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I. Lukianenko

MODELING OF THE INNOVATIVE ACTIVITY OF THE UKRAINIAN INDUSTRIAL ENTERPRISES

This paper aims to evaluate the effect of innovation on the efficiency of the activity of the Ukrainian industrial enterprises. The research is focus not only on the estimation of the most important determinant of the innovation but also of the detection of the Ukrainian firms with higher probability to success. Using generalized Tobit model, it was found that exporters and firms with larger profits and wages are more likely both to innovate and succeed in innovation. Therefore, efficient firms should be supported by government in the first place. The other finding of the modeling results is that the indirect support measures, such as tax relieves within free economic zones, are found to be inefficient and could not be used as the key instrument of the stimulation of the innovative activity of the Ukrainian enterprises.

Keywords: modeling, innovation, industrial enterprises, determinants, financial support, investment, Tobit model.

Introduction and problem formulation. Many theoretical and empirical works have proven that innovation is one of the main determinants of economic growth. The importance of innovation[1] for economic growth has been shown first of all in the classical works of Schumpeter, Solow, Romer, Stizlitz and many others [4; 9; 11; 12; 13]. A comprehensive survey of empirical papers showing a positive link between a country's welfare and its technological level can be found in some papers of western and Ukrainian researchers [2; 13; 15]. All these investigations argue that usage of newer technologies not only increases profits of firms that own them, raises labour productivity, wage, and, consequently, social product, it also raises the quality of social life measured by such aspects as population educational level, ecological situation and other. Hence, innovation produces positive externalities for a society. However, because innovative projects have large sunk cost and higher risk, private investment into them is usually lower than socially optimal. Thus government action to correct this market failure is justified [5; 6; 10].

The majority of countries in the world have introduced various programs supporting firm-level technological development. By looking at international experience, two main patterns of Research and Development (R&D) promotion can be distinguished. Countries with relatively developed technologies usually withdraw from supporting near-market R&D concentrating instead on basic and pre-competitive research, i.e. financing basic science and innovative projects at the very early stage of their development. Countries with less developed technologies involve into R&D of existing firms more heavily providing fiscal incentives and/ or R&D or capital grants even to international companies willing to bring new technologies to existing enterprises.

Since Ukraine belongs to the second group of countries, a less risky and more optimal strategy for it is introduction of a support program for innovative projects on existing enterprises[2]. However, for the efficient use of funds of such a program (minimizing support of potentially failing enterprises while maximizing that of potentially successful ones), program participants should be carefully selected [6; 8; 10; 15]. Hence, the knowledge of the distinctive features of firms that could be successful innovators is very important. Among the factors influencing probability and intensity of innovation demand factors (in particular, firm's operations on foreign markets), quality of human capital, past successes of a firm (profitability and capital investment) can be considered as the major factors. The other actual problem that need of the detailed investigation is the testing of the influence of existing policy measures, namely, state or local budget subsidies for innovation, tax burden, the

[1] In the literature innovation is usually defined as development of new (previously non-existent) products and technologies. In Ukrainian legislation the definition of innovation also includes purchase of technology previously absent in the country or considerably improved compared to similar technologies. In this paper we stick to the latter definition.

[2] We should note, however, that no firm-level support program would be effective if the macroeconomic environment of a country is not investment-friendly (weak property rights protection and contract enforcement systems, corruption etc.). Also, practically nothing has been done to improve information flows between business and research institutions, which is very important for innovation, as can seen from experience of other countries.

impact on firms located in free economic zones. The solving of the mentioned problems is very important for the support of innovative activity of the industrial enterprises.

Analysis of the last publications and the parts of the problem not solving. A large part of empirical literature on innovation determinants deals with testing a well-known Schumpeterian hypothesis [14]. The hypothesis says that innovative activity grows with firm size and market concentration since firms enjoying monopoly profits (usually those are larger firms) have more *resources* to invest in R&D: they can buy research equipment, hire more qualified labour and undertake risky projects[3]. On the other hand, as noted by Arrow, perfectly competitive environment provides the greatest *incentives* for innovation [1]. If we combine these two sides of the medal, we come up to the idea expressed be many scientists who find an inverted-U relationship between competition and innovation [4; 7; 8]. Their message is that in order to start innovating, a firm must have some degree of market power (to earn positive economic profit which it can invest), but incentives to innovate such as entry threat, are also crucial. Other authors do not support this view. For example, Himmelberg, Petersen and others find a positive relationship between R&D intensity and firm profit margin [7; 8; 10]. Blundell, Griffith, Van Reenen find not only a positive link between market share and innovation (although authors stress that *product* competition on the market stimulates innovative activity) but also that positive influence of innovation on firm's market value rises with the increase of its market share [3]. In other words, firms with higher market share have not only greater *opportunities* (larger retained profit) but also more *incentives* to invest in innovation because each innovation brings them higher market value increase than to firms with lower market share [2; 5].

