TECHNOLOGIZATION PROCESSES AND SOCIAL AND ECONOMIC GROWTH: MODELING THE IMPACT AND PRIORITIES FOR STRENGTHENING THE TECHNOLOGICAL COMPETITIVENESS OF THE ECONOMY

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Abstract

The methodology of integral assessment of the technological competitiveness state of the economy has been developed, which includes a system of indicators in the areas of the country's readiness for economy digitization, the quality of innovation activity institutions, the state of digital knowledge dissemination. The integral values of technological competitiveness of the economy for the countries of the European Union and Ukraine have been calculated. A dynamic grouping of countries according to the level of technological competitiveness of the economy has been carried out. Modelling the impact of the parameters of technological competitiveness of the national economy on the basic parameters of social and economic development such as GDP per capita, share of high-tech exports, capital investment and quality of life of population has been realized. The strategic priorities and means of introduction of the collective contractual organizational and institutional system for providing technologization in the processes of social and economic growth of the country (the casestudy of Ukraine) are substantiated.

Keywords: innovation and technological development, competitiveness of the social and economic system, economic integration, prerequisites, factors of technologization

JEL classification: O32, O38, O47, C18, C51

1. Introduction

At present, there is a strong belief that economic growth and improving the quality of life of the population are directly determined by the level of competitiveness of the national economy and the processes of globalization only reinforce this hypothesis. Due to this development, the connections between the systematic introduction of technological innovations and the strengthening of the competitiveness of the national product have been axiomed, which is especially important in the era of digitization. Maximizing efficiency and increasing the rate of strengthening technological competitive advantages requires an understanding of the closest correlations of state policy to intensify the development of technological processes and ensure social and economic growth.

The modern period is characterized by such systemic negative trends as loss of a number of strategically important spheres of the real sector of the economy, deindustrialization, limited production of innovative and high-tech products, raw material export orientation and declining competitiveness in the world markets, high import dependence of domestic consumption. One of the key reasons for the emergence and increase of these trends lies in the reduction of innovation, scientific and technological activities and in the decrease of business demand for modern research and development, the isolation of education and science from the manufacturing sector, the decline of innovation and technological infrastructure. The innovation and technological potential of the national economy has significantly weakened as well.

The social and economic growth and intensification of the competitive positions of the economy requires the implementation of a balanced state policy aimed at strengthening the technological competitiveness of the economy as a leading component of the formation and strengthening of competitive advantages, which characterizes the modernity and progressiveness of used technologies, their spread in the economy and society, quality of the production system, involvement and implementation of advanced technologies, availability of resource supply (primarily investment and financial, intellectual and personnel, technical and technological, educational, research and information one), the effectiveness of the results of innovation and technological activities.

The substantiation of methodical approach to modeling the influence of consequences of the state policy of maintaining the technological competitiveness on social and economic development of economy acquires important theoretical and applied value that, unlike traditional approaches, expects a complex analysis (its information and analytical basis is numerical values of the sub-indices of the Global Innovation Index and the World Index of Digital Competitiveness of the Economy), which provides the calculation of the level of technological competitiveness of the country's economy and the implementation of comparative analysis with other high-tech countries, including EU countries. A thorough applied methodological approach allows clustering and identifying the positions of countries in terms of technological and innovative development, identifying the degree of divergence in terms of technological competitiveness, visualizing problem areas and reserves of state policy to strengthen the technological competitiveness of the economy.

Approbation of this type of methodological approach creates a more informative and analytical basis for substantiating the functions, tools and objectives of the state policy of collective contractual organizational and institutional system to ensure technological competitiveness of the economy as a fundamentally new approach in this area, involving joint efforts and delegation of functions and tasks between the state, associative business structures, education, science and innovation institutions, civil society to share areas of responsibility for the implementation of the main functions of the technologization processes of the national economy.

2. Literature Review

Both the justification of direct links and the study of various aspects of the impact of innovation and technological development on the economic growth of the country have always been the focus of scientific research. For example, innovative changes and their impact on the development of EU regions are quite thoroughly described in the work by R. Ciborowski, I. Skrodzka (2020); the direct connection between the creation and

implementation of advanced technologies and ensuring the competitiveness of the national economy are covered by J. Fagerberg (1996); A. Khryseva, E. Akimova, A. Savchenko (2018) investigated the direction of investment resources on innovation and technological development and ensuring the competitiveness of the economy.

Understanding the non-alternative way of technologization of the economy as a key to ensuring competitiveness and social and economic growth has led to a number of studies in the field of identifying, on the one hand, factors (O. Levytska, O. Mulska, U. Ivaniuk, M. Kunytska-Iliash, T. Vasyltsiv, R. Lupak (2020), O. Mulska, O. Levytska, V. Panchenko, M. Kohut, T. Vasyltsiv (2020)), and, on the other hand, obstacles to systemic innovation and technological economic growth (M. Burhanuddin, F Arif, V. Azizah, A. Prabuwono (2009), S. Hrynkevych, T. Vasyltsiv (2015), economic growth (N. Hossain, Y. Miyata (2012), T. Yalyalieva, D. Napolskikh (2017), Z. Almeida, I. Scheuneman, T. Sequeir, F. Diniz (2017)). Current trends of globalization have made it especially important to develop theoretical and methodological foundations of the state policy of preserving intellectual and personnel support for the creation and implementation of technological innovations in terms of reducing barriers to migration mobility of population.

It should be noted that firstly scientists paid more attention to expanding the typology of innovations. Thus, the classic product and technological innovations were complemented by environmental (S. Borghesi, V. Costantini, F. Crespi (2020)), technological and environmental (T. Requate, W. Unold (2003), S. Khanam, A. Islam, M. Megat, A. Jaafar (2015)), consumer (L. Rubalcaba, S. Michel, J. Sundbo, S. Brown, J. Reynoso (2012)), management (A. Triguero, M. Cuerva, C. Álvarez-Aledo (2017), H. Duran (2015)), social ones (R. Van der Have, L. Rubalcaba (2016), P. Aliha, T. Sarmidi, F. Faizah (2019)) etc. However, it has been further deepened the understanding that a number of them provide a technological breakthrough, while others serve as factors in supporting the innovation and technological development of the economy. Due to this, nowadays, theoretical and applied research directly in the field of technological innovations as a key driver of national competitiveness and economic growth are becoming increasingly important.

However, this is just a theory and only few works concern the empirical proof of not just the connection, but also the specific consequences, the level of impact of technologization on economy, creation, import and introduction of advanced technologies on certain basic parameters of economic and social development in the country. The exceptions are the publications by B. Jun-hong (2013), A. Mohamed, S. Sapuan, M. Ahmad, A. Hamouda, B. Baharudin (2012), C. Zhang, B. Wang, W. Gao (2017), L. Liubokhynets, Ye. Rudnichenko, I. Dzhereliuk, O. Illiashenko, V. Kryvdyk, N. Havlovska (2020), P. Numes, P. Nijkamp (2010, 2011) where an attempt was made to empirically assess the impact of trends in technologization (in various forms and areas such as ecology, oil production, labor market, export potential of industry etc.) to increase GNP and exports, as well as value added in purely raw materials industries, replace manual labor with automated one and at the same time create new digital employment niches, form new industries, and ensure the consumption security.

