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COMPARATIVE ASSESSMENT OF THE INFLUENCE OF A TECHNOLOGICAL FACTOR ON ECONOMIC GROWTH

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The study focuses on the extent to which the technological factor affects economic growth and analyzes its role in enhancing socio-economic differentiation. We develop a methodology for ranking countries according to the level of their technological effectiveness using the specific index. Correlation and regression analysis is used to identify technological factors in economic development. Approbation of the approach took place on the example of the United States and China. The data obtained demonstrate that the increase in R&D costs and the export of high-tech products has a positive effect on economic growth. R&D spending provides 31.6 % to 41.9 % of GDP growth for the United States and China, respectively. Exports of high-tech products support GDP growth at the level of 2.7 % to 4.7 %. The research findings confirm that the technological factor encourages economic development through more efficient allocation of resources, the spread of innovations and the growth of high-tech exports. Regression models have proved this relationship. China ranks first in the index of technological effectiveness and is followed by the United States and Japan. Such countries as Kazakhstan, Brazil and Ukraine are lagging significantly behind some technologically advanced European nations (Romania, Poland, Bulgaria), as well as Turkey and Mexico. Analysis of data from a sample of 30 countries showed that technological differentiation is a direct cause of overall inequality. To bridge this technological gap, it is expedient to develop the existing technological potential in a consistent manner, while concentrating efforts on high-tech sectors capable of strengthening the foundation of the economy

Keywords: economic growth, innovations, global competitiveness, high-tech exports, production platform, USA, China

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1. Introduction

A growing role of science and state-of-the-art technology in ensuring sustainable economic growth has become obvious lately [1, 2]. The innovation type of development has placed a special emphasis on the use of the leading-edge technologies, the production of high-tech products, the implementation of progressive organizational and management decisions [3]. Technology has fundamentally and quickly changed the structure of the world economy and has become one of the primary factors in economic progress. The shifts have outlined the radically new global space, novel conditions for competition in world markets, and modern principles of interaction between enterprises.

The role of technology in today's economy has long been debated among researchers [4, 5]. However, there is still a lack of studies on the reasons behind technological inequality between countries. Currently, one can observe a new bipolar configuration of the global technological space forming, where the USA and China are taking the lead and all other countries are unable to close this gap in the short term [6, 7]. The spread of technological innovations is uneven, which causes technological inequality to emerge that represents a new challenge to sustainable economic development. The availability of technology and capital exacerbates the problem of economic differentiation. At that, the modern form of uneven development can no longer be represented using the common schemes, since it is widely manifested in various fields. Such indicators as labor productivity, living standards, GDP per capita, etc. characterize the overall state of national economies, but do not specify the factors which contributed to obtaining this position. Structural analysis highlights that the technological factor is among the most significant ones determining the objective pattern of uneven development [8]. However, the question remains about the constituent parts of the technological factor (its component base), methods and approaches to assessing the influence of this factor on economic growth. Researchers have different approaches to the selection of a set of technological factor indicators. This poses a problem of methodological consistency that precludes comparative research. For this reason, the topic of this study is becoming relevant, related to the study of the influence of the technological factor on differences in economic growth and inequality between countries.

Thus, the relevant studies point to a distinctive primacy of manufacturability as the main factor in sustainable economic development. Then, we aim to clarify the role of the technological factor. However, even now one can argue that the aggravated cross-country competition implies the need for tools to assess and determine the key determinants of technological economic growth. The results are expected to confirm the significance of the technological factor, allow identifying its parameters and setting their priorities for improving economic policy aimed at sustainable development. These circumstances understood will open up opportunities for countries to narrow the technology gap.

2. Literature review on the technological factor of economic development

Economic theory pays special attention to issues of development and sustainable growth, as well as the causes of differences and factor changes. The sources of economic growth through GDP were specified in [9–13]. These researchers agree that sustainable economic growth is driven by factors such as new technologies and globalization. However, with the availability and access to these factors, it becomes important to build optimal management. The dynamics of economic growth is believed to be based on the results of structural transformations, mastering new technological principles, the introduction of innovations and an increase in labor productivity. At that, the seemingly insignificant differences in the economic growth rates bring about the substantial divergence in countries' economic potential. Determining these discrepancies becomes a relevant scientific task.

It is becoming increasingly obvious that if the economy is not focused on technological innovation, it has no prospects for long-term development [14–17]. Some researchers, such as [14], focus on fundamentally new solutions (patents) that have commercial implementation potential. We can agree with this opinion, because it is innovation that should ensure accelerated economic growth at the expense of competitive advantages. A similar opinion is expressed by [15]. The publication [16] proves that renewed industrialization becomes an important condition for the development of technology. According to [17], entrepreneurial skills are needed to support industrialization.