Other studies also devoted to the link of firm size and innovation [8; 10]. Concerning innovation, firm size is a proxy for such unobservable firm characteristics as management style (bureaucratic in large firms, informal in small ones), access to finance (easier for larger firms), competitive pressure (greater for smaller firms) or, alternatively, market power. Usually, it is found that small firms can keep up with larger ones in the field of innovation because they have greater innovation intensity [4]. However, there is no unanimity on the shape of relationship between firm size and innovativeness. Besides creation of investment-friendly economic environment, financial support to new ideas is very helpful. However, to make this support more efficient, the government should invest into firms with higher probability of success. To select these firms, it is important to know their distinguishing features.

This why the deeply investigation of the problems connected with the estimation of the effective determinants of innovation as well as the determination of the firms with higher probability of success is very important and requires the use of the mathematics methods and models.

Therefore, the object of this paper is to estimate the most important determinants of innovation of Ukrainian industrial enterprises and to find among them the firms with higher probability of success on the base of the elaborated generalized Tobit model.

The main results of the study. The deep analyse of the different empirical and theoretical studies shows that the majority of researchers agree that firm size significantly influences its innovation pattern; firm size and innovativeness are non-linearly related and this relationship depends on production technologies and therefore differs by industries[4].

The difference in innovation patterns between industries is very substantial and found almost in every study of innovation. Other authors insisted on exclusive importance of economic incentives for appearance of innovation. Naturally, both versions are correct to some extent. More over, in the last time some of the researchers propose to distinguish two types of industries by innovation patterns: Schumpeter Mark I (characterized by technology widening or creative destruction) and Schumpeter Mark II (technology deepening or creative accumulation). Industries of the first type have relatively easy entry and noticeable scale (or network) effect. Industries of the second type are capital-intensive with an important role of learning-by-doing.

This why in the elaborated Tobit model we also proposed to use the two measures of firm size: an ordered dummy dividing firms in categories of 50–99, 100–249, 250–999 and over 1000 employees (firms with less than 50 employees is the base category) and log of average annual employment. We also include the square of the last variable to

[3] A large firm can undertake several projects at a time, and possible losses from some of them will be covered by profits on others.

[4] For example, R&D in pharmaceutical industry requires a lengthy research and expensive equipment whereas innovation in software industry can be produced by rather quickly and with PC's only.

catch possible non-linearity of the relation. It is also clear that not only quantity but also quality of labour force (*human capital*) influences firms' innovativeness. To control for it, we include into the regression the average wage variable (usually more skilled employees have higher wages).

Industry dummies control for possible differences between firm sizes and wages determined by the nature of production process and labour supply/demand factors. Industry dummies are constructed according to State Service of Statistic[5] classification and include *extraction (mining)*, *food industry* (processing of agricultural products), *light industry* (clothes and shoes), *paper production* and *wood-processing*, *chemical* (including coke and oil processing), *non-metal mineral products* (mostly construction materials and glass), *metallurgy*, *machine-building*, and *utilities* (production and distribution of energy, gas and water). The base category is "*other*" industry which includes production of small furniture, sports goods production, paper and cardboard processing, scrap metal processing etc.

State support becomes more important in economies with underdeveloped financial markets, such as (post) -transition economies. So, the *government subsidies* have large positive influence on innovation activity of large and well-established firms, which, due to low quality of their product compete by lower prices thus cutting retained earnings which could be invested into new technologies.

Another important corporate governance variable is *FDI.* Presence of foreign capital in a firm often means that it has greater access to finance as well as to advanced technologies, so usually it is expected (and empirically found) that firms with foreign capital spend more on R&D and produce more innovations. So we include presence of *foreign capital dummy* as a corporate governance variable

Since firms that have taken loans constitute just a bit more than 2 % of the sample, and we don't know the purpose of these loans, we cannot include this variable into regression. Hence, we include *past profit* (anyway, innovation is usually financed from firm's own cost and expect it to have positive sign. We also include *property dummy* with categories «private», «state» and «communal» and «collective» as the base category. Naturally, we expect positive influence of private property on innovation.