It should be emphasized that further improvement of the methodology of modeling technological processes and social and economic growth is necessary not only to understand the relevant relationships and interactions, but also to develop more means that are effective, tools, and mechanisms of state policy to strengthen them. Thus, it is paid attention to the works by B. Bozeman (2000), N. Khabiri, S. Rast, A. Senin (2012), P. Mohnen, L-H. Röller (2005), S. Ahmed, Yu. Ypanaque (2011) where it is convincingly argued on the economic, organizational and institutional capabilities of the state regarding the implementation of policy to stimulate internal technologization of the economy and technology transfer, as well as the complementarity of innovation progress at the regional and local levels. On the other hand, the statements of the theory of innovation policy integration (A. Pelkonen (2006)), institutionalism (S. Serger, E. Wise, E. Arnold (2015)) and adsorption of global experience (K. Smith (2016)) are now becoming increasingly clear.

At the same time, we are convinced that at present there are not enough scientific and applied developments in the field of modeling the impact of the technologization processes of the economy on the basic parameters of economic and social development. In their development and improvement, it is important to rely on already proven links of a qualitative

nature, in particular in terms of the impact on employment (F. Bogliacino, M. Pianta (2010)), quality of life (L. Gagliardi, G. Marin, C. Miriello (2016)), export potential (O. Jean, M. Ashoka (1996)), domestic production and consumption (G. Korres, A. Kokkinou (2011)), consumer market development (T. Waroonkun, R. Stewart (2008)), regional and local development (E. Zakharova, E. Kardava, R. Avanesova, E. Avramenko (2015)).

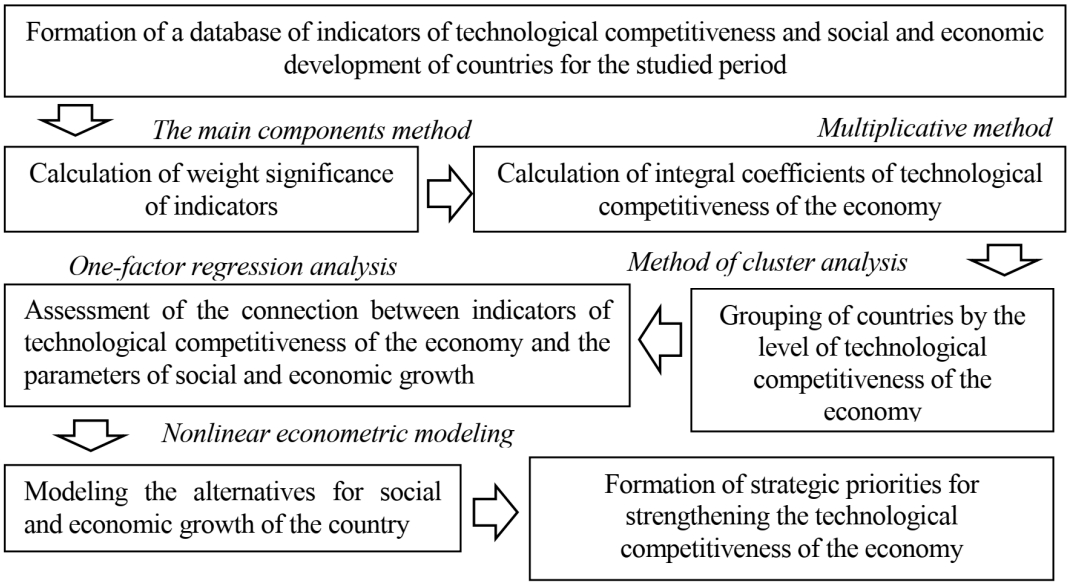
The aim of the study is to develop a methodological approach to modeling the impact of the processes of technologization of the economy on the basic parameters of economic and social development of the country (the case study of Ukraine).

The hypothesis is an effective state policy to stimulate the creation and implementation of technological innovations being a driver of accelerating GDP growth, increasing the share of high-tech exports, rising capital investment and improving the quality of life.

3. Research Method

Modeling the impact of the processes of technologization of the economy on the basic parameters of social and economic development of the EU and Ukraine consists of three key stages, namely assessing the level of technological competitiveness of the economy, assessing the relationship between technological competitiveness and economic growth of the country, modeling alternatives to social and economic growth in Ukraine providing the corresponding values of technological development of individual EU countries (Figure 1).

Figure 1: Methodical stages for modeling the impact of the processes of technologization of the economy on the parameters of social and economic growth



Source: authors' development

The initial stage of the authors' methodology of calculating the integral coefficient of technological competitiveness of the economy is the selection of indicators that demonstrate the key parameters of innovative development, conditions of access to new technologies and resource support of the technology transfer process. The system of information and analytical support is formed from the sub-indices of the Global Innovation Index, the World Index of Digital Competitiveness and Talents during 2016-2018 (Table 1). The process of forming the research base was based on the principles of validity, universality, and comparability.

Table 1. The system of information and analytical support for the analysis of the processes of technologization of the economy and the basic parameters of social and economic development

Economy technologization indicators	Variables of social and economic development
Global Innovation Index	
INST – institutions; CAPIT – human capital and research; INFR – infrastructure; MARKET – market sophistication;	
Global Talent Competitiveness Index	
CONECT – business sophistication; OUTPUT – knowledge and technology outputs; RESUL – creative outputs; COND – market, business and labour landscape; ABILITY – ability to attract talent; GROWTH – access to growth opportunities; RETAIN – ability to retain highly-skilled professionals; VTS – vocational and technical skills; GLOBAL – global knowledge skills;	GDP – gross domestic product per capita in PPP terms; EXPORT – share of high-tech exports; INDEX – Global Quality of Life Index
World Digital Competitiveness Index	
KNOWL – knowledge; TECHN – technology; READY – future readiness	

Source: authors' development

The calculation of the *weight significance of the indicators* is carried out using the method of main components based on formula (1):

$$w_i = |MC_i| / \sum_i^n |MC_i|, \quad (1)$$

where w_i is the weight of *i*- indicator of technologization of the economy;
MC_i is the value of the main component of *i*- indicator;
n is the number of indicators.

Integral coefficients of technological competitiveness of the economy are calculated based on the multiplicative method by formula (2):

$$Coef_t^j = \prod_{i=1}^{n} Ind_{it}^{wi} \quad (2)$$

where $Coef_t^n$ is an integral coefficient of technological competitiveness of the economy of *j*- country in *t*- time interval;
Ind_{it} is an *i*- indicator of the technologization of the economy in the *t*- time interval.

The use of analytical data of global rankings to analyze the impact of selected sub-indices on economic and social development allow tracking and confirming (refuting) the relationship between indicators-characteristics of technological competitiveness of the national economy and social transformations of the economy.

