ІННОВАЦІЇ

UDC 338.45+330.341.1(477)

N. V. Biloshkurska, Candidate of Economic Sciences, Associate Professor,
M. V. Biloshkurskyi, Candidate of Economic Sciences, Associate Professor,
V. A. Omelyanenko, Candidate of Economic Sciences

EVALUATION OF UKRAINIAN INDUSTRY INNOVATIVE DEVELOPMENT WITH A TECHNOLOGICAL PROGRESS PARAMETER

Urgency of the research. *Methodology of evaluation of the level of Ukrainian industry innovation development under the parameter of technological progress is urgent, since it involves the use of publicly available statistical data and reflects the impact of the innovation process on the production.*

Target setting. *The evaluation of the level of innovation development of industry in Ukraine as a whole as well as the largest enterprises, representatives of the main types of industrial activity, should be implemented through the dynamic simulation of J. Tinbergen's production function.*

Actual scientific researches and issues analysis. *The basic methodological principles for technological progress evaluation are laid by such scholars as J. Tinbergen, R. Solow, J. Moroney and C. Ferguson et al. Ideas for evaluating innovation development of national economy as a whole, as well as individual enterprise in particular, have not lost their importance today.*

Uninvestigated parts of general matters defining. *The researchers have not yet sufficiently worked out the problems of evaluating the level of innovation development of industrial production, taking into account its conformity with technological progress and marginal rate of technical substitution.*

The research objective. *It is necessary to evaluate the level of innovation development of Ukrainian industry taking into account the conformity of production with technological progress and the proportionality of production resources in accordance with the marginal rate of technical substitution.*

The statement of basic materials. *The production function simulation under J. Tinbergen's for the Ukrainian industry is implemented. The value of the technological progress parameter and the marginal rate of technical substitution for 10 enterprises of different types of industrial activity have been calculated. The methodological support for evaluating the level of innovation development by developing the "Marginal rate of technical substitution – Technological progress parameter" matrix has been improved. The positioning of the investigated enterprises on the proposed matrix is carried out.*

Conclusions. *The reliability of the evaluation of the level of innovation development both for the economic sector and for the individual enterprise depends on the results of the production function simulation of J. Tinbergen and is provided by developing a "Marginal rate of technical substitution – Technological progress parameter" matrix.*

Keywords: *technological progress; marginal rate of technical substitution; production function; industry; factor; capital.*

УДК 338.45+330.341.1(477)

Н. В. Білошкурська, к. е. н., доцент,
М. В. Білошкурський, к. е. н., доцент,
В. А. Омельяненко, к. е. н.

ОЦІНКА РІВНЯ ІННОВАЦІЙНОГО РОЗВИТКУ ПРОМИСЛОВОСТІ УКРАЇНИ ЗА ПАРАМЕТРОМ ТЕХНОЛОГІЧНОГО ПРОГРЕСУ

Актуальність теми дослідження. *Методичне забезпечення оцінки рівня інноваційного розвитку промисловості України за параметром технологічного прогресу є актуальним, оскільки передбачає використання публічно доступних статистичних даних і відображає вплив інноваційного процесу на виробництво.*

Постановка проблеми. *Оцінку рівня інноваційного розвитку промисловості України в цілому та найбільших підприємств, представників основних видів промислової діяльності, необхідно реалізувати шляхом моделювання виробничої функції Я. Тінберґена в динаміці.*

Аналіз останніх досліджень і публікацій. *Базові методологічні основи оцінки технологічного прогресу закладені такими вченими, як Я. Тінберґен, Р. Солоу, Дж. Мороні і С. Фергюсон та ін. Ідеї щодо оцінки інноваційного розвитку як національної економіки в цілому, так і окремо взятого підприємства зокрема, не втратили своєї важливості і сьогодні.*

Виділення недосліджених частин загальної проблеми. *Дослідниками ще недостатньо опрацьовані проблеми оцінки рівня інноваційного розвитку промислового виробництва з урахуванням його відповідності технологічному прогресу та граничної норми технологічної заміни.*

Постановка завдання. *Необхідно провести оцінку рівня інноваційного розвитку промисловості України з урахуванням відповідності виробництва технологічному прогресу та пропорційності виробничих ресурсів згідно граничної норми технологічної заміни.*

