Рукопис опубліковано:

Zakharkin O. Modeling of the impact of innovation activity of enterprises on the efficiency of their activities / Zakharkin Oleksii, Zakharkina Liudmyla // Středoevropský věstník pro vědu a výzkum. – Praha.: Publishing house Education and Science. – 2015. – № 7 (20). – P. 12–19.

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MODELING OF THE IMPACT OF INNOVATION ACTIVITY OF ENTERPRISES ON THE EFFICIENCY OF THEIR ACTIVITIES

Abstract. The estimation of the real influence of innovations on the results of the enterprise activities is quite difficult process. In this article scientific-methodological approach to the estimation of the influence of innovations on the effectiveness of enterprise activities is worked out. The preponderance of usage of the suggested approach is the possibility of estimation of the influence of innovations on the results of enterprise' operational activities both directly (through the change of the financial markers, included in the list of determinate indexes), and indirectly – through the estimation of the influence of latent indexes through the latent component, which is different from the statistical margin of area.

Keywords: level of innovational activity, level of effectiveness of enterprise activity, "X-efficiency" concepts.

Introduction. The real influence of innovations and the manifestation of their positive impact on the company's results is a quite complex and versatile process. In large measure, this interconnection could be formalized through the net profit, cost, and productivity indexes. However, latent (hidden) influence of innovations remains substantial, which is associated with qualitative changes in the production, stimulation of production and organization of the working process. To provide a quantitative assessment of such impact through deterministic parameters is practically impossible. The complex nature of the influence of innovations on the results of an

enterprisers' work, a combination of their quantitative and qualitative parameters causes the necessity of application of appropriate methodological approaches to evaluation of the impact of innovation on the effective enterprisers' activity.

Analysis of recent researches and publications. Theoretical, methodological, methodical and practical aspects of the manner of the influence of innovations on the results of enterprise activities was researched in the works of many scientists, especially: Copeland T., Koller T., Murrin J. (2005) [1], Fatkhutdinov R. A. (2002) [3], Illiashenko S. M. (2010) [4].

Along with that, questions of the establishment of the definite interconnections between the influence of innovations and the effectiveness of the enterprise functioning still remain unrevealed.

Aim of the article is to formalize the interconnection of the innovations and the results of the enterprise activities and to identify the corresponding quantity markers, which characterize them.

1. The theoretical basis of economic-mathematical research

1.1. Boundary methods for assessing effectiveness as the basis for simulation the impact of innovation on the enterprisers' activity.

Based on the imposed investigations' tasks, we believe boundary methods for assessing the effectiveness (methods of frontier analysis) to be reasonable. Their essence consists in determining the extent of deviation of the actual level of enterprise functioning efficiency from the maximum possible, the potential level of efficiency with existing capital and labor resources, and identifies factors that caused this deviation.

Within the bounds of the development of methodological approach to modeling the impact of innovation activities of enterprises uses the "X-factor" or "X-efficiency" concepts. H. Leibenstein is the author of approach to efficiency estimation with the definition of the factor X-inefficiency, who [6] investigated the differences in achieved by the companies the results (amount of their products) for the same level of technology and capital in his

work, and explaining this by the presence of the maximum level of efficiency. Among these factors, scientist identified the imperfect system of remuneration and motivation of employees, the presence of conflict of interests between owners and top management, etc.

Let us consider innovation as X-factor performance in the proposed guidance approach, which is based on the assumption that under the same operating conditions innovation-active enterprise will be more effective than enterprises that are not conducting innovation activities.

1.2. The construction of economic-mathematical model

The construction of economic-mathematical model, which corresponds to the empirical data and research objectives, is proposed to carry out in the following stages:

1. Problem setting and formalization of the model, including the choice of the objective function, identification of deterministic and stochastic factors effect, the definition of the tools of economic-mathematical modeling.

2. The formation of the information researches' basis, choice of the method to normalize the input data and ensuring their homogeneity

3. The formation of an alternative variants of constructing of the functional form of the under study model and determining the type of distribution for the random multiplier, which is characterized by the level of influence of latent factors on the target parameter

4. Specification of the economic-mathematical model by defining specific functional form of the model and the type of distribution of the random component using the criterion of maximum credibility

5. The calculation of values of the deterministic model parameters and random multiplier, the evaluation of "X-inefficiency" " with the usage of special software for frontier analysis (Frontier 4.1).

6. Qualitative interpretation of the results.

Stages of the offered scientific-methodological approach were described in details in work [7]. The pattern is generalized in the picture 1.

