Simulation Modeling as a Tool for Ensuring Sustainable Development and Competitiveness of an Enterprise

Zaneta Simanaviciene[1], Evgeniy Kislitsyn[2,*] Lyudmila Shaybakova[2]

[1] *Mikolas Romeris University, Vilnius, Lithuania*
[2] *Ural State University of Economics, Ekaterinburg, Russia*
[*] *Corresponding author. Email: kev@usue.ru*

ABSTRACT
The work performed is unique in its kind, since it represents the development of instrumental methods for studying an urgent problem – the increase in competitiveness and ensuring sustainable development of industrial enterprises. The purpose of the study is to develop a system for assessing the impact of institutional factors on the competitiveness and innovation activity of an industrial enterprise. The analytical toolkit is simulation modeling diagrammatically represented by graphical notations illustrating system dynamics model. Based on the available world research, four main components of industrial enterprise competitiveness are identified - the competitiveness of products; strategic positioning; innovation activity of both - the enterprise and the institutional environment; and resource efficiency. Based on the identified components, a methodology for their calculation and for computation of a multiplicative composite indicator describing competitiveness has been developed. The influence of the intra-firm and institutional factors on the enterprise innovation activity is discussed as a separate segment of this method. It is shown that the institutional environment to a greater extent affects the company competitiveness through its innovation activity. The intra-firm factors (such as the enterprise's material, scientific and technical resources, organizational and corporate culture, strategic management) expand the influence of the industrial market institutional environment. Thus, all enterprises located in the same industrial market have equal conditions for their innovative activities. Based on the elaborated system, a simulation model of industrial enterprise competitiveness is developed, which shows it as a set of cause-and-effect relationships and feedback loops. The designed simulation model may be adapted to any manufacturing company and allows simple simulation experiments.

Keywords: *simulation model, competitiveness, innovation activity, institutional environment.*

1. INTRODUCTION

Many research works are dedicated to the study of competition in commodity markets. Various economic theories offer different approaches to studying the phenomenon of competition. Special attention is paid to the competition in industrial markets, the analysis of which is based on the theories of industrial organization, new institutional economics and economic growth. A recent study [1] has revealed that the level of power asymmetry directly affects the economic growth in the industrial market. However, to maintain and stabilize the economic growth, it is necessary to ensure a high level of industrial enterprise competitiveness.

Competitiveness in an industrial context is itself a complex hierarchical structure consisting of many interdependent elements that ensure the efficiency of an enterprise. In many studies, competitiveness is viewed as an integral system that covers almost all aspects of an enterprise's activities. However, the problem with such studies is that they assess a narrow array of independent indicators, neglecting the feedback loops. At the same time, some of the studies from the available pool of works related to the company competitiveness focus only on certain specific features, referring to their basic nature. It is worth mentioning that narrowly focused research in itself, though far from being comprehensive, puts forward new ideas for the development of a unified system for the formation of industrial enterprise competitiveness.

At the same time, the company innovation activity occupies a special place in the system of its competitiveness. The uniqueness of this situation lies in the fact that the company innovation activity is formed both inside the firm and under the influence of the institutional environment [2, 3, 4].

With a huge number of works developing the theoretical and methodological principles of industrial enterprise competitiveness, there is a drastic shortage of available tools in this field. Most often, the basic toolkit is limited to statistical assessment methods and mathematical optimization models of individual segments of the whole picture. However, such tools are not able to reflect the entire process of competitiveness formation in a systemic, holistic manner. Therefore, the main task of this study is to classify and group all components of the competitiveness indicators, which allow assessing the state of industrial enterprise activities, and to develop on this basis a simulation model diagrammatically represented by system dynamics notation.

2. METHODOLOGY

To develop a systemic simulation model of the industrial enterprise competitiveness, it is necessary to study the available approaches to its assessment and analysis. Thus, one of the most popular methods for assessing competitiveness is matrix modeling (the BCG Growth-Share Matrix, Porter's Generic Strategies, the GE–McKinsey Nine-Box Matrix, the Shell Directional Policy Matrix, Hofer - Schendel's Product-Market Evolution Matrix and ADL / LC Models). Undoubtedly, the most commonly used is SWOT analysis, which allows simultaneous investigation of finance, production, marketing, personnel, the enterprise technology and managerial effectiveness. Despite its popularity, this method does not possess the main feature, which is essential for this study - a composite (integral) indicator. In general, all matrix models have another significant drawback - they cannot assess causal relationships that may occur as a company develops its competitive potential. At the same time, the costs of marketing research, which results in construction of the aforementioned matrices, are quite high and inaccessible for most small businesses.