Виклад основного матеріалу. *Реалізовано моделювання виробничої функції Я. Тінберґена для промисловості України. Розраховано значення параметра технологічного прогресу та граничної норми технологічної заміни для 10 підприємств різних видів промислової діяльності. Удосконалено методичне забезпечення оцінки рівня інноваційного розвитку шляхом розробки матриці «Гранична норма технологічної заміни – Параметр технологічного прогресу». Проведено позиціонування досліджуваних підприємств на запропонованій матриці.*

Висновки. *Достовірність оцінки рівня інноваційного розвитку як сектора економіки, так і окремого підприємства залежить від результатів моделювання виробничої функції Я. Тінберґена і забезпечується шляхом розробки матриці «Гранична норма технологічної заміни – Параметр технологічного прогресу».*

Ключові слова: *технологічний прогрес; гранична норма технологічної заміни; виробнича функція; промисловість; фактор; капітал.*

ІННОВАЦІЇ

DOI: *10.25140/2410-9576-2018-2-1(13)-23-28*

Urgency of the research. Nowadays intellectual capital becomes a key economic resource under the conditions of a developed information society and the transition from industrial economics to knowledge economy. Therefore, the development of its intellectual capital and further formation of intellectual potential becomes crucial by forming the competitive advantages of national economy. These features of the post-industrial society allow us to focus on the relevance of education as a type of economic activity in general and higher education in particular, in the structure of the national economy.

Target setting. In order to ensure the reliability and transparency of the evaluation level of Ukrainian industry innovation development, it is necessary to take into account the technological progress parameter and the marginal rate of technical substitution on the basis of publicly visible data.

Actual scientific researches and issues analysis. Basic methodological principles for technological progress evaluation are laid by such scholars as J. Tinbergen [1], R. Solow [2], J. Moroney and C. Ferguson [3] et al. Ideas for evaluation of innovation level both national economy as a whole and individual enterprise in particular, have not lost its importance today.

Uninvestigated parts of general matters defining. Economists have not yet sufficiently worked out the problems of evaluating the level of industrial production innovation development, taking into account its conformity to technological progress and the limit of technical substitution.

The research objective. The main purpose of the research is to implement the evaluation of the level of innovation development of Ukrainian industry, taking into account the conformity of production with technological progress and the proportionality of production resources in accordance with the marginal rate of technical substitution.

The statement of basic materials. Proper evaluation of the level of innovation development of Ukrainian industry is possible only with a number of requirements: firstly, the methodological provision of such an evaluation should be based on real (official) statistical data available in public access; secondly, the research should cover a significant time lag of at least 10 years and reflect the dynamics; thirdly, the object of evaluation must simultaneously be the subject of the innovation process.

It should be noted that nowadays the decisive factor in the innovation development of the industrial sector of the economics is the time factor. It can be considered from the point of view of time saving time as a result of the company participation in the innovation process, or matching of its technological potential with the current innovation dynamics. It means that the efficiency of industrial and economic activity of industrial enterprises is conditioned by the fact that their level of innovation development corresponds to existing innovation technologies in the industry, or keeps ahead of them, and the result of their use is a real time saving of time and other production resources. Here you can talk about extended intensive reproduction, and in the opposite case, when the innovation development of the enterprise is provided by outdated technologies that do not correspond to the technological progress in the industry, – about simple extensive reproduction.

The foregoing allows adding another important requirement to the methodological provision of evaluation of the level of innovation development of Ukrainian industry, namely – the time factor, the formalization of which is realized in autoregressive dynamic economic and mathematical models and can be used in our research. Compliance with all the requirements set to the methodological support of evaluation of innovation development of Ukrainian industry provides the following multiplicative dynamic model of J. Tinbergen's production function:

$$\mathrm{Q} = \mathrm{A}\,\mathrm{K}^{\alpha}\,\mathrm{L}^{\beta}\,e^{\gamma t}, \tag{1}$$

where Q – is the result of the production and economic activity of the evaluation object (the volume of production or sale of industrial products (goods, works, services) in physical or in cash, or income from sales);