In order to confirm the hypothesis of the dependence of social and economic growth of the country on the level of technologization of the economy, the empirical assessments of the impact of technological competitiveness of the economy, innovation, digitalization of the economy and the formation of intellectual staff support on the basic parameters of

economic and social development have been conducted. Assessment of the impact of activation processes of systemic technologization of the national economy on the parameters of economic growth and development of the social sphere has been carried out based on model (3):

$$Parm_t = a + bInd_t \quad (3)$$

where $Parm_t$ is a parameter of social and economic growth of the country in *t*- time interval.

The confirmation of the high density of relationships between the studied variables is presented in Table 2.

Forecasting models of the economic growth of the country are described by functions (4) and (5).

$$Parm_t = a\cos(2Ind_t) - b\,\mathrm{sln}(Ind_t), \quad (4)$$

$$Parm_t = \frac{1}{a - b\ln(Ind_t)}, \quad (5)$$

Table 2. Indicators of significance of modeling the impact of technologization of the economy on the social and economic development of Ukraine

Criterias		$Parm_t$	Ind_t										
			CAPIT	OUTPUT	INFR	CONECT	RESUL	COND	ABILITY	GLOBAL	KNOWL	TEHN	READY
Adjusted R-squared		*GDP*	0.904		0.437	0.432	0.858	0.997		0.930	0.519	0.926	0.985
		EXPORT	0.991				0.664	0.927		0.998		0.769	0.887
		INDEX	0.896	0.485				0.557	0.786	0.865			0.476
Standard regression error		*GDP*	0.023		0.056	0.057	0.028	0.004		0.020	0.052	0.020	0.009
		EXPORT	0.006				0.036	0.017		0.003		0.030	0.021
		INDEX	0.009	0.019				0.018	0.012	0.010			0.019
Sum squared resid		*GDP*	0.001		0.003	0.003	0.001	0.000		0.000	0.003	0.000	0.000
		EXPORT	0.000				0.001	0.000		0.000		0.001	0.000
		INDEX	0.001	0.000				0.000	0.000	0.000			0.000
Log likelihood		*GDP*	8.676		6.025	6.014	8.095	13.83		9.159	6.264	9.064	11.47
		EXPORT	12.73				7.342	9.631		14.75		7.904	8.983
		INDEX	11.69	9.289				9.513	10.60	11.29			9.262
F-statistic		*GDP*	19.79		2.550	2.524	13.10	646.6		27.68	3.162	25.92	132.8
		EXPORT	215.42				4.945	26.35		828.4		7.645	16.75
		INDEX	18.274	2.886				3.511	8.335	13.79			2.816
p-value		*GDP*	0.014		0.036	0.036	0.017	0.003		0.012	0.033	0.012	0.006
		EXPORT	0.043				0.027	0.012		0.022		0.002	0.015
		INDEX	0.146	0.339				0.312	0.212	0.168			0.342
SE of dependent variable		*GDP*	0.075		0.075	0.075	0.075	0.075		0.075	0.075	0.075	0.075
		EXPORT	0.063				0.063	0.063		0.063		0.063	0.063
		INDEX	0.026	0.026				0.026	0.026	0.026			0.026
Information criterions	Akaike	*GDP*	-4.451		-2.684	-2.67	-4.063	-7.890		-4.773	-2.842	-4.71	-6.31
		EXPORT	-7.16				-3.56	-5.09		-8.50		-3.94	-4.66
		INDEX	-6.46	-4.85				-5.00	-5.73	-6.19			-4.84
	Schwartz	*GDP*	-5.052		-3.284	-3.27	-4.664	-8.491		-5.374	-3.443	-5.31	-6.91
		EXPORT	-7.75				-4.16	-5.68		-9.10		-4.53	-5.25
		INDEX	-7.06	-5.46				-5.60	-6.33	-6.79			-5.44
	Hannan-Quinn	*GDP*	-5.659		-3.892	-3.88	-5.271	-9.098		-5.981	-4.050	-5.91	-7.52
		EXPORT	-8.36				-4.76	-6.29		-9.70		-5.14	-5.86
		INDEX	-7.66	-6.06				-6.21	-6.94	-7.40			-6.04

Source: authors' own complications using EViews 11 software. Note: SE is standard error

4. Results and discussion

4.1. Empirical research results

Innovation activity, its scale, trends, structural characteristics and efficiency are the basic prerequisites for the formation of technological competitiveness of the national economy. Technology transfer, commercialization of scientific developments and innovations, as well as other forms of diffusion of modern advanced knowledge and know-how determine the environment of supply of advanced technologies, their implementation and use strengthens technological competitiveness of individual enterprises, industries and types of economic activity, as well as the country's economy as a whole. Instead, the innovation and technological activity in Ukraine is at a low level, and the dynamics of numerous indicators of innovation and technological development indicates a downward trend, which negatively affects the formation and realization of the potential for technological competitiveness of the national economy. This conclusion is confirmed:

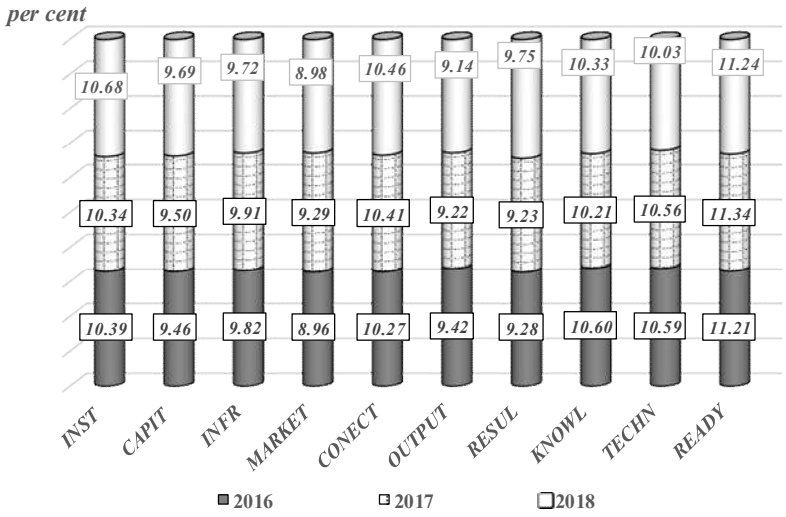
- in statics by a small share of industrial enterprises engaged in innovation (15.8% in 2019), which implement innovations (13.8%) and sell innovative products (14.2%), by a low share of innovative products in total sales of industrial products (1.3%) and its exports (3.8%), by limited funding for innovation (0.47% of GDP), the presence of marked structural shortcomings in financing and spending on innovation, sources of attraction (acquisition, transfer) of new technologies, directions of development of innovation and technological activity, as well as by worse indicators of innovation and technological development in the small business sector;
- in dynamics by a decrease in the number of industrial enterprises that carried out innovative activities (by 46.5% in 2010-2019) and implemented innovations (by 43.5%), by a reduction in the number of introduced innovative products (goods, services), by industrial enterprises (by 10.8%) and the share of innovative products in the total volume of sold industrial products (by 2.5 percentage points), a decrease in the number of enterprises that sold innovative products outside Ukraine (in 2 times), and the volume of such products (in 2.5 times).