Numerous studies [18–20] demonstrate that there is a direct correlation between the technological preparedness of a country and its ranking in the global economy. Research results on this issue are coordinated. These trends, if underestimated, lead to the fact that some countries can find themselves lagging behind. Here, it is important to realize the essence and the role of the technological factor, as well as the opportunities for managing the level of technological effectiveness of the economy. However, in [18, 19] there are no clear indications of quantitative measures of the technological factor.

We agree with [21], who claims that the technological factor is new technologies or their clusters that underlie the changes in the relative cost of production factors, stimulate the development of new industries and enhance the efficiency of traditional ones. Historical regularities in the emergence of fundamental technological innovations give impetus to structural changes in the economy [22]. Therefore, it is important to identify the determinants of economic growth that occurs against the background of technological structural changes. As practice shows, national economies, which for one reason or another were unable to independently create high-tech products, first applied imitation strategies within the country, and then entered foreign markets by occupying particular niches [23–25]. These researchers note the role of R&D spending and high-tech exports in economic growth. However, factor quantitative estimates are not given. The development of the USA and China are interesting cases here. For example, from a country that had mainly copied innovations, China turned into one of the leading innovation-generating nations leaving behind most other countries in terms of the level of technological development. In this context, the patterns of production, distribution, exchange and consumption of goods are largely predetermined by the peculiar nature of the technological processes [8]. At the same time, the observed temporal reduction of cycles is formed precisely due to the technical progress and the use of innovations [26].

The study of the reasons behind technological inequality is believed to lend some insight into the mechanisms that underlie economic changes. According to [27, 28], the choice of a model of economic growth should focus on mobilizing the potential to follow the technological path of evolution. Since the modern development of the theory of evolutionary economics is based, first of all, on the neo-Schumpeterian theory, which determines the need for structural technological changes in ensuring sustainable economic development, such changes provide for the formation of new industries with a high degree of processing of primary raw materials and an increase in the efficiency of traditional ones. Therefore, the issue of developing an integral strategic management system aimed at ensuring innovative structural changes becomes relevant. As we see it, these changes are of a technological nature.

Thus, the literature review demonstrates that economic growth is significantly affected by the flows of developed and exported technologies [29], as well as R&D costs [30–32]. The presence of stable patterns for these factors allows us to use them in the assessment model. The indicators proposed by the researchers (the share of ideas with the potential for commercialization [33], the share of R&D funding in GDP [34], indicators of science, technology and innovation development [35], the number of patents [36]) often reflect the multidirectional dynamics of the technological factor' financial aspects and its qualitative components.

The review confirmed the significance of the technological factor for economic growth. At the same time, there is a clash of researchers' opinions on key determinants. In the context of the literature review, the indicators of the technological factor need to be revised. The question about the approaches to assessing the impact of the technological factor on economic growth is left unanswered, which proves the relevance of the present research.

3. The aim and objectives of the study

The aim of this study is to develop an integrated approach to assessing the impact of a technological factor on economic growth. This will provide an opportunity for a comparative analysis on the countries for technology gaps.

To achieve the stated goal, we aim to fulfill the following objectives:

– to determine the leading countries and outsiders in terms of digitalization of the economy;

– to assess the dependence of economic growth on the technological factor.

4. Materials and methods

In the present study, technological effectiveness refers to the ability of a country to implement structural reorganization in accordance with the model of innovation development and realize its scientific and technological potential. We evaluate the level of technological effectiveness of the economy using the relevant index that serves as the basis for ranking countries. The set of technological factor indicators that will be used in our approach will be adjusted taking into account the literature review.

To calculate the Index (I_i), we use the indicators characterizing various aspects of technological development of the nations under review (Table 1), such as:

– industrial production index (a_i);

– the share of the production of machinery and equipment in total value added (b_i);

– the share in global value added by the economic activity 'Production of computing, electronic and optical equipment' (c_i);

– the share in global value added by the economic activity 'Production of machinery and equipment' (d_i);

– ICT development index (e_i);

– domestic R&D costs, % in GDP (f_i).

For empirical verification, we use official statistics. The frequency of data updating does not allow reflecting the most recent trends that affect economic processes (such as the impact of COVID-19). This is a research limitation. We also need to understand that some trends are short-term in nature, and their impact can be neglected.