K – factor of physical capital (cost of fixed assets or non-current assets, or aggregate assets, etc.);

L – labor factor or factor of human capital (average number of employees or annual wage fund);

parameter A – is a free member (numeric value Q, if $\alpha = \beta = \gamma = 0$);

parameter α – coefficient of elasticity of production volume under the physical capital factor (for how many % Q will increase by K growth of 1%);

parameter β – coefficient of elasticity of production volume under labor factor (or factor of human capital) (for how many % Q by L growth of 1%), with $\beta = 1 - \alpha$;

parameter γ – parameter of technological progress or coefficient of elasticity of production volume according to technological progress;

e – the Euler number (the basis of the natural logarithm);

t – factor of technological progress (serial number of the year) [4, p. 227].

A key component of the given J. Tinbergen's dynamic model of production function is the "technological progress parameter γ" which in our study will reflect the level of innovation development of industrial production at both macro and micro levels. Thus, in the case of $\gamma > 0$, it is concluded that the innovation development of the research object corresponds to the existing technological progress, since advanced modern technologies are introduced into production, the workplaces are automated as well as logistic processes, which ultimately provides an additional increase of $+\gamma$% of output (or sales) of industrial products and the growing return on the scale of production. Then the technological progress parameter $\gamma > 0$ will act as an indicator of extended intensive reproduction. In the opposite case ($\gamma < 0$), the innovation dynamics of the research object can be considered extensive, which corresponds to a simple reproduction, since the introduced innovation technologies in production are outdated, "lagging" from the new ones, in connection with which the firm loses $-\gamma$% of the release (or sale) of industrial products due to the downward impact on the scale of production as a result of inconsistencies in technological progress. For further use in the simulation, let's write the formula (1) in logarithmic form:

$$\ln \mathrm{Q} = \ln \mathrm{A} + \alpha \ln \mathrm{K} + (1 - \alpha) \ln \mathrm{L} + \gamma \mathrm{t}. \quad (2)$$

Having made a number of algebraic transformations, in the form acceptable for modeling the innovation development of industrial production, we write the J. Tinbergen production function as follows [5, p. 59]:

$$\ln \mathrm{Q} - \ln \mathrm{L} = \ln \mathrm{A} + \alpha\,(\ln \mathrm{K} - \ln \mathrm{L}) + \gamma \mathrm{t}. \quad (3)$$

In order to assess the level of innovation development of Ukrainian industry, it is advisable to carry out a simulation of J. Tinbergen's production function for the largest enterprises by types of industrial activities, that take part in the innovation process, which total volume of sales is 5% of the total volume, total assets – 7% of the total volume, and the number of employed workers – 4% of the total number on industry in general (Tab. 1).

Table 1

List of analyzed enterprises by types of industrial activities engaged in innovation process

Name of the type of industrial activity for the CCEA-2010	Enterprise	USREOU code
1. Extraction of crude oil and natural gas	PJSC "Ukrnafta"	00135390
2. Extraction of stone and brown coal	PrJSC "DTEK Pavlogradugol"	00178353
3. Production of food products	PJSC "Myronivsky Hliboproduct"	25412361
4. Manufacture of beverages	PrJSC "Kalsberg Ukraine"	00377511
5. Manufacture of tobacco products	PrJSC "Imperial Tobacco Production Ukraine"	20043260
6. Manufacture of chemicals and chemical products	PJSC "DniproAzot"	05761620
7. Production of basic pharmaceuticals	PJSC "Kyivmedpreparat"	00480862
8. Metallurgical production	PJSC "Southern mining and processing plant"	00191000
9. Machine-building, except for repair and installation of machinery and equipment	PJSC "Motor Sich"	14307794
10. Production, transmission and distribution of electricity	PJSC "DTEK Dniproenergo"	00130872

Source: created on the basis of [6; 7]

To simulate the production function of J. Tinbergen, we form the initial statistical and intermediate calculation data according to the formulas (1-3) for the period of 2002-2016 for each industrial sample of the company (Tab. 2) and carry out statistical information processing. The obtained results of simulation are given in Tab. 2.

