DOI 10.31489/2020Ec4/142-154
JEL: L1, O31
UDC: 330.341 (574)

L.V. Tashenova[1,2,*], A.V. Babkin[2]

[1]Karagandy University of the name of academician E.A. Buketov, Kazakhstan
[2]Peter the Great St. Petersburg Polytechnic University, Russia

[1]larisatash_88@mail.ru, [2]al-vas@mail.ru

[1]https://orcid.org/0000-0001-5022-0421, [2]https://orcid.org/0000-0002-6532-3826

[1]Scopus Author ID: 55356992700

[1]Researcher ID: B-4876-2013, [2]Researcher ID: V-1094-2019

Innovative activity of the enterprises in Kazakhstan: economic and statistical analysis

Abstract

Object: the purpose of the presented scientific article is to conduct an economic and statistical analysis of the innovative activity of the enterprises in Kazakhstan; the object is the enterprises of Kazakhstan, characterized by innovative activity, introducing and using in their activities the results of intellectual labor, represented by new technologies, technical objects, patents for inventions, utility models, industrial designs, etc.

Methods: to achieve the goal of the research, *general scientific methods* were widely used, in particular, *the method of analysis,* which made it possible to determine the entire set of parameters that characterize the innovative activity of enterprises in Kazakhstan; *a generalization method* aimed at establishing existing relationships between the considered economic objects and phenomena; *method of graphic interpretation,* which made it possible to visualize the results obtained; *economic and mathematical methods,* represented by correlation and regression analysis, methods of checking the constructed model based on the Student's, Fisher's test, the coefficient of determination and the Darbin-Watson test; *forecasting methods* based on the constructed multiple regression.

Results: within the framework of the research, the authors built a multiple regression model for the innovation activity of the enterprises in Kazakhstan, the adequacy and correctness of which was verified using the Student's t-test, Fisher's test, the coefficient of determination and the Darbin-Watson test. At the same time, using the Gauss method, the normal system of equations was solved, which made it possible to obtain a standardized regression equation, taking into account the calculated coefficients. It is also important to note that the article provides a comprehensive analysis of the development of the theory of innovation and key approaches to the interpretation of the concept of "innovative activity of an enterprise" based on the research of various scientific materials, including those widely represented in scientometric databases - Scopus, Clarivate Analytics, Google Scholar and RSCI.

Conclusions: using of correlation-regression analysis in terms of constructing multiple regression models is the optimal method that allows not only to effectively and comprehensively describe the innovative activities of the enterprises in Kazakhstan, but also to use it for the subsequent forecasting of the analyzed base indicator (dependent variable). The most important aspect remains the choice of parameters, which should be built on a deep and comprehensive understanding of the economic phenomenon under consideration, while their selection should be based on their strict economic interpretation, in particular by constructing matrices of pair correlation coefficients and taking into account multicollinearity.

Keywords: innovative activity, enterprises of Kazakhstan, inventions, industrial designs, utility models, innovative products, multiple regression, economic and mathematical modeling

Introduction

In the context of modern economic development, the transition of industrial enterprises to a qualitatively new level is identified as the main determinant - an innovative update associated with the process of innovative production, the advantage of which is the effective using of material, technical, production, intellectual and organizational and managerial resources that make up the innovative potential (Krawczyk-Sokolowska et al., 2019), the growth of which determines the further development of an industrial enterprise,

[*]*Corresponding author.*
E-mail address: larisatash_88@mail.ru

its competitive position in the markets, as well as the production of products with high added value (Vinogradova et al., 2017).

Without the process of creating and introducing innovations that define the essence of innovation, it is impossible to resist the forces that change market conditions and activate the forces of competition.

Thus, in the context of modern competition, shortening the life cycle of goods and services, the development of new diverse technologies, the merger of enterprises into clusters, the transition of countries to the fourth industrial revolution, one of the main conditions for the formation of a competitive strategic perspective of any enterprise is increasingly becoming its innovative activity.

In the scientific literature, the concept of innovation is given special attention, a large number of scientific studies, including in the international databases Scopus, Clarivate Analytics, Google Scholar, RSCI, are devoted to the topic of managing the innovative and digital potential of an enterprise, in particular those operating in the field of industrial production.

At the same time, it should be noted that there is no generally accepted definition of the concepts of "innovative activity" and "innovative potential" as an economic category. The analysis showed that the structure of innovation potential, which is the result of innovation, has not been fully investigated. Now, there are several options for the structure of innovation potential, often contradicting each other. A similar scientific problem is also typical for determining the key components of the components of innovation for its comprehensive analysis, assessment and subsequent forecasting, including through the using of multiple regression models.

Literature Review

Innovation activity is one of the most important factors in the development of the modern world. The ability to produce and perceive all kinds of innovations in our dynamic time determines the fate of individual subjects, organizations, peoples and societies. Innovations as a tool of transformation and a form of management of production development have become the object of independent study in all industrialized countries. A whole field of science has emerged - innovation science, which solves the problems of the formation of innovations, their spread, studies the reasons for resistance to innovations, etc. In the center of innovation is the process of change, i.e. transition and transfer of the system under consideration from one state to another.

As noted above, the issues related to the research of the creation, commercialization of innovations and the characteristics of innovative activities of enterprises are relevant, but, at the same time, not fully studied from the standpoint of determining the key components of the studied economic phenomenon.

In order to understand the specifics and essence of innovation, it is necessary to turn to the concept of "innovation".

In modern scientific literature, many definitions are given to the concept of "innovation", various options for classifications are proposed, built on various classification features.

It is generally accepted in the scientific community that the conceptual apparatus of innovations was mainly developed abroad by such scientists as I. Perlaki, J. Schumpeter and many others (Perlaki, 1985; Schumpeter, 1982; Schumpeter et al., 2002). They consider "innovation" in terms of the object and subject of the research being conducted.

Such prominent figures as J. Mansfield, J. Rogers, R. Foster, B. Twiss, F. Nixon also played an important role in the development of the theory of innovation. For example, Nixon defines "innovation" as a set of activities, the result of which leads to the emergence of new / improved business processes or equipment (Nikson, 1990). Also interesting is the point of view of B. Twiss, who interprets "innovation" as a process in which the idea of creating an invention or some kind of innovation acquires economic meaning, potential economic efficiency (Twiss, 1992; Twiss, 1993).

