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Articles

Modelling of the Dependencies of Industrial Development on Marketing Efficiency, Innovation and Technological Activity Indicators

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Abstract: This study is relevant due to the multidimensionality and interdependence of industrial development and the indicators of innovation and technological activities and marketing efficiency. The use of economic and mathematical modelling of dependencies between key macroeconomic parameters of the national economy development made it possible to qualitatively analyse the impact of the indicators of marketing efficiency, innovation and technological activities on the parameters of industrial development. The influence of the volume of financing for innovation activity, the introduction of new technological processes and the volume of production of innovative types of products on the change in the volume of sold industrial products is econometrically taken into account. The multidimensionality of the dependencies of choosing an effective model of the dependence of the volume of sold industrial products on the factors in innovation and technological activities was the reason for building a power model. The uniqueness of using an integrated model of the dependencies of innovation and technological activities and industrial development lies in taking into consideration latent factors that influence changes in industrial production, including funding for innovation in the country's industrial sector, the number of new technological processes and the level of mastering the production of new innovative types of products. The effectiveness of the study is explained by the fact that the selected system of indicators and dependencies helped to identify a number of risks to Ukraines' industrial development, for example, a critical decline in innovation and technological activities of industry.

Keywords: marketing efficiency, innovation and technological activities, industrial development, modelling of the dependencies, indicators.

Introduction

Today, in the conditions of Industry 4.0, ensuring innovative development of industry and bringing the industrial complex of Ukraine to the leading world standards is an urgent need. I n March 2020, the European Commission presented the New EU Industrial Strategy, which aims to implement three key priorities: 1) support the global competitiveness of European industry and the rules of the game (equal conditions) at the national and global levels; 2) transform Europe into a climate-neutral area by 2050; 3) shape the digital future of Europe (the New EU Industrial Strategy). According to the International Monetary Fund's economic classification, nowadays Ukraine belongs to the group of countries "Emerging and Developing Europe" Ukraines' relations with the EU are supported by political association and economic integration which create favourable conditions for economic growth of the national economy.

That is why Ukraine is currently in the process of finalizing the Industrial Development Strategy until 2025, considering the priorities of the new EU industrial strategy and using global technologies of the fourth industrial revolution. After all, modern changes in the technological paradigm associated with the fourth industrial revolution necessitate the use of new approaches to stimulating industrial development. In order to devise a successful strategy of the industrial complex development, it is essential to consider the whole re- source potential and existing results of the country, to define methods of and approaches to developing innovation and technological activities that will help to increase the level of using the available potential and ensure the efficiency of innovation and technological activities. That will also help to ensure an increase in the main resulting indicators of the country; in particular, the quality of industrial products, the volume of manufactured and exported industrial products, innovative products and production processes, and other components that shape the global competitiveness of industrial products of Ukraine. It is also important to take into account the main Global Sustainable Development Goals by 2030, approved at the UN Summit on Sustainable Development, on the basis of which it is advisable to develop Ukraines' industry. At present, the economic policy of Ukraine is aimed at ensuring the implementation of the Global Goals 8.9, 12 and 17, which, in turn should have a positive impact on the development of industry (Trofymenko et al.)

Thus, one of the key conclusions of the Industrial development report 2020 is that industrialization continues to be the main path to successful development, which contributes to the development and strengthening of a country's competitiveness. Advanced digital production (ADP) technologies applied to manufacturing production contribute to economic growth and improve the quality of life and environmental protection, which, in particular, belongs to the 2030 Agenda for Sustainable Development, and ensuring the use of these technologies is part of Global Goal 9 "Build resilient

infrastructure, promote inclusive and sustainable industrialization and foster innovation". These technologies include various approaches to creating and utilising robotic technology, the development of artificial intelligence, additive manufacturing, and the use of Big Data, which accelerates the introduction of innovation and increases the added value of industrial products.

Among the countries and economies that interact with ADP technologies used in production, Ukraine belongs to the group of latecomers in the role of producer, which means a very low level of activity in the implementation and use of innovative technologies of Industry 4.0. For example, according to the Industrial development report 2020 (Industrial development report, 2020), 10 countries with leading economies (China, France, Germany, Japan, the Republic of Korea, the Netherlands, Switzerland, Taiwan, the United Kingdom, the USA), which represent "the frontrunners" group are responsible for 90% of all global patents and 70% of all exports directly related to ADP technologies. "The followers" group includes those which actively use these technologies, but at a slower pace (Australia, Austria, Finland, etc.). Accordingly, "the latecomers" group includes countries with low innovation activity and "the laggards" group represents countries, which are not involved in the global creation and use of these technologies. Thus, the results of the report showed a directly proportional relationship between the development of industrial innovation in countries and the development of their economies.

All of the above determines the relevance of this study. This is because, in this paper, we regard innovation and technological activities as a major component of the formation and strengthening of competitive advantages, which characterises the modern world and progressiveness of technologies used, their spread in the economy and society, the quality of production, attraction and implementation of advanced technologies, the availability and accessibility of the country's resources. We also suggest considering and evaluating the indicators of marketing efficiency as a component that characterises the ability of the industrial sector to market quality and competitive industrial products and develop itself, taking into account the challenges and opportunities of the new industrial revolution. An assessment of the dependence between these factors and the determination of their impact on industrial development in Ukraine will make it possible to predict changes in these factors and identify effective measures to improve industrial development and economic growth. The scientific novelty of this study is the development and application of methodological principles for qualitative and quantitative modelling of the impact of the indicators of marketing efficiency and innovation and technological activity on industrial development of the country.

Literature review

Authors and researchers of various economic theories, models and concepts identify in- novation and technological activities as one of the main factors in industrial development and economic growth. For example, A. Smith, in his study "An Enquiry into the Nature and Causes of the Wealth of Nations" (Smith, 1880) emphasised the decisive influence of the division of labour on its productivity. He called the division of labour a major factor in scientific and technological development, and viewed scientific and technological progress as an important factor in increasing productivity of labour. In other words, he focused on the division of labour as organisational innovation and on the role of technology, i.e. tech- nological innovation, in the development of production, and regarded scientific and techno- logical progress as both the cause and effect of innovative development. An entrepreneurial approach to ensuring economic development and the primacy of innovation act as a main catalyst for innovation processes compared to other catalysts for development according to the theory of economic development by I. Schumpeter (Schumpeter, 2021) and the theory of innovative economy of an entrepreneurial type by P. Drucker (Drucker, 2007).

