy consumption indicators, investments in the digitalization process, as well as the efficiency of using by-products reflects the logical objective dependences of the functioning of various subsystems of industrial enterprises. Informatization process, automation and digitalization processes are accompanied by investments in software, in the purchase of equipment, sensors,

Table 2: Assessment quality of regression models

Dependency equation	Determination coefficient	Fisher's F test	Student's t-test
$Y_C=-7{,}93+0{,}21*x_1+0{,}08*x_2$	0,91	$F_{calcul.} > F_{tabular}$	$t_{calcul.} > t_{tabular}$
$Y_{PAG}=33{,}13+0{,}92*x_1+0{,}038*x_2$	0,83	$F_{calcul.} > 4{,}46$	$t_{calcul.} > 2{,}3$
$Y_{LC}=12{,}46-0{,}029*x_1-0{,}051*x_2$	0,73		

Table 3: Optimization of the functioning of the oil and gas complex of Russia

Indicators	Symbol	Actual value, 2018	Optimizing
Energy resources consumed by enterprises producing crude petroleum and natural gas (million tons of conventional fuel)	x_1	54	56,9
Costs of the extractive industries on information and communication technologies, i.e., for digitalization (billion rubles)	x_2	53,6	64,8
Costs of enterprises producing crude petroleum and natural gas for the production and sale of products (goods, works and services) (trillion rubles)	Y_C	8,7	9,5
Usage level of petroleum (associated) gas (percent of the total resources of petroleum (associated) gas)	Y_{PAG}	84,4	88
Share of labor costs incurred by enterprises in the mining sector (%)	Y_{LC}	7,5	7,5
Energy intensity (ton per 1 million rubles)		6,2	5,99

and modernization of existing production facilities. Technological improvement will be accompanied by additional energy costs (or redistribution in the structure of consumed energy resources), production volumes, despite a temporary reduction on 10% by the end of 2020 (The Ministry of Energy of the Russian Federation, 2021), will grow in the future, which will inevitably lead to an increase in energy consumption. Also, the social aspect in combination with the factors of digitalization and energy saving is not less significant. It is not recommended for petroleum and gas companies to increase the share of labor costs, but it is advisable to maintain the current share. We believe that a further reduction of this indicator in the structure of costs for the production and sale of petroleum and gas products will contribute to a decrease in employment and a subsequent deterioration in the social well-being of society in petroleum and gas producing regions. The abovementioned determines the practical significance of further research of the structure of costs (in particular, material and energy) of petroleum and gas producing enterprises.

7. CONCLUSION

As a result of implementation of a systematic approach to research, covering the versatile aspects of the functioning of the petroleum and gas sector of the Russian economy, in particular, energy-efficient digital resource-saving development, as well as tools of economic and mathematical modeling, a number of scientific results have been achieved.

1. The mathematical dependence of the sales volumes of the petroleum and gas sector of the economy on the costs of digitalization and labor costs has been revealed. The model reflects the direct dependence of the variables, which confirms the effectiveness and feasibility of the further process of transforming the industry and approaching the moment of integration of individual enterprises into a single digital platform, which, through the development of cooperative ties, will provide a synergistic effect in terms of cost optimization.
2. A set of multiple regression equations has been constructed that describe the impact of the costs of energy resources of petroleum and gas enterprises and the costs of digitalization on such resulting indicators as the total costs of enterprises for production and sales, the efficiency of using by-products from oil production and labor capital. The resulting dependencies confirm the need for a rational distribution of costs in the oil and gas sector: maintain or reduce the current level of labor costs, reduce the energy intensity of industrial production and adapt the existing technological infrastructure to the requirements of Industry 4.0.
3. The optimal values of energy-efficient digital resource-saving development of the oil and gas sector of the economy are proposed, according to which the best value of energy consumption exceeds the current one by 5% (in particular, due to the expansion of automation of oil and gas production), digitalization costs - by 20.9%, which will contribute to an increase in sales volumes, respectively, production and sales costs - by 9.4%. As a result of achieving optimal values, the energy consumption of processes at oil and gas enterprises will be reduced by 0.22 tons, which are attributable to 1 million rubles of production and sales costs of oil and gas companies (which is 3.6% lower than the current level).

We believe that in the context of a pandemic, digitalization is acquiring critical importance in terms of managing technological processes, servicing equipment, which necessitates investment in the development of technological and information infrastructure of the oil and gas complex. This statement makes it possible to judge the high practical value of the constructed models for industrial enterprises, since it will provide not only energy saving, but also modernization along the vector of sustainable development.

The research results can be applied within the framework of strategies for socio-economic development, sustainable development, as well as digitalization of the oil and gas complex and industrial enterprises.

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