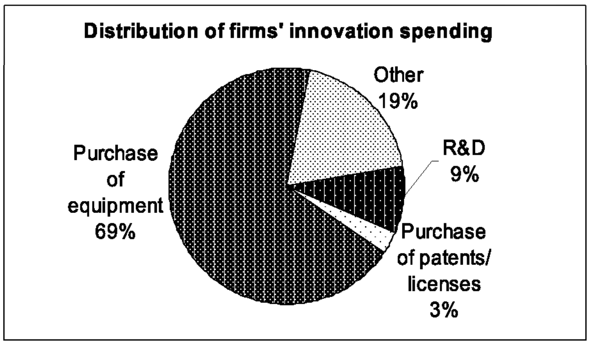
It is possible to combine innovative advantages of small (flexibility, radical ideas) and large (risk dissemination, better access to finance) firms by encouraging cooperation ties between firms located closely to each other. An example of a cooperative structure is a technopark (this formation is more integrated, and firms are not fully independent) or a cluster of firms (here firms are independent, with local government providing cooperation network). As shown by many empirical study, geographical proximity of firms creates knowledge spillovers – both within an industry and between different industries [5]. Advantages of clustering come from demand and supply side [2; 5]. In Ukraine there are no clearly defined clusters, so we construct *simple regional variables* in order to catch possible regional differences in innovation patterns. We divide the country into 5 regions – East, West, Centre, South, and the Kyiv city.

A positive effect of government policy on innovation is usually found, both for developed countries. However, the policies themselves can be very different. Those can include tax relieves for innovative firms, for firms in special economic zones/technoparks or for entire industries (as in India and China) ; grant/subsidy programs for start-ups (as in US and UK), attraction of international financial, technological (Eastern Europe, India) and intellectual (Israel) resources. In the model, we represent policy variables by a *subsidy dummy*, *tax burden* (taxes to production ratio), and the *Special Economic Zone (SEZ) ummy*. Ukraine has rather large number of special economic zones (SEZ) and territories of priority development (TPD) Despite, in 2005 privileges to these territories were cancelled, however, later some of them had their privileges renewed by court decisions.

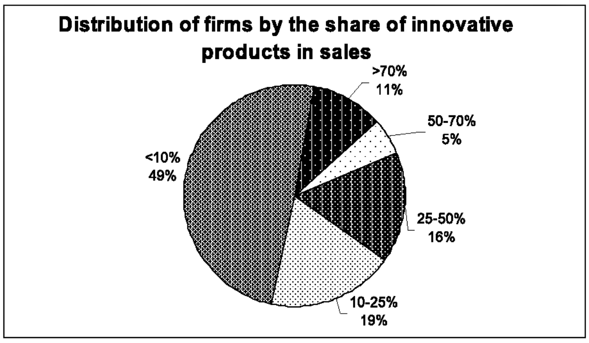
Ukraine is different from other Eastern European countries in the respect that its economy is highly monopolized and industrial lobby groups are strong. However, as many of Ukrainian firms had technologies lagging behind from the newest developments for 10–30 years, they could achieve large improvements in efficiency buying, say, a five-year-old technology. Hence, there is no special need for R&D, and innovative activity of firms is rather low. Moreover, as can be seen from picture 1, in average for last 5 years innovative expenditures are mostly directed at modernization and replacement of obsolete equipment rather than R&D. Picture *2* shows that in average for 5 last years firms mainly earn their profit from traditional outputs and sell very small share of innovative products.

Therefore, successful innovative firms appeared only in newly created industries such as software. In traditional industries, a paradoxical situation arose when exiting firms were actually *more* productive than remaining ones. But the state failure that created this situation can be corrected only by the state itself.

[5] State Service of Statistics of Ukraine.