Table 1

Indicators of the Index of the technological effectiveness of economies

Country	a_i	Ia_i	b_i	Ib_i	c_i	Ic_i	d_i	Id_i	e_i	Ie_i	f_i	If_i	Σ	I_i
Russia	119.0	0.368	19.400	0.420	0.100	0.000	0.100	0.000	7.070	0.694	1.100	0.242	1.725	0.287
Azerbaijan	94.0	0.105	6.300	0.135	0.100	0.000	0.100	0.000	6.200	0.545	0.210	0.027	0.812	0.135
Armenia	179.0	1.000	0.100	0.000	0.100	0.000	0.100	0.000	5.760	0.469	0.230	0.031	1.500	0.250
Belarus	117.0	0.347	0.100	0.000	0.100	0.000	0.100	0.000	7.550	0.777	0.500	0.097	1.221	0.203
Kazakhstan	117.0	0.347	0.100	0.000	0.100	0.000	0.100	0.000	6.790	0.646	0.140	0.010	1.003	0.167
Kyrgyzstan	140.0	0.589	0.100	0.000	0.100	0.000	0.100	0.000	4.370	0.230	0.120	0.005	0.825	0.137
Uzbekistan	160.0	0.800	0.100	0.000	0.100	0.000	0.100	0.000	4.900	0.321	0.220	0.029	1.150	0.192
Ukraine	84.0	0.000	12.300	0.266	0.100	0.000	0.100	0.000	5.620	0.445	0.480	0.092	0.803	0.134
Brazil	86.0	0.021	20.900	0.453	0.100	0.000	1.600	0.059	6.120	0.531	0.200	0.024	1.089	0.181
India	130.0	0.484	22.400	0.486	0.100	0.000	1.600	0.059	3.030	0.000	1.500	0.338	1.368	0.228
Bulgaria	119.0	0.368	19.300	0.418	0.100	0.000	0.100	0.000	6.860	0.658	0.780	0.164	1.609	0.268
Germany	117.0	0.347	44.000	0.956	4.300	0.151	12.500	0.490	8.390	0.921	2.940	0.686	3.551	0.592
Denmark	110.0	0.274	0.100	0.000	0.100	0.000	0.100	0.000	8.710	0.976	2.870	0.669	1.919	0.320
Italy	98.0	0.147	28.400	0.617	1.000	0.032	2.500	0.095	7.040	0.689	1.290	0.287	1.867	0.311
Netherlands	96.0	0.126	0.100	0.000	0.100	0.000	0.100	0.000	8.490	0.938	2.030	0.466	1.531	0.255
Poland	139.0	0.579	23.600	0.512	0.100	0.000	0.100	0.000	6.890	0.663	0.100	0.000	1.754	0.292
Romania	149.0	0.684	35.700	0.776	0.100	0.000	0.100	0.000	6.480	0.593	0.480	0.092	2.144	0.357
United Kingdom	103.0	0.200	30.800	0.669	1.400	0.047	1.400	0.051	8.650	0.966	1.690	0.384	2.317	0.386
Finland	104.0	0.211	29.800	0.647	0.100	0.000	0.100	0.000	7.880	0.833	2.750	0.640	2.331	0.389
France	103.0	0.200	26.700	0.580	1.300	0.043	2.100	0.079	8.240	0.895	2.250	0.519	2.316	0.386
Sweden	106.0	0.232	0.100	0.000	0.100	0.000	0.100	0.000	8.410	0.924	3.250	0.761	1.917	0.319
Australia	120.0	0.379	16.200	0.351	0.100	0.000	0.100	0.000	8.240	0.895	0.100	0.000	1.625	0.271
Canada	122.0	0.400	22.500	0.488	0.100	0.000	0.100	0.000	7.770	0.814	1.600	0.362	2.065	0.344
Mexico	105.0	0.221	32.000	0.695	0.100	0.000	1.900	0.071	5.160	0.366	0.500	0.097	1.450	0.242
Norway	94.0	0.105	31.300	0.680	0.100	0.000	0.100	0.000	8.470	0.935	2.040	0.469	2.188	0.365
Republic of Korea	115.0	0.326	46.000	1.000	4.900	0.172	1.500	0.055	8.850	1.000	4.240	1.000	3.554	0.592
United States	115.0	0.326	31.700	0.688	21.700	0.774	11.000	0.431	8.180	0.885	2.740	0.638	3.742	0.624
Turkey	164.0	0.842	0.100	0.000	0.100	0.000	2.300	0.087	6.080	0.524	0.100	0.000	1.453	0.242
Japan	101.0	0.179	42.200	0.917	11.400	0.405	13.300	0.522	8.430	0.928	3.140	0.734	3.685	0.614
China	135.0	0.537	33.300	0.723	28.000	1.000	25.400	1.000	5.600	0.442	2.120	0.488	4.190	0.698

Note: a_i is the industrial production index; b_i is the share of the production of machinery and equipment in total value added; c_i is the share in global value added by the economic activity 'Production of computing, electronic and optical equipment'; d_i is the share in global value added by the economic activity 'Production of machinery and equipment'; e_i is the ICT development index; f_i is domestic R&D costs, % in GDP; I_i is the index of technological effectiveness. Source: [37]. Latest data for 2019.

The method of Euclidean distances is used to rank the indicators' values; normalization (Ix_i) is calculated by formula (1). The boundaries of normalized indicators are set in the range from 0 to 1.

$$Ix_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}, \quad (1)$$

where X_i is the actual value of the indicator; $X_{\min}$ is the minimum value of the indicator for the sample population; $X_{\max}$ is the maximum value of the indicator for the sample population.