A number of American and European scientists consider innovation as inventive activity, during which there is an intersection of two previously unrelated systems - the individual and innovation. This approach is undoubtedly interesting, but it is limited by the absence of a subsequent implementation initiative, that is, the very idea of commercialization.

An important point is also that many scientists, both foreign and domestic, identify the concepts of "innovation", "novelty" and "novation", defining the concept of "innovation" as an innovation used in the production or management of an organization, like an economic unit.

In general, the development of the theory of innovation in the historical and scientific context can be represented in the form of the Figure 1.

One of the most important aspects of innovation is the diffusion of innovations, which is understood as the process of diffusion of innovations in the business cycles of scientific and technical, production and organizational and economic activities.

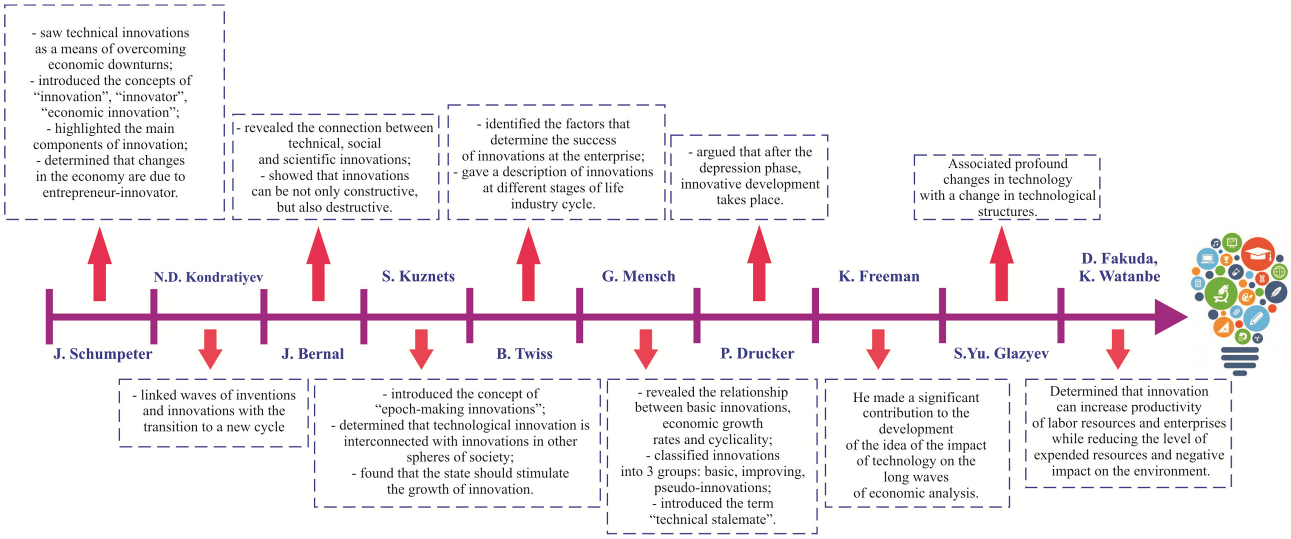

Figure 1. Development of the theory of innovation in the historical and scientific context

Note: compiled by the authors

Diffuse processes are very important, since they contribute to the inflow and outflow of capital, an increase in the number of producers and consumers, and a change in their quality characteristics.

J. Rogers believed that diffusion is a process in which innovations are transmitted through certain channels over a certain period of time among members of a social system (Rogers, 2003).

Innovation diffusion theories are diverse and span multiple disciplines.

In 1952, the Swedish geographer T. Hägerstrand examined the process of diffusion of socio-economic phenomena in rural areas, in particular, the spread of agricultural technology, and carried out its modeling using the Monte-Carlo method (Hägerstrand, 1952).

Diffusion of innovations is a space-time process. L. Suarez-Villa (Suarez-Villa, 2002) presented the conceptual framework of the process in the broadest view. Its essence lies in the fact that within the framework of macroeconomic and regional development associated with the change in the leading industries during the N.D. Kondratieff's "long waves", the emergence of innovation centers and the rate of their diffusion in the economic space play a crucial role (Kondratieff, 1984).

Thus, based on the analysis carried out, it can be concluded that innovation is the result of inventive activity, originating from a novation that is the result of scientific research; at the same time, pronounced features of commercialization characterize novation, in contrast to innovation, with subsequent economic efficiency.

In turn, the innovative activity of an enterprise can be understood as actions aimed at generating and activating an intellectual component, with the aim of creating, using and subsequently commercializing the results of intellectual work, represented by inventions, industrial designs and utility models.

The issues of innovation activity have been repeatedly considered in the works of scientists around the world, in particular, for example, from the standpoint of the effective development of innovation in small and medium-sized enterprises (Harel et al., 2019); as part of the study of issues related to the peculiarities of the using of technology by SMEs (Bagheri et al., 2019; Brigic et al., 2019; Caldas et al., 2019), marketing and product innovations (Quaye et al., 2019; Ramadani et al. ., 2019). A special role in publications is assigned to issues of support for innovation activities both from the state and within the framework of the public-private partnership (Goraczkowska et al., 2019; Hutahayan et al., 2019; Lopes et al., 2019; Yu et al., 2020). In addition, the issues of the innovation component are also studied within the framework of classical economic science (Jakimowicz et al., 2019), as well as taking into account the definition of the role of business incubators and other participants in the analyzed economic phenomenon in building effective regional and national innovation systems (Baskaran et al. , 2019; Perez-De-Lema et al., 2019; Siqueira et al., 2019; Liu et al., 2015).

It should be noted the special role of the universities in the formation of an effective innovative regional system, which is an integral component in the creation (Bellucci et al., 2016; Brochner et al., 2016; Cui et al., 2016) and the subsequent commercialization of innovative products (Dehghani et al., 2015; Kesting et al., 2016; Mamrayeva et al., 2012).

