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The impact of economic entities' innovative activity on the indicators of sustainable development of Ukraine

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Abstract. The article is devoted to substantiating the impact of innovative activity of business entities on the indicators of sustainable development of Ukraine on the basis of the econometric modeling. It is proposed to consider this impact from the point of view of increasing the country's gross domestic product (GDP) and the resulting factor of innovation implementations – the volume of innovative products sold. Analytical data from statistical reporting forms of Ukrainian enterprises were used by summarizing the data taken in the forms of statistical observation of the State Statistics Service of Ukraine. The models are developed based on two methodological approaches: a generalizing indicator of efficiency and effectiveness. According to the results of a study conducted by the authors, the most significant impact on the volume of GDP is exerted, in particular: among the performance indicators – the cost of innovation and the number of business entities that have implemented innovations; efficiency – the share of the volume of scientific and scientific and technical works performed in GDP. In contrast to the current models, the proposed ones provide a high level of accuracy in assessing indicators of the macroeconomic state of Ukraine, as a basis for forming an effective state policy of sustainable development. Based on the developed models, the current directions of improving and reforming the innovation ecosystem to increase the scientific potential of Ukraine are identified.

1. Introduction

The spread of the concept of sustainable development on the basis of use the IV Industrial Revolution determined the need for countries of the world to review approaches to the implementation of innovative activities by business entities and assess its impact on the macroeconomic environment of countries. The basis of sustainable development is a systematic approach to macroeconomic management based on the introduction of innovative technologies.

Ukraine is a participant in the global process of ensuring sustainable development, has approved a strategic framework and targets for its national development until 2030. In particular, among the sustainable development goals 2015-2030, adapted for Ukraine, taking into account the specifics of national development, there is goal No. 9, which defines the areas of industry, innovation and infrastructure. Currently, one of the problems in implementing this goal is the lack of methodological tools that would make it possible to effectively assess the macroeconomic environment in the area indicated by this goal.

Indicators included in the 9th sustainable development goal are determined by the innovative activity of business entities. However, in many regulatory documents, as well as documents of a state strategic nature, the innovative activity of business entities is not considered in the context of the basis for ensuring sustainable development of Ukraine. The principles of sustainable development of Industry, Innovation and Infrastructure are mainly indicated as vectors for the development of innovation activities, which leads to a low level of validity and fragmentation of sustainable development measures in Ukraine.

It should be noted that existing methodologies for assessing macroeconomic indicators of innovative development of countries (in particular, the Competitiveness Index, Innovation Index, Bloomberg, Oslo, Frascati, European scoreboard, etc.) also do not fully cover the components that should be taken into account when shaping Ukraine's sustainable development policy. The approaches laid down in the current methodologies reflect only certain aspects of the country's sustainable development. Almost all of them serve for its generalized vision and provide synthesized results which can help hold the following macroeconomic assessment, but not as its fundamental basis.

In Ukraine, monitoring the progress of innovation processes can be evaluated mainly through a certain system of indicators in the forms of statistical reporting. Conclusions based on the assessment become tools for making managerial decisions at various levels of regulation of innovation processes. However, the indicators used in such reporting are based only on the cost or expert characteristics of the innovation activity of business entities. Therefore, they lead to ambiguous, often contradictory conclusions that are not suitable for justifying management decisions at the national level.

In our opinion, it is advisable to consider the nature of the impact of innovative activity of business entities on the corresponding indicators of sustainable development of Ukraine. This will give a deeper understanding of the need and nature of modern tools of the state innovation policy of Ukraine based on the principles of sustainable development. In particular, it is advisable to consider this impact from the perspective of increasing the country's gross domestic product (GDP) and the resulting factor of innovation implementations – the volume of innovative products sold.

2. Review of Literature

Scientists have developed a number of economic and mathematical models to solve the problem of assessing the impact of indicators of innovation activity of business entities in the context of their impact on the macroeconomic state of the country [1-4]. In Ukraine, the issues of economic assessment of the interaction of indicators of innovative activity of business entities were studied by scientists [5, 6]. Modern econometric models for assessing macroeconomic indicators of countries around the world were developed by the authors [7, 8]. Separate approaches to macroeconomic assessment and forecasting in the context of sustainable development of countries are presented in [9-11].

