A dynamic model of the impact of engineering services on the parameters of the economic system

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Abstract. The article presents the author’s approach to the concept of engineering as a service sector of innovative infrastructure. The key components of engineering as a service are identified. A factor analysis of the impact of the engineering services sector on the development parameters of an innovative economy has been carried out. Based on it, a prognostic dynamic model of the contribution of the engineering services sector to the development of an innovative economy is proposed.

1. Introduction

One of the applied aspects of innovation infrastructure services is the provision of consulting services for the real sector of the economy. The need for this market adjustment and increase the adaptability of innovative infrastructure services to industry, as well as to market requirements, is caused by changes in industry at the beginning of the XXI century:

- significant changes in the use of feedstock and materials;
- the transition from oil production and primary processing to the production of petrochemical products with high added value;
- globalization of labor markets;
- a great need for high-tech products with an emphasis on quality indicators and functionality;
- environmental awareness.

In this regard, the emphasis is shifted to the achievement of sustainable production, backed by high quality services both in the production process in technical systems and in the process of using finished products, their disposal and recycling. In this regard, for the industrial sector of the economy, the task of achieving sustainable production is one of strategically important.

Sustainable production in an innovative economy is the design, construction and organization of operation, obtained on the basis of the development and implementation of process innovations, energy-efficient automated technological systems, which can lead to various benefits, including indicators of energy saving, reduction of capital costs, minimization of impact on the environment and improving safety through the introduction of innovative production technologies and the prevention of education waste. A radical reduction in the size of production equipment and production sites and more effective deep processing of raw materials. Sustainable production in the innovative development of the real sector of the economy involves the development of more rational, environmentally friendly, cost-
effective and efficient technological systems that enhance the efficiency of resource use and minimize waste mainly through the introduction of process innovations.

The service sector, as a component of the economic system of the state, is inconceivable without innovative changes aimed at improving the quality of service during the operation of goods, the consumption of services as a final or intermediate category - for example, as the level of service for a certain type of activity. One of the directions of innovative development of the service sector may be its focus on the infrastructure complex of the services sector, which involves differentiating the time period, methods and sequence of modernization of its facilities based on their priority for consumers. In this case, we are talking about “service-innovative or socially-oriented component of the service sector” [1].

One of the key areas of development of the services sector for the real sector of the economy is engineering activity, as a factor in the growth of the scientific, technical and innovative component of the economic system as a whole, providing an increase in high-tech and high-tech products through integration with the field of science and knowledge, which are represented by joint R&D and programs innovation development. Directions for increasing the effectiveness of science and engineering are quite diverse; include chains of interactions and direct and feedback flows.

Based on an analysis of the regulatory framework and publications of researchers on engineering activities, we believe that engineering is a type of service that includes certain subspecies. For example, GOST R 57306-2016 “Engineering. Terminology and basic concepts in the field of engineering ”defines engineering as a type of economic activity, which is primarily a “provision of services”. Distinctive features of the “service” are the obligatory participation of the consumer (customer) in the process of providing the service and consumption of the service in the process of its provision. The service does not involve the transfer of the result of the activity to the customer at a time at the time of completion of work. Nevertheless, since a specific contract in the field of engineering can cover various stages of the life cycle of the created object, the fulfillment of the contract may also involve the transfer to the customer of certain assets having their own value.

Summarizing, we present the author's definition of an engineering service. An engineering service is an independent type of economic relationship arising between a customer and an engineering contractor for a specific project, the distinguishing feature of which is the practical novelty of the engineering services provided and the commercial nature of their provision.

2. Materials and methods

Based on the foregoing, we believe that the modeling of engineering development factors should be tied to the innovative aspects of the real sector of the economy. The specifics of modeling indicators of innovation activity at different levels of economic system management are presented in detail in [2-6]. In this regard, we have selected the following simulated parameters for industrial types of economic activity for 2016-2018:

- the proportion of organizations engaged in engineering;
- cooperation with other organizations in the development of technological innovations, as a percentage of the total number of organizations having technological innovations;
- the proportion of organizations transferring new technologies;
- the proportion of organizations participating in joint research projects from among organizations with technological innovations.

As the research methods during the simulation, the following were used: comparison, component analysis, factor analysis, construction of a dynamic model.

3. Results and discussion

The results of product design and innovation-active production (technical and economic systems) in the provision of innovative infrastructure services include such areas as:
in terms of the production process and products: an increase in the types of products and faster production; higher yield; cost reduction; stability and reliability of technical and economic systems; integration of technological production - optimization based on energy consumption; organization of multi-purpose technological systems; integration / exclusion of individual stages of technological systems; integrated design strategies for energy-efficient technological systems; development of new technologies (for example, for reuse of raw materials); development of new separation methods (for example, isolation); product miniaturization; intensification of technological systems;

in terms of environmental friendliness of production: agreed limits on environmental impact; stimulation of the use of renewable energy sources; carbon credits and quotas trading;

in terms of economic benefits: an increase in the added value created, optimization of production costs and investments in its development; labor productivity growth; shortening the payback period of investments;

in terms of innovation: shortening the period for new products to enter the market, narrowing the gap between fundamental research and development, and timing for new products to enter the market, accelerating the diffusion of innovations, increasing the intensity of innovation costs, increasing the level of innovation activity; development of new technologies (for example, for reuse of raw materials); development of new separation methods (for example, isolation).

