UDC 330.341.1

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MODELLING OF REGIONAL INNOVATIVE DEVELOPMENT INDICATORS

The aim is to identify trends and research prospects of innovative development of Ukrainian regions through economic and mathematical methods. The innovation activity modeling by individual groups of regions using economic and mathematical methods has been done, including correlation and regression analysis. The innovative activity and its special aspects at the regional level have been analyzed. The grouping of Ukrainian regions according to the degree of innovation activity has allowed to compare the activity of individual groups and regions of Ukraine, to establish that there is a significant asymmetry of innovation activity in the regions. The factors, which influence the innovative development of individual regions according to their innovation activity have been investigated. The economic and mathematical models have been received as a result of correlation and regression analysis, reflecting the dependence of the number of companies that implement innovative products on the major innovative development factors in individual groups of regions. The regression equation based on the verification of collinearity and connection quality factors has been established which corresponds to the average growth index number of enterprises implementing innovative products to regions characterized by varying degrees of innovation activity and adequately reflect the trend line for each group of regions. It has been determined that the dynamics of the number of companies, implementing innovative products is influenced by such factors as: the number of industrial enterprises implementing innovations, the number of companies engaged in innovative activities, the number of executed scientific and technological projects, funding of scientific and technical activities , development of innovative products manufacture. Scientific novelty of research proposals is based on reasonable modeling of possible scenarios of innovative development of regions and justification of concrete proposals to enhance innovation capacity within individual groups of regions. Built econometric models for each group of regions give rise to their use as predictive options and may be taken into account in the development of innovative strategies for regional development and regional innovation programs.

Keywords: *innovation, innovative activity, innovation development, region, econometric models, correlation and regression analysis.*

INTRODUCTION

Problem. The state and prospects of innovative development of Ukraine are extremely important at this stage, because innovation can significantly improve the quality and competitiveness of industrial products and ensure its access to international markets. However, the declared position of the "innovative type of development" of the economy of Ukraine remains viable, as evidenced by the decline of the national economy, the loss of competitive position in the international arena and a further decline in exports of national products.

Summarizing the experience of implementing innovative transformations by Ukraine gives reason to believe that at this stage there is no innovative development strategy, uniting into a whole the needs of individual regions, characterized by varying degrees of economic development. Therefore, special attention should be paid to the study of innovation development indicators in certain areas, because they are the cells forming the economic, social, scientific, technological priorities, achievements and benefits, activation of which influences further economic development. Thus the development of measures to enhance innovation and regulation development can not be based on a common approach for all regions of Ukraine.

Analysis of recent research and publications. There are many publications in Ukrainian literature concerning the problems of activation and regulation of innovative development of Ukraine in general and in particular regions. O.Amosha, O. Zhyhor, O. Kolisnyk, N. Potapova, L. Fedulova and others have made a significant contribution to the study of these issues. [1-5]. Without denying the value of the research, it should be noted that the introduction of innovative development model requires constant monitoring of the existing situation, the study of the laws of the economy, fact-finding and selection of effective ways of innovation. Therefore the problem of finding indicators and landmarks which are able to become

a driving force for innovation and stimulus for further innovation development remains urgent.

The aim of the article (problem). The aim of the study is to identify trends and to research prospects of innovative development of Ukrainian regions through economic and mathematical methods.

RESEARCH RESULTS

Improving the efficiency of implementation of the state innovation policy requires concerted action at all levels of innovative processes regulation. The shift of emphasis in management at the regional level is a key aspect of decentralization. In this aspect, it is advisable to identify homogeneous degree of innovative development of regions and to justify measures to enhance innovation within individual groups. The basic meaning of division of regions according to different degrees of innovative development is that this approach will make more effective recommendations for specific areas, solve problems and improve their social and economic development. This will allow justify regional innovation development strategy, which can form the basis of a comprehensive national innovative strategy development in the future.