Pic. 1. Share of innovation



Pic. 2. Innovative products share

So, as was mention above, after deep analysis we divided all the possible the determinants of innovation on 3 set. set of firm-level, industry-level and macroeconomic variables and the general general form of empirical model aimed at finding the determinants of innovation is very simple and can be represented by an equation

$$I = f\,(firm,\ industry,\ macro), \quad (1)$$

where and innovation indicator (I) is regressed on a set of firm-level, industry-level and macroeconomic variables. There are, however, two major problems with estimation of this kind of equation. First, innovation measure is often non-linear and/or censored and therefore, adequate regression techniques are needed for estimation. Second, endogeneity problem can be quite severe: on the one hand, innovating firms have better performance indicators, whereas on the other hand, better performing firms tend to innovate more [14]. It also can happen that some unobserved firm characteristics, such as management quality, influence both innovation and performance.

Among innovation inputs the most commonly used are innovation intensity measures – R&D or innovation spending per employee or per unit of sales [3; 6; 7]. Using innovation intensity as innovation measure implies usage of Tobit model for estimation: the first equation (probit) estimates the probability of non-zero innovation spending, while the second equation (OLS) estimates determinants of innovation spending conditional on it being non-zero.

Besides innovation intensity, measures of innovation inputs can include a share of R&D or engineering staff in total number of employees, a dummy for a presence of R&D department in a firm, average wage in a firm as a proxy for human capital *etc.*, but these are mostly included as RHS variables in regressions where dependent variable is either innovation output or non-innovative parameter of a firm performance (e.g. exports, profitability *etc*). Innovation output measures among other include patent counts, innovative sales per worker or share of sales of innovative product in total sales. The main drawback of these measures is that they don't measure depth of innovation: both patents and new products can indicate either radically new or merely improved products.

Since innovation input and output measures describe the same process from different sides, the common sense tells us that instead of choosing between them, it would be useful to consider several innovation measures (or at least two – one of innovation input and another of innovation output). Such a model has been developed, for example, by Griffith [6].

The model includes four equations, first estimating determinants of innovation inputs, then innovation production function, and finally, the "utility" of innovation or its effect on firm performance. Estimating these equations sequentially and using outputs of a previous equation as inputs of the next one allows avoiding endogeneity usually present in innovation firm-level data.

So, the developed model for Ukrainian economy is estimated in three steps: (1) determination of factors influencing probability and intensity of innovative investment; (2) estimation of knowledge production function (showing to what extent innovative spending is transformed into innovative products/processes); (3) estimation of firm's Cobb-Douglas production function in order to find the increase in labour productivity due to knowledge input. The last equation includes capital per worker as a control variable; hence, since the data on capital of Ukrainian firms is highly unreliable[6], we cannot estimate the third equation, limiting our attention to the first two.

[6] Many firms have large idle capital stock (especially old ones), some firms misreport the amount of their capital for taxation reasons (for example, depreciate and write off some equipment before it actually stops operating).

Formally the model can be presented as follows. The first equation considers innovation effort (r_i^*) of the firm *i*:

$$r_i^* = z_i'\beta + e_i \quad (2),$$

where r_i^* is a latent variable, z_i – a vector of independent variables influencing firm's innovative effort, β – a vector of parameters of interest, e_i – error term. Firm's innovative activity can be measured with the help of innovative expenditures r_i, but only if a firm performs and reports such expenditures. Hence, we introduce a binary variable rd_i, that equals 1 for firms performing innovative expenditures and 0 for other firms:

$$rd_i = \begin{cases} 1, \ if \ rd_i^* = \alpha w_i + v_i > 0 \\ 0, if \ rd_i^* = \alpha w_i + v_i < 0 \end{cases} \quad (3),$$

where rd_i^* is a latent variable such that when it exceeds a certain threshold *c*, a firm decides to start innovating, *w* is a vector of factors determining the decision to start innovative activity, α is a vector of parameters of interest, v_i – an error term.

If a firm performs R&D, we can observe the amount of resources invested in it:

$$r_i = \begin{cases} r_i^* = z_i'\beta + e_i \ , if \ rd_i > 0 \\ 0 . \qquad\qquad if \ rd_i = 0 \end{cases} \quad (4).$$

Assuming that errors e_i and v_i are normally distributed with zero means and variances $\sigma_v^2 = 1$ and σ_e^2 and correlation coefficient ρ_{ev}, we can estimate the system of equations (3) and (4) with the help of generalized Tobit model, using Heckman procedure

The next equation of the model is knowledge (innovation) production function:

$$g_i = \gamma r_i^* + \delta x_i + u_i \quad (5),$$

where g_i is an innovation indicator measured by binary variables that are equal to 1 if a firm introduced product/process innovation and 0 if it did not; r_i^* denotes firm's innovative effort taken as predicted values from equation (4), x_i is a vector of other knowledge production factors, *(γ, δ)* is a vector of parameters to be estimated. By using fitted values, possible endogeneity between innovation effort r_i^* and knowledge g_i is eliminated.