In this regard, for a real business, the achievement of innovation-active production through the provision of innovative infrastructure services becomes not only a necessity factor, but also as a factor in achieving innovative activity in order to increase competitiveness. Engineering in an innovative economy, as a type of innovative infrastructure services, in the era of the fourth industrial revolution involves increasing the level of innovative activity of production by servicing the innovative activity of industrial enterprises in all or certain phases of the life cycle of the innovation process.

In the forecast model, the indicator “the proportion of organizations engaged in engineering” (I) will be used as an independent variable, and the most correlated indicators included in the first, most important factor attribute for the development of engineering, which we denote as the following, as independent variables will be used:

- F1 - cooperation with other organizations in the development of technological innovations, as a percentage of the total number of organizations having technological innovations;
- F2 - the proportion of organizations transferring new technologies;
- F3 - the proportion of organizations participating in joint research projects from among organizations with technological innovations.

The analysis tool used is the Statistica software product.

As a result of the regression analysis, the following initial forecasting model was obtained:

\[ I = 1.52 + 0.10 \times F1 - 0.44 \times F2 + 0.58 \times F3. \]

The adequacy of the obtained regression equation is confirmed by the following conclusions:

- the coefficient of determination of the model was 0.61, therefore, a 61% change in engineering services is explained by factors included in the model, namely, cooperation with other organizations in the development of technological innovations, as a percentage of the total number of organizations with technological innovations; the proportion of organizations transferring new technologies; the proportion of organizations participating in joint projects for the implementation of research among organizations with technological innovations;
- statistically significant (p-value less than 0.05) was the parameter F3 - the proportion of organizations participating in joint projects to carry out research among organizations with technological innovations;
the Fisher criterion of the predictive model was 0.0004, which indicates a relatively low statistical error of the model and allows using it for forecasting;
• the average value of the residuals of the model tends to zero, which also indicates the adequacy of the prognostic model;
• there is no autocorrelation in the residues, which is confirmed by the value of the Durbin-Watson criterion (Durbin-Watson = 1.53, with a normative value of 2), which also allows the use of this model for forecasting engineering services.

Based on the presented regression equation, the following conclusions can be drawn that factor F3 is the most influential in engineering activity - the share of organizations participating in joint research projects among organizations with technological innovations, the elasticity coefficient with this factor was 0.58, therefore, an increase in the share of organizations participating in joint research projects from among organizations with technological innovations by 1% will ensure an increase in the share of organizations, carrying out engineering, by 0.58%.

The next most influential factor in engineering services is the F2 factor — the proportion of organizations transferring new technologies, the elasticity coefficient of which was "minus" 0.44, which implies feedback from the dependent variable, therefore, a 1% increase in the number of organizations transferring new technologies leads to a decrease in the share of engineering organizations by 0.44%, which can be explained by two reasons: firstly, or by the insufficient development of the institute for the transfer of technological solutions in the field of engineering services, and secondly, the effect of the effect of "information and personnel leakage", which implies a certain closeness of the engineering services system.

The remaining factor F1 - cooperation with other organizations in the development of technological innovations, as a percentage of the total number of organizations having technological innovations, has an elasticity coefficient of 0.10 with the resulting indicator, therefore, a 1% increase in the level of cooperation will lead to an increase in the share of organizations engaged in engineering, by 0.10%.

Thus, the total positive contribution of the identified factors to the development of engineering services is 0.24 percentage points.

The results of economic and mathematical modeling are somewhat different from the results presented in the studies of the analytical centers discussed above. For example, the results of analytical studies have shown the importance of the personnel component in the provision of engineering services for the industrial sector of the economy, however, according to the results of our model, it is the transfer of new technologies and knowledge that negatively affects the development of the engineering services sector due to weak communication mechanisms between these two sectors. As a result, human resources in the engineering sector are poorly used and affect the level of innovative activity of industrial enterprises. Another contradiction revealed is that integration with external partners in analytical studies is not so significant than what we obtained on the basis of the economic-mathematical model. The results of the regression model showed its greatest impact on the development of the engineering services sector, however, in analytical reports it is not so much expressed as, for example, the staffing of innovation processes, which also confirms the focus on closed innovation models. The joint implementation of research work, which, according to the modeling results, showed an influence on the development of the engineering services, is not mentioned in the analytical reports, therefore, fundamental scientific activity has been moved beyond the activation of innovative processes in the industrial complex, where own fundamental research is predominant without involving intermediaries in form of engineering companies.

To build a medium-term forecast of the volume of engineering services rendered and the share of organizations engaged in engineering, we will change the independent variables within 5%, as a standard assumption in assessing the statistical significance of the prognostic model and the simulated variables included in it. The volume of engineering services rendered was calculated based on the proportion at the starting date of the forecast: for example, the share of engineering organizations was correlated with the volume of engineering services rendered and based on the proportion, having a forecast value for
the share of engineering organizations, the corresponding forecast volume of engineering services rendered was calculated.

Based on the prognostic model, we believe that the share of engineering organizations in the medium term will increase from 19.4% to 22.7%, and the volume of engineering services provided will increase from 67.1 billion rubles to 78.6 billion rubles, providing an average annual growth rate of 105.4%.

4. Conclusions

Thus, the simulation results allow us to conclude and reinforce the conclusions obtained in previous chapters of the work that the development of engineering services will be more efficient and oriented to the needs of the real sector of the economy when introducing open business models into management practices and using open interaction in the innovation sphere, which is confirmed the greatest level of influence on these processes with such indicators as joint cooperation, technological transfer, implementation of joint projects in. We believe that the findings can be taken as the basis for the development of programs and strategies for innovative development of individual industrial organizations and supply chains of innovative products, as well as innovative infrastructure services in general.

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