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TECHNOLOGICAL MANAGEMENT OF CLUSTER INNOVATIONS IN THE EDUCATION SYSTEM, PERSONNEL DEVELOPMENT AND LOGISTICS IN REALISING THE POTENTIAL IN POST-WAR RENEWAL

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Abstract

The aim of the article is to model the effectiveness of technological management of cluster innovations in the education system, personnel development and logistics in realising the potential in post-war renewal. The procedure for assessing the effectiveness of technological management is proposed to be carried out using production functions of great epistemological and methodological importance. The logic of determining innovation costs by clusters is proposed and schematically presented. Justifying and detailing the taken factors for the study of innovation costs by clusters, it is determined that they are one of the key factors of influence on technological management in the post-war economic recovery of Ukraine. The results of calculating the efficiency of technological management of cluster innovations in the system of education, personnel development and logistics in the realisation of potential in the post-war reconstruction showed the need to form a state policy of development of Ukraine, which will provide increased funding for research, innovation and educational projects, as well as the expansion of the network of logistics hubs.

Keywords: *management, clusters, innovation, education, personnel, logistics, potential, post-war reconstruction.*
JEL Codes *Q55, J01, O15, O3.*

Introduction

In the current evolutionary conditions of development, Ukraine is experiencing the biggest crisis during its existence. The combination of negative factors affecting the national economy requires reactive actions and strategies that should best reduce the tension in society, economy and finances. In such a context, measures of technological management of cluster innovations in the education system, personnel development and logistics should positively influence the efficiency of potential realisation in the post-war renewal of Ukraine. To date, there remains a set of pressing problems of further rearmament of the national economy and its segments. A complete revision of logistics flows, reforming education and science, stimulating the intellectual development of the nation. Especially effective are the measures of forming cluster innovations based on strong human, financial, transport and technical-technological potentials. Consequently, there is a need to improve the methodology and tools to improve the technological management of cluster innovations in the education system, personnel development and logistics in order to comprehensively restore the development of Ukraine.

Literature review

The problematics of improving the efficiency of technological management of cluster innovations in the system of education, personnel development and logistics in the realisation of potential in the post-war renewal is almost not covered in the scientific sources of domestic and foreign scientists. Fragmentary aspects of improving the development of innovation, smart economy, science, clusters, education and finance were reflected in the works of scholars (Nakonechny, S. et al., 2006; Aranchiy, V. et al., 2022; Tsyganchuk, R., 2013; Hilorme, T. et al., 2019; Gryshchenko, I. et al., 2021; Levchenko, V. et al., 2019; Khodakivska, O. et al., 2022). Some scientists have proposed a model of innovative reconstruction of the state aimed at the development of the economy by investing in green industry. The authors have proposed innovative modelling directions for assessing the resource potential of each sector of the Ukrainian economy and a procedure for selecting priority industries requiring investment flows for the development of a green economy (Bublyk, M. et al., 2023). Other scientists have conducted a very interesting and thorough study of natural and anthropogenic disasters, which allows them to determine new ways of developing of smart economy and the logic of the formation of technological management in crises (Nielsen, B. et al., 2023). Researchers have emphasised the need to activate cluster innovations in logistics as the main condition for the development of the transport industry. They provided promising strategies for the development of the transport and logistics system of Ukraine within the framework of transport and logistics clusters (Smoliar, L. et al., 2022). The authors rightly pointed out that the invasion of Ukraine by Russia had significant consequences for the whole world, which affected human, financial, social and environmental levels. In this case, the scenarios of sustainable development of Ukraine under the conditions of war should be reconsidered (Da Costa, JP et al., 2023). Modelling tools that are adaptive to our study were used in the works (Prokopenko, O. et al., 2022; Solodovnik, O. et al., 2021; Mazur, N. et al., 2021). Education, personnel and logistics should certainly be improved and reformed.

Without diminishing the fundamental contribution of the scientific works of these scientists to the formation of a common vision of improving the process of technological management of cluster innovations in the system of education, personnel development and logistics in the realisation of potential in post-war reconstruction, we note the insufficiency of scientific sources on the selected problematic.

Methodical approach

We propose to investigate the procedure for assessing the effectiveness of technological management of cluster innovations in the system of education, personnel development and logistics using production functions that have great epistemological and methodological significance. Moreover, such a function, which is an economic and statistical model, thoroughly investigates the relationship between the factors of economic development at the macro-, meso- or micro-levels. Modelling the current state of technological management, it is advisable to use statistical data, which should be brought to a comparable form.

The production function in our case will show the result of the approximation of the statistical array characterising the current state of functioning of technological management. The

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practical need to obtain the production function in the modelling of technological management is due to the importance of this tool to analyse the efficiency of education, personnel, logistics and innovation. In our case, based on the data of statistical reporting of Ukraine 2013-2020 with the help of linear and nonlinear production functions we will investigate the efficiency of technological management of cluster innovations in the form of dependence of innovation costs by clusters on:

the number of implemented types of innovative products (goods, services);

the number of researches and development by type of their implementation;

the number of employees by scientific titles involved in the implementation of research and development;

the number of educational institution employees by scientific titles involved in the implementation of scientific research and development. If we study, analyse and further carry out forecasting of such dependence, it can be schematically represented (Fig. 1).