Schumpeter identified an enterprise as the main centre of innovative development of society, in particular, its innovative potential, and P. Drucker identified knowledge and intellectualization of labour as key factors in productivity and viewed innovation as the main form of business organisation. Marketing is one of the major stimulating components of entrepreneurial activity, which is evidenced by the research of Morris & Paul (1987), and entrepreneurship, in its turn, stimulates innovation. Therefore, it is feasible to single out marketing efficiency indicators as a factor feature of economic development.

Scientific schools of those, who study marketing (Lambin, 1970; Malhotra, 2010) suggest considering the evolution of marketing theories of the national economy in accordance with the development of its concepts. The first is the concept of improving production based on consumer preferences for widely available goods (the concept of management focuses on improving production and reducing prices). The second is the concept of traditional marketing (the assumption is based on defining needs and demands of target markets). The next one is the concept of social marketing (socially-oriented or socially responsible marketing), the essence of which lies in a combination of satisfied consumers' needs and long-term social well-being (Kotler, 2005). The concept of smart marketing (maintaining the welfare of consumers and society as a whole) is identical in content to social marketing.

The modern theory of economic growth since its beginning has also taken into account the impact of innovation. For instance, R. Solow developed a neoclassical theory of economic growth (Solow, 1997) and noted that the growth of total GDP was explained by population growth, technological progress and investment. These studies were continued

by P. Romer and R. Lucas who also noticed the endogenous nature of major industrial and technological innovations, based on investment in scientific and technological progress and human capital, and saw scientific and technological progress itself as a factor generated by internal causes of economic growth. In particular, P. Romer (Romer, 1986) as well as R. Lucas (Lucas, 1988) emphasised the importance of R&D, knowledge and development of human capital, so this determines the significance of scientific and technological progress in the production function.

The present paradigm of economic competitiveness of countries is based on their ability to form and use innovations (Von Krogh, Ichijo, & Nonaka, 2000). Today, many modern scientists identify and model the impact of various factors on economic growth and industrial development. Schwab et al. (Schwab, Sala-i-Martín, & Samans, 2018) singled out such factors in innovative development of countries as the ability to innovate, the quality of research institutions, companies' expenditure on R&D, cooperation of universities and industries in scientific and research work, public procurement of advanced technological products, the availability of scientists and engineers, patent applications that were considered in research on innovation, the stage of development and competitiveness of nations. Enterprises take an important role, because they change the direction of their business under the influence of information from the external environment and produce innovations and new technologies (Rudnichenko et al., 2021). For example, Ilyash et al. (Ilyash et al., 2020) believe that one of the crucial factors in the growth of investment attractiveness is access to resources for implementing investment projects in the field of innovation, intellectual property, and for creating and introducing advanced technologies, a digital economy. This explains the feasibility of determining the impact of the industry's innovation activities indices on the industrial products' revenue (Ilyash, Dzhadan, & Ostasz, 2018).

Nowadays scholars use different methodologies for assessing innovation and techno- logical activities and innovation competitiveness. Edsand evaluates them in terms of the creation and introduction of modern and advanced technologies (Edsand, 2019). Some scientists single out the integral index of economy's innovative technological competitiveness (Vasyltsiv et al.), emphasise the influence of priority factors in the development of industrial enterprises (Palyvoda et al.), determine the factors ensuring the economic security of investment activities of an industrial enterprise (Zlotenko et al.), etc.

In this paper, we were guided by the need to take into account and fully assess the main factors influencing the industrial development of Ukraine. Thus, in order to determine their relationships and opportunities for effective forecasting of industrial development, we formed indicators of marketing efficiency and innovation and technological activities, which allowed us to determine their impact on Ukraines' industrial development and provide appropriate recommendations.

Research methodology

The methodology for studying dependencies of marketing efficiency, innovation and technological activities and their influence on the development of the country's industry is based on the system of indicators shown in Figure 1. The peculiarity of the authors' approach lies in two aspects. First, the influence of (1) the factors in innovation activity in industry and (2) factors in intensification of technological growth in this type of economic activity is separated and taken into account. Secondly, it is proposed to model the growth of marketing efficiency based on the improvement in the quality and efficiency of innovation and technological activity rather than on the improvement in marketing policy of enterprises and marketing costs, because, the former has a more strategic and competitive nature.

When conducting economic and mathematical modelling of dependencies between key macroeconomic parameters of the national economy development, several methodological approaches are usually used, which comprise the method of linear extrapolation, the method of linear interpolation, the least squares method, the method of empirical dependency.

The first two methods are used when the predicted values are determined on the basis of the mean increment (the method of linear extrapolation has its own specifics associated with the need to establish potential values based on the mean increment in the previous period, whereas the method of linear interpolation is more commonly applied when forecasting is carried out within the potential period, if the values of the base and final stages of the potential period are known). In the practice of economic and mathematical modelling, the least squares method is used in the vast majority of cases, when the forecast of potential values of the studied indicator is based on finding the influence of individual factors by constructing an appropriate functional dependency.

