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EXPORT OF HIGH-TECH GOODS IN THE CONTEXT OF INNOVATION TRANSFER FOR SOCIAL-ECONOMIC DEVELOPMENT: FACTOR ANALYSIS

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Abstract: *The purpose of the study is to determine factors that have the greatest influence on the growth of export of high-tech goods in the context of innovation transfer for social-economic development. Factor analysis tools, including principal component analysis and the Varimax rotation (orthogonal transformation) method in Statgraphics software, are used to identify the most significant indicators of the impact on export of high-tech goods, as a key determinant characterizing the quality of scientific and educational potential, and to determine the latent signs of their interaction. A modified logistic function is used to normalize input data for 11 investigated factors in a sample of 28 countries. Ten linear combinations of variables are obtained, which explain most of the data variability. The first four components have eigenvalues greater than or equal to 1.0. Together, they account for 88.520% of the variability of the original data. After orthogonal transformation by the Varimax method, the factor load matrix is obtained. The econometric models, which describes the influence of independent indicators on the export of high-tech goods, are represented. Next, the four most influential indicators from the 11 investigated factors are revealed, namely: the country's research and development expenditure, GDP in current prices, research staff and researchers in the sector of business enterprises, the percentage of ICT staff from total employment. They are taken to develop multiple linear regression models, which describes the influence of independent indicators on the effective export of high-tech goods. The quality results of the factor analysis are confirmed using the Kaiser-Meier-Olkin test and the Bartlett test. Regression analysis with strict screening of non-significant variables using the Backward Stepwise Selection tool confirms the significance of the indicator of scientific research personnel and researchers in the sector of business enterprises, which has the greatest impact on the export of high-tech goods. A pair regression model is obtained, and it is confirmed that increase of research staff and researchers in the sector of business enterprises by 1% causes increase of export of high-tech goods in average by 0,73%.*

Keywords: business, coopetition, education, high-tech, innovation, knowledge, R&D, science, technology, transfer.

JEL Classification: I23, M21, O31.

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Introduction

Technological progress and innovation have led to more efficient use of labour and capital investment, leading to increased productivity. Increasing productivity has been the main driver of economic growth in most countries of the world for more than two decades, but today the need for innovation is more urgent than ever.

Thanks to the transfer of innovations, there is a movement of knowledge or technologies from one organization to another, from universities and scientific institutions to business, where knowledge can be transformed into innovations – new products and services that will benefit society, new forms of work organization and communication, and in general people's lives.

The relevance of innovation transfers as a tool for managing innovative activities of firms is illustrated by the effectiveness of technology transfer and use in global markets and the creation of innovation transfer networks in different countries. However, the widespread adoption of this tool may require a certain level of innovative activity from companies that can take advantage of new technologies that appear at any moment in time, thereby increasing the competitive advantage that results from their use.

The analysis of the state of innovative activity in Ukraine according to international indices, the main indicators of the activity of industrial enterprises of Ukraine in the high-tech sector, the impact of innovative activity on the economy of Ukraine, the implementation of priority directions of innovative activity at the expense of budget funds and the number of developed and transferred technologies indicates, in general, the positive dynamics of these indicators, especially in the high-tech sector and, accordingly, about a certain level of efficiency of the entire scientific, technical and innovation system of Ukraine.

However, the gap between innovation development of Ukraine and developed countries continues to increase. This suggests that it is necessary not only to develop knowledge-intensive production in the context of preservation and multiplication of scientific and technical, innovation, and human potentials, but also to increase the level of export of domestic high-tech goods, competing with the leading countries in terms of innovation development.

Therefore, the identification and substantiation of factors that positively affect the level of export of high-tech goods in the process of transfer of innovations is an urgent problem.

The purpose of the study is to determine the factors that have the greatest influence on the growth of the export of high-tech goods in the context of the transfer of innovations.

Literature Review

Pisarenko and other authors carefully studied the state of scientific and innovation activity in Ukraine based on data from the main managers of budget funds, the State Statistics Service of Ukraine, foreign sources of information (world ratings, international scientometric databases), characterizing the current situation and development trends (Stan naukovo-innovatsiynoyi diyal′nosti v Ukrayini, 2021). Mazur & Osadcha (2006) analysed the main problems of Ukraine's innovation model and the consequences of an ill-conceived innovation policy, points to the need to accelerate the implementation of measures related to the scientific and technical development of the economy, strengthening its scientific potential. Novikova et al. (2022) described the state of technology transfer, risks, and management in this context. However, issues related to the formation and development of the knowledge economy and the strengthening of innovation development in Ukraine are insufficiently covered.