It should also be noted that a number of scientists consider innovation activity through the prism of sustainable entrepreneurship development and the role of R&D (Soltanzadeh et al., 2019; Soltysik et al., 2019; Mamrayeva et al., 2018).

In the context of the Fourth Industrial Revolution, the transition of a number of economies to a digital basis, a special role is assigned to the using of various digital tools in the structure of enterprises' innovation activities (Krykavskyy et al., 2019; Mahmood et al., 2020). In particular, a number of authors pay attention to the specifics of the using of blockchain, big data, cyber-physical systems and new-type laboratories in the process of building digital potential by companies, industrial enterprises and integrated structures (Galvin et al., 2020).

Despite of the significant contribution of these scientists, the research of the problem posed cannot be considered exhaustive. The works of the listed authors have created theoretical and methodological foundations for the formation of a system of innovative activities of enterprises and the innovative infrastructure of regions, various approaches and aspects of building a mechanism for the diffusion of innovations into production and consumption are proposed. However, the accumulated experience needs to be rethought and the development of such combinations that would correspond to the ongoing changes in the economy, the emergence and strengthening of an import substitution strategy aimed at enhancing domestic innovative developments and their introduction into the country's economy, taking into account the characteristics of the potential of the regions, their specific capabilities.

Methods

To achieve the goal set in the article and related to the economic and statistical analysis of the innovative activities of enterprises in Kazakhstan, the following methods were used:

1. *general scientific methods,* including:

– *an analysis method* that allows us to determine a complex set of indicators characterizing the innovative activity of enterprises in Kazakhstan (15), as well as to highlight the assumed dependent variable, which the selected parameters can influence (in our case - “the volume of innovative products (goods, services), billion tenge”);

– *a generalization method* aimed at establishing the existing relationships between the analyzed economic objects and phenomena, as well as allowing to determine anomalous points within the considered dependent variable;

– *the method of structuring and content analysis* will allow organizing all the information received related to the assessment of innovative activities of enterprises;

– *the method of functional and structural research of objects* will make it possible to build all possible options for the implementation of the goal and tasks related to the economic and statistical analysis of the scientific problem under consideration;

– *a method of graphic interpretation,* which contributes to the visual presentation of the results obtained using the MS Office application package and the Corel Draw graphic editor in terms of creating a picture reflecting the key stages of the development of the theory of innovation in the structure of scientific knowledge;

2. *economic-mathematical and economic-statistical methods* presented by:

– *Irwin criteria,* which allows checking the presence of anomalous points in the considered trend (in our case - according to the dependent y variable - “the volume of innovative products (goods, services), billion tenge”);

– *the method of constructing multiple regression,* including on the basis of a detailed analysis of the choice of regression coefficients based on the construction of a matrix of paired correlation coefficients, their assessment, studying the presence of multicollinearity between the values under consideration;

– *methods of checking the constructed model* based on:

• Student's t-test, taking into account the confidence level = 0,05;

• Fisher Criterion, understanding the peculiarity and number of factors of the constructed model, the number of observations included in the analysis at $\alpha = 0,05$, and also taking into account that $F_{fact} > F_{table}$, which will indicate the significance of the constructed regression equation;

• Coefficient of determination: at the same time, taking into account that to assess the adequacy of the model, R must be more than 85%;

• Durbin-Watson Statistic, taking into account the range fact 1,5 <DW <2,5, calculated on the basis of the obtained residuals;

– *forecasting methods* based on the constructed multiple regression;

– *Gaussian elimination,* which allows solving a system of equations and building a standardized form of regression equations.

It is also important to note that the sequence and stages of the research presented in this scientific article comply with the standards, algorithms generally accepted in scientific circulation and reflected, including in scientific and periodical literature.

The reliability of the data is ensured by the reliability of the calculations and measurements carried out, as well as the nature of their subsequent interpretation; the reproducibility of the data is due to the verification of the results obtained in MS Excel.

Results

The innovative activity of enterprises is a complex economic phenomenon, since today, as noted earlier in the article, there is still no consensus among scientists regarding the set of indicators that can be included in the analysis and used for subsequent research.

The presented author's approach is based, first of all, on the experience of studying the issues of innovation, certain aspects of the features of the commercialization of the results of intellectual work, as well as on conducting many years of research in the field of studying the features of the functioning of industrial enterprises and integrated structures, including those represented by innovative-active industrial clusters, constituting their innovative and digital potential, the study of which, of course, in the context of building a new type of economy, is especially relevant and significant.

Considering all of the above, the following indicators were selected for analysis:

1) Dependent variable:

y – the volume of innovative products (goods, services), billion tenge;

2) Independent variables:

$\mathbf{x_1}$ – number of enterprises with innovations, units;

$\mathbf{x_2}$ – number of innovative-active enterprises, units;

$\mathbf{x_3}$ – the level of activity of enterprises in the field of innovation, in percent;

$\mathbf{x_4}$ – costs for innovations, billion tenge;

$\mathbf{x_5}$ – the number of organizations that have created and using new technologies and equipment, units;

$\mathbf{x_6}$ – the number of created and used new technologies and equipment, units;

$\mathbf{x_7}$ – internal costs for research and development work (R&D), billion tenge;

$\mathbf{x_8}$ – number of organizations that carried out R&D, units;

$\mathbf{x_9}$ – number of employees who performed R&D, thousand people;

$\mathbf{x_{10}}$ – average monthly nominal wages of employees by type of economic activity "Research and Development", thousand tenge;

$\mathbf{x_{11}}$ – investments in fixed assets by type of economic activity "Research and Development", billion tenge;

$\mathbf{x_{12}}$ – granted patents for inventions, units;

$\mathbf{x_{13}}$ – granted patents for utility models, units;

$\mathbf{x_{14}}$ – granted patents for utility models, units;

$\mathbf{x_{15}}$ – granted patents for breeding achievements, units.

All initial data are presented in table 1.