The level of technological effectiveness is calculated using the cumulative method as a weighted mean:

$$I_i = \frac{\sum\left(Ia_i + Ib_i + Ic_i + Id_i + Ie_i + If_i\right)}{6}. \quad (2)$$

The closer the Index value is to 1, the higher the level of technological effectiveness of economy.

To determine the econometric relationship between economic growth and indicators characterizing the technological factor, a linear multiple regression model was applied.

$$Y = F(X_1, X_2, X_3 \ldots, X_n)\beta + \varepsilon, \quad (3)$$

where X_1, X_2, X_3..., X_n denote factors; ε denotes error; β denotes a vector of the parameters under evaluation.

The gross domestic income of the United States and China for the period of 1996–2019 was taken as dependent variables (Table 2).

Table 2

Indicators of the US economic development

Year	GDP	Elc	CTech	HTExp	RD
1996	8073.122	341.800	350.090	54.470	197.792
1997	8577.554	329.500	331.820	45.190	212.709
1998	9062.818	311.200	312.100	45.255	226.934
1999	9630.664	346.300	321.480	48.261	245.548
2000	10252.345	371.000	316.040	48.389	269.513
2001	10581.821	368.800	339.020	49.927	280.238
2002	10936.419	406.200	377.520	57.251	279.891
2003	11458.244	451.500	433.450	60.502	293.852
2004	12213.729	508.700	433.690	65.692	305.640
2005	13036.640	609.600	411.950	70.263	328.128
2006	13814.611	701.000	425.740	73.326	353.328
2007	14451.859	875.900	415.210	244.480	380.317
2008	14712.844	1103.500	441.090	246.884	407.238
2009	14448.933	1203.500	465.060	154.108	406.405
2010	14992.053	1126.100	484.170	168.939	410.093
2011	15542.581	913.300	454.040	169.464	429.791
2012	16197.007	781.000	419.170	172.387	434.349
2013	16784.849	605.000	349.250	172.145	454.822
2014	17521.747	499.900	384.130	179.264	476.458
2015	18219.298	465.000	358.960	178.350	495.095
2016	18707.188	477.000	366.290	176.668	516.590
2017	19485.394	488.100	372.630	156.937	548.983
2018	20529.049	495.882	394.412	156.366	582.545
2019	21374.419	501.659	426.900	156.362	601.553

Source: [37].

The independent variables were represented by the volume of electronics production (Elc), costs incurred in installation and maintenance of equipment/technologies (CTech), the volume of high technology exports (HTExp), and investment in R&D activities (RD). Data are given in Table 3.

Table 3

Indicators of China's economic development

Year	GDP	Elc	CTech	HTExp	RD
1996	863.75	45.88	22.25	115.30	4.86
1997	961.60	53.95	26.02	128.45	6.14
1998	1029.04	75.01	34.83	137.99	6.66
1999	1094.00	104.98	47.05	139.06	8.20
2000	1211.35	132.34	58.50	145.05	10.82
2001	1339.40	156.75	68.28	158.07	12.59
2002	1470.55	205.80	89.44	160.40	15.56
2003	1660.29	247.51	106.37	112.38	18.60
2004	1955.35	292.90	125.67	164.36	23.76
2005	2285.97	320.25	138.51	216.34	29.90
2006	2752.13	336.99	147.23	268.32	37.66
2007	3550.34	342.61	154.92	342.61	48.77
2008	4594.31	390.99	181.84	390.99	66.43
2009	5101.70	359.27	176.42	359.27	84.93
2010	6087.16	474.52	228.32	474.52	104.32
2011	7551.50	540.19	267.03	540.19	134.44
2012	8532.23	593.89	299.10	593.89	163.15
2013	9570.41	656.00	335.45	656.00	191.20
2014	10475.68	653.87	341.72	653.87	212.62
2015	11061.55	652.24	350.98	652.24	228.49
2016	11233.28	594.55	328.15	594.55	237.96
2017	12310.41	654.19	358.69	654.19	264.07
2018	13894.82	731.89	405.53	731.89	303.70
2019	14342.90	789.56	440.63	753.69	325.22

Source: [37].

Based on the purpose of the study, we put forward two hypotheses about the nature of the patterns observed:

H1. Growing R&D costs accelerate economic growth. Such an increase is expected to stimulate R&D in industries with comparative advantage. Consequently, this strengthens the country's exports (foreign trade surplus).

H2. Arrested technological development adversely affects competitiveness and, as a result, economic growth, since outdated equipment results in higher resource intensity and low labor productivity.

We test the hypotheses and the methodology for assessing the level of technological effectiveness using the sample of 30 countries. The aggregate of research objects embraces several developed countries, developing countries with high GDP, as well as developing countries not included in leading world economies. The selection is due to the need to cover a wide range of economies characterized by a wide variety of development conditions.