The result of these trends is the low position of the Ukrainian economy in the rankings of leading international organizations on competitiveness indices, including innovation and technology one – Global Competitiveness, World Competitiveness Index, Digital Competitiveness, Global Innovation Index, International Index of Property Protection, etc.

The most informative form of presenting the results of research in the field of technological competitiveness of the economy, in particular for a comprehensive description of the situation and tracking its trends is the calculation and presentation of integral indicators (coefficients). This method of research allows integrating the parameters differentiated by the research problem into a single system. The applied value of integral assessments is to enable a comparative analysis of the level of technological competitiveness of leading high-tech enterprises, industries and sectors of the economy, economic activities, regions and countries; to assess the effectiveness of public policy in this area, as well as to signal the improvement of the environment of technological development or, conversely its deterioration.

Based on certain weight coefficients of key parameters that describe the level of technologization of the economy on the example of the EU and Ukraine (Figure 2), it is established that the state of technological competitiveness of the economy determines the country's readiness for digital economy, the quality of innovation institutions and digital knowledge. Together, these three factors determined the state of technological competitiveness of the economy of the EU and Ukraine in 2018 at 32.25%, in particular by factors; the weight significance was 11.24%, 10.68%, 10.33%, respectively. It should be emphasized that the levels of importance of these factors were the highest in 2016 and 2017, which serves as a confirmation of the high relevance of the development of the digital information technology sector and the infrastructure of innovation and technology in Ukraine.

Figure 2: Weight coefficients of indicators of technological competitiveness of the economy, 2016-2018.

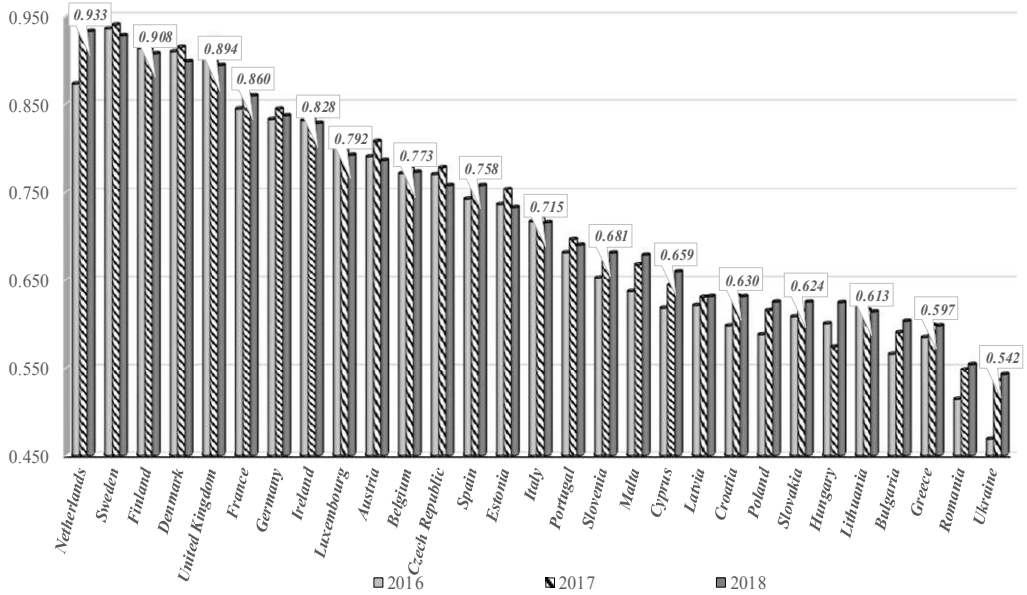


Source: authors' own complications by formula (1)

At the same time, other components of the index have a significant impact on the level of technological competitiveness of the economy, in particular it is the quality of the market environment (8.98% in 2018 and 8.96% in 2016), the results of knowledge and technology application in the economy (9.14 % in 2018 and 9.22% in 2017), the use of intellectual creativity (9.23% in 2017 and 9.28% in 2016).

The results of the calculations have confirmed the lowest competitive advantages for the economy of Ukraine compared to other EU countries (in 2018 the value of the integral index was 0.542). Among the EU-28 countries in 2018, the lowest positions of technological competitiveness were occupied by Romania with an integral coefficient of 0.554, and the highest one by the Netherlands (0.933). In 2016, the leading country in terms of the level of technological competitiveness of the economy was Sweden with an integral coefficient of 0.936 (0.928 in 2018). It should be noted that the countries with the level of technological competitiveness of the economy above the average in 2018 included the Netherlands, Sweden, Finland, Denmark, Great Britain, France, Germany, Ireland, Luxembourg, Austria, Belgium, the Czech Republic, Spain and Estonia (Figure 3).

Figure 3: Integral coefficients of technological competitiveness of EU countries and Ukraine, 2016-2018

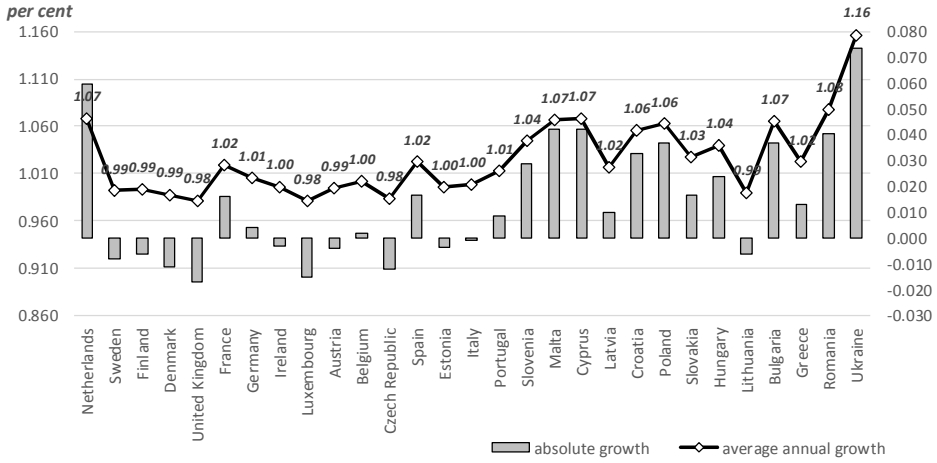


Source: authors' own complications by formula (2) ranked by the values of integral indices in 2018

It should be stressed that for most EU countries there is an increase in the level of technological competitiveness of the economy in 2016-2018 (Figure 4). The largest increase in the integral coefficient of technological competitiveness (at 1-1.1% level) was characteristic for the Netherlands, Malta, Cyprus, Bulgaria, Croatia, Poland, and Slovenia. This trend is an evidence of the intensification of innovation in recent years and the growing level of commercialization of research in the EU countries, which previously had a relatively lower level of economic development among the studied countries.