By consequently estimating equations (3), (4) and (5), we learn not only which firms are more inclined to innovate but also which firms are more able to translate innovative expenditures into new product or technology.

The data used are taken from the form "1-innovation" that industrial enterprises (except for small[7] ones) fill in for the State Service of Statistic. Total sample included observations on more than 12 thousand of enterprises for 2010–2012. After exclusion of enterprises created after 2010, liquidated during 2010–2012 or those that did not work during at least one of these three years, 7500 enterprises remained in the sample. The results of estimation are shown in tables 1 and 2. The estimates that we received are in line with the theory and other empirical findings.

As we can see from the table 1 and 2, Exporters have both larger probability of innovating and higher innovation intensity. Furthermore, an exporting firm has greater incentives to obtain tangible results (new products or technologies) from its innovation spending, as the last equation shows. Higher quality of human capital and profitability also increase probability of innovation and innovation intensity because innovation is financed almost entirely from firm's own funds, and personnel qualification is a necessary condition for introduction of advanced technologies. The probability and intensity of innovation increases with the firm size: larger firms in Ukraine have more resources to innovate. Since they are often also exporters, they have incentives to innovate in order to remain competitive in the world markets. Subsidies from state or local budget increase both probability and intensity of innovations supporting finding of the other researchers [8].

An important result is negative coefficient of SEZ/TPD dummy. It suggests that firms in such territories have fewer incentives to perform innovation because they already have a competitive advantage over other firms – hence, they don't need to compete by quality or struggle to lower their cost in order to increase profit. Regional dummies turned out to be not significant, except for Kyiv dummy, which was positive significant in the innovation intensity equation perhaps indicating that there are more high-tech firms in Kyiv. Interactions of regional dummies with SEZ/TPD dummies were also insignificant. Hence, there is no regional difference in probability and intensity of innovation between firms in different regions. The coefficients on subsidies and SEZ/TPD variables confirm superiority of direct subsidies over broad tax privileges policy measures to increase innova-

[7] Small enterprises are those using a simplified tax regime. An industrial enterprise can switch to this regime if it employs less than 50 people.

Table 1. **Innovation intensity equation (Heckman method)**

Dependent variable	**Permanent innovative activity**		**Innovation intensity**
Control variables	Coefficient (st. error)	Marginal effectsa	
Exporter	1.655*** (0.104)	0.328	1.079** (0.477)
Human capital	0.035*** (0.007)	0.013	0.106*** (0.034)
Profit-2010	0.206** (0.082)	0.074	0.363 (0.587)
Subsidies	1.004*** (0.227)	0.257	0.068 (0.723)
SEZ/TPD	-0.134** (0.066)	-0.049	0.185 0.319
Firm size dummy			
50–99	0.237** (0.11)	0.083	-
100–249	0.476*** (0.103)	0.163	-
250–999	0.889*** (0.103)	0.273	-
> 1000	1.542*** (0.118)	0.340	-
Industry dummy			
Extraction	-0.84*** (0.217)	-0.324	-
Food	-0.105 (0.126)	-0.038	-
Light	-0.230 (0.148)	-0.086	-
Paper and wood-processing	-0.411** (0.165)	-0.157	-
Chemical	0.259** (0.152)	0.088	-
Non-metal mineral goods	-0.148 (0.142)	-0.055	-
Metallurgy	0.017 (0.146)	0.006	-
Machine-building	0.088 (0.125)	0.031	-
Utilities	-1.27*** (0.236)	-0.474	-
Property type			
Private	-0.07*** (0.211)	-0.023	-
State	-0.02*** (0.224)	-0.006	-
Communal	0.864** (0.335)	0.245	-

* – coefficients significant at 10 % level; ** – at 5 % level; *** – at 1 % level.