5. Results comparing technological effectiveness of economies

5. 1. Leading countries and outsiders in terms of technological innovation

The global economy in the context of Industry 4.0 demonstrates a number of specific features that distinguish it from the previous development stages. Firstly, technological innovation is becoming increasingly expensive, which causes a significant increase in R&D costs [38]. Secondly, the rate of technological change has increased dramatically. The terms of development and implementation of new solutions were reduced in the first place [8]. Technological gap can now be measured exponentially [39].

Look at a range of indicators characterizing the level of technological effectiveness of national economies. The share of domestic R&D costs in GDP is one of them (Fig. 1). The highest level of R&D funding in GDP is observed in the Republic of Korea, Sweden, Japan, Germany, the United States, China and other countries leading in the Global Competitiveness Report.

Analysis of the current changes in the global economy indicates that the importance of the comparative advantages of the lower order – cheap labor, basic production resources and the availability of raw materials – is decreasing [40]. At the same time, advantages of a higher order are gaining in significance, such as the ability of countries to develop high-tech industries, to manufacture and export products with a high intellectual component and in-depth processing [41]. For instance, the United States and China account for 90 % of the market capitalization value of the world's 70 largest digital platforms, 75 % of all patents related to blockchain technologies, more than 75 % of the world market for public cloud computing, about 50 % of global spending on IoT, 40 % of world data centers, 36 % of the global value of e-commerce [42], and 69 % of supercomputers [43]. These areas are of significant potential and can have a serious impact on economic restructuring. Therefore, a special focus of the analysis is put on such indicator as the share of high-tech production (including computing, electronic and optical technology) (Fig. 2). China, Germany, Italy, the United States and Japan have the largest share in global value added in the production of computing, electronic and optical equipment. Norway, Canada, Australia, Sweden, Romania, Poland, etc. are relatively poorly represented in these world markets.

High-tech industries focusing on domestic production can be viewed as sources of economic growth. Data on the share of machinery and equipment production in GDP show similar trends (Fig. 3). High-tech industries strongly stimulate the economic growth of the leading countries – the Republic of Korea, China, the United States, Germany, and Japan, – while countries with low competitiveness demonstrate poor results.

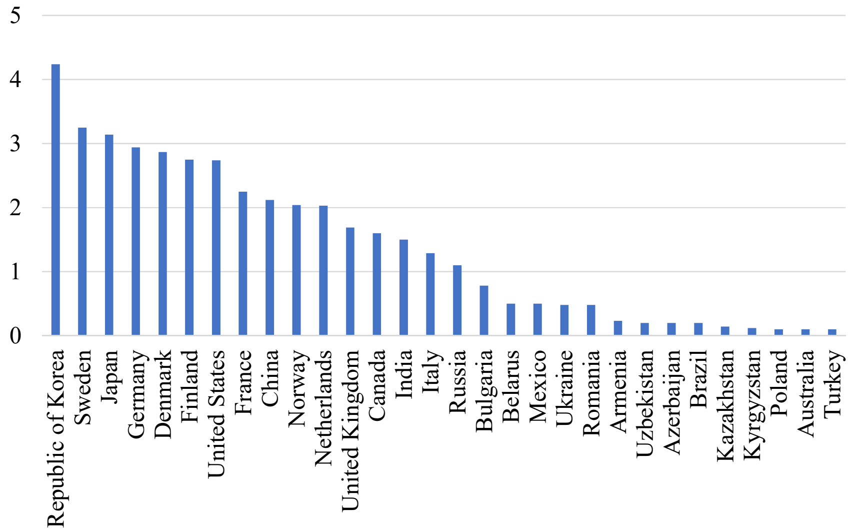

Fig. 1. Domestic R&D funding in GDP, % [37]

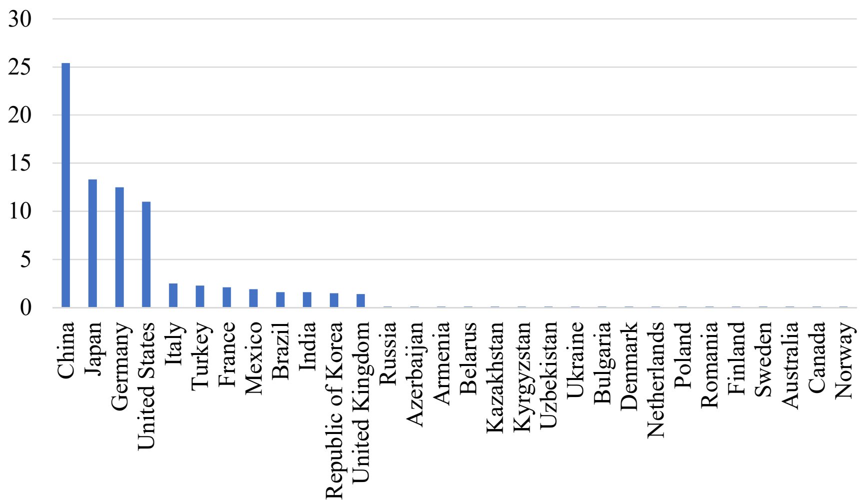

Fig. 2. Countries' share in global value added in the production of computing, electronic and optical equipment [37]