Despite numerous developments of Ukrainian and foreign scientists and practitioners, the problem of modelling the impact of innovative activity of business entities on the indicators of sustainable development of Ukraine still remains insufficiently solved. Therefore, existing developments cannot serve as an effective basis for ensuring its sustainable development.

Currently, in Ukraine, Form No. 1-NN – survey of the innovation activity of an organization (enterprise) for the corresponding period (2014-2016, 2016-2018, 2018-2020, etc.) is used to monitor the innovation activity of enterprises of various types of activity. The survey program provides for obtaining quantitative and qualitative data on the innovation activity of enterprises in 11 main sections and is analogous to the European Monitoring of Oslo. In these documents, most of the indicators of macroeconomic assessment of innovative activity of business entities are mainly quantitative in nature and practically do not correlate with qualitative estimates. This leads to limited opportunities for using analytical indicators obtained on the basis of such an assessment, and, accordingly, unfounded conclusions and decisions made.

3. Purpose

The purpose of the work is to determine the impact of innovative activity of business entities on the indicators of sustainable development of Ukraine on the basis of the econometric modeling.

4. Methodology

To execute research, we useage statistics which presents annual indicators of innovation activity in Ukraine.

Traditionally, in scientific sources, methodological approaches to evaluating innovations are divided into two groups according to a generalizing indicator of efficiency or effectiveness. In this paper, these groups will be used for research, testing constructed hypotheses, complex modelling, and obtaining reliable conclusions.

The results of this study should ensure that the indicators of innovation activity of Ukrainian enterprises are comparable with the conclusions of international experts to summarize visions of implementing a sustainable development policy in Ukraine.

5. The Results

The author's approach to modelling involves determining the strength and tightness of the relationship between indicators of innovation activity in Ukraine and such macroeconomic indicators that determine the level of sustainable development of the national economy as a whole (GDP and products sold).

The use of software products (the package extension "Data Analysis" of Microsoft Excel) allowed us to determine the following equations of the multi-factor model of the dependence of GDP (Y_1) and the volume of innovative products sold (Y_2) on the indicators of the flow of innovation processes in the country, practical measures of the state to stimulate and regulate innovation, the implementation of priority areas of innovation activity. Equation of multi-factor dependence of GDP (in mln UAH) has the form:

$$Y_1 = -432,3237*X_1+5,474*X_2-4815,1648*X_3-4,0409*X_4-5807,817*X_5- \\ +400,3506*X_6+8249,7868*X_7+5527726,46$$

The equation of multi-factor dependence of the volume of innovative products sold has the form:

$$Y_2 = -5,3276*X_1-5,2912*X_2+21,235*X_3+ 0,1197*X_4+5,149*X_5+5,5856*X_6+6,2576*X_7-36702,6$$

Checking the reliability of the model based on multiple correlation coefficients (R_1=0.9773, R_2=0.9427) and determination (R_1^2=0.9551, R_2^2=0.8887), we see that they are close to 1, which indicates the adequacy of the model and its compliance with use in further analysis.

Commenting on the weighting factors in both equations, we can state a significant positive impact of such performance indicators as innovation costs and the number of industrial enterprises that implemented innovations. For the volume of innovative products sold, a positive trend is also formed by the number of organizations that carried out research work (research), the number of employees involved in the implementation of research, and the number of innovatively active industrial enterprises. The results of the multivariate regression equation for significant indicators are shown in Table 1.

A summary analysis of all indicators for certain functions describing the interdependencies of innovation activity indicators and GDP is shown in Table 2.

Most of the equations that most accurately describe the interdependence of the resulting indicator and the factors that affect it reflect the hyperbolic nature of the relationship. This trend was formed due to a drop in both the macroeconomic indicators of dependent variables and the indicator of results in 2013-2017, compared to the upward trend in 2001-2012. The undulating development of the world economy in general and the economy of Ukraine in particular, under the influence of various factors, is reflected by the mathematical function of the quadratic equation.