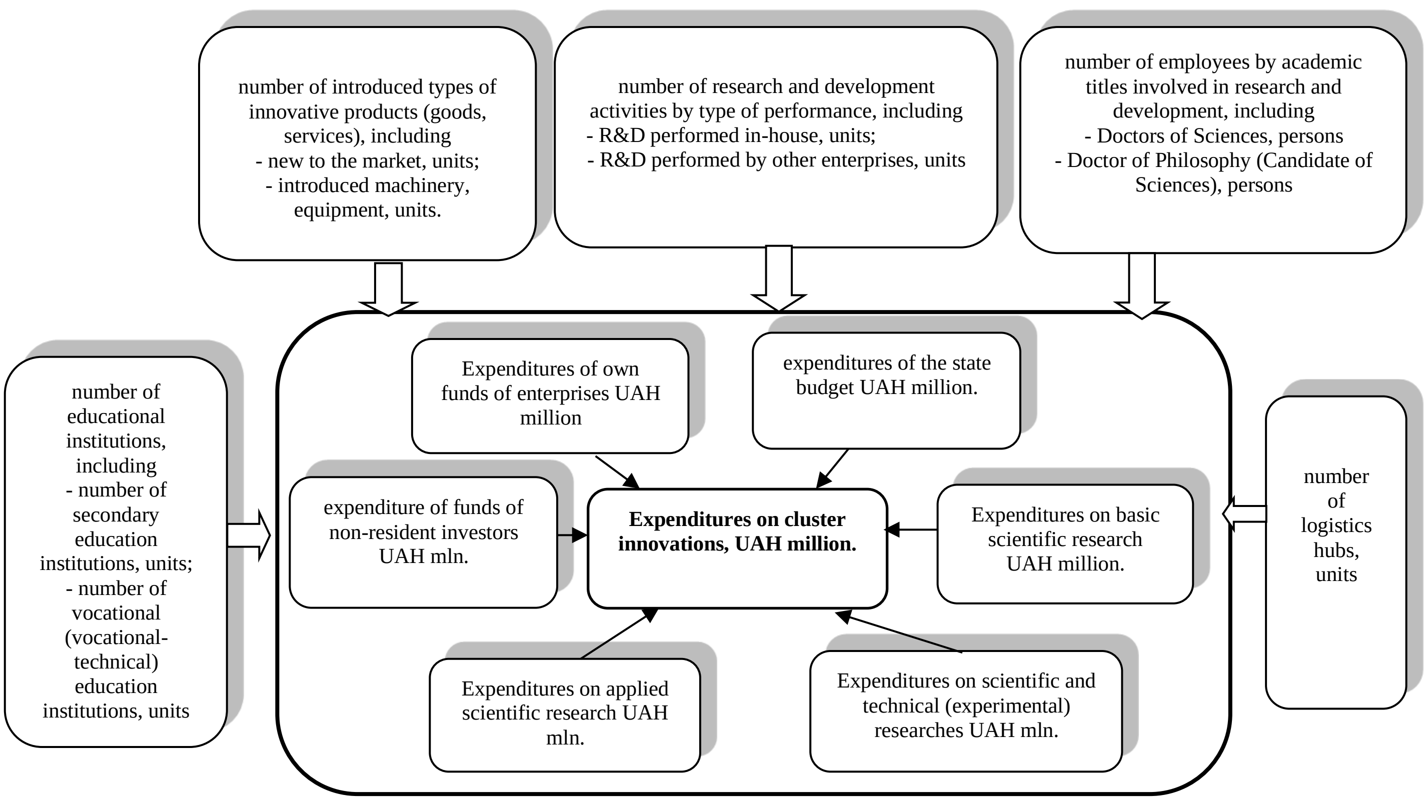

Figure 1. Schematic representation of innovation costs by cluster and impact factors by the types of their execution and implementation

**Source: suggested by the authors.*

In justifying and detailing the factors taken to investigate innovation costs by cluster, it is realised that they are among the key factors influencing technology management in the post-war economic recovery. Figure 1 shows the performance indicator in incision: expenditures of enterprises' own funds;

expenditures of the state budget;

expenditures of non-resident investors' funds;

expenditures of basic scientific researches;

expenditure of applied scientific researches;

expenditure on scientific and technical (experimental) developments and factors affecting it also by type, namely:

the number of implemented types of innovative products (goods, services), including new for the market and introduced machines and equipment;

number of research and development activities by type of their performance, including R&D performed in-house and R&D performed by other enterprises;

number of employees by scientific titles involved in the performance of research and development, including doctors of sciences and doctors of philosophy (candidates of sciences);

number of educational institutions, including the number of secondary education institutions and the number of vocational (professional and technical) education institutions;

number of logistics hubs.

Consequently, it can be emphasised that the factors are well chosen and the driving force in the research, analysis and prediction of the resultant performance indicator of technological management of cluster innovations and its implementation in post-war economic recovery using economic and mathematical methods and models.

It should be emphasised that the main purpose of the calculation of regression models and analysis of statistical coefficients characterising the efficiency of technological management of cluster innovations is to determine the production function that most accurately determines the relationship between the factor and the indicator, that is, the pre-stated factors and the indicator of innovation costs by clusters, which in further research will allow forecasting the effectiveness of management implementation. In this case, the methodology of modelling production regression models is represented by the equation:

$$Y = a_1 X + a_0 \quad (1)$$

In general, nonlinear production regressions, which are common in the scientific world, are represented by the following equations:

$$Y = a_1 / X + a_0 \quad (2)$$
$$Y = a_1 \ln X + a_0 \quad (3)$$
$$Y = a_1 e^X + a_0 \quad (4)$$
$$Y = a_1 \sqrt{X} + a_0 \quad (5)$$
$$Y = a_1 X^2 + a_0 \quad (6)$$
$$Y = a_1 X^3 + a_0 \quad (7)$$
$$Y = a_1^X a_0 \quad (8)$$

To calculate and process the data of dependence of innovation costs by clusters on the stated factors of technological management, we use Microsoft Excel spreadsheets and built-in statistical functions: “TRANSP”, “LINEAR”, “CORREL”, “F-RATIO”. According to this methodology, we calculate the impact of each of the factors of technological management on innovation by cluster using linear and non-linear functions for 2013-2020.