Table 1. Initial data for 2008-2019 in the context of the analyzed parameters

Year	Indicators															
	y	**x_1**	**x_2**	**x_3**	**x_4**	**x_5**	**x_6**	**x_7**	**x_8**	**x_9**	**x_{10}**	**x_{11}**	**x_{12}**	**x_{13}**	**x_{14}**	**x_{15}**
2008	111,5	11172	399	4	113,5	208	823	34,8	421	16,3	81,8	5,9	1755	110	84	1
2009	82,6	10096	447	4	61,1	140	487	39	414	15,8	90,9	3,8	1687	105	236	21
2010	142,2	10937	572	5,2	235,5	338	1037	33,5	424	17,0	103,6	5,9	1868	116	260	79
2011	235,9	10723	762	7,1	194,9	562	1365	43,4	412	18,0	121,4	8,9	1887	123	270	50
2012	379,0	21452	1622	7,6	325,6	713	1608	51,3	345	20,4	148,5	14,8	1400	126	274	67
2013	578,3	22070	1774	8	431,9	664	2374	61,8	341	23,7	153,6	11,5	1500	163	280	122
2014	580,4	24068	1940	8,1	434,6	681	2469	66,3	392	25,8	171,6	9,3	1504	165	282	97
2015	377,2	31784	2585	8,1	663	865	3704	69,3	390	24,7	184,9	11,2	1504	166	282	98
2016	445,8	31077	2879	9,3	1533,8	735	7780	66,6	383	23,0	208,8	11,5	1011	577	182	123
2017	844,7	30854	2974	9,6	907,2	704	5291	68,9	386	22,1	228,4	16,3	865	591	129	91
2018	1179,2	30501	3230	10,6	861,9	748	5957	72,2	384	22,4	240,7	7,3	778	950	219	87
2019	981,3	28414	3206	11,3	545,1	839	5831	82,3	386	21,8	255,3	11,6	730	1049	229	24

Note - compiled by the authors on the basis of statistical compilations characterizing the science and innovation activities of Kazakhstan

Graphical interpretation of the dynamics of factor Y - "the volume of innovative products (goods, services), billion tenge" to conduct a visual analysis that allows us to determine the presence or absence of abnormal points in the structure of the series under consideration (Figure 2).

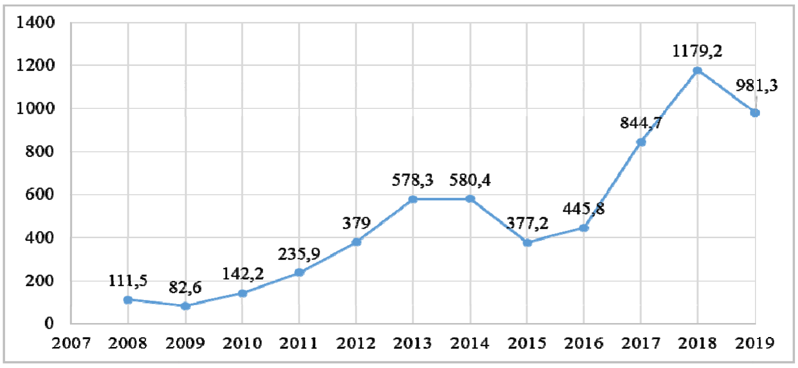

Figure 2. The volume of innovative products (goods, services) produced by enterprises of Kazakhstan for the period 2006-2019, billion tenge (graphic interpretation for visual identification of abnormal points)

Note: compiled by the authors

Visual analysis of the trend made it possible to assume that there are no abnormal points, but to confirm the hypothesis put forward, it is advisable to use the Irwin criteria. For n = 12, the threshold value of the Irwin criteria should not exceed λ_{cr} = 1,3.

In order to calculate the value of the Irwin criteria for the indicators under consideration, it is necessary to determine:

1. mean value (calculated in table 2);
2. unbiased estimate of variance (D (y) - formula 1);
3. standard deviation based on unbiased variance estimate - formula 2;
4. directly the value of Irwin criteria (using formula 3).

$$D(y) = \frac{\sum (y_i - \bar{y})^2}{n-1} = \frac{1379639{,}309}{12-1} = 125421{,}755 \quad (1)$$

$$\sigma(y) = \sqrt{D(y)} = \sqrt{125421{,}755} = 354{,}149 \quad (2)$$

$$\lambda = \frac{|y_i - y_{i-1}|}{\sigma(y)} \quad (3)$$

Table 2. Calculated values of the Irwin criteria in the context of 12 considered indicators

t	y	$(y_i - y_{avr})^2$	λ
1	111,5	146950,833	-
2	82,6	169943,192	0,0816
3	142,2	124356,145	0,168
4	235,9	67050,787	0,265
5	379	13419,292	0,404
6	578,3	6965,293	0,563
7	580,4	7320,228	0,00593
8	377,2	13839,562	0,574
9	445,8	2405,085	0,194
10	844,7	122400,853	1,126
11	1179,2	468346,328	0,945
12	981,3	236641,71	0,559
Total (amount for y): 5938,1		1379639,309	
Average y value = 494,8			
Note – complied by the authors			

According to the data obtained, it can be concluded that no anomalous values are observed.

To construct a matrix of paired correlation coefficients and a matrix of interfactor correlations, the Microsoft Office software package was used (Table 3)

Table 3 – The matrix of pairwise correlation coefficients

Parameter	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
Y	1															
X1	0,761133	1														
X2	0,868211	0,969242	1													
X3	0,900815	0,865868	0,945388	1												
X4	0,522348	0,816321	0,797942	0,6915	1											
X5	0,701276	0,872256	0,866248	0,904262	0,626187	1										
X6	0,732733	0,86587	0,915959	0,850293	0,92889	0,704445	1									
X7	0,855109	0,926603	0,957828	0,934006	0,664982	0,880349	0,820508	1								
X8	-0,43862	-0,53457	-0,48591	-0,52286	-0,31391	-0,63012	-0,29584	-0,52057	1							
X9	0,609004	0,845796	0,77108	0,734825	0,59995	0,853415	0,596143	0,84154	-0,60599	1						
X10	0,909788	0,915229	0,984493	0,971802	0,742308	0,846289	0,902744	0,951165	-0,4315	0,711543	1					
X11	0,434257	0,656037	0,612352	0,634745	0,484044	0,743481	0,468697	0,585117	-0,69844	0,582855	0,589392	1				
X12	-0,88766	-0,83057	-0,91738	-0,86795	-0,71919	-0,65334	-0,8865	-0,84542	0,414756	-0,51724	-0,93394	-0,51471	1			
X13	0,865205	0,651567	0,806373	0,814906	0,589065	0,528326	0,832079	0,74178	-0,1609	0,323615	0,86645	0,25479	-0,92092	1		
X14	-0,04368	-0,01722	-0,03574	0,099508	-0,22184	0,305308	-0,22728	0,09901	-0,3177	0,306127	-0,02845	0,007885	0,260983	-0,25497	1	
X15	0,298465	0,587657	0,488252	0,453098	0,645316	0,582157	0,452626	0,442828	-0,53151	0,737769	0,409256	0,457441	-0,23892	0,044953	0,345577	1

Note – complied by the authors.