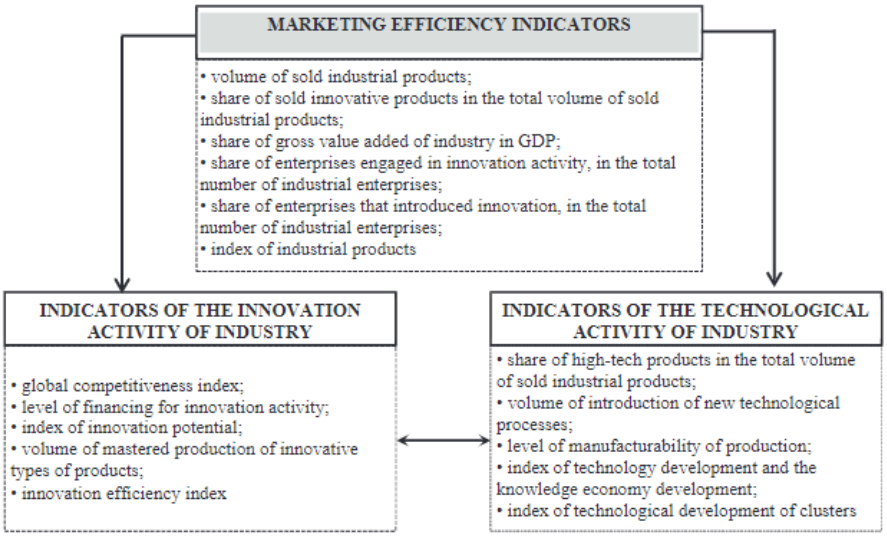


Figure 1.
The system of the indicators of marketing efficiency and innovation and technological activities as a basis of industrial development of the economy.

Thus, the combination of these two methods helps to make a more systematic and comprehensive assessment of the impact of innovation and technological factors on marketing efficiency in industry.

The problem statement is based on the approximation of the dependency of one of the analytical equations: of a linear (formula 1), parabolic (formula 2), and hyperbolic (formula 3) type (Schmidt, 2005; Zdrok et al., 2010):

$$Y = ax + b,$$

$$Y = ax^2 + bx + c,$$

$$Y = \frac{a}{x} + b\ ,$$

In turn, correlation forms of the dependency can be described by models (formulas 4-5) (Bruckheimer & Steward, 1972):

$$Y = bx^a\ ,$$

$$Y = ax \times bzc,$$

We would like to note that most studies prove that in the construction of economic and mathematical dependencies between different macroeconomic indicators, the equations and (4) are the most effective. Accordingly, in contrast to the approaches that use correlation-regression analysis methods to identify the relationship between dependent and independent variables, this study has a dual purpose: to find the most influential factor – an indicator of the total sales

of industrial products and to prove/disprove this hypothesis and identify the most effective form of dependency.

The advantage of the authors' methodological approach is that it first presupposes a qualitative analysis of the impact of the indicators of marketing efficiency, as well as of innovation and technological activities on the parameters of industrial development of the economy. Then there is a quantitative analysis, namely making calculations to build a linear dependency of the selected indicators of innovation and technological activities on the development of industry based on the use of the least squares method.

Some symbols were introduced and used for modelling: y – the volume of sold industrial products, x_1. – the volume of financing for innovation activity in the industrial sector of the country, x_2 – the number of introduced new technological processes, x_3 –the number of units of mastered production of new innovative types of products.

Taking into account the influence of the volume of financing and the volume of production of innovative types of products, it is proposed to calculate the coefficients of change in the volume of sold industrial products on the basis of an economic and mathematical model $y = ax + b$ *by* the system of linear equations (formula 6) (Schmidt, 2005; Zdrok et al., 2010):

$$\begin{cases} nb + a_1 \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i \\ b \sum_{i=1}^{n} x_i + a_1 \sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} x_i y_i \end{cases}$$

where *a, b* are linear regression coefficients; n is the number of periods; . is an indicator of innovation activity of industry; y is an indicator of the volume of sold industrial products.

The solution to the constructed systems of equations needed the calculation of the values of the constants *a, b* in each case, which was performed using deviations of arithmetic means (formulas 7 and 8) (Zdrok et al., 2010):

$$a = \frac{\sum y - b \sum x}{n}$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}$$

Since the main task of this stage of the study is to find the most effective form of dependency of the volume of sold industrial products on the factors in innovation and technological activities, it was decided to build a

power model. This stage is preceded by linearization of variables by taking the logarithm of both sides of the equation (formula 9):

$$lny = lnb + alnx,$$

To determine the accuracy of the calculations and evaluate the effectiveness of the linear and power dependency, it is necessary to calculate the following indicators for each selected factor (formulas 10-12) (Zdrok et al., 2010):

– correlation coefficient: $r=\frac{(x-\bar{x})(y-\bar{y})}{\sqrt{(x-\bar{x})^2 * (y-\bar{y})^2}}$;

– coefficient of determination: $R^2=1-\frac{\sum(y-y^p)^2}{\sum(y-\bar{y})^2}$;

– average approximation error: $\bar{A}=\frac{\sum\left|\frac{y-y^p}{y}\right|}{n}*100$.

The authors' suggestions concerning the research methodology are also different from others because they include the use of linear and power methods. Due to this, the variability of methodological tools increases, as, it is necessary to take into account the advantages of short- and long-term forecasting of consequences and to identify direct and indirect positive consequences of increasing funding for innovation, of introducing new technological processes and mastering the production of innovative products for industrial development.

Results

Creating conditions for industrial and technological development with marketing tools stimulates an increase in the country's competitiveness in world markets. The development of Ukraines' market economy coincided with the intensification of globalization processes in the world economy, which influenced the prioritization of industrial development. The Table 1 shows the results of analysing the dynamics of the indicators of marketing efficiency of Ukraines' industrial development for 2013-2019.

Table 1.
The values of the indicators of marketing efficiency of Ukraines' industrial development in 2013-2019

Indicators	Years							Growth rates (%)	
	2013	2014	2015	2016	2017	2018	2019	2019 / 2018	2019 / 2013
Volume of sold industrial products, UAH billion	917.0	1428.8	1776.6	2158.0	2625.9	3045.2	3019.4	99.2	3.3 p.
Share of sold innovative products in the total volume of sold industrial products, %	3.3	2.5	1.4	...	0.7	0.8	1.3	0.5	-2.0
Share of gross value added of industry in GDP, %	19.2	19.7	19.6	20.9	21.9	24.8	...	-	-
Share of enterprises engaged in innovation activity, in the total number of industrial enterprises, %	16.8	16.1	17.3	18.9	16.2	16.4	15.8	-0.6	-1.0
Share of enterprises that introduced innovations, in the total number of industrial enterprises, %	12.9	12.1	15.2	16.6	14.3	15.6	13.8	-1.8	0.9
Industrial production index, %	95.7	89.9	87.7	104.0	101.1	103.0	99.5	-3.5	-3.8

The obtained results testify to the high growth prospects of Ukrainian industry and, at the same time, to the importance of marketing support. However, the industrial sector of the economy needs significant innovation and technological support. In particular, the share of sold innovative products in the total volume of sold industrial products remains low (in 2019, the figure was 1.3%); the share of enterprises engaged in innovation activity was 15.8% in the total number of industrial enterprises, while the share of enterprises that introduced innovations was 13.8%.