Results

In the process of mathematical transformations and static calculations, we obtained linear production regression and nonlinear production regressions of the costs of cluster innovations in technological management, which are presented in Table 1.

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Table 1. Data processing results for determining the production function of the costs of cluster innovations in technology management, 2013-2020

Production function in general form	Production function of innovations costs by cluster	Regression parameters		Coefficient of determination R^2	Correlation coefficient r	The calculated F-value of Fisher's test, F_{calc}
		a_1	a_0			
Impact factor: number of innovative products (goods, services) introduced in the reporting year, units						
$Y = a_1 X + a_0$	$Y=3,67X+12409,48$	3,67	12409,48	0,85	0,69	1,78
$Y = a_1 / X + a_0$	$Y=-18694942,75/X+28198,93$	-18694942,75	28198,93	0,57	0,96	0,98
$Y = a_1 \ln X + a_0$	$Y=7712,82LnX-40069,00$	7712,82	-40069,00	0,61	0,33	1,24
$Y = a_1 e^X + a_0$	$Y=8886,51e^{X}+13769,87$	8886,51	13769,87	0,55	0,70	2,26
$Y = a_1 \sqrt{X} + a_0$	$Y=305,98\sqrt{X}+4789,31$	305,98	4786,31	0,83	0,80	1,60
$Y = a_1 X^2 + a_0$	$Y=0,56X^{2}+16100,81$	0,56	16100,81	0,76	0,78	2,06
$Y = a_1 X^3 + a_0$	$Y=0,68X^{3}+17246,87$	0,68	17246,87	0,93	0,82	2,66
$Y = a_1^X a_0$	$Y=-78964,00^{X}\cdot(34512,69)$	-78964,00	34512,69	0,87	0,62	4,28
Impact factor: number of scientific research and development (R&D) by types of their implementation, units						
$Y = a_1 X + a_0$	$Y=5,367X+10315,70$	5,36	10315,70	0,84	0,88	3,55
$Y = a_1 / X + a_0$	$Y=-31508918,08/X+35960,32$	-31508918,08	35960,32	0,93	0,96	5,07
$Y = a_1 \ln X + a_0$	$Y=12755,35LnX-76897,58$	12755,35	-76897,58	0,89	0,62	4,30
$Y = a_1 e^X + a_0$	$Y=8886,51e^{X}+13769,87$	8886,51	13769,87	0,55	0,70	2,26
$Y = a_1 \sqrt{X} + a_0$	$Y=501,40\sqrt{X}-2400,50$	501,40	-2400,50	0,36	0,60	3,42
$Y = a_1 X^2 + a_0$	$Y=0,56X^{2}+16609,52$	0,56	16609,52	0,85	0,87	2,98
$Y = a_1 X^3 + a_0$	$Y=0,68X^{3}+18650,15$	0,68	18650,15	0,92	0,81	2,61
$Y = a_1^X a_0$	$Y=-76483,28^{X}\cdot(30825,85)$	-76483,28	30825,85	0,57	0,30	1,09
Impact factor: the number of employees with scientific titles involved in the performance of scientific research and development, persons						
$Y = a_1 X + a_0$	$Y=0,38X+35221,59$	0,38	35221,59	0,86	-0,30	3,93
$Y = a_1 / X + a_0$	$Y=1362163078,41/X+8735,27$	1362163078,41	8735,27	0,82	0,96	3,33
$Y = a_1 \ln X + a_0$	$Y=-13181,23LnX+174471,03$	-13181,23	174471,03	0,84	-0,59	3,65
$Y = a_1 e^X + a_0$	$Y=23104,44e^{X}+5336,74$	23104,44	5736,74	0,55	0,70	2,26
$Y = a_1 \sqrt{X} + a_0$	$Y=-80,58\sqrt{X}+48366,76$	-80,58	48366,76	0,35	-0,60	3,30
$Y = a_1 X^2 + a_0$	$Y=0,56X^{2}+28708,52$	0,56	28708,52	0,94	0,72	4,17
$Y = a_1 X^3 + a_0$	$Y=0,20X^{3}+26589,76$	0,20	26589,76	0,58	-0,62	3,89
$Y = a_1^X a_0$	$Y=-1852,17^{X}\cdot(32016,69)$	-1852,17	32016,69	0,98	0,83	14,09
Impact factor: number of educational institutions, units						
$Y = a_1 X + a_0$	$Y=-1,22X+54146,65$	-1,22	52146,65	0,72	-0,47	2,16
$Y = a_1 / X + a_0$	$Y=522176685,46/X-7955,84$	522176685,46	-7955,84	0,71	0,96	2,05
$Y = a_1 \ln X + a_0$	$Y=-30065,72LnX+315726,84$	-30065,72	315726,84	0,71	-0,46	2,11
$Y = a_1 e^X + a_0$	$Y=12835,93e^{X}+9228,03$	12835,93	9228,03	0,55	0,70	2,26
$Y = a_1 \sqrt{X} + a_0$	$Y=-454,29\sqrt{X}+82221,04$	-454,29	82221,04	0,91	0,54	2,34
$Y = a_1 X^2 + a_0$	$Y=0,56X^{2}+37097,17$	0,56	37097,17	0,78	0,86	2,27
$Y = a_1 X^3 + a_0$	$Y=0,20X^{3}+32069,27$	0,20	32069,27	0,43	-0,48	1,96
$Y = a_1^X a_0$	$Y=-19717,49^{X}\cdot(38749,23)$	-19717,49	38749,23	0,84	0,92	32,35
Influence factor: the number of logistics hubs, units						
$Y = a_1 X + a_0$	$Y=129,12X+19266,01$	129,12	19266,01	0,51	0,55	0,58
$Y = a_1 / X + a_0$	$Y=12801,56/X+21686,07$	12801,56	21686,07	1,00	0,96	1,00
$Y = a_1 \ln X + a_0$	$Y=1472,98LnX+17652,58$	1472,98	17652,58	0,75	0,76	0,77