Table 1. Results of a multivariate regression equation for significant indicators

Names of factors, units of measurements	**Identification of the factor in the equation**	**Coefficients for the GDP dependence equation**
	Free member	**3937233**
Share of the volume of innovative products sold (goods, services) (%of the total volume of products sold (goods, services), %	Variable X_1	392,954
Number of new technological processes introduced into production, units	Variable X_2	0
The number of new or significantly improved low-waste, resource-saving technological processes introduced into production, units	Variable X_3	2385,9
Number of introduced types of innovative products (goods, services), units	Variable X_4	-1,37981
The number of introduced types of innovative products (new types of machinery, equipment, devices, apparatuses), total, units	Variable X_5	-219,538
Share of research costs in GDP, %	Variable X_6	-5047097
Investments in fixed assets, mln UAH	Variable X_7	-358,15
Production of innovative types of products and names has been introduced	Variable X_8	0
Volume of innovative products (goods, services) sold, mln UAH	Variable X_9	-12,8606
Share of the volume of scientific and technical works performed in GDP, %	Variable X_{10}	1350710

Sources: developed by the authors

The most significant coefficient in models of interdependence on macroeconomic indicators belongs to the factor "introduced into the production of innovative types of products, names" (R^2=0.97505), but in the multi-factor equation, the coefficient of influence for this indicator is 0, so for an in-depth correlation and regression analysis, we use the factor "specific weight of the volume of scientific and technical work performed in GDP, %" for which R^2 = 0.96251.

In paired regression, the identified variables will be the following indicators: "Specific weight of the volume of scientific and technical work performed in GDP, %" – an independent variable or factor (X) and "GDP, mln UAH" – dependent variable or indicator (Y). Let us define a type of equation that describes statistical data using the graphical capabilities of Microsoft Excel. Consider exponential, linear, logarithmic, 2nd degree polynomial, powerline, and linear trend line filtering. The criterion for choosing the type of function (form of dependence) is the the rate of the coefficient of determination (R2). The closer the value of this metric is to 1, the better the given function describes the statistics.

The analysis showed that the optimal form of dependence is a polynomial trend line of the 2nd degree, since the value of the approximation reliability acquires the greatest value of the considered variants of dependencies (R^2 = 0.96251) – Fig. 1.

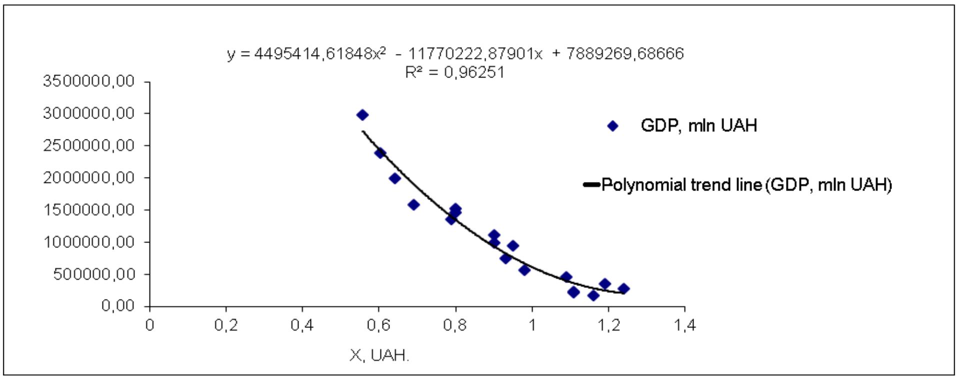

Fig:1 Polynomial trend line of the 2nd degree

Table 2. Types of equations describing the dependences of the influence of factors on GDP and their corresponding coefficients of determination