The tendencies of innovative developing taking place at the regional level have been analyzed to reveal the main laws of innovative activity. Comparing the effectiveness of participation of each region in the innovation process of the country as a whole has been made. A conducted ranking on the basis of integral index-number of innovative activity allowed to find out obvious disproportion and the problems of regional innovative development and to distinguish regions with different degrees of innovation activity. (Table 1.)

Table 1

Grouping of Ukrainian regions on the degree of innovative activity in 2013

The degree of innovative activity of region industry	The interval index-number value	The groups of regions on the degree on innovative activity
High level	$R_i \geq 0{,}07$	Kyiv, Harkiv oblast', Donetsk oblast'
Medium level	$0{,}03 \leq R_i \leq 0{,}07$	Poltava, AR Crimea, Dnipropetrovs'k, L'viv, Zaporizhia, Ivano-Frankivsk, Odesa, Sumy, Luhans'k oblast's
Moderate level	$0{,}02 \leq R_i \leq 0{,}03$	Khmel'nyts'k, Mykolayiv, Kyyiv, Vinnyts'a, Cherkasy oblast's
Low level	$R_i \leq 0{,}02$	Volyn', Zhytomyr, Zakarpat'a, Rivne, Ternopil', Kherson, Chernivtsi, Kirovohrad, Chernihiv oblast's, city Sevastopol'

Source: own elaboration; according to [6]

In previous publications we have noted the differences in concentration of industrial and innovative activities in different regions [7]. It should be noted that positions of regions have not significantly changed comparing to previous years. However, there was some curtailment of innovative activity in Zaporizhzhia region and as a result this region has moved from the group of regions with high degree of innovative activities into the region with medium degree. The result was a reduction in the number of regions in the first group from four to three.

At the same time, the positions of Odesa and Vinnytsia areas, which were able to rise in ranking and enter the group of regions with medium and moderate degrees respectively, have been improved. The result was an increase in the regions number of the second group (regions with the medium degree of innovative activity) from 7 to 9 with simultaneous reduction of the third group of regions (regions with medium degree of innovative activity) from 6 to 5. The numbers of region from the fourth group during 2011-2013 has not changed and amounted to 10 regions.

A conducted analytical grouping of Ukrainian regions in the degree of innovative activity characterizes only the general features of relations and their tendencies, but does not allow to assess numerically the power of connection. On the basis of analytical grouping a given task could be done with the help of empirical correlation relation. Therefore, a logical continuation of research was to identify the relations between the separate indicators characterizing the state of innovative activities of Ukrainian regions and to identify dependences of influence of separate factors on integral estimation change. Thanks to the established relationship reserves of innovative activity increase of Ukrainian industry can be revealed. Econometric methods and models allow to predict the possible economic situation, to know the way of their development in future. Besides, econometric calculations make it possible to compare the results of activity of one subject with another, and their assessment is necessary for achieving economic effectiveness.

The correlation and regression analysis has been applied for the research of quantitative key factors effect on the activation on innovative activity. This analysis allows to assess numerically the nature and mechanism of interaction of factor and effective features. The impact assessments of the various factors on the analysis object received with its help allows to increase the strategic plans quality, and objectivity of decisions, and also to predict the situation development, by changing specific characteristics of investigation object. It is possible to determine the degree and power of connection between parameters with the help of correlation and regression analysis. Assessment of connection degree between the parameters and selection of parameters between which there is a strong linear relation allowed to select those key factors that influence the development of innovative activity. Further verification of such an assumption has been conducted with the help of regression analysis.

In the course of the research it has been found that there is a significant asymmetry of innovative activity in the regional context in Ukraine. Therefore, to study specific proposals on increase of innovative potential it is

advisable to build econometric models for each of the regions separately, which will simulate possible scenarios of development. Basic parameters shown in statistical yearbooks will serve as information base for analysis characterizing innovative activity of Ukrainian regions. Building of econometric models in context of individual regions groups will contribute to both the identifying of problematic moments in their activity and the outlining the prospects for their functioning.