$Y = a_1 e^X + a_0$	*Y=0,50e^X+21709,40*	0,50	21709,40	0,57	0,47	0,98
$Y = a_1\sqrt{X} + a_0$	*Y=958,25√X+17661,92*	958,25	17661,92	0,71	0,73	0,74
$Y = a_1 X^2 + a_0$	*Y=4,12X²+20249,61*	4,12	20249,61	0,59	0,50	0,73
$Y = a_1 X^3 + a_0$	*Y=0,62X³+20706,30*	0,62	20706,30	0,55	0,69	0,78
$Y = a_1^X a_0$	*Y=-15694469,35^X·(39424,35)*	-15694469,35	39424,35	0,60	0,78	9,17

**Source: calculated by the authors.*

So, the obtained production regression models of the costs of cluster innovations in technological management for the last eight years are comparable in terms of correlation coefficients, coefficients of determination, Fisher's criterion, to determine the density of the correlation coefficient, which characterises the relationship between the factor and the indicator, to find out the quality and adaptability of the production model, which in the future modelling will allow strategic planning and forecasting of technological management. At the next stage, we will conduct ranking using the built-in statistical function "RANG. So, according to the coefficient of determination, correlation coefficient and the calculated value of Fisher's F criterion and determined the best production functions of the dependence of the costs of cluster innovations on the factors of technological management:

number of innovative products (goods, services) implemented in the reporting year, units *$Y=0,68X^3+17246,87$* (coefficient of determination R^2=0.93; correlation coefficient r =0.82; Fisher's F criterion $F_{calc.}$=2,66);

Number of scientific research and development (R&D) by type of their performance, units *Y=-31508918,08/X+35960,32* (coefficient of determination R^2 =0,93; correlation coefficient r =0,96; Fisher's F criterion $F_{calc.}$ =5,07);

number of employees by scientific titles involved in research and development performance, persons *$Y=-1852,17^X\cdot(32016,69)$* (coefficient of determination R^2=0,98; correlation coefficient r =0,83; Fisher's F criterion $F_{calc.}$ =14,09);

number of educational institutions, units *Y=-454,29√X+82221,04* (coefficient of determination R^2=0,91: correlation coefficient r =0,54, Fisher's F criterion $F_{calc.}$ =2,34);

number of logistics hubs, units *Y=12801,56/X+21686,07* (coefficient of determination R^2=1,00; correlation coefficient r =0,96; Fisher's F criterion $F_{calc.}$ =1,00) (Table 2)

Table 2. Ranking and determination of qualitative production functions of the dependence of cluster innovations costs on technological management factors, 2013-2020

Production function in general form	**Production function of innovation costs by cluster**	**Ranking by the coefficient of determination R^2**	**Ranking by correlation coefficient, r**	**Ranking by the calculated F value of the Fisher's test, $F_{calc.}$**
Impact factor: number of types of innovative products introduced in the reporting year (goods, services), units				
$Y = a_1 X + a_0$	*Y=3,67X+12409,48*	3	6	5
$Y = a_1/X + a_0$	*Y=-18694942,75/X+28198,93*	7	1	8
$Y = a_1 \ln X + a_0$	*Y=7712,82LnX-40069,00*	6	8	7
$Y = a_1 e^X + a_0$	*Y=8886,51e^X+13769,87*	8	5	3
$Y = a_1\sqrt{X} + a_0$	*Y=305,98√X+4789,31*	4	3	6
$Y = a_1 X^2 + a_0$	*Y=0,56X²+16100,81*	5	4	4
$Y = a_1 X^3 + a_0$	*Y=0,68X³+17246,87*	1	2	2