However, there is a downward trend in the level of technological competitiveness of the economy (about 1%) for the economies of Sweden, Finland, Denmark, Great Britain, Ireland, Luxembourg, Austria, the Czech Republic, Estonia, Italy and Latvia. Although the level of technological competitiveness of Ukraine in 2016-2018 increased by 1.16%, in the ranking of the EU economy, Ukraine occupies the last positions, approaching the level of Romania. It is noteworthy that Romania is showing an improvement in the values of the integral coefficient of technological competitiveness of the economy.

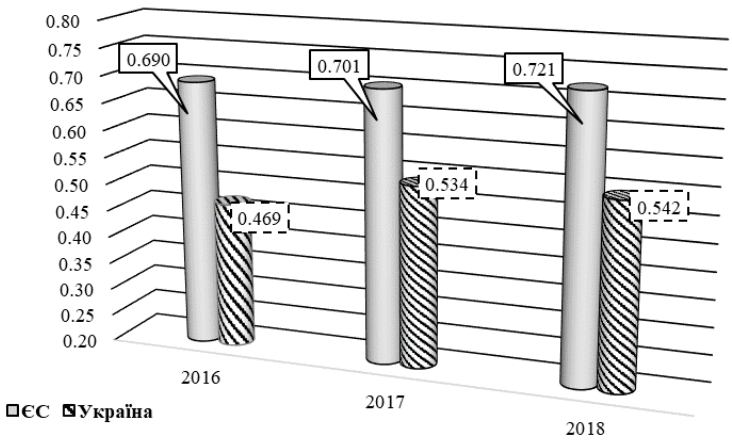
Figure 4: Average annual increases in the coefficients of technological competitiveness of the EU countries and Ukraine, 2016-2018



Source: authors' own complications based on the data of Figure 3

It should be stated that the value of the divergence of the levels of technological competitiveness of the EU-28 and Ukraine in 2016-2018 decreased by 0.042 (Figure 5). In 2018, the differentiation of values between Ukraine and the EU-28 was 0.179 (or about 18%). The average annual divergence rate was 3.3%. Thus, in 2016 for the EU-28 the index was 0.69, in 2017 it increased to 0.701 (there was an increase by 0.011), in 2018 it increased to 0.721 (0.02 more than in 2017 and 0.031 more than in 2016).

Figure 5. Integral coefficients of technological competitiveness of the EU-28 and Ukraine, 2016-2018



Source: authors' own complications by formula (2)

Thus, the level of technological competitiveness of Ukraine's economy is significantly low, which requires intensification of efforts to increase it. This can be achieved if Ukraine implements a state policy focused on the creation and implementation of advanced technologies, intensification of innovation, especially in the field of technological innovation, development of the intellectual sphere and implementation of its results in real production, development of innovation and technological infrastructure, improvement of the resource support of the technologization of the economy, formation of a favorable environment for strengthening the technological competitiveness of the national economy. It is also important to intensify Ukraine's cooperation in the high-tech sphere with the EU countries that are leaders in the level and pace of increasing the technological competitiveness of the economy.

In order to confirm the weak positions of technological competitiveness of Ukraine's economy, as well as to identify disparities between certain groups of EU countries, clustering of countries based on integral coefficients of technological competitiveness in 2016 and 2018 was done. Six groups of countries were identified according to the level of technological competitiveness of the economy. In 2016, none of the EU countries entered the cluster with Ukraine, and in 2018 – Greece (Table 3).

Table 3. Results of the cluster analysis of the grouping of the EU-28 countries and Ukraine according to the integral index of technological competitiveness of the economy, 2016-2018

Countries	Euclidean distances	Clusters, characteristics	Countries	Euclidean distances	Clusters, characteristics
2016					
Bulgaria	3.79	I, below average	Cyprus	4.83	II, average
Greece	7.27		Malta	4.83	
Croatia	2.32		Denmark	3.46	IV, the highest
Hungary	5.16		Netherlands	4.67	
Romania	4.04		Finland	3.55	
Slovakia	3.36		Sweden	4.89	
Czech Republic	4.94	III, above average	United Kingdom	4.41	
Spain	5.70		Belgium	3.39	VI, high
Italy	5.06		Germany	3.76	
Latvia	5.36		Estonia	6.00	
Lithuania	4.81		Ireland	5.16	
Poland	4.97		France	5.10	
Portugal	2.46		Luxembourg	7.55	
Slovenia	4.78		Austria	5.07	
Ukraine	0.00	V, low			
2018					
Greece	5.144317	I, low	Bulgaria	2.204495	III, below average
Ukraine	5.144317		Croatia	3.317951	
Czech Republic	4.317809	II, above average	Hungary	5.030447	
Latvia	4.549740		Romania	3.527662	
Lithuania	3.797825		Slovakia	2.267951	
Poland	2.929870		Italy	4.504861	V, average
Portugal	3.117981		Cyprus	4.658517	
Slovenia	3.689057		Malta	4.942582	
Denmark	4.265069	IV, the highest	Belgium	3.875095	VI, high
Germany	4.447434		Estonia	4.622124	
Ireland	5.629371		Spain	4.906563	
Netherlands	5.039483		France	4.727511	
Finland	3.163581		Luxembourg	7.608353	
Sweden	4.168157		Austria	5.767816	
United Kingdom	4.464506				

Source: authors' own complications based on the data of Figure 3 using Statistica 7 software

Therefore, in 2016 Denmark, the Netherlands, Finland, Sweden and the Great Britain formed the group of countries with the highest level of technological competitiveness. The second group, characterized by a high level of technological competitiveness, included Belgium, Germany, Estonia, Ireland, France, Luxembourg and Austria. Conventional outsiders among the countries on the criterion of technological competitiveness of the

economy were Bulgaria, Greece, Croatia, Hungary, Romania and Slovakia, which are characterized by significant differentiation for EU countries on all indicators of technological competitiveness, especially in terms of innovation and technological development, the formation of technological infrastructure, digitization of the economy. Nevertheless, the level of technological competitiveness of Ukraine's economy was inferior even to these economies, which did not allow Ukraine to enter this group of countries.

The results of the analysis confirm the improvement of Ukraine's position on the technologization of Ukraine's economy, which together with Greece in 2018 formed a cluster of low level of technological competitiveness. In 2018, the highest level of technological competitiveness of the economy was characteristic for Denmark, Germany, Ireland, the Netherlands, Finland, Sweden and Great Britain. Belgium, Estonia, Spain, France, Luxembourg and Austria were also characterized by a high level of technological competitiveness of the economy.

It is necessary to pay attention to a number of countries whose level of technological competitiveness of economies is the lowest in the EU (Bulgaria, Croatia, Hungary, Romania and Slovakia). It is noteworthy that in 2016-2018, most countries maintained their positions; Germany and Ireland improved the level of technological competitiveness and moved from the group of high level of technological competitiveness to the group of countries with the highest level. Spain moved from the above average group to high one, and Italy moved from average to above average group.