Factors	Linear	Logarithmic	Polynomial	Degrees	Exponential
Share of the volume of innovative products sold (goods, services) (% of the total volume of products sold (goods, services), %	y =-312389,10496x + 2550814,21789 R^2 = 0,85991	**y = -1073516,50071ln(x) + 2540259,15634 R^2 = 0,92551**	y = 33384,48847x^2 - 619530,66206x + 3076009,44707 R^2 = 0,92490	y = 3158462,44717$x^{-1,02358}$ R^2 = 0,70324	y = 3766764,77566$e^{-0,33303x}$ R^2 = 0,81679
Number of new technological processes introduced into production, units	y = 735,98698x - 219857,19806 R^2 = 0,26347	y = 1446154,84809ln(x) - 9673776,47848 R^2 = 0,25357	y = -0,00483x^2 + 757,38751x - 241126,65197 R^2 = 0,26348	y = 3,19377$x^{1,66928}$ R^2 = 0,28237	y = 186429,64859$e^{0,00081x}$ R^2 = 0,26954
The number of new or significantly improved low-waste, resource-saving technological processes introduced into production, units	y = 1318,31905x + 337604,49422 R^2 = 0,03408	y = 783438,28569ln(x) - 3866823,72389 R^2 = 0,03762	y = -7,56706x^2 + 10075,03237x - 2101907,37002 R^2 = 0,04247	y = 791,63729$x^{1,09294}$ R^2 = 0,06118	y = 278337,73496$e^{0,00184x}$ R^2 = 0,05575
Number of introduced types of innovative products (goods, services), units	y = -65,75255x + 1469336,82567 R^2 = 0,26623	y = -575062,88971ln(x) + 5885103,94882 R^2 = 0,27780	y = 0,00520x^2 - 186,52038x + 1809558,65298 R^2 = 0,29219	**y = 1251633001,57349$x^{-0,88225}$ R^2 = 0,54648**	y = 1420641,01728$e^{-0,00010x}$ R^2 = 0,51254
The number of introduced types of innovative products (new types of machines, equipment, devices, apparatuses), total, units	y = 2244,83379x - 746413,31508 R^2 = 0,36522	y = 2045475,37236ln(x) - 12565785,78118 R^2 = 0,38881	y = -2,67480x^2 + 7258,62779x - 2934668,11514 R^2 = 0,39731	y = 0,05902$x^{2,45895}$ R^2 = 0,46962	y = 92484,99424$e^{0,00263x}$ R^2 = 0,41883
Share of research costs in GDP, %	y = -2953729,45015x + 3620773,65399 R^2 = 0,90268	y = -2409176,39474ln(x) + 602668,34181 R^2 = 0,94679	**y = 3450890,80678x^2 - 8797205,21121x + 5874349,74320 R^2 = 0,95128**	y = 476437,95994$x^{-2,52142}$ R^2 = 0,86676	y = 12598844,82770$e^{-3,22632x}$ R^2 = 0,90013
New technological processes introduced	y = 735,98698x - 219857,19806 R^2 = 0,26347	y = 1446154,84809ln(x) - 9673776,47848 R^2 = 0,25357	y = -0,00483x^2 + 757,38751x - 241126,65197 R^2 = 0,26348	y = 3,19377$x^{1,66928}$ R^2 = 0,28237	y = 186429,64859$e^{0,00081x}$ R^2 = 0,26954
Production of innovative types of products and names has been introduced	y = 144488,22910x - 296994,73203 R^2 = 0,91460	y = 827187,78107ln(x) - 596904,75349 R^2 = 0,67625	y = 7895,10939x^2 - 5518,84933x + 203028,86275 R^2 = 0,97286	y = 93456,08140$x^{1,05039}$ R^2 = 0,91137	**y = 165849,34724$e^{0,16319x}$ R^2 = 0,97505**
Volume of innovative products (goods, services) sold, mln UAH	y = 22,24565x + 622817,76518 R^2 = 0,19849	y = 147017,88160ln(x) - 62456,04346 R^2 = 0,45933	y = -0,00310x^2 + 135,78126x + 357449,52816 R^2 = 0,58652	**y = 161503,07611$x^{0,20369}$ R^2 = 0,73693**	y = 363466,70874$e^{0,00004x}$ R^2 = 0,47428
Share of the volume of scientific and technical works performed in GDP, %	y = -3674314,16534x + 4431662,85491 R^2 = 0,91247	y = -3241222,07886ln(x) + 695395,84735 R^2 = 0,94986	**y = 4495414,61848x^2 - 11770222,87901x + 7889269,68666 R^2 = 0,96251**	y = 524795,30684$x^{-3,39544}$ R^2 = 0,87122	y = 29979358,8786$e^{-3,99280x}$ R^2 = 0,90057

Sources: developed by the authors

Consequently, the model of GDP dependence on the specific weight of the volume of scientific and technical work performed, based on the collected statistical data, takes the form of a polynomial trend line of the 2nd degree:

$$Y = 4495414{,}61848x^2 - 11770222{,}87901x + 7889269{,}68666 \qquad (1)$$

Substituting the value of the independent variable in Equation (1), we calculate the calculated value of the indicator. According to calculations, the amounts of statistical and calculated values of the indicator are almost the same (22920288 and 22427568.68 mln UAH). At the same time, their dynamics coincide, which confirms the reliability and correctness of the chosen equation describing the dependence.