The first stage Problem setting	**- specification of the aim of research** *(formalization of the influence of innovation activity of enterprises on the effectiveness of their activity);* **- choice of the target function** (*as the target function it was chosen the maximum of the index of the income from the operational activity (OP*): $$OP_{it} = f(\beta; X_{it}) + (\upsilon_{it} - u_{it}),\ i = 1,..., N,\ t = 1,..., T,$$ *OP_{it} - value (logarithm) of profit of the i enterprise operating activities in the period of time t; β – vector of unknown parameters; X_{it} – vector of controlled deterministic variables of the i enterprise in the period of time t; υ_{it} – statistical error; u_{it} – component of inefficiency which reflects influence of the vector of controlled latent variables;* **- identification of the determinate and stochastic factors of influence** (*the composition of the influence factors on the amount of profit of operating activities looks as follows (table.1)*); **- choice of the instruments of the economical-mathematical modeling**
The second stage Information base of research	**- the formation of information base of research;** **- stabilization of the income index from the operational activity in order to avoid substractive results according to the formula**: $$OP_{it} = OP_{it}^{*}, \qquad OP_{it}^{*} = OP_{it} + \lvert -OP_{it}\ \max \rvert + 1$$ **- stabilization of the input and output data through the passing to the relative indexes**
The third stage Of the functional dependence modeling and random element's distribution	**а) functional dependence:** Model 1 (Cobb-Douglas production function): $$\ln(OP_{it}) = \beta_0 + \beta_1 \ln(C_{1it}) + \beta_2 \ln(C_{2it}) + \beta_3 \ln(C_{3it}) + +\beta_4 \ln(E_{it}) + \beta_5 \ln(A_{it}) + (\upsilon_{it} - u_{it})$$ Model 2 (Translogarithmic function): $$\ln(OP_{it}) = \beta_0 + \beta_1 \ln(C_{1it}) + \beta_2 \ln(C_{2it}) + \beta_3 \ln(C_{3it}) + \beta_4 \ln(E_{it}) + \beta_5 \ln(A_{it}) + \beta_6 \ln(C_{1it})^2 +$$ $$+ \beta_7 \ln(C_{2it})^2 + \beta_8 \ln(C_{3it})^2 + \beta_9 \ln(E_{it})^2 + \beta_{10} \ln(A_{it})^2 + \beta_{11} \ln(C_{1it}) \ln(C_{2it}) + \beta_{12} \ln(C_{1it}) \ln(C_{3it}) +$$ $$+ \beta_{13} \ln(C_{1it}) \ln(E_{it}) + \beta_{14} \ln(C_{1it}) \ln(A_{it}) + \beta_{15} \ln(C_{2it}) \ln(C_{3it}) + \beta_{16} \ln(C_{2it}) \ln(E_{it}) + \beta_{17} \ln(C_{2it}) \ln(A_{it}) +$$ $$+ \beta_{18} \ln(C_{3it}) \ln(E_{it}) + \beta_{19} \ln(C_{3it}) \ln(A_{it}) + \beta_{20} \ln(A_{3it}) \ln(E_{it}) + (\upsilon_{it} - u_{it})$$ **в) type of random element's distribution :** - truncated; - semi-normal.
The fourth stage Specification of the economic-mathematical model	**- formation of the matrix of the logarithmic input;** **- choice of the type of the function and the type of the distribution of the random element using the rule "likelihood-ratio test":** $$LR = 2(l_L - l_S) = \frac{2 \ln L_L}{L_S},$$ l_L, l_S – the value of logarithmic function of likelihood of long and short models correspondently.
The fifth stage of The model's parameters	**- calculation of the value of the determinated model parameters and random element** using the necessary software Frontier 4.1; **- estimation of level of "x-inefficiency"**
The sixth stage Interpretation of the results	**- rating of the enterprise** according to its level of effectiveness; - **comparative analysis** of the indexes of innovation activity of the enterprises and their financial results, taking into account calculated values of effectiveness

Picture 1 – Scientific- methodological approach to the estimation of the influence of innovation activity on the effectiveness of the enterprise's functioning (compiled by the authors).

According to the author's approach the composition of the deterministic influence factors on the amount of profit of operating activities looks as follows (table.1)

Table 1 – Composition of the vector of deterministic factors for the calculation of the efficiency level of enterprise innovative activities (compiled by the authors).

Name of variable	Index	Economic content
The input parameters of the production process		
C_1 ($costs_1$)	The amount of the operating activities expenses per revenue unit	Characterizes the effectiveness of the enterprise's current activities
C_2 ($costs_2$)	The amount of expenses per revenue unit	Characterizes the enterprise orientation for technological renovation and activities expansion
C_3 ($costs_3$)	The amount of research and developments expenses per revenue unit	Characterizes enterprise innovation activities in research work and developments
Output parameters of the production process		
OP (operating profit)	The amount of net operating profit per revenue unit	Determines the efficiency (profitability) of enterprise innovation activities
Extra parameters		
E (Employees)	The number of employees (for European enterprises) or the average number of employees per 1 enterprise in a given industry (for national enterprises)	Characterizes the scope of enterprise activities; indirectly reflects productivity
A (Assets)	The market capitalization (for European enterprises) or total assets per 1 enterprise (for national enterprises)	Reflects the scope of enterprise activities and its property base; indirectly characterizes enterprise opportunities for the implementation of innovations

It should be noticed that in the table 1. the set of control variables there are only indexes with deterministic impact on profit of operating activities. At the same time the influence of the latent factors on the target indexes can be substantial, which leads to the necessity of taking them into account when constructing the objective function along with the vector of deterministic variables.