Unfavourable trends in the field of innovation and technological development are typical for Greece. Thus, from the group of countries with a level of technological competitiveness of the economy below average, Greece in 2018 entered the cluster of low level.

Ukraine's low position in the ranking of countries by the level of development of innovative sectors of the economy, positive changes in technological activities, ensuring the technological competitiveness of the economy are due to objective and subjective, internal and external causes and factors. In particular, these are the instability of the economic, legal and political environment, and the general state of the economy, competitive environment and domestic market, underdevelopment and low capacity of infrastructure of innovation and research activities, low activity of business entities in terms of creation, commercialization and transfer of new technologies, as well as weakness of the financial and investment infrastructure in terms of supporting innovation and technology activities of the private sector.

4.2. Modeling and forecasting

A regression analysis was performed to confirm the thesis of the close connection between technological competitiveness and economic growth. Thus, a reverse connection was found between the intensification of research in the field of innovation, including human capital, and GDP per capita (formula 5).

$$\begin{matrix} 7{,}665 & 4{,}539CAPIT_t \\ GDP_t = (4{,}707^*) - (-4{,}449^*) \\ R^2 = 0{,}952 \quad DW = 2{,}98 \end{matrix}, \qquad (5)$$

It should be emphasized that the development of human capital and the improvement of labor market conditions should demonstrate a direct favorable connection with GDP. However, some factors to ensure the technological competitiveness of the country are inertial, characterized by lag dependence, some of them are characterized by critical growth limits, the achievement of which will have a destructive impact on the economic development of the country, including GDP.

Instead, other models demonstrate the favorable impact of the parameters of technological competitiveness of Ukraine's economy on GDP. In particular, with the improvement of innovation infrastructure and strengthening the ties of entities (by 1%) engaged in innovation and technology activities, with business representatives it can be expected GDP growth per capita in Ukraine by 1.39% and 1.9% respectively (formula 5-6).

$$\begin{matrix} -1{,}744 & 1{,}387INFR_t \\ GDP_t = (-1{,}286^*) + (1{,}597^*) \\ R^2 = 0{,}718 \quad DW = 2{,}23 \end{matrix}, \qquad (5)$$

$$GDP_t = \begin{matrix} -2,478 \\ (-1,357^*) \\ R^2 = 0,716 \end{matrix} + \begin{matrix} 1,903CONECT_t \\ (1,589^*) \\ DW = 2,22 \end{matrix}, \quad (6)$$

It is remarkable that the increase in the values of the indicator of global knowledge leads to a significant increase in GDP per capita. This may mean that knowledge and innovation are closely linked to the country's technological development and thus attract investment in innovative sectors of the economy, which contributes to increasing the competitiveness of the economy and GDP growth (formula 7).

$$GDP_t = \begin{matrix} -1,522 \\ (-4,118^*) \\ R^2 = 0,965 \end{matrix} + \begin{matrix} 1,296GLOBAL_t \\ (5,262^*) \\ DW = 2,09 \end{matrix}, \quad (7)$$

It is important that the development of the digital economy sector of Ukraine, as evidenced by the variables of digital knowledge (formula 8) and technology (formula 9), contributes to an increase in GDP per capita.

$$GDP_t = \begin{matrix} -3,596 \\ (-1,591^*) \\ R^2 = 0,760 \end{matrix} + \begin{matrix} 2,277KNOWL_t \\ (1,778^*) \\ DW = 2,31 \end{matrix}, \quad (7)$$

$$GDP_t = \begin{matrix} -0,606 \\ (-2,997^*) \\ R^2 = 0,963 \end{matrix} + \begin{matrix} 0,664TEHN_t \\ (5,091^*) \\ DW = 2,08 \end{matrix}, \quad (8)$$

The indicator of high-tech export deserves special attention, which is an evidence of high technological competitiveness and innovation of the economy. The results of empirical calculations suggest that there is a close link between the share of high-tech exports and factors of economy technologization such as human capital and research, creative performance results, market and regulatory conditions in the labor market, global knowledge, technology and readiness for the future that are quite natural.

Thus, human capital and research, as well as the improvement of market and regulatory conditions in the labor market (formula 9-10) have a favorable impact on the growth of the share of high-tech exports (by 3.87 and 1.8%, respectively).

$$EXPORT_t = \begin{matrix} -5,383 \\ (-12,785^{**}) \\ R^2 = 0,995 \end{matrix} + \begin{matrix} 3,873CAPIT_t \\ (14,677^{**}) \\ DW = 2,90 \end{matrix}, \quad (9)$$

$$EXPORT_t = \begin{matrix} -2,122 \\ (-3,732^*) \\ R^2 = 0,963 \end{matrix} + \begin{matrix} 1,803COND_t \\ (5,133^*) \\ DW = 2,15 \end{matrix}, \quad (10)$$

Empirical assessments confirm the highest relevance of state policy aimed at preserving and developing human capital of Ukraine (especially in the context of global and large-scale attitudes of the majority of the population to external labor and further stationary migration), as well as creating a favourable environment to innovation and intellectual creativity. Only under such conditions it could be expected an increase in domestic exports, in particular high-tech and, accordingly, competitive one in foreign markets.

Instead, the level of favorable innovation environment in Ukraine is low. This is confirmed by the reverse relationship between the variables of creative activity results, global knowledge, technology and the share of domestic high-tech exports (Table 4).

Furthermore, there is an inverse link between the level of quality of life and the output of knowledge and technology, the ability of employers to attract talented people. In particular, with the increase in the value of human capital and research, market and regulatory conditions in the labor market and the ability of employers to attract gifted people by 1%, the quality of life in Ukraine becomes worse by 1.59%, 0.685% and 0.56%, respectively.

The results of modeling are additional evidence of the imperfection of the domestic environment of technological activity, as well as the low level of innovation and technological development and its impact on the indicators of social recovery in the country.

Instead, it was found that improving the use of knowledge and technology in business has a positive effect on the quality of life in Ukraine (correlation coefficient is 0.919, coefficient of determination is 0.743), which confirms the need to intensify state policy to support and

stimulate the creation and implementation of new knowledge and technologies in business practice.