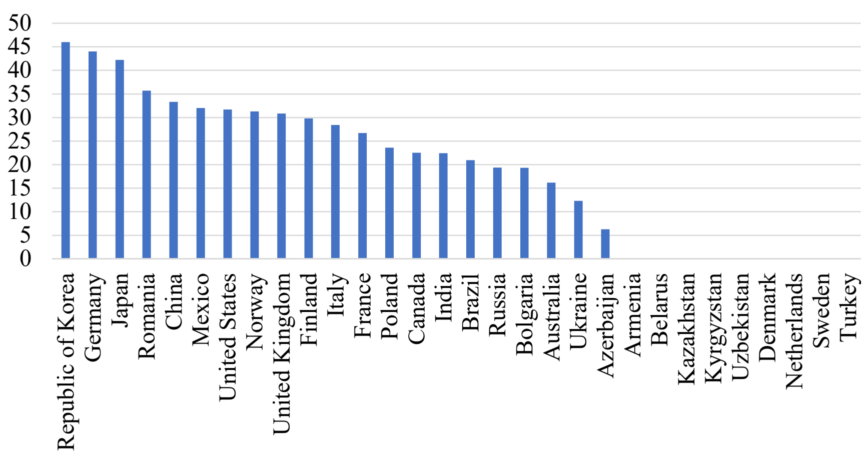

Fig. 3. Share of the machinery and equipment production in GDP, % [37]

Analysis of the countries indicates that some of them did not demonstrate high values of the indicators reviewed, but the level of their technological effectiveness is much higher (the group of "backward" countries embraced Denmark, the Netherlands, Sweden, Norway, and Canada). To gain a comprehensive picture and rank the countries, we have calculated the integral index of the technological effectiveness that covers financial aspects of development, as well as qualitative characteristics of economic growth. The Index calculation methodology is presented in section 4 of the paper. The countries' ranking is presented in Table 4.

Table4

Index of the countries' technological effectiveness

Country	Index value	Rank
China	0.69828	1
USA	0.62373	2
Japan	0.61418	3
Republic of Korea	0.59228	4
Germany	0.59190	5
Finland	0.38850	6
United Kingdom	0.38609	7
France	0.38602	8
Norway	0.36472	9
Romania	0.35740	10
Canada	0.34413	11
Denmark	0.31979	12
Sweden	0.31947	13
Italy	0.31125	14
India	0.30998	15
Poland	0.29236	16
Russia	0.28743	17
Australia	0.27082	18
Bulgaria	0.26817	19
Netherlands	0.25511	20
Armenia	0.25008	21
Turkey	0.24219	22
Mexico	0.24163	23
Belarus	0.20344	24
Uzbekistan	0.19172	25
Brazil	0.18143	26
Kazakhstan	0.16718	27
Kyrgyzstan	0.13742	28
Azerbaijan	0.13526	29
Ukraine	0.13377	30

As shown in Table 4, China ranks first and is followed by the United States and Japan. Kyrgyzstan, Azerbaijan and Ukraine hold the bottom positions in the ranking. It is noteworthy that in terms of the level of technological development, Kazakhstan, Brazil and Ukraine lag significantly behind some European nations (Romania, Poland, and Bulgaria), Turkey and Mexico. These countries do not exhibit sufficient potential to introduce innovations independently, but with regard to successful transfer and adaptation of foreign high technologies, they are significantly ahead of other countries with a similar development level. This fact also justifies their relatively high ranking positions regarding overall competitiveness.

5. 2. Assessment of the dependence of economic growth on the technological factor

As articulated earlier, an increase in GDP can result from various factors. To substantiate the relationship between economic growth and the technological factor, we construct a number of models. The parameters of the regression models for the USA and China are given in Tables 5, 6. The parameters of the multiple regression model were obtained using STATISTICA software.

Table 5

Parameters of the regression model of the relationship between economic growth and the technological factor in the USA

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Elc	–1.297	0.545	–2.379	0.028
CTech	5.374	2.351	2.286	0.034
HTExp	2.711	2.034	1.333	0.198
RD	31.624	0.927	34.108	0.000
Const	488.452	649.169	0.752	0.461

We have obtained a model with good quality characteristics; in this case, the coefficient of determination R^2=0.996, normalized R-squared=0.995, multiple R=0.998.

Table 6

Parameters of the regression model of the relationship between economic growth and the technological factor in China

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Elc	10.933	9.739	1.123	0.276
CTech	–25.913	25.078	–1.033	0.314
HTExp	4.739	0.775	6.111	0.071
RD	41.920	9.738	4.305	0.000
Const	205.300	104.960	1.956	0.065

The model obtained for China is also characterized by good quality characteristics: the coefficient of determination R^2=0.999, normalized R-squared=0.999, and multiple R=0.999. Checking of the model adequacy according to the F-test produced the following results: the calculated value F=10.09 at the level of significance p=0.01.