According to world estimates, the level of innovative industrial enterprises is actively reducing in Ukraine. In 2019, the country was ranked only 53rd among 60 countries with a score of 48.05 out of 100 possible, thus trailing the leaders (Denmark, Germany, Fin- land, South Korea and Singapore received 86-87 scores) of the ranking by almost twice.

In the conditions of digitalization of the economy, an innovative and technological component of marketing efficiency of the country's industrial development is also of value (Table 2).

Table 2.
The indicators of innovation and technological activities of Ukraine's industrial development in 2013-2019

Indicators	Years							Growth rates (%) / Absolute deviations (±)	
	2013	2014	2015	2016	2017	2018	2019	2019 / 2018	2019 / 2013
Indicators of innovative marketing									
Global Competitiveness Index	4.14	4.05	4.14	4.03	4.12	4.22	4.31	0.09	0.17
Level of financing for innovation activity, % to GDP	0.7	0.5	0.7	0.7	0.3	0.3	0.4	0.1	-0.3
Innovation potential index	37.9	38.2	39.1	38.9	41.0	40.5	40.7	0.2	2.8
Volume of mastered production of innovative types of products, units	3138	3661	3136	4139	2387	3843	2148	55.9	68.5
Innovation efficiency index	33.7	34.4	33.9	32.5	34.2	36.6	34.1	-2.5	0.4
Indicators of technological marketing									
Share of high-tech products in the total volume of sold industrial products, %	3.3	2.5	1.4	…	0.7	0.8	1.3	0.5	-2.0
Volume of the introduction of new technological processes, units	1576	1743	1217	3489	1831	2002	2318	115.8	147.1
Level of manufacturability of production, % to GDP	2.4	1.6	1.2	…	0.6	0.7	0.9	0.2	-1.5
Index of technology development and the knowledge economy development	32.0	38.0	36.4	34.1	32.8	36.7	34.6	-2.1	2.6
Index of technological development of clusters	35.4	31.2	33.3	32.5	32.5	35.5	37.3	1.8	1.9

In 2019, Ukraine was ranked only 85th in terms of global competitiveness. Weak positions were recorded in the field of financial systems (136th place), institutions development (104th place) and macroeconomic indicators (133rd place). Singapore, the USA, Hong Kong, the Netherlands, Switzerland, Japan, Germany are in the first positions in the ranking.

The problem of financing innovation remains unresolved, as Ukrainian investors do not have sufficient funds, and foreign ones face many obstacles to investment in Ukraine. The main source of funding for innovation costs is enterprises' own funds – 88.1% of total expenditure on innovation, and they are aimed mainly at the purchase of equipment and other fixed assets, with minimal expenditure on the acquisition of technology and on conducting scientific research.

It is important to note that in 2019, Ukrainian innovatively-active industrial enterprises introduced 2148 innovative types of products, only 760 of them were new types of machinery and equipment. At the same time, the effectiveness of innovation in Ukraine in the reporting year amounted to 36.3 points out of 100 possible (China, Switzerland, the Netherlands, Great Britain were the leaders).

In 2019, the share of high-tech products in the total volume of industrial sales was characterised by a slight increase (1.3%), however, compared to 2013 it decreased by 2.5 times. In addition, in 2019, the number of introduced new technological processes rose by 15.0% compared to 2018 and fell by 66% compared to 2016. It should be mentioned that 40.6% of technologies purchased by industrial enterprises are equipment, 25.0% of them are purchased outside Ukraine.

According to the Global Innovation Index, in 2019, Ukraine took 28th place (36.4 points). The strengths of Ukraine include such sub-index indicators as the level of creation of new knowledge (17th place), the number of issued patents in relation to GDP (17th place), the number of patented utility models (1st place), the volume of computer software spending (19th place), the volume of ICT services exports (11th place) and the number of patented utility models in relation to GDP at purchasing power parity (1st place in the world).

In Ukraine, cluster development is 1.5 times lower than in European countries, where funding for technology parks is at the level of 62-100%, while in Ukraine such clusters are self-financing.

To increase the accuracy of our calculations and to construct a forecast model, statistical information for 2007-2019 was processed (Table 3), which was caused by the following reasons: 1) the longer the study period is, the more accurate the forecast will be; 2) the use of the statistical base of the study since 2007 was conditioned by the stabilization of macroeconomic indicators of Ukraines' development.

To build a mathematical dependency, it is necessary to solve a system of equations for determining the impact of each selected factor in innovation and technological activities of industry on the volume of sold products. The calculated data are presented in Appendix A, Tables A.1-A.3.

Table 3.
The indicators of the formation of innovation and technological activities of Ukrainian industry in 2007-2019

Indicators	Years													Average annual values of indicators
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Volume of sold industrial products, UAH billion	717.1	917.0	806.6	1322.4	717.1	1367.9	917.0	1428.8	1776.6	2158.0	2625.9	3045.2	3019.4	1601.5
Growth rates, %	30.0	27.9	-12.0	64.0	-45.8	90.8	-33.0	77.2	24.3	21.5	21.7	16.0	-0.8	21.7
Financing for innovation activity, UAH billion	10.8	12.0	7.9	8.0	14.3	11.5	9.6	7.7	13.8	23.2	9.1	12.2	14.0	11.9
Growth rates, %	75.7	10.8	-33.7	1.2	78.2	-19.9	-16.7	-3.2	79.5	68.2	-60.8	33.6	14.8	17.5
New technological processes that have been introduced, units	1419	1647	1893	2043	2510	2188	1576	1743	1217	3489	1831	2002	2318	1991
Growth rates, %	23.9	16.1	14.9	7.9	22.9	-12.8	-28.0	-7.9	-30.2	186.7	-47.5	9.3	15.8	13.2
The production of innovative products that has been mastered, units	2526	2446	2685	2408	3238	3403	3138	3661	3136	4139	2387	3843	2148	3012
Growth rates, %	4.9	-3.2	9.8	-10.3	34.5	5.1	-7.8	36.4	-14.3	32.0	-42.3	61.0	-44.1	4.7