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$Y = a_1^X a_0$	$Y=-78964,00^X\cdot(34512,69)$	2	7	1
Influencing factor: number of research and development (R&D) by type of their implementation, units				
$Y = a_1 X + a_0$	$Y=5,367X+10315,70$	5	2	3
$Y = a_1/X + a_0$	$Y=-31508918,08/X+35960,32$	1	1	1
$Y = a_1 \ln X + a_0$	$Y=12755,35LnX-76897,58$	3	6	2
$Y = a_1 e^X + a_0$	$Y=8886,51e^X+13769,87$	7	5	7
$Y = a_1\sqrt{X} + a_0$	$Y=501,40\sqrt{X}-2400,50$	8	7	4
$Y = a_1 X^2 + a_0$	$Y=0,56X^2+16609,52$	4	3	5
$Y = a_1 X^3 + a_0$	$Y=0,68X^3+18650,15$	2	4	6
$Y = a_1^X a_0$	$Y=-76483,28^X\cdot(30825,85)$	6	8	8
Impact factor: number of employees with academic titles involved in research and development, persons				
$Y = a_1 X + a_0$	$Y=0,38X+35221,59$	3	5	3
$Y = a_1/X + a_0$	$Y=1362163078,41/X+8735,27$	4	1	6
$Y = a_1 \ln X + a_0$	$Y=-13181,23LnX+174471,03$	3	6	5
$Y = a_1 e^X + a_0$	$Y=23104,44e^X+5336,74$	4	4	8
$Y = a_1\sqrt{X} + a_0$	$Y=-80,58\sqrt{X}+48366,76$	4	7	7
$Y = a_1 X^2 + a_0$	$Y=0,56X^2+28708,52$	2	3	2
$Y = a_1 X^3 + a_0$	$Y=0,20X^3+26589,76$	2	8	4
$Y = a_1^X a_0$	$Y=-1852,17^X\cdot(32016,69)$	1	2	1
Influencing factor: number of educational institutions, units				
$Y = a_1 X + a_0$	$Y=-1,22X+54146,65$	4	7	5
$Y = a_1/X + a_0$	$Y=522176685,46/X-7955,84$	6	1	7
$Y = a_1 \ln X + a_0$	$Y=-30065,72LnX+315726,84$	5	6	6
$Y = a_1 e^X + a_0$	$Y=12835,93e^X+9228,03$	7	4	4
$Y = a_1\sqrt{X} + a_0$	$Y=-454,29\sqrt{X}+82221,04$	1	5	2
$Y = a_1 X^2 + a_0$	$Y=0,56X^2+37097,17$	3	3	3
$Y = a_1 X^3 + a_0$	$Y=0,20X^3+32069,27$	8	8	8
$Y = a_1^X a_0$	$Y=-19717,49^X\cdot(38749,23)$	2	2	1
Influencing factor: number of logistics hubs, units				
$Y = a_1 X + a_0$	$Y=129,12X+19266,01$	8	6	8
$Y = a_1/X + a_0$	$Y=12801,56/X+21686,07$	1	1	2
$Y = a_1 \ln X + a_0$	$Y=1472,98LnX+17652,58$	2	3	5
$Y = a_1 e^X + a_0$	$Y=0,50e^X+21709,40$	6	8	3
$Y = a_1\sqrt{X} + a_0$	$Y=958,25\sqrt{X}+17661,92$	3	4	6
$Y = a_1 X^2 + a_0$	$Y=4,12X^2+20249,61$	5	7	7
$Y = a_1 X^3 + a_0$	$Y=0,62X^3+20706,30$	7	5	4
$Y = a_1^X a_0$	$Y=-15694469,35^X\cdot(39424,35)$	4	2	1

**Source: calculated by the authors.*

As a result of analysing the main statistical indicators, production regression models of costs of cluster innovations depending on the factors of technological management are selected. The quality of the production model is indicated by the correlation coefficient, coefficient of determination and Fisher's F criterion. Let us briefly characterise them. Since in the selected production regression models $F_{calc.} > F_{table.}$ ($F_{table.}$ =0.99), then with reliability P=0.95, the selected econometric models of dependence of costs of cluster innovations on the specified factors can be considered adequate to the initial data, so, based on the accepted models, as noted earlier, we can conduct economic analysis and forecasting of this indicator. Further, we analyse the correlation coefficients of the selected production models of costs of innovations by clusters. The obtained dependences are evaluated by the level of closeness of connection indices. If their absolute value is less than 0.3- the relationship is weak; when it is within 0.3-0.7- average, if 0.7 - close and when the absolute value is equal to 1 it indicates a practically functional relationship. Therefore, they are high enough, that is, the relationship between the resultant indicator and the selected factors is close and direct. The coefficients of determination of the investigated and selected production models of costs of cluster innovations are also high enough and indicate the quality of the production models and the variation of costs of cluster innovations, which is on average 95.06% due to the factors implemented in the calculation of production regression models. Therefore, it can be concluded that these production regression models are of high quality and are well chosen with the help of statistical coefficients.

In the next stage, we forecast the factors influencing the costs of cluster innovations using the built-in statistical function "FORECAST" for 2024-2025, namely:

number of innovative products, goods and services Implemented in the reporting year, total units, including (new for the market, units; introduced machinery, equipment, units);

research and development (R&D), total units (of which: R&D performed in-house, units; R&D performed by other enterprises, units;

number of employees involved in the performance of scientific research and development - total, persons, of them (doctors of sciences, persons; PhDs, candidates of sciences, persons);

number of educational institutions, units, of which (number of secondary education institutions, units; number of vocational or vocational-technical education institutions, units);

number of logistics hubs, units (Table 3).

Table 3. Forecasting the influencing factors on the costs of cluster innovations, 2024-2025

Years	Number of innovative products (goods, services) implemented in the reporting year, total units, X			Research and development (R&D), total units, X			Number of employees involved in performance of research and development - total, persons, X			Number of educational institutions, units, X			Number of logistics hubs, units, X
	total, units	new to the market, units	introduced machinery, equipment, units	total, units	R&D performed by own resources, units	R&D performed by other companies, units	total, persons	doctors of sciences, persons	Doctor of Philosophy (PhD), persons	total, units	number of secondary education institutions (units)	number of vocational (vocational and technical) education institutions (units)	
2024	4152	713	684	4421	3630	842	79810	7078	18154	15712	14946	716	35
2025	4164	721	682	4683	3844	893	80778	7139	19504	15801	14964	717	37

**Source: calculated by the authors.*

Analysing the forecasted factors, their growth should be noted, which is logical and justified. Concluding the study of cluster innovations costs, we will carry out the forecasting of this resultant indicator using selected qualitative production regression models presented by a block of tables and figures (Tables 4,5,6,7,8 and Figures 2,3,4,5,6).