Table 3 shows that the analyzed Y – "the volume of innovative products (goods, services), billion tenge" is really influenced by factors, 11 of which (X1-X7, X9-X10, X12-X13) significantly exceed 50%. At the same time, it should be noted that at the initial stage of building the model, the author decided to include factors in the model, according to which the correlation coefficient, *according to the Chaddock scale,* is not lower than 0,5 (which corresponds, at least, to the presence of a noticeable connection strength).

The table also shows that there is multicollinearity between the above factors, as a result of which only 4 factors were selected for building the model: X3, X10 and X12-X13 (further in the analysis, these indicators will be designated as X1, X2, X3 and X4, respectively).

Using the add-in "Data Analysis", we will carry out calculations to estimate the indicators of the future regression model (Tables 4-6).

Table 4. Regression statistics

Regression statistics	
Multiple R	0,922781026
R-square	0,851524822
Normalized R-square	0,752541369
Standard error	173,7047959
Note – calculated by the authors.	

Table 4 shows that the reduced *coefficient of determination* exceeds 85%, which indicates that the model is consistent with the data; such a model is considered viable. It is also important to note that the normalized R-square (reduced coefficient of determination) is also quite high, which also confirms the significance of the constructed regression.

Table 5. ANOVA results

Index	df	SS	MS	F	F Significance
Regression	4	1038289,172	259572,2931	8,602698755	0,011634539
Residuals	6	181040,1367	30173,35612	-	-
Total	10	1219329,309	-	-	-
Note – calculated by the authors.					

Next, write out the actual value of Fisher's F-criterion = 8,6 (Table 5). Taking into account the fact that we are working with a four-factor model, as well as the fact that we have 12 observations, we will use the table of the already calculated values of Fisher's F-criterion at $\alpha = 0,05$. As a result, we get: $F_{act} = 8,6 > F_{table} = 3,36$, which indicates the significance of the regression equation (thus, the relationship is proved).

Table 6. Calculated Regression Coefficients

Parameter	*Coefficients*	*Standard error*	*t-statistics*	*P-Value*	*Bottom 95%*	*Top 95%*	*Bottom 95%*	*Top 95%*
Y-intersection	67,7	1131,33418	0,059827854	0,954235687	-2700,589716	2835,96031	-2700,589716	2835,96031
4	95,0	107,7661793	0,881443293	0,411992409	-168,7045654	358,6841173	-168,7045654	358,6841173
81,8	-0,7	5,956692009	-0,124992065	0,904612512	-15,3200395	13,83096104	-15,3200395	13,83096104
1755	-0,2	0,499933536	-0,402169604	0,701494362	-1,424351366	1,022235222	-1,424351366	1,022235222
110	0,2	0,393806643	0,627125785	0,553675887	-0,716643842	1,210576441	-0,716643842	1,210576441
Note – calculated by the authors.								

The calculations made it possible to obtain $t_{cr} = 2,2$ (taking into account the confidence level = 0,05); in our case: $t_a > t_{cr}$ and $t_b > t_{cr}$, hence parameters a and b are significant (Table 6), while $t_c < t_{cr}$, $t_d < t_{cr}$, $t_e < t_{cr}$ means parameters c, d and e are insignificant.

The final view of the model is as follows (Formula 4):

$$y = 67,7 + 95x^1 - 0,7x^2 - 0,2x^3 + 0,2x^4 \qquad (4)$$

Next, show the residuals that we received in the calculation process, and then, using formula (5), it is possible to calculate the Durbin-Watson coefficient (Table 7):

$$DW = \frac{\sum (e_i - e_{i-1})}{\sum e_i^2}, \quad (5)$$

where: $e_i = y - y(x)$

Table 7. Calculation of the Durbin-Watson Statistics

Observation	Predicted value	Residuals	Calculated values	
1	66,71227807	15,88772193	-	-
2	137,5694792	4,630520816	21,44172303	126,724577
3	302,7059158	-66,80591583	4463,03039	5103,164481
4	428,6799705	-49,67997055	2468,099474	293,2980018
5	451,9106767	126,3893233	15974,26104	31000,39623
6	447,6976484	132,7023516	17609,91411	39,85432626
7	438,0422429	-60,84224293	3701,778524	37459,51006
8	734,8602652	-289,0602652	83555,83689	52083,46567
9	781,5762357	63,12376433	3984,609623	124033,5906
10	973,561133	205,638867	42287,34363	20310,5545
11	1063,284154	-81,98415448	6721,401586	82727,00249
		Final total values:	**180787,7**	**353177,6**
Note – calculated by the authors				

Thus, the Durbin-Watson coefficient in our case is 1,95.

It is generally accepted that if the obtained coefficient lies in the range 1,5 <DW <2,5, then there is no autocorrelation. Consequently, the constructed econometric model is effective and can be used in further research.

Using the obtained regression equation, the forecast for Y for 2020-2022 will be: 2020 – 1072,13 billion tenge; 2021 – 1183,25 billion tenge; 2022 – 1281,61 billion tenge.