Table 2

Ranking of Ukrainian industrial enterprises by the parameter of technological progress

Enterprise	Parameter A	Income elasticity under total capital (*α*)	Income elasticity under human capital (*β*)	Marginal rate of technical substitution (MRTS)	Technological progress parameter (*γ*)	R^2	F
PrJSC “DTEK Pavlogradugol”	13.838	0.190	0.810	-0.235	0.215	0.992	625.6
PJSC “DTEK Dniproenergo”	34.313	0.230	0.770	-0.299	0.173	0.974	226.0
PJSC “DniproAzot”	19.566	0.274	0.726	-0.378	0.160	0.985	388.4
PJSC “Southern mining and processing plant”	11.249	0.358	0.642	-0.558	0.155	0.937	89.5
Industrial production as a whole	13.963	0.323	0.677	-0.477	0.127	0.978	268.7
PJSC “Kivmedpreparat”	39.354	0.188	0.812	-0.231	0.142	0.974	223.9
PJSC “Ukrnafta”	15.722	0.342	0.658	-0.520	0.121	0.905	57.0
PrJSC “Kalsberg Ukraine”	8.959	0.567	0.433	-1.309	0.102	0.914	63.4
PJSC “Motor Sich”	0.679	0.971	0.029	-33.313	0.009	0.965	164.5
PrJSC “Imperial Tobacco Production Ukraine”	33.722	0.518	0.482	-1.077	-0.001	0.920	57.5
PJSC “Myronivsky Hliboproduct”	1.629	0.948	0.052	-18.296	-0.074	0.960	144.2

Source: created by the authors on the basis of the annual financial statements of enterprises [7] and the official website of the State Statistics Service of Ukraine [8]

The results of modeling the innovation development of Ukrainian industrial enterprises, given in Tab. 2, are indicative of their high statistical significance and reliability, since all the values of the determination coefficient R^2 are approximate to 1, and the actual values of the F-criterion are in large excess over the tabular ones. In addition, 2 indicators, namely the marginal rate of technical substitution (MRTS) and the parameter of technological progress (*γ*) is the key one in assessing the level of innovation development. The first index reflects the cost of human capital to compensate the reduction of 1 million UAH of physical capital, while the value MRTS < -1 indicates the predominance of the physical capital factor over human capital in the structure of productive resources (characteristic of PJSC “Myronivsky Hliboproduct”, PrJSC “Kalsberg Ukraine”, PrJSC “Imperial Tobacco Production Ukraine” і PJSC “Motor Sich”), and MRTS > -1 – on the significance of the factor of labor or human capital (typical for PJSC “Ukrnafta”, PrJSC “DTEK Pavlogradugol”, PJSC “DniproAzot”, PJSC “Kyivmedpreparat”, PJSC “Southern mining and processing plant” і PJSC “DTEK Dniproenergo”). The second index, in case of *γ* > 0, reflects the correspondence of the enterprise to technological progress (typical for all sample enterprises, except PJSC “Myronivsky Hliboproduct” і PrJSC “Imperial Tobacco Production Ukraine”) and, accordingly, a satisfactory level of innovation development.

To complete the analysis, it is expedient to compare the obtained values of MRTS and the parameter γ of each sample enterprise with the values of these indices for industrial production as a whole, having formed the matrix "Marginal rate of technical substitution – Technological progress parameter" (Fig. 1).