tion. Tax variable turned out to be insignificant, probably because enterprises use various tax minimization schemes, and the amount of taxes they pay is not strongly connected to their performance. The FDI dummy had a negative sign but was insignificant in all specifications. This can be explained by the already mentioned impossibility do distinguish "true" FDI from returned domestic capital, and also by rather small share of firms with foreign capital in the sample. Industry variables show that industries less likely to innovate are those most technologically backward – extraction and utili-

Table 2. **Estimation of knowledge function**[8] (probit)

Dependent variable is a binary variable that equals 1 if a share of innovative product in sales in 2012 was larger than in 2011		
Independent variables	*Marginal effect*[a]	*St. deviation*
Innovative intensity (fitted values from the previous equation)	0.020***	0.005
Investment intensity	0.007***	0.001
Exporter	0.114***	0.027
Subsidies	0.032***	0.013
SEZ/TPD	-0.011**	0.005
Industry		
Extraction	-0.035***	0.006
Food	-0.001	0.011
Light	-0.014	0.010
Paper and wood-processing	-0.002	0.012
Chemical	0.024	0.018
Non-metal mineral goods	-0.006	0.011
Metallurgy	0.007	0.014
Machine-building	0.035**	0.015
Utilities	-0.040***	0.006
Property type		
Private	0.216***	0.023
State	0.981***	0.005
Communal	0.975***	0.008
Firm size		
Log employment	0.045***	0.011
Log employment squared	-0.003***	0.001
LR $chi^2(17)$ = 743.77, Prob > chi^2 = 0.0000, Pseudo R^2 = 0.1648		

[a] evaluated at means, for dummies – the impact of their change from 0 to 1 on the probability that dependent variable equals 1.
* – coefficients significant at 10 % level; ** – at 5 % level; *** – at 1 % level.

ties. Modernization in such industries is also the most costly. Machine building, the most technologically advanced industry, is also the most likely to get tangible innovation results, as table 8 shows.

As table 2 also shows the results of estimation of probability that innovative spending of an enterprise is transformed into a new product. Innovation intensity has a positive sign as expected; however, its influence is lower than that of export activity. Probably, the competition on external markets makes enterprises to faster bring their innovations to the final product stage.

Conclusions. Technological development becomes ever more important determinant of a country's growth and welfare. However, under free market conditions investment into innovation is lower than socially optimal because innovation creates positive externalities. Therefore, appropriate government policies are needed to foster the development of new technologies by private firms. A necessary (but not sufficient) condition is creation of macroeconomic environment favourable for enterprise development. By appropriate policy, the government can soften this market failure and even help a country to make a "technological leap". Besides creation of investment-friendly economic environment, financial support to new ideas is very helpful. However, to make this support more efficient, the government should invest into firms with higher probability of success. To select these firms, it is important to know their distinguishing features. Indirect support measures, such as tax relieves within free economic zones, are found to be inefficient. Therefore, inefficient firms should not be supported and should be allowed to exit. Besides, a microeconomic program of firm-level subsidies is needed to reduce risk of development of a new product or technology. A necessary condition for success of such a policy is the selection process for participants of such a program. Hence, we need to know the characteristics of enterprises that increase the probability of their success in innovation.

[8] Unfortunately, we don't have the data on process innovations, so we estimate this equation only for product innovations.

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Лук'яненко І. Г.

МОДЕЛЮВАННЯ ІННОВАЦІЙНОЇ АКТИВНОСТІ УКРАЇНСЬКИХ ПРОМИСЛОВИХ ПІДПРИЄМСТВ

У статті досліджуються проблеми впливу інновацій на ефективність діяльності промислових підприємств України. При цьому фокусом дослідження є не тільки визначення та кількісна оцінка основних факторів, що стимулюють запровадження інновацій на підприємствах, але й визначення підприємств з найбільшою імовірністю досягнення успіху. Розрахунки на основі розробленої економетричної Tobit моделі показали, що підприємства-експортери та підприємства з найбільшими прибутками та фондом заробітної плати є одночасно і найбільш успішними в здійсненні інновацій і схильними до інновацій. Такі підприємства мають пріоритет на підтримку держави. Також емпірично було показано, що непрямі методи підтримки діяльності підприємств, наприклад звільнення (або зменшення) від оподаткування у вільних економічних зонах, є неефективними і не можуть використовуватись як інструменти стимулювання інноваційної діяльності українських підприємств.

Ключові слова: моделювання, інновації, промислові підприємства, чинники, фінансова підтримка, інвестиції, модель Тобіта.

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