Ali et al. (2022) studied knowledge management on the case of Saudi Arabia. Zeynalli et al. (2022) confirmed the innovation's impact on the economy based on Azerbaijan evidence. Iastremska et al. (2023) found relationships of innovation activity in experience economy development.

Samoilikova A.V. (2020) characterised and formalised the impact of financial factors on innovation development. Rzayev & Samoilikova (2020) determined financing structure of R&D as driver of economic development and growth. Samoilikova et al. (2021) also studied tax incentives as a factor to increase innovation development.

Strielkowski et al. (2022) determined key trends in funding innovation, especially performed by business. Samoilikova & Artyukhov (2023) analysed the interconnection in the collaboration between science and business and especially its impact on receipts from intellectual property. Soumadi (2023) deeply investigated patents, intellectual property, and their protection for innovation increase.

Privarnikova & Kostiuchenko (2012) analysed high-tech sector of economics based on the evidence of Ukraine. Bolshenko (2013) developed principles and methods of encouragement of employees to work in R&D and high-tech spheres. Koibichuk et al. (2022) paid attention on the problem of employment in high-tech business and its effectiveness.

The issue of foreign trade commodity structure and in particular the trade with high-tech commodities was studied by Melnyk & Zubko (2012). Navarro et al. (2023) studied the determinants of high-tech exports based on the experience of OECD countries. Zhang & Sun (2019) also investigated the factors affecting the export of high-tech goods, using the example of Jiangsu Province.

However, the issue of knowledge-intensive production in Ukraine, as well as in other countries of the world, including the export of high-tech goods and drivers of its increase, is still relevant and requires further research.

Methodology and research methods

To identify the most significant indicators of the impact on the export of high-tech goods and latent signs of their interaction, the tools of factor analysis were used, including the analysis of the main components and the method of rotation (orthogonal transformation) Varimax in the software provided by Statgraphics.

A modified logistic function was used to normalize input data for 11 investigated factors in a sample of 28 countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden, Greece, Italy, Portugal, Spain, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Malta, and Ukraine. Input indicators of the study are the following:

K1 – export of high-tech goods, million (Eurostat, n.d.h);

K2 – spending on research and development of countries, billion (Eurostat, n.d.b);

K3 – researchers in the R&D sector, per million people (World Bank, n.d.b);

K4 – articles in scientific and technical journals, pcs. (World Bank, n.d.c);

K5 – GDP in current prices, billion (World Bank, n.d.a);

K6 – share of research personnel and researchers in the total number of active population, % (Eurostat, n.d.g);

K7 – share of GBARD in total government expenditures, % (Eurostat, n.d.e);

K8 – research staff and researchers in the sector of business enterprises, person (Eurostat, n.d.d);

K9 – percentage of the ICT sector in GDP, % (Eurostat, n.d.c);

K10 – personnel from total employment, % (Eurostat, n.d.a);

K11 – share of persons with at least basic digital skills, % (Eurostat, n.d.f).

The information base is the data of Eurostat and the World Bank databases.

Multiple linear regression models were constructed. The quality results of the factor analysis were confirmed using the Kaiser-Meier-Olkin test (Kaiser, 1974; Cattell, 1966) and the Bartlett test (Bartlett, 1955).

Also, the procedure of cruel screening of insignificant variables using the tool Backward Stepwise Selection was established. A pair regression model is obtained for the most significant factor indicator.

Results

Because the model of innovation development is a model of the complete innovation cycle – from the formation of an innovation idea to the mass production of a finished product, it should include all components of the innovation system: fundamental and applied science, research and development, production of a prototype and mass production. Its strength depends on the coopetition of education and business, the level of scientific research and development.

The Organization for Economic Cooperation and Development (OECD) divides all types of economic activity into 5 technological sectors depending on the intensity of scientific expenditures: high-tech sector – a sector with a share of spending on science of more than 20%, medium-high-tech – from 5% to 20%, medium-technological – from 1.8% to 5%, medium-low-tech – from 0.5% to 1.8% and low-tech – less than 0.5% (OECD, 2016).