To build a mathematical dependency, we solved a system of equations for determining the impact of each selected factor in innovation and technological activities of industrial enterprises on the volume of sold products (a system of equations (13) – for the amount of funding for innovation, (14) – for the number of new technological processes, (15) – for the volume of manufacturing innovative types of products):

$$\begin{cases} 12b + a \times 140224.40 = 17799646.40 \\ b \times 140224.40 + a \times 1838732536.24 = 217262180514.49 \end{cases}$$

$$\begin{cases} 12b + a \times 23558.00 = 17799646.30 \\ b \times 23558.00 + a \times 50107512.00 = 36080910143.50 \end{cases}$$

$$\begin{cases} 12b + a \times 37010.00 = 17799646.40 \\ b \times 37010.00 + a \times 118118534.00 = 56964095080.40 \end{cases}$$

where *a, b* are the coefficients of linear regression.

Based on the calculations, the following linear model is obtained (Figure 2):

– for financing innovation:

$y = 942271.38 + 46.3\ x^1$.

– for introducing new technological processes:

$y = 904797.91 + 294.68\ x^2$.

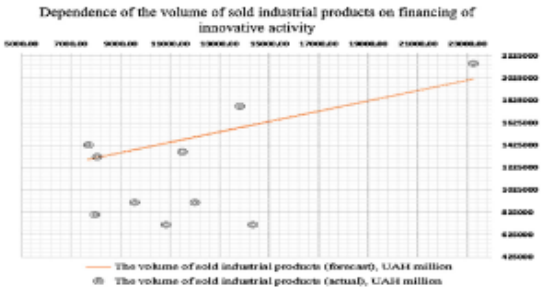
– for mastering the production of innovative types of products:

$y = -121079.64 + 520.2\ x^3$

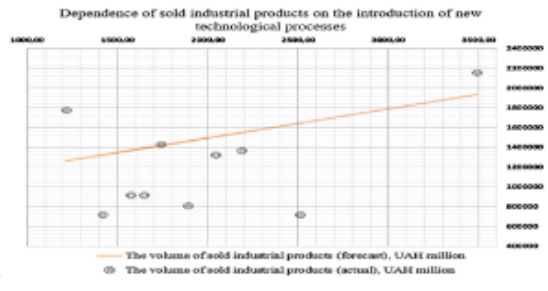
The analysis of the linear regression model shows that mastering the production of innovative products has the greatest impact on the volume of sold industrial products, as an increase in mastering the production of innovative products by one unit provides an increase in sales of industrial

products by 520.2 million UAH. In particular, with a rise in the indicator of introducing new technological processes by one unit, the indicator of sold industrial products is expected to increase by 294.7 million UAH, and if the financing for innovation rises by UAH 1 million, the indicator of sold industrial products will increase by UAH 46.3 million.

Years	x_1	y (fact)	y (forecast)
2007	10.8	717.1	1443.3
2008	12.0	917.0	1497.6
2009	7.9	806.6	1310.4
2010	8.0	1322.4	1314.8
2011	14.3	717.1	1605.9
2012	11.5	1367.9	1473.8
2013	9.6	917.0	1385.0
2014	7.7	1428.8	1298.6
2015	13.8	1776.6	1581.8
2016	23.2	2158.0	2017.8
2017	9.1	2625.9	1364.4
2018	12.2	3045.2	1506.2
2019	14.0	3019.4	1655.0



Years	x_2	y (fact)	y (forecast)
2007	1.4	717.1	1322.9
2008	1.6	917.0	1390.1
2009	1.9	806.6	1462.6
2010	2.0	1322.4	1506.8
2011	2.5	717.1	1644.4
2012	2.2	1367.9	1549.6
2013	1.6	917.0	1369.2
2014	1.7	1428.8	1418.4
2015	1.2	1776.6	1263.4
2016	3.5	2158.0	1932.9
2017	1.8	2625.9	1444.4
2018	2.0	3045.2	1494.7
2019	2.5	3019.4	1481.9



Years	x_3	y (fact)	y (forecast)
2007	2.5	717.1	1192.9
2008	2.4	917.0	1151.3
2009	2.7	806.6	1275.7
2010	2.4	1322.4	1131.6
2011	3.2	717.1	1563.3
2012	3,4	1367,9	1649,2
2013	3,1	917,0	1511,3
2014	3.7	1428.8	1783.4
2015	3.1	1776.6	1510.3
2016	4.1	2158.0	2032.0
2017	2.4	2625.9	1120.6
2018	3.8	3045.2	1878.0
2019	2.3	3019.4	1801.1

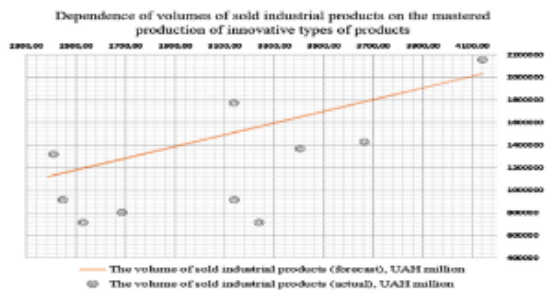


Figure 2.
Linear regression of the influence of factors in innovation and technological activities on the volume of sold products of Ukrainian industry in 2007-2019

We need to find the parameters of the equation by using the least squares method (a system of equations (19) – for the amount of funding for innovation, (20) – for the volume of introducing new technological processes, (21) – for the volume of producing innovative types of products):

$$\begin{cases} 12b + a \times 111.08002 = 169.1053 \\ b \times 111.08002 + a \times 1042.6914 = 1575.8916 \end{cases}$$

$$\begin{cases} 12b + a \times 90.5533 = 169.1053 \\ b \times 90.5533 + a \times 684.148 = 1276.4003 \end{cases}$$

$$\begin{cases} 12b + a \times 96.2013 = 169.1053 \\ b \times 96.2013 + a \times 771.6366 = 1356.0904 \end{cases}$$

where *a, b* are power regression coefficients.