The key indicators characterizing the innovative activity in certain groups of regions have been used to identify relationships and their influence on the resulting index *Y* have been studied, where *Y* is the number of enterprises, that have implemented innovative products, units, x_1 is the number of executed scientific and technical works, units, x_2 is the number of industrial enterprises, units, x_3 is the number of industrial enterprises involved in innovative activities, x_4 is the expenditure on innovative activities, mln. UAH, x_5 is the number of industrial enterprises implementing innovation, units, x_6 is the implementation of new manufacturing processes at industrial enterprises, units, x_7 is the development of manufacture of innovative products, names, x_8 is the volume of sales of innovative products, mln. UAH, x_9 is the scientific and technical works funding, mln. UAH.

Comparing with the help of the correlation matrix correlation of coefficients of resultant variable (*Y*) with all factorial (x_1, ... x_9), those factors whose relationship is relatively small (<0.3) have been excluded from further analysis. Then factors that are in a functional or correlation interconnection have been identified and have a high degree of connection, that is collinear (multicollinear). When building a regression model such indicators were excluded from equation parameters to eliminate collinearity.

Such selection made it possible to form a set of the most significant connections, and correspondingly, the impact factors on the innovative activity parameter under examination (in our case - the number of companies that implemented innovative products). In the next phase of the research the parameters, previously selected as significant, were tested on connection quality with the help of the regression analysis.

The results obtained according to the group of regions with a high degree of innovative activity indicate the presence of a stable relationship between the number of companies that have implemented innovative products, the number of executed scientific and technical works, the scientific and technical works funding, the number of industrial enterprises involved in innovative activities and the number of industrial enterprises implementing innovations.

The dependence between the number of enterprises that implemented innovative products, the number of industrial enterprises involved in innovative activities and the number of industrial enterprises implementing innovations has been revealed for the second group of regions. However, the pair correlation coefficients matrix analysis showed a high degree of connection between indices x_3 and x_5, so in order to eliminate collinearity the number of industrial enterprises implementing innovation were excluded from equation parameters.

The pair coefficients correlation matrix analysis has showed the weak ,in some cases reversed, connection between the resulting index *Y* and the most of indicators for the third group of regions as the pair correlation coefficient magnitude is <0.3. Therefore, those kind of indicators for building regression models were not taken into account.

What concerns the fourth group of regions, the results indicate the presence of medium and close connection between the resulting index *Y* and indices x_2 - x_7, but a number of indicators are interconnected in a functional (correlation) dependence and because of that they were excluded from the equation parameters.

The next phase of the multiple correlation analysis was connection model setting or the multiple regression equation. Linear equation of correlation dependence of the resulting index *y* from the factors (x_1 ... x_n) can be expressed as:

$$Y = a_0 + a_1x_1 + a_2x_2 + ... + a_nx_n \quad (1).$$

The connection characteristics were evaluated using the multiple correlation coefficient, which shows what part of the general correlation makes up the oscillations under the influence of factors x_1, ... x_n put in the multifactor model for research. Identifying the comparative magnitude of the effect of the investigated phenomena and their reserves was conducted with the help of calculating the partial elasticity and beta coefficients. Partial elasticity coefficient shows the resulting index average change in percentage with the change by 1% of each factor when others are constant. In order to determine factors, which have the highest improving reserves of studied index, the partial β-coefficients have been calculated, showing that average deviation part, on which the resulting index changes with the particular productive factor index change to its standard deviation.

Economic and mathematical models have been received as a result of correlation and regression analysis. These models reflect the enterprises number dependence, selling the innovative products of the major factors of innovative development in the context of individual regional groups. The regression equations have been established on the bases of testing the collinearity and connection quality factors used in the model, corresponding to average enterprises number increase, selling the innovative products for regions, characterized by varying degrees of innovative activity and adequately reflect the trend line for each region group.(table 2-5). The data of 2008-2013 have been used to make the model. [6; 8-12]

According to the results of regression analysis the increase of each regression equation parameters by unit at the other constant factors for the first group of regions (regions with a high degree of innovation activity in the industry) will cause the increase of the enterprises number, selling the innovative production at: the increasing of the number of executed scientific and technical works, the number of industrial enterprises involved in innovation activity and at the increasing the funding of scientific and technical works (Table 2).