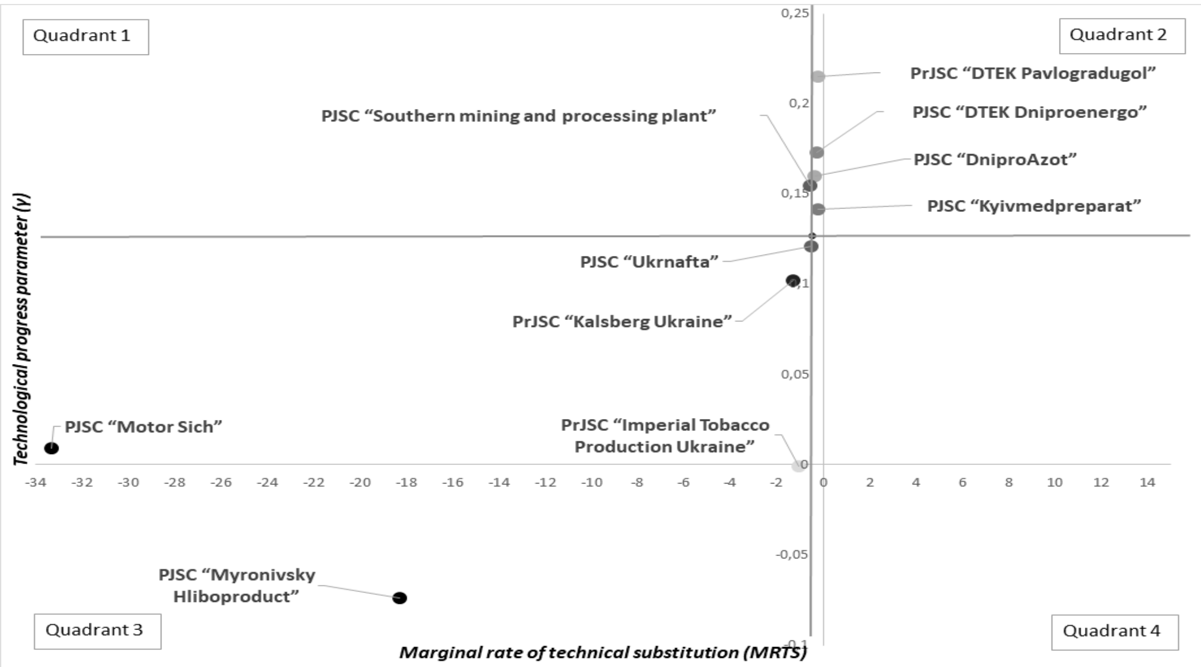

Fig. 1. Positioning of industrial enterprises on the matrix "Marginal rate of technical substitution – Technological progress parameter"
Source: created by the authors

From the data of Fig. 1 it can be seen that only the metallurgical enterprise, namely the PJSC "Southern mining and processing plant", was found in the quadrant 1 of the matrix. It is characterized by higher values of the marginal rate of technical substitution and the parameter of technological progress, than for the industry as a whole. Notable is the lack of enterprises in quadrant 3 of the proposed matrix, characterized by worse value of these indices than in general for industry, as well as the predominance of human capital over physical in the structure of productive resources, which may indicate a low level of labor automation and mechanization. The following four enterprises are found in the quadrant 2 of the proposed matrix "Marginal rate of technical substitution – Technological progress parameter" – PrJSC "DTEK Pavlogradugol", PJSC "DniproAzot", PJSC "Kyivmedpreparat" i PJSC "DTEK Dniproenergo", for which typical is the predominance of the labor factor (or human capital) over physical capital, as well as the degree of compliance with technological progress, higher than for the industry as a whole. The most enterprises are found in the quadrant 3 of the proposed matrix "Marginal rate of technical substitution – Technological progress parameter", namely: PJSC "Ukrnafta" (labor factor prevails), PrJSC "Kalsberg Ukraine" and PJSC "Motor Sich", which innovation development corresponds to technological progress, but it is worse than the industry as a whole; PJSC "Myronivskyi Hliboproduct" and PrJSC "Imperial Tobacco Production Ukraine", which lag behind technological progress (innovation development takes place extensively), but where physical capital is the prevailing factor in the structure of productive resources. None of the investigated enterprises was included to quadrant 4.

Conclusions. Thus, according to the results of the conducted evaluation of the level of innovation development of Ukrainian industry under technological progress parameter, we can draw the following conclusions: first, the proportionality of Ukrainian industry is characterized by the marginal rate of technical substitution -0,48, which indicates twice as higher significance of the factor labor (human capital), compared with the factor of physical capital, the low level of mechanization and automation of modern industrial production and means that the saving (reduction) of 1000 employed in industry it is possible to compensate by 2 million UAH of total assets; and secondly, the results of the simulation of the production function of J. Tinbergen of ten industrial enterprises of different types of activities are reliable and statistically significant, therefore the obtained values of the marginal rate of technical substitution and the parameter of technological progress, after comparing it with the data of industrial production in general, are combined in the author's matrix "Marginal rate of technical substitution – Technological progress parameter"; Third, the positioning of the investigated industrial enterprises on the proposed matrix can increase the reliability of the evaluation of their innovation level as both the parameter of technological progress and the marginal rate of technical substitution, taking into account the proportionality of production resources – physical and human capital.