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Table 4. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=0.68X3+17246.87 (influence factor: number of innovative products, goods, services, units introduced in the reporting year)

Years	*Production function Y=0.68X3+17246.87 Influencing factor: number of types of innovative products (goods, services) introduced in the reporting year, units*		
	Actual value of innovations expenditures, UAH million, Y	**Theoretical value of innovations expenditures by clusters, UAH million, Y**	**Forecasted value of innovations expenditures by clusters, UAH million, Y**
2013	16358,40	19380,71	
2014	15536,50	19736,35	
2015	22960,60	19379,35	
2016	32486,90	20061,39	
2017	17526,70	18870,03	
2018	22491,70	19860,11	
2019	24604,60	18707,51	
2020	26081,80	20011,75	
2024			28070,40
2025			28278,33

**Source: calculated by the authors.*

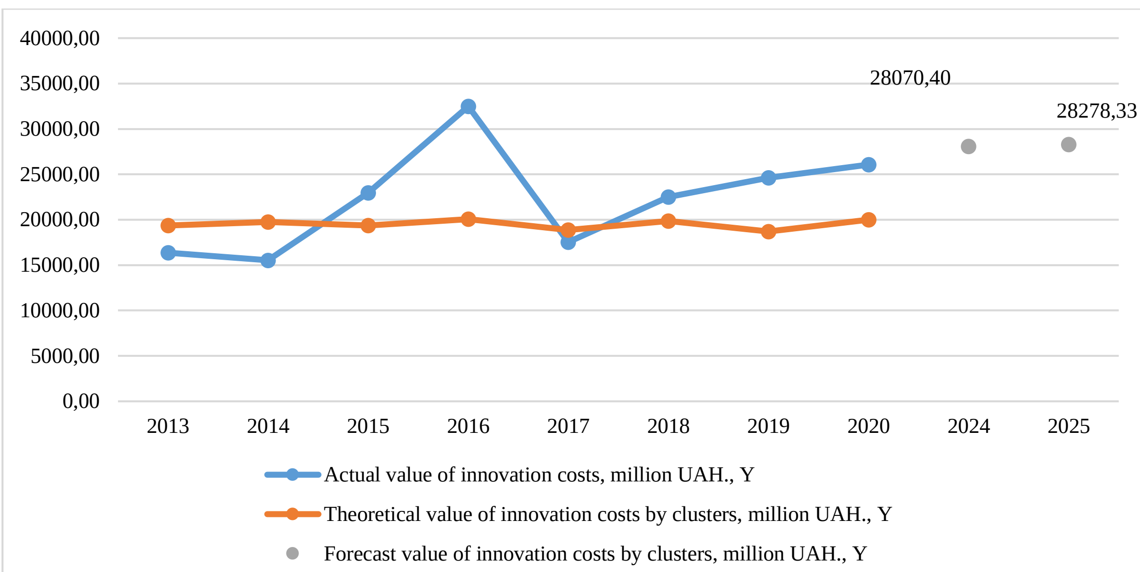

Figure 2. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=0.68X3+17246.87 (influence factor: number of innovative products, goods, services, units introduced in the reporting year)
**Source: calculated by the authors.*

Table 5. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=-31508918.08/X+35960.32 (influence factor: number of research and development, R&D, by type of their implementation, units)

Years	*Production function Y=-31508918.08/X+35960.32 Influencing factor: the number of research and development (R&D) by type of performance, units*		
	Actual value of innovations expenditures, UAH million, Y	**Theoretical value of innovations expenditures by clusters, UAH million, Y**	**Forecasted value of innovations expenditures by clusters, UAH million, Y**
2013	16358,40	16729,98	
2014	15536,50	18002,43	
2015	22960,60	20510,99	
2016	32486,90	23140,35	
2017	17526,70	21438,74	
2018	22491,70	26140,79	
2019	24604,60	25165,53	
2020	26081,80	26922,40	
2024			28833,89
2025			29232,01

**Source: calculated by the authors.*

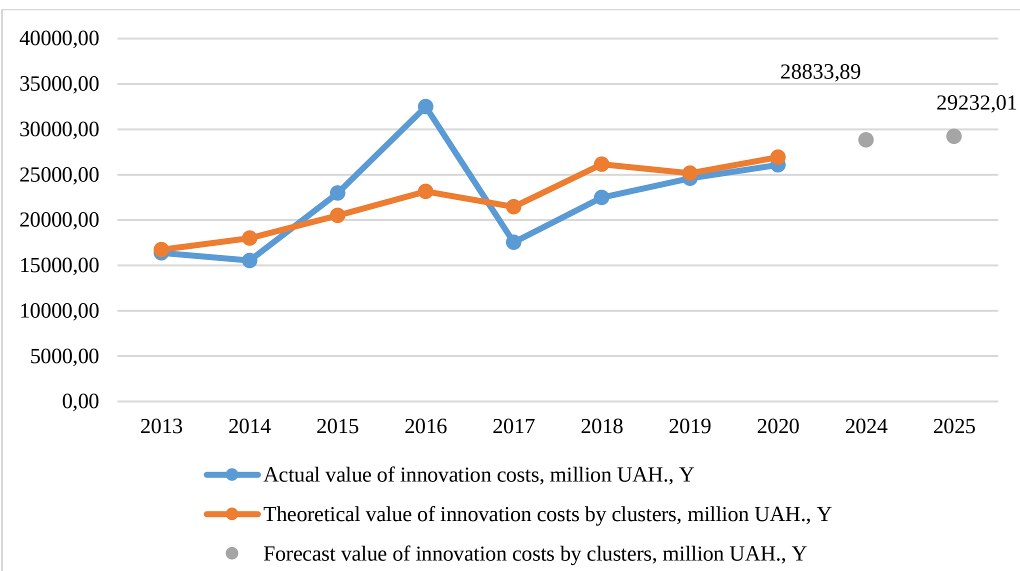

Figure 3. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using a nonlinear production function Y=-31508918.08/X+35960.32 (influence factor: the number of research and development, R&D, by type of their implementation, units)