To calculate the standardized variables and build a standardized regression equation, we use the previously obtained pair correlation coefficients and construct a normal system of equations (Formulas 6-9):

$$0,901 = \beta1+0,972\beta2-0,868\beta3+0,815\beta4 \quad (6)$$
$$0,91 = 0,972\beta1+\beta2-0,934\beta3+0,866\beta4 \quad (7)$$
$$-0,888 = -0,868\beta1-0,934\beta2+\beta3-0,921\beta4 \quad (8)$$
$$0,865 = 0,815\beta1+0,866\beta2-0,921\beta3+\beta4 \quad (9)$$

Solve this system of linear equations by the Gaussian elimination (Formula 10):

$$\beta1 = 0,612;\ \beta2 = -0,153;\ \beta3 = -0,262;\ \beta4 = 0,258 \quad (10)$$

The standardized form of the regression equation is the following (Formula 11):

$$t(y) = 0,612x^1-0,153x^2-0,262x^3+0.258x^4 \quad (11)$$

Discussions

Despite of the broad reflection of the scientific problems considered in this article in the publications of the scientific community, the issues of determining the component composition of innovative activity in order to form and effectively manage the innovative potential of enterprises are still controversial. At the same time, there is no clear opinion between scientists regarding the allocation of the role and place of "innovative potential". It is important to note that very often there is an identification of concepts related to innovation and digital activity, especially industrial enterprises and clusters, which are actively moving to digital platforms and unifying various processes: from production to marketing and logistics. In our opinion, it is advisable to separate these concepts.

Future scientific research of the authors will be related to the study of the features of the functioning of backbone innovative-active industrial clusters, combining both innovative and digital components, actively meeting the realities of modern economic development and the transition to building a new type of economy in the context of the Fourth Industrial Revolution.

Conclusions

The results obtained show that the selection of factors for assessing the innovation activity of enterprises by describing using economic and statistical methods, in particular those presented, for example, by multiple regression equations, is advisable to carry out taking into account the calculated pair correlation coefficients, as well as multicollinearity, excluding those factors that do not have an effect on the dependent variable. At the same time, the most important aspect of conducting a study of this kind is to check the adequacy of the constructed model using the coefficient of determination, Fisher Criterion, Student's t-test and the Durbin-Watson coefficient. If the model is correct, then it can be used later to predict the analyzed indicator.

References

Bagheri, M., Mitchelmore, S., Bamiatzi, V., & Nikolopoulos, K. (2019). Internationalization Orientation in SMEs: The Mediating Role of Technological Innovation. *Journal of International Management*, *25*(1), 121-139. https://doi.org/10.1016/j.intman.2018.08.002

Baskaran, A., Chandran, V. G. R., & Ng, B. K. (2019). Inclusive Entrepreneurship, Innovation and Sustainable Growth: Role of Business Incubators, Academia and Social Enterprises in Asia. *Science Technology and Society*, *24*(3), 385-400, Article 0971721819873178. https://doi.org/10.1177/0971721819873178

Bellucci, A., & Pennacchio, L. (2016). University knowledge and firm innovation: evidence from European countries. *Journal of Technology Transfer*, *41*(4), 730-752. https://doi.org/10.1007/s10961-015-9408-9

Brigic, M., & Alibegovic, S. D. (2019). Development of innovations under the impact of intrapreneurship activities in production enterprises. *Ekonomski Vjesnik*, *32*(2), 321-334.

Brochner, J., & Lagerqvist, O. (2016). From ideas to construction innovations: firms and universities collaborating. *Construction Economics and Building*, *16*(1), 76-89. https://doi.org/10.5130/AJCEB.v16i1.4668

Caldas, L. F. D., Paula, F. D., & de Macedo-Soares, T. (2019). Industry innovation spending and openness to collaboration as levers for firm performance. *European Journal of Innovation Management*, *22*(4), 617-638. https://doi.org/10.1108/ejim-04-2018-0075

Cui, Y., Jiao, J., & Jiao, H. (2016). Technological innovation in Brazil, Russia, India, China, and South Africa (BRICS): An organizational ecology perspective. *Technological Forecasting and Social Change*, *107*, 28-36. https://doi.org/10.1016/j.techfore.2016.02.001

Dehghani, T. (2015). Technology commercialization: From generating ideas to creating economic value. *International Journal of Organizational Leadership*, *4*(2), 192-199.

Galvin, P., Burton, N., & Nyuur, R. (2020). Leveraging inter-industry spillovers through DIY laboratories: Entrepreneurship and innovation in the global bicycle industry. *Technological Forecasting and Social Change*, *160*, Article 120235. https://doi.org/10.1016/j.techfore.2020.120235

Goraczkowska, J., & Tomaszewski, M. (2019). Support of innovation activity in small and medium - sized enterprises in the Greater Poland Voivodeship. *Ekonomia I Prawo-Economics and Law*, *18*(2), 183-195. https://doi.org/10.12775/EiP.2019.014

Hägerstrand, T. (1952). *The propagation of innovation waves*. Lund studies in geography: Series B, Human geography, 4. Lund: Royal University of Lund, Dept. of Geography.

Harel, R., Schwartz, D., & Kaufmann, D. (2019). Small businesses are promoting innovation!! Do we know this? *Small Enterprise Research*, *26*(1), 18-35. https://doi.org/10.1080/13215906.2019.1569552

Hutahayan, B., & Yufra, S. (2019). Innovation speed and competitiveness of food small and medium-sized enterprises (SME) in Malang, Indonesia Creative destruction as the mediation. *Journal of Science and Technology Policy Management*, *10*(5), 1152-1173. https://doi.org/10.1108/jstpm-12-2017-0071

Jakimowicz, A., & Rzeczkowski, D. (2019). Firm ownership and size versus innovation activities over the business cycle: near-zero inertia as a sign of the transition from the fifth to the sixth Kondratieff wave. *Oeconomia Copernicana*, *10*(4), 689-741. https://doi.org/10.24136/oc.2019.033

Kesting, P., Song, L. J., Qin, Z. H., & Krol, M. (2016). The role of employee participation in generating and commercialising innovations: insights from Chinese high-tech firms. *International Journal of Human Resource Management*, *27*(10), 1059-1081. https://doi.org/10.1080/09585192.2015.1060512

Kondratieff, N. (1984). *The long wave cycle.* New York: International Moneyline.