Having analyzed the models' data, we can conclude that there are no factors with a high probability of insignificance (t-Statistic for each model are greater than the critical value at a significance level of p=0.01), i.e. all regressions are significant.

To evaluate the degree of adequacy of the constructed trend equation to the real process, the mean approximation error was computed. Its value (3.167 % for China and 1.54 % for the United States) indicates that the degree of the quadratic equation's adequacy to the real conditions of the relationship between economic growth and the technological factor is high.

Fig. 4 provides a visual distribution of actual and calculated values of the regression models.

Analysis of the models for the United States and China allows us to deduce that R&D costs are significant regressants contributing to economic growth; the factor impact on GDP growth in the United States and China is 31.6 % and 41.9 %, respectively; export of high-tech products provides an increase in GDP by 2.7 % and 4.7 %, respectively. It is worth noting that the obtained negative coefficients in the regression models suggest a weak correlation between the effective feature (economic growth through GDP) and some factor variables. For China, the indicator "Costs incurred in installation and maintenance of equipment/technologies" reveals an inverse relationship with GDP. A similar trend is observed in the United States for the indicator "Production of electronics". Our calculations confirm that the strongest relationship is observed between GDP and development costs, as well as the share of high-tech industries in global value added.

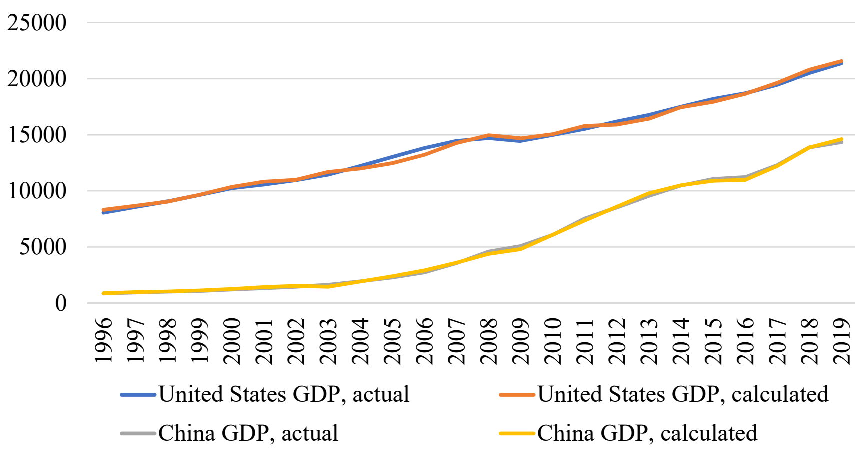

Fig. 4. Actual and calculated values of the regression models of the relationship between economic growth and the technological factor

The current research proves that countries with substantial R&D funding and a large share of high-tech products in GDP and total exports are characterized by sustainable economic growth. Thus, the H1 hypothesis was confirmed.

The H2 hypothesis was partially confirmed: countries capable of using their innovative potential effectively are characterized by an elevated level of competitiveness. However, the use of outdated technologies does not always results in a decrease in global competitiveness, since these processes can be influenced by the institutional environment, which was beyond the scope of the present study.

6. Discussion of the results comparing technological effectiveness of economies

Testing the approach using the case studies of China and the United States makes it possible to extrapolate their experience to countries with a low level of technological effectiveness. For example, the China and USA lead the global market for technological innovation. The country's competitiveness in this field is due to the highly dynamic nature of American business, strong institutional underpinnings, finance mechanisms and a powerful innovation ecosystem [1]. Index of the countries' technological effectiveness (Table 4) confirms this trend. The calculated values of the Index indicate the leading positions of these countries. The rapid growth of the renewable energy sector is a testament to why China will continue to dominate the sectors in which it invests heavily [44]. Currently, the PRC accounts for 90 % of the world's supply of mobile phones and personal computers. In 2018, the country's share in global semiconductor consumption was 41 %; by 2024, it is forecasted to increase to 54 % [45]. Significant funds received from low- and medium-tech industries in China are directed to those economic sectors, which enjoy research, development and implementation of high-tech solutions.

It is noteworthy that in terms of the level of technological development, Kazakhstan, Brazil and Ukraine lag significantly behind some European nations (Romania, Poland, and Bulgaria), Turkey and Mexico. These countries do not exhibit sufficient potential to introduce innovations independently, but with regard to successful transfer and adaptation of foreign high technologies, they are significantly ahead of other countries with a similar development level. India is among the countries with high technological growth potential. India is now at a stage where machine learning tools are rapidly replacing entry-level programmers in the IT sector. So far, India is ranked 15th, but the situation may change soon.

The comparison showed the advantage of the proposed methodological approach. We have been able to analyze the technicality of countries using universal data sets. The Index of the countries' technological effectiveness can be a good alternative to other methods of assessment.