**Source: calculated by the authors.*

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Table 6. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=-1852.17X·(32016.69), where the influence factor is the number of employees by academic ranks involved in research and development, persons

Years	Production function Y=-1852.17X·(32016.69) Influencing factor: number of employees with academic titles involved in research and development, persons		
	Actual value of innovations expenditures, UAH million, Y	Theoretical value of innovations expenditures by clusters, UAH million, Y	Forecasted value of innovations expenditures by clusters, UAH million, Y
2013	16358,40	16979,98	
2014	15536,50	18252,43	
2015	22960,60	20760,99	
2016	32486,90	23390,35	
2017	17526,70	21688,74	
2018	22491,70	26390,79	
2019	24604,60	25415,53	
2020	26081,80	27172,40	
2024			28633,89
2025			29032,01

**Source: calculated by the authors.*

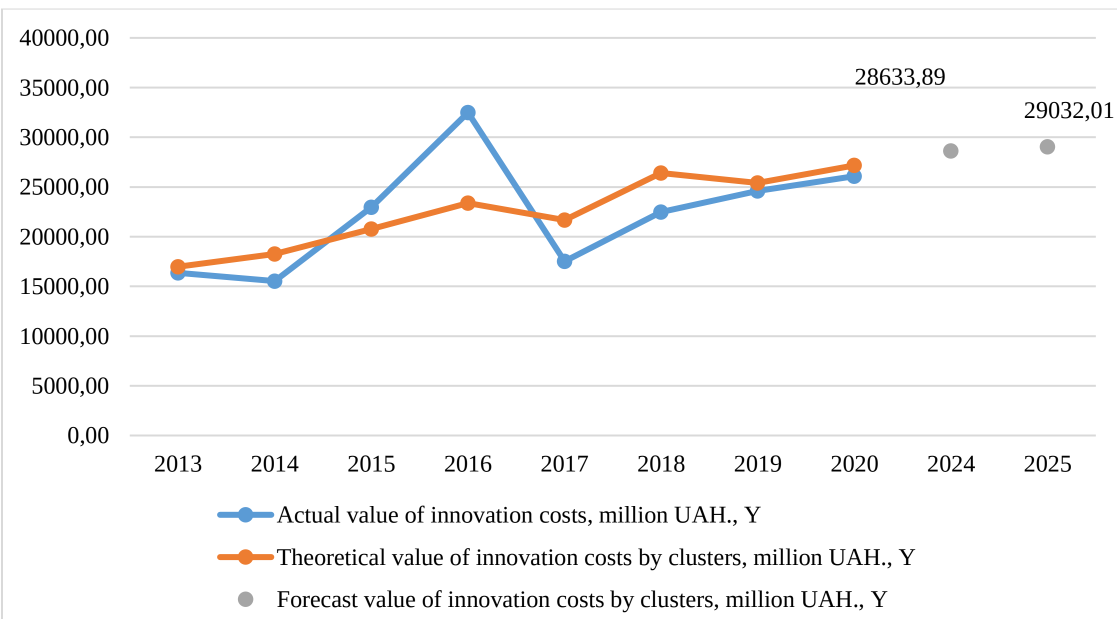

Figure 4. Actual, theoretical and forecast values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y= 1852.17X·(32016.69), where the influence factor is the number of employees by academic ranks involved in research and development, persons

**Source: calculated by the authors.*

Table 7. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=-454.29√X+82221.04 (influence factor: number of educational institutions, units)

Years	***Production function Y=-454.29√X+82221.04*** ***Influencing factor: number of educational institutions, units***		
	Actual value of innovations expenditures, UAH million, Y	**Theoretical value of innovations expenditures by clusters, UAH million, Y**	**Forecasted value of innovations expenditures by clusters, UAH million, Y**
2013	16358,40	17546,23	
2014	15536,50	20575,20	
2015	22960,60	21106,43	
2016	32486,90	21804,36	
2017	17526,70	23066,04	
2018	22491,70	24335,61	
2019	24604,60	24896,29	
2020	26081,80	25460,69	
2024			26138,59
2025			26216,55