Krawczyk-Sokolowska, I., Pierscieniak, A., & Caputa, W. (2019). The innovation potential of the enterprise in the context of the economy and the business model. *Review of Managerial Science*. https://doi.org/10.1007/s11846-019-00374-z

Krykavskyy, Y., Pokhylchenko, O., & Hayvanovych, N. (2019). Supply chain development drivers in industry 4.0 in Ukrainian enterprises. *Oeconomia Copernicana*, *10*(2), 273-290. https://doi.org/10.24136/oc.2019.014

Liu, J. S., Lu, W. M., & Ho, M. H. C. (2015). National characteristics: innovation systems from the process efficiency perspective. *R & D Management*, *45*(4), 317-338. https://doi.org/10.1111/radm.12067

Lopes, T. D., Casson, M., & Jones, G. (2019). Organizational innovation in the multinational enterprise: Internalization theory and business history. *Journal of International Business Studies*, *50*(8), 1338-1358. https://doi.org/10.1057/s41267-018-0156-6

Mahmood, T., & Mubarik, M. S. (2020). Balancing innovation and exploitation in the fourth industrial revolution: Role of intellectual capital and technology absorptive capacity. *Technological Forecasting and Social Change*, *160*, Article 120248. https://doi.org/10.1016/j.techfore.2020.120248

Mamrayeva, D. G., & Tashenova, L. V. (2012). Market of intellectual industrial property in the Republic of Kazakhstan: current state and development trends. *Actual Problems of Economics*(133), 404-413.

Mamrayeva, D., Stybaeyeva, A., & Tashenova, L. (2018). The research of global innovation capital: a review and analytical comparison. *Economic Annals-XXI*, *167*(9-10), 4-7. https://doi.org/10.21003/ea.V167-01

Nikson, F. (1990). *The role of enterprise management in ensuring the quality and reliability of standards.* Moscow: Publishing house of standards

Perez-De-Lema, D. G., Hansen, P. B., Madrid-Gujjarro, A., & Silva-Santos, J. L. (2019). Influence of the business environment in the dynamics of innovation and in the performance of SMEs. *International Journal of Innovation Management*, *23*(5), Article Unsp 1950044. https://doi.org/10.1142/s1363919619500440

Perlaki, I. (1985). Group decision-making and problem-solving. *Ekonomicky Casopis*, *33*(6), 556-566.

Quaye, D., & Mensah, I. (2019). Marketing innovation and sustainable competitive advantage of manufacturing SMEs in Ghana. *Management Decision*, *57*(7), 1535-1553. https://doi.org/10.1108/md-08-2017-0784

Ramadani, V., Hisrich, R. D., Alili, H. A., Dana, L. P., Panthi, L., & Abazi-Bexheti, L. (2019). Product innovation and firm performance in transition economies: A multi-stage estimation approach. *Technological Forecasting and Social Change*, *140*, 271-280. https://doi.org/10.1016/j.techfore.2018.12.010

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press

Schumpeter, J. A. (1982). The crisis in economics - 50 Years ago. *Journal of Economic Literature*, *20*(3), 1049-1059.

Schumpeter, J., Becker, M. C., & Knudsen, T. (2002). The fundamental phenomenon of economic development. *American Journal of Economics and Sociology*, *61*(2), 405-437. https://doi.org/10.1111/1536-7150.00167

Siqueira, A. C. O., & Honig, B. (2019). Entrepreneurs' ingenuity and self-imposed ethical constraints: creating sustainability-oriented new ventures and knowledge. *Journal of Knowledge Management*, *23*(10), 1965-1983. https://doi.org/10.1108/jkm-11-2018-0707

Soltanzadeh, J., Elyasi, M., Ghaderifar, E., Soufi, H. R., & Khoshsirat, M. (2019). Evaluation of the effect of R&D subsidies on Iranian firms' innovative behavior Reconceptualizing behavioral additionality. *Journal of Science and Technology Policy Management*, *11*(1), 17-48. https://doi.org/10.1108/jstpm-11-2018-0109

Soltysik, M., Urbaniec, M., & Wojnarowska, M. (2019). Innovation for Sustainable Entrepreneurship: Empirical Evidence from the Bioeconomy Sector in Poland. *Administrative Sciences*, *9*(3), Article 50. https://doi.org/10.3390/admsci9030050

Suarez-Villa, L. (2002). High technology clustering in the polycentric metropolis: a view from the Los Angeles metropolitan region. *International Journal of Technology Management*, *24*(7-8), 818-842.

Suarez-Villa, L. (2002). Regional inversion in the United States: The institutional context for the rise of the Sunbelt since the 1940s. *Tijdschrift Voor Economische En Sociale Geografie*, *93*(4), 424-442. https://doi.org/10.1111/1467-9663.00214

Twiss, B. C. (1992). Innovate - how to gain and sustain competitive advantage - Ohare,M. *R & D Management*, *22*(1), 100-101. https://doi.org/10.1111/j.1467-9310.1992.tb00797.x

Twiss, B. C. (1993). Technology infrastructure and competitive position - Tassey,G. *R & D Management*, *23*(3), 268-269. https://doi.org/10.1111/j.1467-9310.1993.tb00831.x

Vinogradova, E. Y., Andreeva, S. L., Babkin, A. V., Galimova, A. I., & Ieee. (2017). Corporate Information System - Element of Efficient Human Resources Management of the Industrial-Economic Complex. *Proceedings of 2017 Ieee Vi Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations) (Spue)*, 63-66.

Yu, H., Song, C. J., & Song, Z. J (2020). Impact of state ownership as political capital on the technological innovation of private sector enterprises: evidence from China. *Asian Journal of Technology Innovation*. https://doi.org/10.1080/19761597.2020.1835501

Л.В. Ташенова, А.В. Бабкин

Қазақстан кәсіпорындарының инновациялық қызметі: экономикалық-статистикалық талдау

Аңдатпа

Мақсаты: Ұсынылған ғылыми мақаланың мақсаты — Қазақстандағы кәсіпорындардың инновациялық қызметіне экономикалық және статистикалық талдау жүргізу; объект — бұл жаңа технологиялармен, техникалық объектілермен, пайдалы модельдерге, өнеркәсіптік үлгілерге және т.б. патенттермен ұсынылған интеллектуалды еңбек нәтижелерін енгізетін және өз қызметіне қолданатын инновациялық қызметімен сипатталатын Қазақстанның кәсіпорындары.