Analysing the average scientific intensity of economic activities (on average 0.61 across Ukraine), we can conclude that for Ukraine only the 'Scientific research and development' sector is high-tech. This sector has attracted 73.6–82.4% of the total volume over the past 3 years funding of science (Stan naukovo-innovatsiynoyi diyal′nosti v Ukrayini, 2021).

At the same time, the more scientific and research personnel employed in business, the better developed the transfer of innovations, the closer the coopetition of business, education, and science, the higher the level of export of high-tech goods, and the stronger the position of the country as a whole in international markets.

To carry out a factor analysis of the impact on the export of high-tech goods, the above following indicators for a sample of 28 countries were used as input indicators of the study: K1 – export of high-tech goods, million (Eurostat, n.d.h); K2 – spending on research and development of countries, billion (Eurostat, n.d.b); K3 – researchers in the R&D sector, per million people (World Bank, n.d.b); K4 – articles in scientific and technical journals, pcs. (World Bank, n.d.c); K5 – GDP in current prices, billion (World Bank, n.d.a); K6 – share of research personnel and researchers in the total number of active population, % (Eurostat, n.d.g); K7 – share of GBARD in total government expenditures, % (Eurostat, n.d.e); K8 – research staff and researchers in the sector of business enterprises, person (Eurostat, n.d.d); K9 – percentage of the ICT sector in GDP, % (Eurostat, n.d.c); K10 – personnel from total employment, % (Eurostat, n.d.a); K11 – share of persons with at least basic digital skills, % (Eurostat, n.d.f).

Since the input indicators are measured in different units of measurement, to develop a regression model describing the impact of relevant indicators on the export of high-tech goods, it is necessary to conduct a normalization procedure. A modified logistic function (1) was used for data normalization.

$$y_{ij} = \frac{1}{1 + e^{-3\frac{x_{ij}-p_i}{q_i-p_i}}}, \quad (1)$$

where y_ij is the standardized value of the i-country of the j-indicator, q_i is the value of the x_ij indicator (maximum value), for which the transformation function acquires a value not less than 0.95; p_i is the value of the indicator x_ij, for which the transformation function acquires a value of 0.5 (median value).

A fragment of the normalized values of the study indicators is presented in Table 1.

Table 1. Fragment of data normalization results

Country	Indicator				
	K1	K2	K3	K4	K5
Austria	0,53	0,51	0,81	0,51	0,50
Belgium	0,61	0,51	0,72	0,54	0,50
Denmark	0,51	0,57	0,95	0,53	0,53
Finland	0,49	0,50	0,90	0,50	0,50
France	0,84	0,55	0,68	0,86	0,53
Germany	0,95	0,61	0,75	0,95	0,55
Ireland	0,60	0,50	0,75	0,47	0,50

Table 1 (cont.). Fragment of data normalization results

Country	Indicator				
	K1	K2	K3	K4	K5
Luxembourg	0,47	0,49	0,71	0,42	0,49
Netherlands	0,76	0,51	0,79	0,65	0,51
Sweden	0,54	0,67	0,93	0,58	0,57
Greece	0,48	0,50	0,48	0,50	0,50
Italy	0,59	0,52	0,29	0,87	0,52
Portugal	0,48	0,50	0,65	0,53	0,50
Spain	0,53	0,51	0,40	0,80	0,51
Bulgaria	0,48	0,49	0,30	0,44	0,50
Croatia	0,47	0,50	0,24	0,45	0,50
Cyprus	0,47	0,49	0,17	0,43	0,49
Czech Republic	0,60	0,61	0,54	0,54	0,58
Estonia	0,48	0,49	0,52	0,43	0,49
Hungary	0,54	0,95	0,44	0,47	0,95
Latvia	0,48	0,49	0,23	0,43	0,49
Lithuania	0,48	0,49	0,43	0,43	0,49
Poland	0,55	0,52	0,41	0,69	0,53
Romania	0,50	0,50	0,14	0,43	0,51
Slovakia	0,50	0,49	0,40	0,46	0,50
Slovenia	0,48	0,49	0,70	0,44	0,49
Malta	0,47	0,49	0,24	0,42	0,49
Ukraine	0,48	0,51	0,14	0,50	0,56

Source: calculated by the author.