Based on the calculations and on the values of intermediate indicators a and b for each factor in innovation and technological activities of industrial enterprises, which influences the sales of industrial products, presented in Tables 4-6, we have the following power model (Figure 3):

– for financing innovation:

$y = 45551 \times_1 {}^{0.3612}$

– for introducing new technological processes:

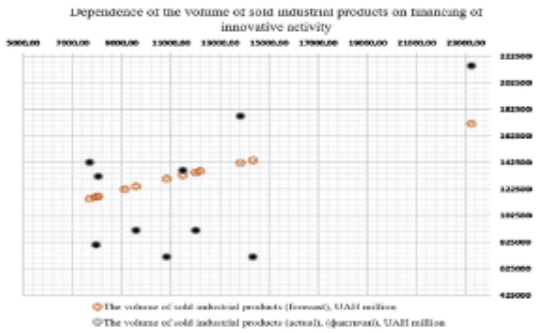
$y = 74533.2043 \times_2 {}^{0,3807}$

– for mastering the production of innovative types of products

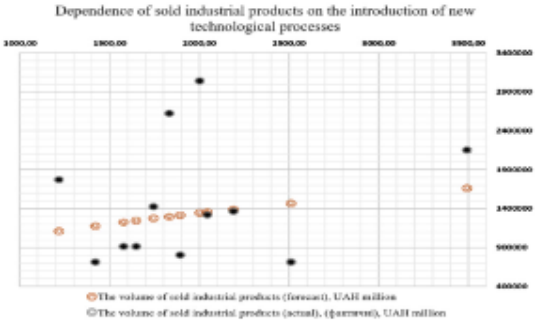
$y = 4428805 \times_3 {}^{0.9978}$

The analysis of the power regression equation gives reasons for asserting that with an increase in mastering the production of innovative products by 1.0%, an increase in the volume of sold industrial products by 0.997% is expected. With a rise in the value of the indicator of introducing new technological processes, the volume of sold industrial products is projected to increase by 0.381%. The financing for innovation has the smallest impact on the value of the indicator (0.361%).

Years	x_1	y (fact)	y (forecast)
2007	10.8	717.1	1305.2
2008	12.0	917.0	1354.7
2009	7.9	806.6	1167.7
2010	8.0	1322.4	1172.7
2011	14.3	717.1	1444.7
2012	11.5	1367.9	1333.4
2013	9.6	917.0	1248.2
2014	7.7	1428.8	1154.0
2015	13.8	1776.6	1425.6
2016	23.2	2158.0	1720.0
2017	9.1	2625.9	1226.9
2018	12.2	3045.2	1362.2
2019	14.0	3019.4	1309.7



Years	x_2	y (fact)	y (forecast)
2007	1.4	717.1	1181.2
2008	1.6	917.0	1250.1
2009	1.9	806.6	1318.1
2010	2.0	1322.4	1357.0
2011	2.5	717.1	1467.6
2012	2.2	1367.9	1392.9
2013	1.6	917.0	1229.3
2014	1.7	1428.8	1277.4
2015	1.2	1776.6	1114.1
2016	3.5	2158.0	1663.6
2017	1.8	2625.9	1301.5
2018	2.0	3045.2	1346.5
2019	2.5	3019.4	1321.0



Years	x_3	y (fact)	y (forecast)
2007	2.5	717.1	1099.6
2008	2.4	917.0	1064.8
2009	2.7	806.6	1168.7
2010	2.4	1322.4	1048.3
2011	3.2	717.1	1408.8
2012	3,4	1367,9	1480.4
2013	3,1	917,0	1365.4
2014	3.7	1428.8	1592.4
2015	3.1	1776.6	1364.5
2016	4.1	2158.0	1799.8
2017	2.4	2625.9	1039.2
2018	3.8	3045.2	1671.4
2019	2.3	3019.4	1655.1

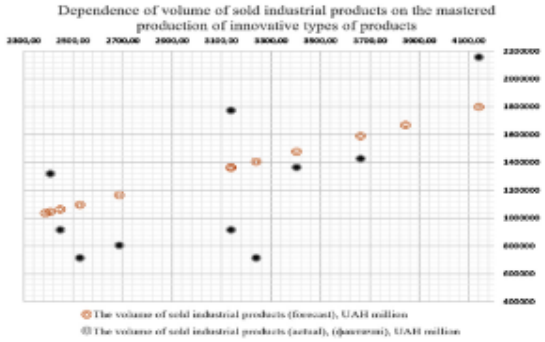


Figure 3.
Power regression of the influence of factors in innovation and technological activities on the volume of sales in Ukraines' industry in 2007-2019.

As we can see from Table 4, the linear dependency does not show as high accuracy as the power dependency does, so the latter should be used in further forecasting of the impact of innovation and technological activities on Ukraines' industrial development. Since the indicator of the volume of manufacturing innovative products has a greater impact on the total volume of sold products, it is most expedient to use this model for forecasting in this case.

Table 4.
Generalisation of the calculations and comparison of the results of using linear and power regression dependencies

Indicators	Linear model			Power model		
	r_{xy}	R^2	A	r_{xy}	R^2	A
Financing of innovation activity	0.2549	0.0650	44.63	0.2264	0.0513	2.80
New technological processes that have been introduced	0.2253	0.0508	46.60	0.2078	0.0432	2.78
The production of innovative types of products that has been mastered	0.4036	0.1629	42.43	0.3859	0.1489	2.60

In view of the above, the following applied conclusions can be drawn regarding the priority of using linear and/or power methods. For example, when it comes to the short- term period of influence, it is more appropriate to use linear models. Linear models are also more methodological and practical when it comes to the "point" effects of the impact of the growth in the volume and efficiency of innovation and technological activities on the increase in industrial production. However, when the forecasts are medium and long- term, the task is to predict the impact of increasing funding for innovation, of introducing new processes and mastering the production of innovative products on more complex macroeconomic parameters, such as increasing efficiency in industry, the positive effects of industrial development on related types of economic activity, socio-economic progress of territories, realisation of the potential of the real sector of the economy etc. In this case, it is much more promising and expedient to apply power models of relationship and dependence.