Calculated multiple correlation coefficient for the model indicates the presence of a functional linear relation between the studied features, and the multiple

determination coefficient indicates that the variation in the number of companies selling innovative products are 100% conditioned by these factors.

Table 2

The results of correlation and regression analysis for the regions with a high degree of innovation activity

Peculiarities and statistical characteristics	Index and its meaning
Efficient feature: Y	Number of enterprises selling innovative products, units
factor variable: x_1	Number of completed executed scientific and technical works, units
x_3	The number of industrial enterprises involved in innovation activities, units
x_9	Funding of scientific and technical work, mln UAH
regression model	$Yx_1,x_3,x_9=31,298+0,001x_1+0,244x_3+0,005x_9$
multiple correlation coefficient	R=1
multiple determination coefficient	$R^2=1$
elasticity coefficient (ε)	$\varepsilon_1=0,090$; $\varepsilon_3=0,382$; $\varepsilon_9=0,114$
Beta - coefficient (β)	$\beta_1=0,555$; $\beta_3=0,335$; $\beta_9=0,701$

Source: own elaboration

According to the analysis of partial coefficients of elasticity the number of enterprises involved in innovative activity has the greatest impact on the number of enterprises selling the innovation products. 1 % increase of them will cause increase to 0.38%. of the number of enterprises selling the innovative products.

According to β- coefficient analysis the funding of scientific and technical works and the number of executed scientific and technical works have the greatest impact of studied factors with regard to their variation on the number of enterprises selling the innovative products.

Let us interpret the results for the regions of the second group, characterized by an average degree of innovative activity (Table. 3). The results obtained in the course of correlation and regression analysis showed that there is a tight relationship between the number of industrial enterprises involved in innovative activities and the number of companies selling innovative products (R = 0,91). According to the determination coefficient the change of enterprises number selling the innovative products to 83 % depends on the number of industrial enterprises involved in innovative activity.

Table 3

The results of correlation and regression analysis for the regions with moderate degree of innovative activity

Peculiarities and statistical characteristics	Index and its significance
Efficient feature: Y	Number of enterprises selling innovative products, units
factor variable: x_3	The number of industrial enterprises involved in innovation activities, units
regression model	$Yx_3=4,976+0,573x_3$
multiple correlation coefficient	R=0,91
multiple determination coefficient	$R^2=0,83$
elasticity coefficients (ε)	$\varepsilon_3=0,879$
Beta - coefficients (β)	$\beta_3=0,909$

Source: own elaboration

The share of unaccounted factors accounted for 17%. Calculation of elasticity showed that at 1% change in the number of industrial enterprises engaged in innovative activity the resultant variable (in this case - the number of companies that implement innovative products) will increase by 0.88%. This factor significantly affects the number of companies that implement innovative products as β_3 = 0,909.

Let us carry out the economic interpretation of the results for regions with moderate innovative activity in the industry, given in Table 4. Presented in Table 4 correlation coefficient R indicates the presence in the following models correlation with a high degree of connection (R> 0,8), and the proportion of the influence of the factors taken into account in the model R^2 is 65%. The parameter a_1 = 0.575 means that an increase in the number of companies that implement innovations by 1 unit will increase the number of companies that implement innovative products to 0.575 units, an increase of 1% will increase the number of companies that implement innovative products to 0, 77% (as evidenced by the coefficient of elasticity ε_5 = 0,770). The impact of this indicator on the resultant variable is significant, since the beta coefficient β_5 = 0,808.

Results of correlation analysis in regions with low innovative activity indicate that the greatest impact on the dynamics of the number of companies that implement innovative products in these regions is an indicator of the industrial enterprises that implemented innovations (A_5 = 0.952), increasing of which by 1 unit would increase the

number of companies that implement innovative products to 0.952 units and an increase of 1% would increase the number of companies that implement innovative products to 1.075% (table 5).