References

1. Tinbergen, J. (1942). On the theory of long-term economic growth. *Weltwirtschaftliches Archiv*, 10, 511–549 [in English].

2. Solow, R. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, *39, 3,* 312–320 [in English].

3. Moroney, J. R. & Ferguson, C. E. (1970). Efficient estimation of neoclassical parameters of substitution and biased technological progress. *Southern Economic Journal*, 37, 2, 125–131 [in English].

4. Tinbergen, J. & Haag, D. (1973). Exhaustion and technological development: a macro-dynamic policy mode. *Zeitschrift für Nationalökonomie*, 33, 213–234 [in English].

5. Biloshkurska, N. V. (2015). Upravlinnia promyslovym vyrobnytstvom v Ukraini: innovatsiinyi aspekt [Management of industrial production in Ukraine: innovative aspect]. *Ekonomichnyi prostir – Economic space*, *98,* 54–62 [in Ukrainian].

6. State Statistics Service of Ukraine (2011). Klasyfikatsiia vydiv ekonomichnoi diialnosti (KVED-2010) [Classification of Types of Economic Activities (CTEA-2010)]. *ukrstat.gov.ua.* Retrieved from http://kved.ukrstat.gov.ua/KVED2010/kv10_i.html [in Ukrainian].

7. Ofitsiinyi sait Ahentstva z rozvytku infrastruktury fondovoho rynku Ukrainy [Official site of the Agency for the development of the stock market infrastructure of Ukraine]. *smida.gov.ua.* Retrieved from: https://smida.gov.ua [in Ukrainian].

8. Ofitsiynyi sayt derzhavnoyi sluzhby statystyky Ukrayiny [Official site of the State Statistics Service of Ukraine]. *ukrstat.gov.ua.* Retrieved from: http://www.ukrstat.gov.ua [in Ukrainian].

Література

1. Tinbergen, J. Zur Theorie der Langfristigen Wirtschaftsentwicklung / Jan Tinbergen. – Weltwirtschaftliches Archiv. – Vol. 55. – 1942. – P. 511–549.

2. Solow, R. Technical change and the aggregate production function / R. Solow // The Review of Economics and Statistics. – 1957. – Vol. 39 (3). – P. 312–320.

3. Moroney, J. R. Efficient estimation of neoclassical parameters of substitution and biased technological progress // J. R. Moroney, C. E. Ferguson // Southern Economic Journal. – 1970. – Vol. 37. – No. 2. – P. 125–131.

4. Tinbergen, Jan. Exhaustion and technological development: a macro-dynamic policy model / Jan Tinbergen, Den Haag // Zeitschrift für Nationalökonomie. – 1973. – Vol. 33. – P. 213–234.

5. Білошкурська, Н. В. Управління промисловим виробництвом в Україні: інноваційний аспект / Н. В. Білошкурська // Економічний простір. - 2015. - № 98. - С. 54-63.

6. Класифікація видів економічної діяльності (КВЕД-2010) [Електронний ресурс]. – Режим доступу : http://kved.ukrstat.gov.ua/KVED2010/kv10_i.html.

7. Офіційний сайт Агентства з розвитку інфраструктури фондового ринку України [Електронний ресурс]. – Режим доступу : https://smida.gov.ua.

8. Офіційний сайт державної служби статистики України [Електронний ресурс]. – Режим доступу : http://www.ukrstat.gov.ua.

The research was publicly funded by Ministry of Education and Science of Ukraine for developing of research project № 0117U003855 "Institutional and technological design of innovation networks for Ukraine national security systemic providing".

Received for publication 25.12.2017

Бібліографічний опис для цитування :

Biloshkurska, N. V. Evaluation of Ukrainian industry innovative development with a technological progress parameter / N. V. Biloshkurska, M. V. Biloshkurskyi, V. A. Omelyanenko // Науковий вісник Полісся. – 2018. – № 1 (13). Ч. 2. – С. 23-28.