The 4P method for assessing the company competitiveness is based on comparison of four factors in business activities of competitive companies, namely: product, price, placement, and promotion. The essence of the method is expert assessment of the proposed indicators and their comparison with the market leader. This approach is subjective, since the scores are given by experts who may see and analyze the situation fragmentarily.

The analysis of the company internal environment can also serve as a basis for assessing competitiveness. Business profitability, managerial effectiveness, commercial activity and liquidity may be chosen as the competitiveness indicators. Proponents of the theory of workable or effective competition, offer to choose the resource efficiency as such indicator, since this allows taking into account various components of business activity. However, to apply this method, it is necessary to obtain complete information about the company functioning in the market under the study, which can be highly problematic.

The available economic literature [5] allows systematizing and identifying four main components of the company competitiveness - product marketability, strategic positioning, resource efficiency and innovation activity (Table 1). The integral indicator of competitiveness is multiplicative (this type has been chosen due to the fact that all factors are interdependent and produce an effect only if they are considered in the aggregate) and is based on the identified constituent units:

$$K = \alpha \times K_{\mathrm{Pr}od}^{\beta_1} \times SP^{\beta_2} \times RE^{\beta_3} \times IA^{\beta_4} \qquad (1)$$

where KProd is the product marketability, SP – the level of strategic positioning in the market, RE – resource efficiency, IA – innovation activity, α, β – model coefficients.

Within the framework of this study, the authors propose to expand the category of strategic positioning and to include in its assessment not only the company's share in the market, but also the level of its market power:

$$SP = CR_C \times K_B' \qquad (2)$$

where CRC is the company market share, and KB' – the normalized Bain Index.

To assess the efficiency of resources used by the company, the authors apply the resource approach [6], which allows calculating the resource efficiency by the following formula (3):

$$RE = \alpha \times \sum_{i=1}^{6} (\beta_i \times \frac{V}{IR_i}) \qquad (3)$$

where V is the total revenue, IRi – the volume of investments in the i-th resource, α – the normalization

factor for the resource efficiency indicator, βi – the resource significance coefficient.

The innovation activity of an industrial enterprise is the most important component of its competitiveness [7; 8; 9]. It consists of such indicators as innovation policy, implemented projects, technologies and patents, R&D, etc. A specific feature of this competitiveness component is that the innovation activity is formed under the influence of both the intra-firm institutions and the institutional environment.

The intra-firm institutions create conditions for the growth of the company innovation activity. The main factors of such activity within an industrial enterprise are its material, scientific and technical resources. In addition, the primary engine of innovation activity is the corporate culture at the enterprise. Its influence contributes to the formation of innovative susceptibility and the necessary competitive spirit within the company. Another factor is the organizational structure and management system, which should be flexible, autonomous and decentralized, if characterized from the point of view of the innovation activities. To ensure a high level of innovation activity, the organizational structure should have a small number of management levels, democratic leadership and the predominance of horizontal ties.

Strategic planning is another link in the chain of the intra-firm factors influencing the company innovation activity. Though the internal factors are extremely important, at the same time, they are difficult to measure. For example, at present there is no universal technique to measure the level of corporate culture or the level of strategic planning at an enterprise. When studying the organizational structure of management, the assessment is possible only by experts, who should take into account the specific parameters that have been identified by the authors of this article earlier.

It is also difficult to overestimate the influence of the industrial market environment and institutions on the innovation activity of individual enterprises. The main feature of the institutional environment is the market competitive nature. To assess the competitive landscape, the authors offer to use the concept of power asymmetry, which consists of three elements: structural, interactional and institutional asymmetry [10]. Structural asymmetry reflects direct and indirect market inequality and is measured based on the values of the Bain, Hall-Tydeman and Herfindahl-Hirschman indices. Interaction asymmetry reflects the level of inequality between the industrial market and the adjacent organizational fields. Institutional asymmetry reflects the institutional incentives and constraints existing on the market:

$$PA = SA \times IA \times IEA \quad (4)$$

where SA is the level of structural asymmetry, IA – the level of interactional asymmetry, and IEA – level of institutional asymmetry.

In addition to the competitive environment, another factor of innovation activity is the educational and research environment. This indicator may be attributed to the fact that the national economy is showing a noticeable tendency to workforce downsizing in the scientific and technical sector and the overall reduction of R&D workforce. To assess the human resource potential within the framework of this article, the authors take into account the quantitative indicators characterizing the number of university graduates (bachelor's and master's degrees) and the average professional level of graduates in the areas of their specialization correlated with the types of activity specified in the Russian National Classifier of Economic Activity Types. To assess scientific activity in the industrial sector, the authors use quantitative indicators showing the number and percentage of theses defended for scientific degrees in sciences correlated with the types of activities specified in the Russian National Classifier of Economic Activity Types.