Table 4

The results of correlation and regression analysis for regions with moderate innovative activity

Feature and statistical characterization	Index and its meaning
Efficient feature: Y	Number of companies that implement innovative products, units
Factor variable: x_5	number of industrial enterprises implementing innovations, units
Regression model	$Yx_5=8,479+0,575x_5$
Multiple correlation coefficient	R=0,81
The coefficient of multiple determination	$R^2=0,65$
Elasticity coefficient (ε)	$\varepsilon_5=0,770$
The beta coefficients (β)	$\beta_5=0,808$

Source: own elaboration

Other options do not affect the resulting feature so significantly. However, spending on innovation and introduction of new technological processes in industrial enterprises (presented parameters A_4 and A_6) is the limiting factor of the number of companies that implement innovative products in the regions assigned to the fourth group. Thus, the increase in costs for financing innovation reduces the number of companies that implement innovative products. Based on this dependency it can be assumed that this is due to the reluctance of businesses to spend money on innovation, development, because innovative projects are often risky and are not always able to provide a quick payback and profit from such investments.

Table 5

The results of correlation and regression analysis for regions with low innovative activity

Feature and statistical characterization	Index and its meaning
Efficient feature: Y	Number of companies that implement innovative products, units
Factor variable: x_4	expenditure on innovation, mln.UAH
x_5	number of industrial enterprises implementing innovation, units
x_6	introduction of new technological processes at industrial units
x_7	Mastering the production of innovative products, names
regression model	$Yx_4,x_5,x_6,x_7=0,183-0,033x_4+0,952x_5-0,008x_6+0,008x_7$
Multiple correlation coefficient	R=0,98
The coefficient of multiple determination	$R^2=0,97$
Elasticity coefficient (ε)	ε_4= -0,090; ε_5=1,075; ε_6= -0,010; ε_7=0,017
The beta coefficients (β)	β_4= -0,166; β_5=1,074; β_6= -0,040; β_7=0,044

Source: own elaboration

Introduction of new processes in industry is also constraining factor in the regions of the fourth group and its growth also reduces the number of companies that implement innovative products. This is another proof that business owners want to get quick profits, and therefore are very reluctant to implement new processes and technologies, as this causes the growth of expenses associated with the purchase of new technologies, training and retraining of personnel, equipment installation.

The value of multiple correlation coefficient R = 0,98, indicating a significant tight relationship of indicator with factors, and therefore the model has a high degree of reliability (98%). The coefficient of determination R^2 = 0,97. This means that the change in the number of companies that implement innovative products to 97% depends on the impact of 5 selected factors. The share of unaccounted factors accounts for 3%. Analysis of β-coefficients shows that the number of industrial enterprises implementing innovation has the greatest impact, of all studied factors with regard to their variation, on the number of companies that implement innovative products.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The results of the study suggest a direct effect on the dynamics of the number of companies that implement innovative products of such factors as the number of industrial enterprises that implemented innovations, the number of companies engaged in innovative activities, the number of executed scientific and technological projects, funding of research and scientific technical work, mastering the production of innovative products. The models for individual groups of regions give rise to their use as predictive options and may be taken into account in the development of innovative strategies for regional development and regional innovation programs to justify the priorities of economic development that will serve as

the subject of further research in this direction.