Table 4. The results of econometric modeling of the impact of indicators of technological competitiveness of the economy on the parameters of social and economic development of Ukraine

	Impact on GDP	
	$GDP_t = \underset{(-4,118^*)}{-1,522} + \underset{(5,262^*)}{1,296GLOBAL_t}$ $R^2 = 0,965 \quad DW = 2,09$	$GDP_t = \underset{(28,437^{**})}{3,982} - \underset{(-25,429^{**})}{2,200COND_t}$ $R^2 = 0,929 \quad DW = 2,42$
	$GDP_t = \underset{(-9,781^{**})}{-2,366} + \underset{(11,527^{**})}{1,764READY_t}$ $R^2 = 0,993 \quad DW = 2,92$	$GDP_t = \underset{(-3,094^*)}{-2,480} + \underset{(3,620^*)}{1,890RESUL_t}$ $R^2 = 0,929 \quad DW = 2,42$
Impact on high technology exports	$EXPORT_t = \underset{(2,996^*)}{3,087} - \underset{(-2,224^*)}{1,492RESUL_t}$ $R^2 = 0,832 \quad DW = 2,52$	Influence on quality rating життя $INDEX_t = \underset{(7,550^{**})}{4,500} - \underset{(-4,275^*)}{1,597CAPIT_t}$ $R^2 = 0,948 \quad DW = 2,97$
	$EXPORT_t = \underset{(42,656^{**})}{2,446} - \underset{(-28,783^{**})}{1,099GLOBAL_t}$ $R^2 = 0,998 \quad DW = 2,92$	$INDEX_t = \underset{(0,649)}{0,539} + \underset{(1,699^*)}{0,919OUTPUT_t}$ $R^2 = 0,743 \quad DW = 1,83$
	$EXPORT_t = \underset{(5,435)}{1,618} - \underset{(-2,765^*)}{0,531TEHN_t}$ $R^2 = 0,884 \quad DW = 2,80$	$INDEX_t = \underset{(5,174^*)}{3,060} - \underset{(-1,874^*)}{0,685COND_t}$ $R^2 = 0,778 \quad DW = 2,58$
	$EXPORT_t = \underset{(5,528^*)}{3,065} - \underset{(-4,093^*)}{1,435READY_t}$ $R^2 = 0,944 \quad DW = 2,12$	$INDEX_t = \underset{(9,298^{**})}{2,831} - \underset{(-2,887^*)}{0,556ABILITY_t}$ $R^2 = 0,893 \quad DW = 2,22$

Source: authors' own complications using EViews 11 software

The favorable dependence of the quality of life on the factor of global knowledge (the corresponding regression coefficient is statistically significant at the level of 5%) can be interpreted in favor of the conclusion that the involvement of technology transfer, including knowledge, will promote the development of the social sphere (formula 11). The readiness of the country's economy for the future has a positive effect on the level of quality of life. A 1% increase in this indicator improves the level of quality of life by 0.54% (formula 12).

$$INDEX_t = \underset{(7,046^{**})}{1,279} + \underset{(3,713^*)}{0,449GLOBAL_t}, \quad R^2 = 0,932 \quad DW = 2,98 \tag{11}$$

$$INDEX_t = \underset{(2,187^*)}{1,105} + \underset{(1,678^*)}{0,536READY_t}, \quad R^2 = 0,738 \quad DW = 2,92 \tag{12}$$

The key stage of modeling is to predict the impact of changes in the values of technological competitiveness indicators on the basic social and economic indicators of Ukraine's development, which aims to determine the expected results of effective state policy to strengthen technological competitiveness of Ukraine. Based on the modeling, it is possible to obtain hypothetical characteristics of social and economic development of Ukraine if the values of economic divergence of Ukraine decrease and a group of countries with a level of technological competitiveness is below average, average and above average. To confirm the

thesis, the forecasting of GDP per capita (formula 13) and the quality of life index (formula 14) are carried out.

$$GDP_t = \underset{(0.135^{**})}{3{,}333}\cos(2CONECT_t) - \underset{(0.136^{**})}{3.426}\sin(CONECT_t), \quad (13)$$

$$R^2 = 0.955 \quad AICC = -9.308$$

$$GDP_t = \frac{1}{\underset{(0.889^{**})}{3{,}163} - \underset{(0{,}249^{**})}{0{,}787}\ln(RESULT_t)}, \quad (14)$$

$$R^2 = 0{,}929 \quad AICC = -7{,}927$$

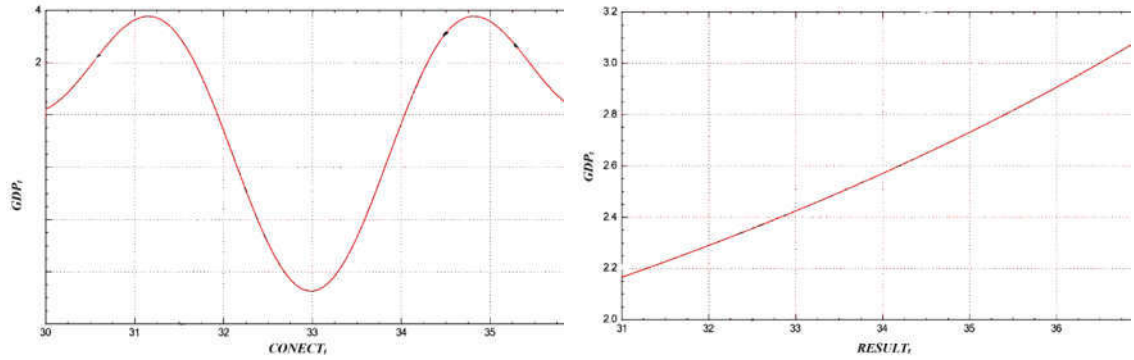
Provided that Ukraine will be characterized by the value of the indicator of quality of business links and research sector in Slovakia that is a country that fell into the group below average level of technological competitiveness, the forecasting value of GDP per capita will be 3.45 thousand dollars, in Italy (group of countries with an average level of technological competitiveness) it will be 5.87 thousand dollars, in Czech Republic (above average) it will be 6.58 thousand dollars.

Modeling the situation that Ukraine receives the position of Slovakia on the indicator of results of creative activity, it is obtained the forecasting value of GDP per capita for 3.34 thousand dollars. If Ukraine reaches the values of the corresponding indicator of Cyprus (country with an average level of innovative development), the volume of GDP per capita may be about 4.60 thousand dollars, and when reaching the level of the Czech Republic (country with above average level of innovative development), it will be 5.42 thousand dollars.

The obtained model of dependence of GDP per capita on the indicator of the quality level of links between business and research sector for Ukraine is wavy (Figure 6). Thus, the highest values of GDP per capita in Ukraine can be achieved with the maximum growth of the performance of creative activity and the values of the quality of relations between business and research sector in the range of 30-32 and 34-36, respectively.

Figure 6: Visualization of the dependence of GDP per capita on individual indicators of technological competitiveness of Ukraine

a) quality level of links between business and research sector	b) effectiveness of creative activity



Source: authors' development, using CurveExpert Professional software

Based on the prognostic model of the quality of life index (formula 15), it is determined that if Ukraine achieves the values of the quality level of connections between business and research sector of Hungary, the quality of life will be 106.2, and when the values reach Cyprus and the Czech Republic, it will be 113,26 and 124,43, respectively.

$$INDEX_t = \left(\frac{1}{\underset{(0{,}005^{**})}{0{,}022} - \underset{(0{,}000^{**})}{0{,}003}OUTPUT_t}\right), \quad (15)$$

$$R^2 = 0{,}886 \quad AICC = 10{,}445$$

Empirical and prognostic assessments confirm the thesis (Table 5) that a higher level of quality of life in the country can be obtained because of improving cooperation between business and science, research, commercialization of research and technology transfer.