Given the risks and threats to the industrial and technological development of Ukraine, there is an objective need to develop promising ways of improving the system of state regulation in terms of international, investment and environmental components on the basis of marketing, thus, ensuring economic security. Therefore, it is necessary to improve the investment climate; encourage industry to increase funding for the modernization of fixed assets; organise a comprehensive, uniform and high-quality structure of foreign trade in high-tech products; improve the system of state regulation in environmental protection; stimulate industrial enterprises to reduce energy intensity of their production; strengthen control over the use of natural resources.

Conclusion and discussion

While testing the authors' methodology for qualitative and quantitative modelling of the impact of such indicators as marketing efficiency, innovation and technological activities, industrial development, it was found that a number of important indicators of Ukraines' industrial

development improved from 2013 to 2019. On the one hand, in the early 90s of the twentieth century, Ukraines' industry was characterised by one of the greatest economic potential in Europe, and the country was a powerful producer of both domestic and export products. On the other hand, the modern period is characterised by such systemic negative trends as the loss of strategically important industries, deindustrialization, limited production of innovative and high-tech products, raw material oriented exports and reduced competitiveness in world markets, high import dependence of domestic consumption. One of the key reasons for the emergence and increase of these trends lies in the reduction of innovation and technological activities.

In substantiating government management decisions to restore innovation and techno- logical activities in industry, it is essential to rely on the results obtained during the study of modelling of the impact that the indicators of innovation and technological activities have on the volume of industrial production. Their key provisions are as follows:

a) there is a statistically significant relationship between the dependent variable – the volume of industrial production and independent variables – the volume of funding for innovation in the industrial sector, the number of new technological processes, the number of units of mastered production of new innovative products;
b) "the number of mastered production of new types of innovative products" factor has the greatest impact on the growth of industrial production.

The system of strategic priorities of state regulation, which ensures the growth of in- novation and technological activities as a basis for Ukraines' industrial development should focus on strengthening external and internal innovation and technological competitiveness of the economy by developing internal competition and strengthening competitiveness of production on the basis of advanced technological innovations and information technologies, by providing system support for the elements of an innovation infrastructure, by forming and realising intellectual and personnel potential of technological development.

Further scientific research in the field of industrial and technological development can be used to discuss and prove the following hypotheses: 1) the budget policy of Ukraine is inconsistent with the priorities of state innovation policy, which are usually aimed at financing state innovation funds, targeted innovation programmes, highly effective innovation projects and programmes of the state support of industrial innovation activity, instead of being aimed at developing innovation projects and solutions; 2) the low level of effectiveness of innovations in industry is caused by a substantial gap between innovation contribution and innovation result. For example, in 2019, Ukraine produced more innovative industrial products compared to its level of innovation investment in industry and took 5th place among 131 countries (China, Switzerland, the Netherlands, Great Britain were the leaders).

Scientific inquiry should explain why Ukraine is lagging behind the world's major economies in terms of scientific and technological development of its industry. Therefore, future research ought to focus on finding effective mechanisms for rapid adaptation to the digital economy and for increasing financial capacity in order to ensure large-scale technological transformation. It is important not to lose the success of our country in the technological vector of development, which was achieved due to the adoption of the Strategy for the development of high-tech industries until 2025, the formation of the National Committee for Industrial Development, the creation of an integration platform "Industry 4.0 in Ukraine". Thus, it is necessary to determine the roadmap for uniting organisations of different sectors of the economy in order to accelerate the development of Ukrainian industries with high value-added.

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Appendices

Table A 1.
Calculated data for assessing the impact of funding for innovation activity on the volume of sales in Ukraine's industry in 2007-2019 (a linear model)

Periods	Volume of sold industrial products, billion UAH (y)	Financing for innovation activity, billion UAH (x_1)	x_1y	x_1^2	x_1-x_{1cp}	$y-y_{cp}$	$(x_1-x_{1cp})^2$	$(y-y_{cp})^2$	$(x_1-x_{1cp})*(y-y_{cp})$	$y-y^*$	$(y-y^*)^2$	$(y-y^*)/Y$
2007	717,1	10,8	7759487,0	117094,0	-0,9	-766,2	747,1	587104058,2	662301,2	-726,2	527376577,8	0,0010
2008	917,0	12,0	10999107,2	143860,8	0,3	-566,3	95,4	320659853,6	-174882,5	-580,6	337058436,3	0,0006
2009	806,6	7,9	6411996,6	63200,9	-3,7	-676,8	13953,7	457994972,7	2527989,2	-503,8	253815598,7	0,0006
2010	1322,4	8,0	10639436,8	64730,1	-3,6	-160,9	13248,6	25887348,5	585638,0	7,6	58222,5	0,0000
2011	717,1	14,3	10278505,7	205460,7	2,6	-766,2	7014,7	587104058,2	-2029378,2	-888,9	790061877,7	0,0012
2012	1367,9	11,5	15704605,5	131804,2	-0,2	-115,4	41,9	13312165,6	23625,6	-105,9	11214314,4	0,0001
2013	917,0	9,6	8769243,7	91443,3	-2,1	-566,3	4506,1	320659853,6	1202055,6	-468,0	219009267,6	0,0005
2014	1428,8	7,7	10996202,8	59226,9	-4,0	-54,5	15915,8	2966409,9	217285,3	130,2	16964424,3	0,0001
2015	1776,6	13,8	24541470,5	190818,3	2,1	293,3	4529,8	86024797,1	624239,8	194,8	37930682,5	0,0001
2016	2158,0	23,2	50129957,9	539609,7	11,5	674,7	133267,0	455255366,2	7789128,5	140,2	19665229,8	0,0001
2017	2625,9	9,1	23941303,2	83128,8	-2,6	1142,6	6593,9	1305440706,7	-2933938,8	1261,5	1591258802,0	0,0005
2018	3045,2	12,2	37090863,7	148354,8	0,5	1561,9	244,8	2439525492,6	772723,0	1539,0	2368496037,5	0,0005
2019	3019,4	14,0	42271010,6	196102,5	2,1	1417,9	4,6	20105490,5	30430,1	1729,1	29897031,8	0,0006
r_{xy}	0,2549											
R^2	0,0650											
$\overline{A}$	44,63											