**Source: calculated by the authors*.

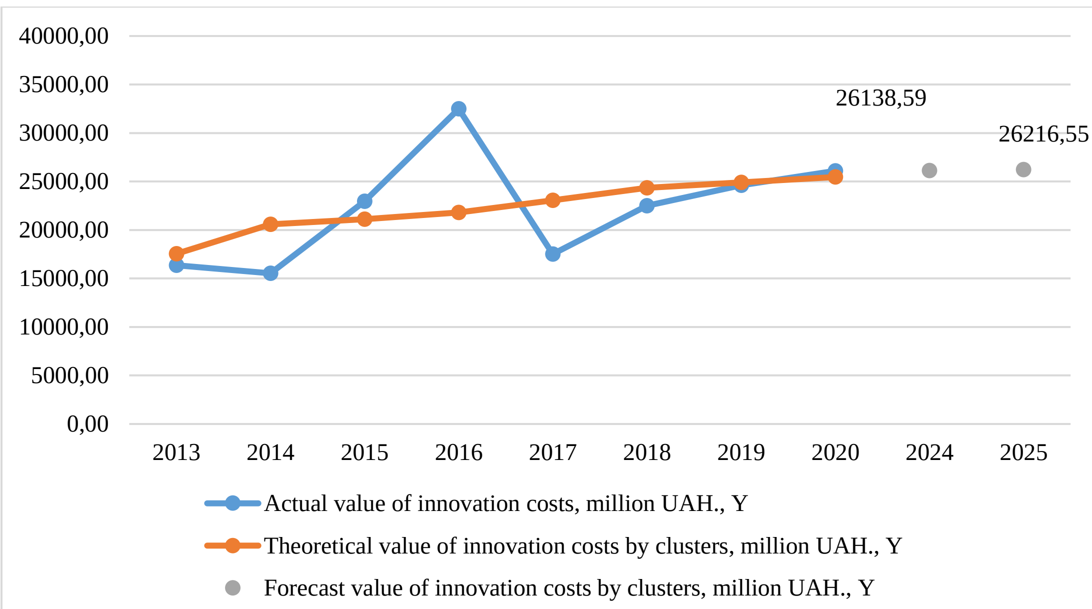

Figure 5. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=-454.29√X+82221.04. Influencing factor: number of educational institutions, units

**Source: calculated by the authors*.

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Table 8. Actual, theoretical and forecasted values of innovation costs by clusters in the technology management system, 2013-2020, 2024-2025, using the nonlinear production function Y=12801.56/X+21686.07 (influence factor: number of logistics hubs, units)

Years	***Production function Y=12801.56/X+21686.07 Influencing factor: number of logistics hubs, units***		
	Actual value of innovations expenditures, UAH million, Y	**Theoretical value of innovations expenditures by clusters, UAH million, Y**	**Forecasted value of innovations expenditures by clusters, UAH million, Y**
2013	16358,40	23095,67	
2014	15536,50	23067,96	
2015	22960,60	23159,84	
2016	32486,90	23197,27	
2017	17526,70	23095,67	
2018	22491,70	23178,13	
2019	24604,60	24378,44	
2020	26081,80	24262,59	
2024			26251,46
2025			26305,77

**Source: calculated by the authors.*

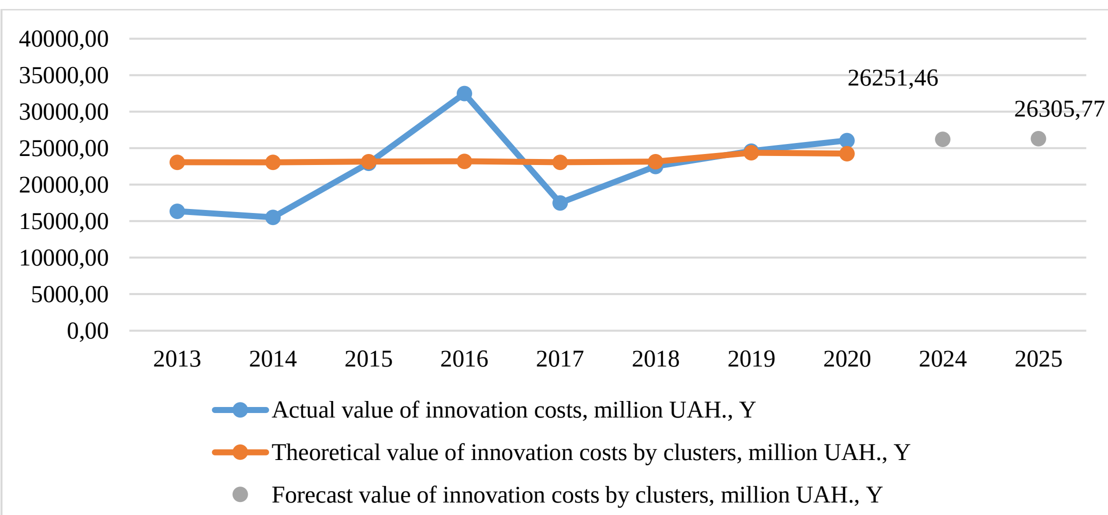

Figure 6. Actual, theoretical and forecasted values of innovation costs by clusters, 2013-2020, 2024-2025, using the n onlinear production function Y=12801.56/X+21686.07 (influence factor: number of logistics hubs, units)

**Source: calculated by the authors.*

Consequently, the conducted modelling and analysis of the main economic indicators of technological management in the education system, personnel development and logistics allows us to conclude that the use of linear and non-linear production functions in the processing and forecasting of the mentioned phenomenon is particularly appropriate. Analysis and synthesis of factors of technological management is particularly useful in planning public policy, including innovation processes and management strategy, especially acute in the future, during the implementation of the post-war economic recovery of Ukraine.

Conclusions

Thus, the article proposes a methodology for determining the technological management of cluster innovations in the education system, personnel development and logistics in the realisation of potential in post-war renewal. It should be emphasised that there is a need to form a state policy for the development of Ukraine, which will provide for increased funding for basic scientific and applied research, investment in scientific and technological (experimental) development, expansion of the number of scientific institutions, institutions of secondary education, vocational (professional and technical) education, to attract personnel involved in research and development, including doctors of science, to create new logistics hubs, etc. The proposed activities will contribute to improving the efficien cy of technological management of cluster innovations in the education system, staff development and logistics in realising the potential in post-war renewal.

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