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МОДЕЛЮВАННЯ ІНДИКАТОРІВ РЕГІОНАЛЬНОГО ІННОВАЦІЙНОГО РОЗВИТКУ

Мета полягає у виявленні тенденцій та дослідженні перспектив інноваційного розвитку регіонів України за допомогою економіко-математичних методів. Здійснено моделювання інноваційної діяльності за окремими групами регіонів з використанням економіко-математичних методів, зокрема кореляційно-регресійного аналізу. Проаналізовано інноваційну активність та її особливості на регіональному рівні. Здійснене групування регіонів України за ступенем активності інноваційної діяльності дозволило порівняти інноваційну активність окремих груп регіонів України та встановити, що в Україні спостерігається значна асиметрія активності інноваційної діяльності у регіональному розрізі. Досліджено чинники, які впливають на інноваційний розвиток окремих груп регіонів відповідно до їх інноваційної активності. В результаті застосування кореляційно-регресійного аналізу отримано економіко-математичні моделі, що відображають залежність кількості підприємств, що реалізують інноваційну продукцію від основних факторів інноваційного розвитку в розрізі окремих груп регіонів. На основі перевірки колінеарності та якості зв'язку факторів, що використані в моделях, встановлені рівняння регресії, які відповідають середньому приросту показника кількості підприємств, які реалізують інноваційну продукцію для регіонів, що характеризуються різним ступенем інноваційної активності та адекватно відображають лінію тренду для кожної групи регіонів. Встановлено, що на динаміку кількості підприємств, що реалізують інноваційну продукцію впливають такі чинники, як: кількість промислових підприємств, що впроваджували інновації, кількість підприємств, що займаються інноваційною діяльністю, кількість виконаних наукових та науково-технічних робіт, фінансування наукових та науково-технічних робіт, освоєння виробництва інноваційних видів продукції. Наукова новизна результатів дослідження визначається обґрунтованими пропозиціями щодо моделювання ймовірних сценаріїв інноваційного розвитку регіонів та обґрунтування конкретних пропозицій щодо нарощення інноваційного потенціалу в межах окремих груп регіонів. Побудовані економетричні моделі для кожної групи регіонів дають підставу для їх використання в якості прогнозних варіантів і можуть бути враховані при розробці інноваційних стратегій розвитку регіонів та регіональних інноваційних програм.

Ключові слова: *інновації, інноваційна діяльність, інноваційний розвиток, регіон, економетричні моделі, кореляційно-регресійний аналіз.*

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МОДЕЛИРОВАНИЕ ИНДИКАТОРОВ РЕГИОНАЛЬНОГО ИННОВАЦИОННОГО РАЗВИТИЯ

Цель заключается в выявлении тенденций и исследовании перспектив инновационного развития регионов Украины с помощью экономико-математических методов. Осуществлено моделирование инновационной деятельности по отдельным группам регионов с использованием экономико-математических методов, в

частности корреляционно-регрессионного анализа. Проанализированы инновационную активность и ее особенности на региональном уровне. Осуществлена группировка регионов Украины по степени активности инновационной деятельности позволило сравнить инновационную активность отдельных групп регионов Украины и установить, что в Украине наблюдается значительная асимметрия активности инновационной деятельности в региональном разрезе. Исследованы факторы, которые влияют на инновационное развитие отдельных групп регионов в соответствии с их инновационной активности. В результате применения корреляционно-регрессионного анализа получено экономико-математические модели, отражающие зависимость количества предприятий, реализующих инновационную продукцию от основных факторов инновационного развития в разрезе отдельных групп регионов. На основе проверки коллинеарности и качества связи факторов, использованы в моделях, установлены уравнения регрессии, которые соответствуют среднему прироста показателя количества предприятий, реализующих инновационную продукцию для регионов, характеризующихся разной степенью инновационной активности и адекватно отражают линию тренда для каждой группы регионов. Установлено, что на динамику количества предприятий, реализующих инновационную продукцию влияют такие факторы, как: количество промышленных предприятий, которые внедряли инновации, количество предприятий, занимающихся инновационной деятельностью, количество выполненных научных и научно-технических работ, научных и научно-технических работ, освоение производства инновационных видов продукции. Научная новизна исследования определяется обоснованными предложениями по моделированию возможных сценариев инновационного развития регионов и обоснование конкретных предложений по наращиванию инновационного потенциала в рамках отдельных групп регионов. Построенные эконометрические модели для каждой группы регионов дают основание для их использования в качестве прогнозных вариантов и могут быть учтены при разработке инновационных стратегий развития регионов и региональных инновационных программ.

Ключевые слова: *инновации, инновационная деятельность, инновационное развитие, регион, эконометрические модели, корреляционно-регрессионный анализ.*

Одержано 15.02.2015 р.