1.3. Summarizing

The advantage of propounded scientific-methodological approach application is the possibility to estimate the influence of the innovations upon the results of the operational activities of the enterprise both directly (by the change of corresponding financial rates, enlisted into determinate parameters – research and development expenses and substantial expenses) and indirectly by means of latent parameters estimation through the random component, which is different from static error.

2. An approbation of valuation model of dependence of enterprises innovation activities and their effectiveness on the illustration of European companies

2.1 An Analytical Base

In order to guarantee the adequacy of informational support, having being used in the model, the mass of input data was formed exclusively out of statistical sources of Eurostat [2]. In order to provide comparability homogeneity of indexes, the data concerning companies was investigated in the perspective of separate groups, which were composed according to the indication of sectored appurtenance and the basic direction of the enterprises activities. Stochastic analysis of European companies' effectiveness was carried out in the perspective of chemical industry enterprises and the basic subdivisions of machine manufacturing, which are highlighted according to the ICB («Industry Classification Benchmark») classification. [5]. It has to be noticed that in this research the factor of national appurtenance of the enterprises to the EU was not taken into consideration, because we consider, that this factor doesn't play for the enterprises under study a significant role, because of conditions of high level of integration and convergence of the countries' markets of the given region and also taking into account the international character of the most companies' activities, which are under study.

2.2 The Results of the Approbation of the Model

While analyzing the results of the research, we can make a conclusion, that for the most companies under study, the rating, given to them according to the results of the evaluation of effectiveness matches the rating of innovation activities. In order to demonstrate it more clearly, let us present the formed valuations of the rating for the enterprises of EU in the table 2.

Table 2. – The comparative analysis of the valuations of the rating for the European enterprises according to the level of effectiveness and innovation activities (compiled by the authors).

Name of the enterprise	The rating according the level of effectiveness	The rating according the level of the innovation activities
Chemical industry (totally 47 enterprises under study)		
Mitsui Chemicals	1	7
Auriga Industries	2	2
Showa Denko	3	16
Johnson Matthey	4	37
Sumitomo Chemical	5	5
Nippon Kayaku	6	11
Teijin	7	8
Mitsubishi Chemical	8	4
…	…	…
Avery Dennison	47	40
Production of the building construction and materials (11 enterprises)		
Nippon Sheet Glass	1	1
Taiheiyo Cement	2	5
Kajima	3	4
…	…	…
Aerospace and defense industries (19 enterprises)		
Ultra Electronics	1	11
Thales	2	3
Rockwell Collins	3	9
SAAB	4	4
…	…	…
United Technologies	19	17
General purpose industrial grade production (12 enterprises)		
Cookson	1	4
NGK Insulators	2	6
…	…	…
General Electric	12	11

Name of the enterprise	The rating according the level of effectiveness	The rating according the level of the innovation activities
Electrical equipment production (14 enterprises)		
Vacon	1	10
SPX	2	13
Fuji Electric	3	1
…	…	…
Laird	14	6
Electronic equipment production (24 enterprises)		
Barco	1	7
Sharp	2	6
Ingenico	3	11
JP Radio	4	2
…	…	…
Molex	24	21
Production of industrial carrier vehicles (8 enterprises		
Deere	1	5
…	…	…
Caterpillar	8	6
Production of equipment, industrial machines and mechanisms (33 enterprises)		
Vitec	1	12
Duerr	2	7
Georg Fischer	3	9
…	…	…
Illinois Tool Works	33	32

By summarizing the data, given in the table 2, we can make a conclusion, that the interdependence of the level of the innovation activity with the level of effectiveness of enterprises' activities is proved in about 70-75% of cases. Errors or significant discrepancies in the analyzed rates can be predetermined by the following reasons:

- the calculations of ratings are made by using average evaluations for the period under study, during which some significant discrepancies may occur;

- a criterion of innovation activities was used being mere quantitative parameters (the coefficient of correlation of innovative expenses to the amount of the enterprise's capital). At the same time the quality of innovation strategy, organizational particularities of the establishment of innovations as well as other inherent factors, which may have an influence on the results of innovations were not taken into consideration;

- the distribution of enterprises into groups was made merely according to the characteristic of branch appurtenance and it has been adjusted upon the scale of activities, that's why there can be revealed apparent some significant discrepancies in the establishment of industrial enterprises' business of the one group, that are not related to branch specialization.

Conclusion. On the basis of approbation of scientific-methodological approach to the data of European enterprises of chemical industry and the enterprises of 7 machinebuilding subindustries for the period of 2003-2010, it was proved the existence of the interconnection between the level of the enterprise' innovation activity and effectiveness of their activities. According to the results of research of 70-75% of the analyzed enterprises, it is approved the statement that the higher rating of the enterprise according to the level of innovation activity (according to the proportion of the expenses for innovations and enterprise capital) responses to its higher rating according to the level of effectiveness, defined on the basis of the establishment of the bounds of the effectiveness by the methods of stochastic analysis.

Despite the denoted simplifications, which were permitted in the model, the suggested scientific-methodological approach allows to make accurate enough research of interdependence between the levels of innovation activity and of enterprises' effectiveness.

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