The factor analysis procedure using principal component analysis and the Varimax rotation (orthogonal transformation) method was carried out in Statgraphics software. As a result, four models of factor loadings with values of eigenvalues greater than one were obtained (Table 2).

Table 2. Results of factor analysis

Factor Number	Eigenvalue	Percent of Variance	Cumulative Percentage
1	3,26731	32,673	32,673
2	2,52559	25,256	57,929
3	1,9717	19,717	77,646
4	1,08744	10,874	*88,520*
5	0,554079	5,541	94,061
6	0,370089	3,701	97,762
7	0,122169	1,222	98,984
8	0,0535037	0,535	99,519
9	0,0307986	0,308	99,827
10	0,0173173	0,173	100,000

Source: Constructed by the author using Statgraphics software.

So, as a result of the analysis, 10 linear combinations of variables were obtained, which explain most of the data variability. The first 4 components have eigenvalues greater than or equal to 1.0. Together, they account for 88.520% of the variability of the original data.

After orthogonal transformation by the Varimax method, the factor load matrix was obtained (Table 3).

Table 3. Factor loading matrix after orthogonal transformation using the Varimax method

Indicator	Factor 1	Factor 2	Factor 3	Factor 4
K2	0,0843986	0,966514	0,0999217	0,181008
K3	0,90852	0,0264404	0,121754	0,154739
K4	0,148212	0,0484804	0,968926	-0,119232

Table 3 (cont.). Factor loading matrix after orthogonal transformation using the Varimax method

Indicator	Factor 1	Factor 2	Factor 3	Factor 4
K5	-0,0491509	0,983605	0,0086505	0,113876
K6	0,908002	0,0981895	0,195767	-0,0206647
K7	0,725706	0,0709643	0,164298	-0,202351
K8	0,150117	0,0554267	0,972649	-0,0816378
K9	-0,0485029	0,2095	-0,115692	0,924335
K10	0,160132	0,0991296	-0,0871356	0,947895
K11	0,798713	-0,171404	-0,0706259	0,253288

Source: Constructed by the author using Statgraphics software.

Table 4 shows the contribution of each factor to the total variance: the greater the value of 'Estimated Communality', the greater the weight of the indicator.

Table 4. Results of the weighted influence of indicators

Variable	Estimated Communality	Specific Variance
K2	0,984021	0,0159794
K3	0,864876	0,135124
K4	0,977351	0,0226488
K5	0,982938	0,0170624
K6	0,87286	0,12714
K7	0,599625	0,400375
K8	0,978317	0,0216826
K9	0,914023	0,0859768
K10	0,941566	0,058434
K11	0,736465	0,263535

Source: Constructed by the author using Statgraphics software.

Thus, the econometric model for factor F1, which describes the influence of independent indicators on the export of high-tech goods, is represented by the following formula:

$$\begin{aligned} F1 = {} & 0{,}0843986 * K2 + 0{,}90852 * K3 + 0{,}148212 * K4 - 0{,}0491509 * K5 + 0{,}908002 \\ & * K6 + 0{,}725706 * K7 + 0{,}150117 * K8 - 0{,}0485029 * K9 + 0{,}160132 \\ & * K10 + 0{,}798713 * K11 \end{aligned} \tag{2}$$

The values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations (Z-score standardization).

The quality results of the factor analysis were confirmed using the Kaiser-Meier-Olkin (KMO) test and Bartlett's test. Bartlett's Test of Sphericity tests the null hypothesis that there are no correlations between variables in the general population. The Kaiser-Meyer-Olkin sampling adequacy criterion allows you to check to what extent the correlation between pairs of variables can be explained by other variables (factors). The null hypothesis that the correlation matrix is one is considered accordingly according to Bartlett's sphericity test at the selected level of significance. A p-value less than the selected level of significance indicates the statistical significance of the difference of the correlation coefficient from 0 and the acceptability of factor analysis. The value of the KMO statistic exceeding 0.5 also confirms that factor analysis is an acceptable method for analysing the correlation matrix.

The factor test on the measure of adequacy of the KMO sample has a value of 0.568195 and indicates the statistical quality of the conducted factor analysis.