The third factor of the institutional environment is the financial environment. This indicator reflects the level of investments in research and development (grants and federal targeted programs), which in the Russian Federation lags far behind similar indicators in the countries of the European Union. Many researchers argue that the slowdown in the innovative development results from inadequate financial support of innovators by the government. In addition to the amount of funds allocated for R&D, this indicator also takes into account the institutional incentives that contribute to the development of innovations. Tax benefits and exemptions are some of such stimuli to business.

$$Fin = \alpha \times V_{Fin} + \beta \times T \quad (5)$$

where VFin is an indicator showing the volume of public investment in research and development, and T is an indicator of tax benefits.

It follows from the above, that the development of the institutional environment is a direct factor influencing the development of the company innovation activities in the industrial markets. The indicator of innovation activity consists of its two basic components:

$$IA = II \times IE \quad (6)$$

where II is the indicator showing the influence of the internal institutions, and IE - the influence of the external institutional environment.

3. RESULTS

Based on the goals of the chosen research method, a simulation model of the company competitiveness diagrammatically represented by the system dynamics

notation has been developed. The choice of the notation is determined by the high level of the model abstraction, when specific details are not reflected, but the system is graphically represented in the form of data store circles and arrows reflecting data flows. In addition, there are causal relationships and feedback loops between the indicators, which also contributed to the choice of the system dynamics notation. The rules require that at the first stage of the system dynamics modeling, the main indicators should be identified, namely, - competitiveness and 4 of its components: product competitiveness, strategic positioning, resource efficiency and innovation activity (Fig. 1).

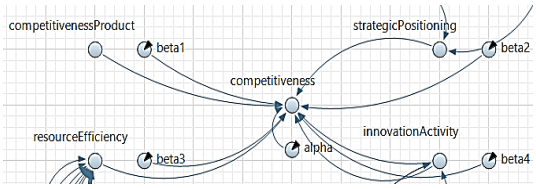

Figure 1 Causal loop diagram of the competitiveness indicator.

The model basic indicators are dynamic variables (or computer model objects) that allow changing formulas directly while programming. During the model simulation, the variables will dynamically change their values which allows tracing the main trends and predicting the growth of the company competitiveness. Coefficients α and β act as parameters due to the fact that they are exogenous and do not change during the simulation experiment. Their values are calculated by building regression models from panel data (within one industrial market for a period of 10 years).

The dynamic variable reflecting the value of strategic positioning is calculated by the above mentioned formula and depends on two dynamic variables - the Bain index and the market share. These indicators are also presented as dynamic variables, since they reflect dependencies that change over time. The variable reflecting the total market size deserves special mention since it is the sum total of the data obtained from other enterprises (Fig. 2).

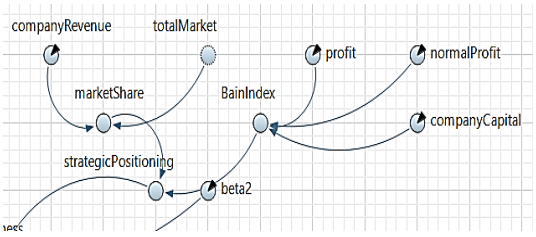

Figure 2 Causal loop diagram of the strategic positioning indicator.

The resource efficiency is calculated using the previously proposed method. The main task here is to calculate the influence of each type of resource on the overall efficiency. It should be noted that within the same branch of industry, the efficiently evaluating elasticities of each resource taken separately, coincide (Fig. 3).

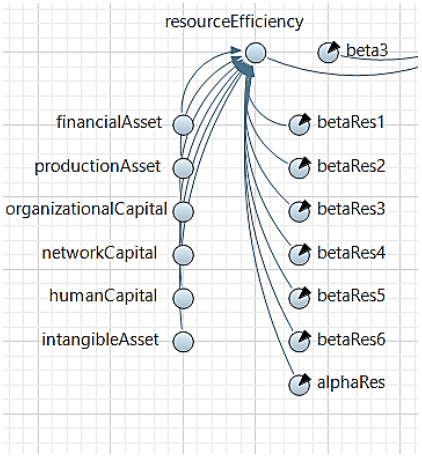

Figure 3 Causal loop diagram of the resource efficiency indicator.

The authors pay particular attention to the company innovation activity, which consists of two integrated elements – the intra-firm factors and the institutional environment. The influence of the intra-firm factors at this stage of the research is represented only by an indicator which describes the material, scientific and technical resource. This may be explained by the impossibility to study the other factors mentioned in this work since the timeframe was too limited. However, these factors are also embedded in the model and can be added later.