During the research, we have confirmed the hypotheses put forward. Assessment of the dependence of economic growth on the technological factor showed a strong relationship between GDP and R&D costs (Tables 5, 6). These results prove that sustainable economic growth is explained in most cases by significant funding for R&D (the presence of a large share of high-tech products in the country's GDP) and the export of high-tech products.

Therefore, technologies determine competitive advantages of states at large. However, qualitative factors of economic growth prevail in a continuous innovation process. What determines additional limitations of our methodological approach. Special focus should be placed on a specific feature of the periods when changes occur, i.e. the periods of the so-called "technological gap" [46]. This is when the foundations of the future economy are set. Technological incentives crucial for growth are based on the ability to deliver better results. If technological inequality is excessively gross, it can jeopardize economic growth. Creating favorable conditions for the use of high technologies will not only support the competitiveness of production and attract investment in the economy, but also help resolve such issues as enhancing the efficiency of resource exploitation.

Hence, scientific and technological progress is the central stimulus for economic development, which in production processes is implemented through investment and innovation. At that, the dynamics of economic growth in the long run is dependent on a wide array of factors forming supply and demand for technological change: the current technological capability of the national economy [19]; the development stage of financial institutions; companies' awareness of R&D, and the effectiveness of technology transfer within the innovation infrastructure [47]; the nature of the state scientific and technical, scientific and technological, structural, and stabilization policy, and the level of state guarantees for the protection of intellectual property rights [25]; conditions of foreign economic activity, and competitiveness of products and services in the global market [48]. The characteristics of the listed factors vary significantly across countries, but the multicausality of the factors indicates that their combinations at certain time intervals can both reduce and boost the level of technological effectiveness.

At the same time, it is worth noting that the proposed approach has certain application limits and cannot be seen as a cure-all. The quality of economic growth is contingent not only on the share of high-tech output, but also on the use of advanced technologies in traditional sectors of the economy, which are expected to account for three-quarters of the value of the digital economy [49]. Consideration of qualitative factors in the methodological approach creates prospects for further research.

7. Conclusions

1. Using the author's approach, we ranked the countries according to the level of technological factor in the economy. China ranks first in the index of technological effectiveness and is followed by the United States and Japan. Kyrgyzstan, Azerbaijan and Ukraine hold the bottom positions in the ranking. It is noteworthy that in terms of the level of technological development, Kazakhstan, Brazil and Ukraine lag significantly behind some European nations (Romania, Poland, and Bulgaria), Turkey and Mexico.

2. In modern conditions, the influence of the technological factor on the parameters of economic growth comes to the fore. The results of empirical testing have confirmed the consistency of the approach. The quality parameters of the regression model make it possible to assert that the increase in R&D costs and the export of high-tech products has a positive effect on economic growth. The significant regressants contributing to economic growth are R&D costs, the factor impact on GDP growth in the United States and China is 31.6 % and 41.9 %, respectively; export of high-tech products provides an increase in GDP by 2.7 % and 4.7 %, respectively.

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DEFINING THE SOCIO-DEMOGRAPHIC PREDICTORS OF PRIORITY INVESTMENT IN THE CONTEXT OF TASKS FOR THE FINANCIAL SUBSYSTEM OF STARTUP-MANAGEMENT

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This research has investigated the retrospective trends in financing startups in Ukraine corresponding to the socio-demographic characteristics of startuppers (founders). Studying the dependences between the amount of funding and the qualitative characteristics of startuppers has made it possible to determine the socio-demographic predictors of making a positive decision regarding the financing of startups.

As the current study has shown, in order to receive an investment, a startupper must meet the investor's expectations regarding reliability, qualifications, experience, and potential prospects. The investor analyzes not only the business idea of the startup but also the potential recipient for compliance with a series of socio-demographic predictors such as gender, age, level, and specialization of education. It has been proven that the largest amount of funding for startups in Ukraine is received by male funders, aged 35 to 45, who have a higher technical education. Startup investors consider such startuppers a priority for their investments since they see the least risks and a high probability of successful deployment of invested funds.

The identified investors' preferences when choosing startup founders can be extrapolated to the startup environment of any country, however, they may change over time, depending on the specificity of the situation in the investment country.

To rationally solve problems in the financial subsystem of startup management, it is necessary to preliminary determine the socio-demographic predictors of priority investment of startups of the respective country and area of activity. The practical tools for determining such predictors have been tested during this study.

The practical significance of the research is due to the growing pace of development of startup technologies, the need to improve the effectiveness of the startup management financial subsystem, and increase the efficiency of the startup support infrastructure

Keywords: startup, startupper, startup management, financial support to startup management, priority startup investment, socio-demographic predictors

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1. Introduction

The formation of an innovative model of development, the use of the intellectual potential of the nation, especially its younger generation, causes the need to obtain external investment resources to build a new economic structure and integrate it into the world economic community. The issues related to startups and the formation of a startup environ-