Bartlett's Test of Sphericity is a multivariate normality test for the distribution of variables. The test checks whether the correlations are different from 0. A p-level value less than 0.05 indicates that the data are suitable for factor analysis. Therefore, both criteria, the values of which are 0.56 and 0.0, respectively, indicate the sufficient adequacy of the factor analysis.

Next, the four most influential indicators were taken to develop a regression model (Tables 5-6), which describes the influence of independent indicators on the effective export of high-tech goods (Table 5).

Table 5. Results of determining the most influential indicators

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0,106172	0,101693	1,04405	0,3073
K2	0,308059	0,615067	0,500854	*0,6212*
K5	-0,255455	0,633124	-0,403483	0,6903
K8	0,713919	0,108557	6,57644	0,0000
K10	0,0435393	0,0603984	0,72087	0,4783

Source: Constructed by the author using Statgraphics software.

The results of variance analysis are shown in Table 6.

Table 6. Results of variance analysis

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	0,272392	4	0,068098	15,33	*0,0000*
Residual	0,102165	23	0,00444194		
Total (Corr.)	0,374557	27			

Source: Constructed by the author using Statgraphics software.

R-squared = 72,7238 percent, R-squared (adjusted for d.f.) = 67,9802 percent. Standard Error of Est. = 0,0666479, Mean absolute error = 0,040324.

The resulting multiple linear regression model for describing the relationship between K1 (export of high-tech goods) and 4 independent variables is as follows:

$$K1 = 0{,}106172 + 0{,}308059 * K2 - 0{,}255455 * K5 + 0{,}713919 * K8 + 0{,}0435393 * K10 \quad (3)$$

Since the P-value in Table 5 is less than 0.05 only for the K8 indicator, there is a statistically significant relationship between the variables at the 95.0% confidence level between this indicator and the resulting feature. Therefore, for further modelling, the procedure of cruel screening of insignificant variables using the tool Backward Stepwise Selection was applied (Tables 7-8).

Table 7. Impact index

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0,152383	0,0513689	2,96644	0,0064
K8	0,727637	0,0915484	7,94811	*0,0000*

Source: Constructed by the author using Statgraphics software.

Table 8. Results of variance analysis

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	0,265347	1	0,265347	63,17	*0,0000*
Residual	0,109209	26	0,00420036		
Total (Corr.)	0,374557	27			

Source: Constructed by the author using Statgraphics software.

As a result, a pair regression model was obtained:

$$K1 = 0{,}152383 + 0{,}727637 * K8 \quad (4)$$

The statistical indicators are as follows: R-squared = 70,843 %; R-squared (adjusted for d.f.) = 69,7216 %; Standard Error of Est. = 0,0648102, Mean absolute error = 0,0412756.

The R-squared statistic shows that the fitted model explains 70,843% of the variability in K1. The adjusted R-squared statistic is 69.7216% and indicates a sufficiently high significance of the obtained model. The standard error of the estimate shows that the standard deviation of the residuals is 0.0648102. This value can be used to construct predicted bounds for new observations. The average absolute error of 0.0412756 also indicates the high accuracy of the model.

It was confirmed that increase of research staff and researchers in the sector of business enterprises by 1% causes increase of export of high-tech goods in average by 0,73%.

Conclusions

As a result of the research factors that have the greatest influence on the growth of export of high-tech goods in the context of innovation transfer for social-economic development were determined.

Based on the factor analysis, principal component analysis and the Varimax rotation (orthogonal transformation) method in Statgraphics, the search and classification of factors that affect the export of high-tech goods, the 4 most influential indicators out of 11 studied for a sample of 28 countries were identified, namely: research and development costs of countries; GDP in current prices; research staff and researchers in the sector of business enterprises; percentage of ICT personnel from total employment. They were taken to develop multiple linear regression models, which describes the influence of independent indicators on the effective export of high-tech goods. The quality results of the factor analysis are confirmed using the Kaiser-Meier-Olkin test and the Bartlett test.

Because of regression analysis with strict screening of non-significant variables using the Backward Stepwise Selection tool, the significance of the indicator of research staff and researchers in the sector of business enterprises was identified, which means that it has the greatest impact on the export of high-tech goods. A pair regression model was obtained.

It was confirmed that increase of research staff and researchers in the sector of business enterprises by 1% causes increase of export of high-tech goods in average by 0,73%.

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