The influence of the institutional environment is comprehensively reflected in the corresponding dynamic variable. This influence depends on (or rather, is multiplied by) four components - the competitive, scientific-educational, financial and regulatory environments. Each of them is presented in the form of the same dynamic variable that changes under the influence of these factors (Fig. 4).

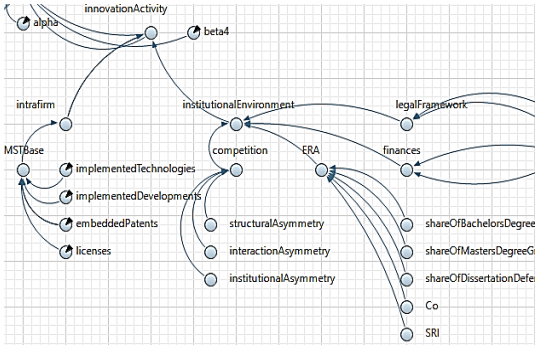

Figure 4 Causal loop diagram of the innovation activity indicator.

The developed simulation model contains an integrated approach to the analysis and forecasting of the company competitiveness. It reflects the degree of

influence of each individual factor, which come together to form a whole system by establishing cause-and-effect relationships. Further work over this model will make it possible to transform it into an agent-based model, in which two main agents will be developed - the enterprise and the institutional environment.

4. CONCLUSION

As a result of the study, the following significant results were obtained:

1. Based on the available research works studying the competitiveness of industrial enterprises, the main factors for its achievement were identified - the competitiveness of products, strategic positioning, resource efficiency and innovation activity. These factors are combined into a single method that allows calculating a composite competitiveness index.

2. Since the study focuses mainly on the innovation activity of an industrial enterprise, this approach allowed systematizing the factors influencing such activities. It is proved that the innovation activity is influenced by both the intra-firm factors and the institutional environment. On the basis of this idea, an original system for calculating the level of innovation activity of an industrial enterprise was developed. The authors took into account the fact that the innovation activity of the enterprises operating in the same industrial market is influenced by the institutional environment in the same way, but each company may enhance it in different ways due to the intra-firm interactions. The influence of the institutional environment is represented by four of its components - competitive, scientific-educational, financial and regulatory.

3. A simulation model of the company competitiveness was developed, which displays it as a set of cause-and-effect relationships and feedback loops. The model reveals the dependence of the resulting indicators on the intra-firm factors and the institutional environment. The model allows carrying out simple experiments. Besides, it may be expanded and adjusted it to any industrial enterprise and any market.

REFERENCES

[1] S.V. Orekhova, E.V. Kislitsyn, Influence of power asymmetry on economic growth of industry markets: A Russian case, Espacios 2019.

[2] N.V. Lazareva, O.V. Takhumova, Yu.N. Krivokora, Model of Small Business Development and Its Competitiveness. In: Conditions of Institutional Transformations, 6 (2018), pp. 755-762.

[3] A.S. Veselova, L.S. Veselova, Internationalization, innovations, institutions as drivers of competitiveness for Chinese companies, Innovations, 4 (2017) pp. 103-108.

[4] N.V. Malcev, L.F. Shaybakova, Evaluation of the Innovation activity Efficiency While Developing the Sectoral Technology Policy in the Region, In: Solovev D. (Ed.), Systems and Technologies, FarEastCon, 138 (2019), Smart Innovation, Systems and Technologies pp 858-868.

[5] D.S. Voronov, I.S. Pelymskaya, A dynamic approach to monitoring the competitiveness of machine-building enterprises in the region. Economics and management of control systems, 3.1 (33) (2019) pp. 115-122.

[6] S.V. Orekhova, Institutional choice factors of a resource strategy for firms. J. of Institutional Studies, 8(4) (2016) pp. 106–122.

[7] K. Fantazy, S.A. Tipu, Exploring the relationships of the culture of competitiveness and knowledge development to sustainable supply chain management and organizational performance. J. of Enterprise Information Management, 32(6) (2019), pp. 936-963.

[8] X. Zhao, B. Sun, The influence of Chinese environmental regulation on corporation innovation and competitiveness. J. of Cleaner Production, 112 (2016) pp. 1528-1536.

[9] G. Dosi, M. Grazzi, D. Moschella, Technology and costs in international competitiveness: From countries and sectors to firms. Research Policy, 44(10) (2015) pp. 1795-1814.

[10] S.V. Orekhova, E.V. Kislitsyn, Yu.S. Bausova, Study of Power Asymmetry in Industry Markets: A Russian Case. J. of Applied Economic Sciences, 13 5(59) (2018) pp. 1181-1190.