Әдістері: Зерттеу мақсатына қол жеткізу үшін жалпы *ғылыми әдістер* кеңінен қолданылды, атап айтқанда Қазақстан кәсіпорындарының инновациялық қызметін сипаттайтын параметрлердің бүкіл жиынтығын анықтауға мүмкіндік берген *талдау әдісі*; қаралып отырған экономикалық объектілер мен құбылыстар арасындағы қазіргі өзара байланысты белгілеуге бағытталған *қорыту әдісі*; алынған нәтижелерді көрнекі түрде көрсетуге мүмкіндік берген графикалық *түсіндіру әдісі*; корреляциялық-регрессиялық талдаумен ұсынылған *экономикалық-математикалық әдістер*, Стьюдент, Фишердің, анықтау коэффициентінің және Дарбин-Уотсон тестінің негізінде құрылған модельді *тексеру әдістері*, құрылған бірнеше регрессияға негізделген *болжау әдістері*.

Нәтижелері: Жүргізілген зерттеу шеңберінде авторлар Қазақстан кәсіпорындарының инновациялық қызметінің көптеген регрессиясының моделін құрды, оның барабарлығы мен дұрыстығы Стьюдент, Фишер өлшем шарттарын, детерминация коэффициентін және Дарбин-Уотсон өлшем шарттарын пайдалана отырып тексерілді. Сонымен қатар, Гаусс әдісін қолдана отырып, есептелген коэффициенттерді ескере отырып, стандартталған регрессия теңдеуін алуға мүмкіндік беретін қалыпты теңдеулер жүйесі шешілді. Сондай-ақ, мақалада әртүрлі ғылыми материалдарды, соның ішінде Scopus, Clarivate Analytics, Google Scholar және РИҒД ғылыми-метрикалық мәліметтер базасында кеңінен ұсынылған зерттеу негізінде инноватика теориясының дамуына және «кәсіпорынның инновациялық қызметі» ұғымын түсіндірудің негізгі тәсілдеріне жан-жақты талдау жасалғанын атап өткен жөн.

Қорытынды: Бірнеше регрессиялық модельдерді құру тұрғысынан корреляциялық-регрессиялық талдауды қолдану — бұл Қазақстандағы кәсіпорындардың инновациялық қызметін тиімді және жан-жақты сипаттап қана қоймай, талданатын базалық индикаторды (тәуелді айнымалы) кейіннен болжау үшін қолдануға мүмкіндік беретін оңтайлы әдіс. Қарастырылып отырған экономикалық құбылысты терең және жан-жақты түсінуге негізделетін параметрлерді таңдаудың маңызды аспектісі болып қалады, ал оларды таңдау олардың қатаң экономикалық интерпретациясына негізделуі керек, атап айтқанда жұптық корреляция коэффициенттерінің матрицаларын құру және мультиколинирлеуді ескеру.

Кілт сөздер: инновациялық қызмет, Қазақстан кәсіпорындары, өнертабыстар, өнеркәсіптік үлгілер, пайдалы модельдер, инновациялық өнімдер, көптік регрессия, экономикалық-математикалық модельдеу.

Л.В. Ташенова, А.В. Бабкин

Инновационная деятельность предприятий Казахстана: экономико-статистический анализ

Аннотация

Цель: Целью статьи является проведение экономико-статистического анализа инновационной деятельности предприятий Казахстана; в качестве объекта выступают предприятия Казахстана, характеризующиеся инновационной активностью, внедряющие и использующие в своей деятельности результаты интеллектуального труда, представленные новыми технологиями, объектами техники, патентами на изобретения, полезные модели, промышленные образцы и др.

Методы: Для достижения цели исследования широко использованы общенаучные методы, в частности, метод анализа, позволивший определить всю совокупность параметров, характеризующих инновационную деятельность предприятий Казахстана; метод обобщения, нацеленный на установление существующих взаимосвязей между рассматриваемыми экономическими объектами и явлениями; метод графической интерпретации, позволивший наглядно представить получаемые результаты; экономико-математические методы, представленные корреляционно-регрессионным анализом, методами проверки построенной модели на основе критерия Стьюдента, Фишера, коэффициента детерминации и критерия Дарбина-Уотсона; методы прогнозирования на основе построенной множественной регрессии.

Результаты: В рамках проведенного исследования авторами построена модель множественной регрессии инновационной деятельности предприятий Казахстана, адекватность и корректность которой была проверена с использованием критерия Стьюдента, Фишера, коэффициента детерминации и критерия Дарбина-Уотсона. При этом, используя метод Гаусса, была решена нормальная система уравнений, позволившая получить стандартизированное уравнение регрессии, с учетом рассчитанных коэффициентов. Важно также заметить, что в статье проведен комплексный анализ развития теории инноватики и ключевых подходов к трактовке понятия «инновационная деятельность предприятия» на основе исследования разнообразных научных материалов, в том числе широко представленных в наукометрических базах данных – Scopus, Clarivate Analytics, Google Scholar и РИНЦ.

Выводы: Использование корреляционно-регрессионного анализа в части построения моделей множественной регрессии является оптимальным методом, позволяющим не только эффективно и комплексно описывать инновационную деятельность предприятий Казахстана, но и использовать его для последующего прогнозирования анализируемого базового показателя (зависимой переменной). Важнейшим аспектом остается выбор параметров, который должен быть построен на глубоком и всестороннем понимании рассматриваемого экономического явления, тогда как их отбор должен осуществляться на основании их строгой экономической интерпретации, в частности, путем построения матриц парных коэффициентов корреляции и учета мультиколлинеарности.

Ключевые слова: инновационная деятельность, предприятия Казахстана, изобретения, промышленные образцы, полезные модели, инновационная продукция, множественная регрессия, экономико-математическое моделирование.