We will analyse the correspondence of the constructed model, in particular, we will check its adequacy to statistical data using the Fischer criterion. To do this, calculate the calculated value of the criterion using the formula:

$$F_{est} = \frac{R^2}{1-R^2} * \frac{n-m-1}{m}. \quad (2)$$

$$F_{est} = \frac{(0,96251)}{1-(0,96251)} * \frac{18-1-1}{1} = 359,432915$$

The tabular value of the Fischer criterion is calculated with a given probability p (p=0.95) and the number of degrees of equality k_1=m and k_2=n-m-1. for the statistical data collected by us, the number of observations is n = 18, so the number of degrees of freedom is k_1=1 and k_2=16. Tabular value of the Fischer criterion: F_{table} = 4.49, since the inequality $F_{est\ holds}>F_{table}$ (359.43>4.49), then with probability p=0.95, we assert that the constructed model is adequate relative to statistical data and suitable for further analysis and forecasting.

Let's estimate the tightness and direction of the link between variable X and variable Y using the correlation coefficient, the formula of which has the form:

$$Kcorell[X,Y] = \frac{\sum_{ui=1}^{n}(Xi-\overline{X})*(Yi-\overline{Y})}{\sqrt{\sum_{i=1}^{n}(Xi-\overline{X})^2 * \sum_{i=n}^{n}(Yi-\overline{Y})^2}} \quad (3)$$

The correlation coefficient is calculated using the built-in function of Microsoft Excel. To do this, use the CORELL category function. The following value of the correlation coefficient r [x;y] = = -0.94695 is obtained. from the obtained value, we conclude: since r [x; y] < 0, the relationship between X and Y is inverse; since 0.7 < |r [x;y]| < 1, the relationship between X and Y is strong.

Let's estimate the effect of the variation of the Factor X on the variation of the indicator Y using the coefficient of determination, which is: R^2 = 0.96251, that is, the variation of the indicator by 96.25% is due to the variation of the factor. Consequently, the indicator of innovation efficiency "the share of the volume of scientific and technical work performed in GDP, %" has the greatest impact on GDP volumes. There are negative trends in the field of sustainable development in Ukraine, in particular, problems associated with low amounts of funding for scientific and technical work. These problems increase in the context of an economic recession, as opportunities to invest in sustainable development are narrowing.

6. Conclusion

The results of the study indicate that the nature of the impact of innovation activity of business entities on the corresponding indicators of sustainable development of Ukraine should be studied on the basis of a combination of performance indicators and efficiency of innovation activities. This will ensure a comprehensive and systematic assessment, and will allow determining input and output indicators for the formation country's sustainable development policies.

It is proved that in the conditions of the assessment, among the performance indicators, innovation costs and the number of industrial enterprises that introduced innovations have the most significant impact. The results of econometric studies indicate a positive and significant impact of the level of knowledge intensity of GDP on the overall economic dynamics. So, the state policy aimed at increasing the share of scientific and technical work in GDP is a top priority for ensuring sustainable development in Ukraine.

In contrast to the current models, the proposed ones provide a high level of accuracy in assessing indicators of the macroeconomic state of Ukraine, as a basis for forming an effective state policy of sustainable development. Within the framework of this, current directions of sustainable development of Ukraine in terms of Industry, Innovation and infrastructure are highlighted:

— dissemination of institutions for stimulating the creation, use and protection of intellectual property rights in the real sector of the economy;

— definition of the legal mechanism for changing the structure of priority areas of innovation activity and the system of their formation;

— strengthening the institutional capacity of the main managers of budget funds to make decisions on investing projects based on the result of an analysis of income and expenses.

This approach will provide a favourable innovative climate that will allow business entities to successfully commercialize their scientific and technical products, and, in turn, will contribute to the growth of the socio-economic level of the regions. The results obtained are comparable to the estimates of international methodologies for evaluating innovation activity in Ukraine.

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