Table 5. The results of forecasting the impact of individual indicators of technological competitiveness of the economy on the parameters of social and economic growth in Ukraine

Parameters	Actual values of indicators, 2018	Predicted values		
		Groups of countries by the level of technological competitiveness of the economy		
		below average	average	above average
GDP per capita, thousand dollars of USA	3.1	3.34-3.45	4.6-5.87	5.42-6.58
Quality of life index	95.96	106.2	113.26	124.43

Source: authors' own complications based on formulas (4-5) using CurveExpert Professional software

One of the priority tasks of Ukraine in line with strengthening the technological competitiveness of the economy is the search of new resources for economic growth and the formation of new types of economic relations in a systemic crisis. To create favorable conditions for the development of an innovative economy, Ukraine has to choose a new approach to the formation of the intellectual property market, as well as the use and commercialization of knowledge and innovation. The main difference between the latest tactics is that advanced technologies, innovations, know-how and knowledge become the intellectual reserve of the country and are the main resource of its development. One of the conditions for Ukraine's integration into the new economic system is the creating effective mechanisms for the use of intellectual resources, especially those covered by intellectual property rights.

5. Discussion

Ukraine's strategic priorities on the path to becoming its technologically capable economy lie in three following planes:

1) forming of a digital society based on knowledge and new technologies;
2) creating a digital state on the basis of e-government and e-inclusive democracy;
3) introducing digital business within the digital single market.

Such goals are declared in the national strategic documents, but are not supported by specific programs for their implementation. At the same time, sectoral digital modernization in Ukraine is reflected in key strategies and concepts for the development of basic sectors of the economy and spheres of public life (industry, energy, transport, agriculture, defence industry, trade, financial sector, ICT industry, social and humanitarian sphere).

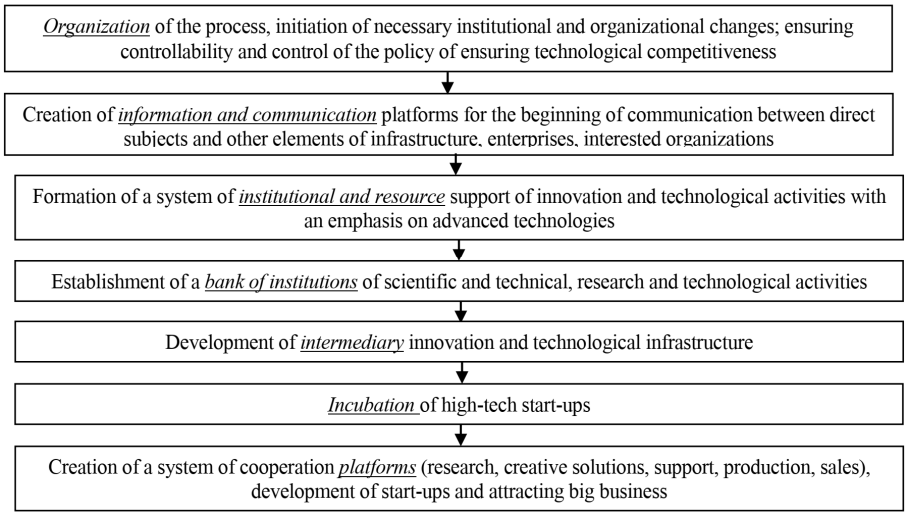
The policy of intellectualization and digitization of Ukraine's economy in the focus of its structural and technological restructuring should take into account three development priorities that are intellectualization of the economy (smart specialization, creativity, formation of new knowledge); digitization of the economy and society (digital state, digital society, digital market); technological modernization of production as a factor in the formation of technological competitiveness.

One of the main conditions of technological development of the economy is the institutional infrastructure of innovation and technological activity. Lower level of development of its elements and their capacity in Ukraine in comparison with high-tech states is due, among other reasons, to disinterest and, accordingly, non-involvement in its development of all parties responsible for innovation and technological modernization of the country. The formation of a high-quality and effective institutional infrastructure of technological competitiveness of the Ukrainian economy requires the introduction of a new approach, namely the creating a collective contractual organizational and institutional system in this area, the sequence of its formation is presented in Figure 7.

It is a question of joint efforts, and delegation of functions and tasks between the state, associative business structures, associations of the organizations of education, science, innovations, and the organizations of civil society. Subjects of collective contractual regulation should distribute areas of responsibility for the main functions of the process development of technologization of the national economy such as organization of institutional infrastructure, information and communication, identification of institutional resource support, creating a bank of institutions to support innovation and technological activity,

innovation and technology mediation, incubation of start-ups, cooperation and introduction of high-tech products in the market.

Figure 7: Collective contractual organizational and institutional system to ensure technological competitiveness of the economy of Ukraine



Source: authors' development

6. Conclusion

Poor links of the domestic technological system are the low level of development of the intellectual property market and the transfer system of modern advanced technologies. The task of formation and implementation of state policy tools aimed at improving these aspects of the technologization environment of the domestic economy has been actualized. It is necessary to implement in practice the developed authors' model, which defines institutions (innovation agencies, R&D centres, spinning organizations, scientific clusters, intellectual property centres, technology transfer centres, bridge organizations) and processes (industrial and scientific and technological cooperation, system of intermediaries of technology transfer and means of their interaction, processes of commercialization of intellectual property) that are absent or insufficiently functioning.

A significant impact of the processes of technologization of the economy was found on the basic parameters of social and economic development of the country. In particular, the following factors have a direct impact on GDP growth as human capital and research (regression coefficient – 0.418), as well as the links between the R&D sector and business (0.54); employers' ability to attract talented people (0.748), the ability of enterprises to retain qualified personnel (0.236) and the availability of prerequisites for career growth (0.41); digital knowledge (0.398), advanced technologies (0.18) and readiness to create and implement the technologies of the future (1.323). If the level of technological competitiveness of Ukraine's economy increases and it moves to groups of countries with higher integral values, GDP per capita will increase significantly, and the quality of life in the country will be also improved.

The competitiveness of the EU and Ukraine is determined by intellectual, information and communication, innovation and technological indicators, which, in turn, are closely correlated with each other and form the modern digital society. The implementation of sustainable digital development goals can be complicated by the lack of a clear strategic argument and tactical management of these processes. The expansion of tasks and functions in the field of managing the development of technological competitiveness of Ukraine's economy requires the institutionalization of a collective contractual organizational and institutional system with the participation of the state, public sector, business associations, and education, science and research institutions.

The system implementation algorithm includes the process organization, creating information and communication platforms, the formation of the system of institutional and

resource support, creating a bank of scientific and technical and research and technological infrastructure institutions, the development of intermediary infrastructure, the incubation of high-tech start-ups, creating a system of cooperation platforms.

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