Table A2.
Calculated data for assessing the impact of the number of introduced new technological processes on the volume of sales in Ukraine's industry in 2007-2019 (a linear model)

Periods	Volume of sold industrial products, billion UAH (y)	New technological processes that have been introduced, thousand units (x_2)	x_2y	x_2^2	x_2-x_{2cp}	$y-y_{cp}$	$(x_2-x_{2cp})^2$	$(y-y_{cp})^2$	$(x_2-x_{2cp})*(y-y_{cp})$	$y-y^*$	$(y-y^*)^2$	$(y-y^*)/Y$
2007	717,1	1,4	1017531,8	2013,6	-0,5	-766,2	296,1	587104058,2	416955,3	-605,9	367081037,9	0,0008
2008	917,0	1,6	1510357,5	2712,6	-0,3	-566,3	100,0	320659853,6	179035,2	-473,1	223823960,1	0,0005
2009	806,6	1,9	1526800,3	3583,4	-0,1	-676,8	4,9	457994972,7	47485,5	-656,1	430436439,5	0,0008
2010	1322,4	2,0	2701680,4	4173,8	0,1	-160,9	6,4	25887348,5	-12844,8	-184,4	34011013,0	0,0001
2011	717,1	2,5	1799862,5	6300,1	0,5	-766,2	299,0	587104058,2	-418998,6	-927,4	860011426,0	0,0013
2012	1367,9	2,2	2993021,0	4787,3	0,2	-115,4	50,6	13312165,6	-25940,9	-181,6	32990274,2	0,0001
2013	917,0	1,6	1445247,9	2483,8	-0,4	-566,3	149,9	320659853,6	219240,2	-452,2	204465025,1	0,0005
2014	1428,8	1,7	2490466,6	3038,0	-0,2	-54,5	48,5	2966409,9	11991,3	10,4	108450,4	0,0000
2015	1776,6	1,2	2162126,7	1481,1	-0,7	293,3	556,8	86024797,1	-218850,6	513,2	263353948,5	0,0003
2016	2158,0	3,5	7529366,7	12173,1	1,5	674,7	2328,2	455255366,2	1029519,6	225,1	50667115,3	0,0001
2017	2625,9	1,8	4807954,6	3352,6	-0,1	1142,6	17,5	1305440706,7	-151008,2	1181,5	1395955742,8	0,0005
2018	3045,2	2,0	6096494,2	4008,0	0,0	1561,9	1,5	2439525492,6	60653,7	1550,5	2403909559,7	0,0005
2019	3019,4	2,5	7548001,5	6001,2	0,5	1417,9	0,3	20105490,5	71901,8	1729,1	29897030,8	0,0006
r_{xy}	0,2253											
R^2	0,0508											
$\overline{A}$	46,60											

Table A3.

Calculated data for estimating the impact of the production volume of innovative types of products on the volume of sales in Ukraine's industry in 2007-2019 (a linear model)

Periods	Volume of sold industrial products, billion UAH (y)	The production of innovative types of products that has been mastered, thousand units (x_3)	x_3y	x_3^2	x_3-x_{3cp}	$y-y_{cp}$	$(x_3-x_{3cp})^2$	$(y-y_{cp})^2$	$(x_3-x_{3cp})*(y-y_{cp})$	$y-y^*$	$(y-y^*)^2$	$(y-y^*)/Y$
2007	717,1	2,5	1811335,7	6380,7	-0,6	-766,2	311,6	587104058,2	427682,5	-475,9	226451171,9	0,0007
2008	917,0	2,4	2243068,8	5982,9	-0,6	-566,3	407,3	320659853,6	361373,6	-234,3	54893706,6	0,0003
2009	806,6	2,7	2165588,4	7209,2	-0,4	-676,8	159,3	457994972,7	270137,3	-469,1	220061152,3	0,0006
2010	1322,4	2,4	3184359,4	5798,5	-0,7	-160,9	457,2	25887348,5	108792,1	190,8	36422363,7	0,0001
2011	717,1	3,2	2321894,4	10484,6	0,2	-766,2	23,7	587104058,2	-117871,3	-846,3	716141195,1	0,0012
2012	1367,9	3,4	4655050,5	11580,4	0,3	-115,4	101,7	13312165,6	-36786,5	-281,2	79093384,0	0,0002
2013	917,0	3,1	2877657,4	9847,0	0,1	-566,3	2,9	320659853,6	-30484,1	-594,3	353159756,7	0,0007
2014	1428,8	3,7	5230979,9	13402,9	0,6	-54,5	332,7	2966409,9	-31417,1	-354,5	125693974,3	0,0003
2015	1776,6	3,1	5571429,2	9834,5	0,1	293,3	2,7	86024797,1	15202,7	266,3	70934939,5	0,0002
2016	2158,0	4,1	8932086,2	17131,3	1,1	674,7	1112,7	455255366,2	711723,6	126,0	15876463,7	0,0001
2017	2625,9	2,4	6267934,3	5697,8	-0,7	1142,6	486,0	1305440706,7	-796553,9	1505,2	2265702120,0	0,0006
2018	3045,2	3,8	11702710,9	14768,6	0,8	1561,9	575,8	2439525492,6	1185220,3	1167,2	1362245985,4	0,0004
2019	3019,4	2,3	6944010,6	50140,3	-9,6	1417,9	91,3	201054900,5	-135460,7	1729,1	29897030,8	0,0006
r_{xy}	0,4036											
R^2	0,1629											
$\overline{A}$	42,43											