



ASSESSMENT OF THE DEVELOPMENT OF FOREIGN TRADE IN HIGH-TECH PRODUCTION OF UKRAINE UNDER THE ASSOCIATION WITH THE EU

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Abstract. *Purpose* – the purpose of article should assess the main factors affecting the development of trade in high-tech products of Ukraine in the context of association with the EU and the spread of a new industrial revolution.

Research methodology – the scheme of research of trade of high-tech products of Ukraine from the EU on the basis of qualitative and quantitative economic-statistical analysis, analysis of comparative advantages and correlation-regression analysis.

Findings – the results of the analysis show that the main factors determining the low presence of Ukraine in the world market of high-tech products are the outdated structure of production, a low level of R&D costs, and a decrease in the innovative activity of Ukrainian enterprises. The article presents the author's recommendations on improving the effectiveness of foreign trade in high-tech products of Ukraine in the EU market.

Research limitations – the absence of a state development strategy for the production of high-tech products does not make it possible to accurately determine indicators of scientific research of the potential of Ukraine.

Practical implications – correlation-regression analysis results can be used in the private and state sectors of the economy of Ukraine.

Originality/Value – the original combination of schemes and methods allowed us to identify new critical places for export development in the context of the association of Ukraine with the EU.

Keywords: high-tech products, export-import, comparative advantages of export, EU-Ukraine association.

JEL Classification: C150, F130, F170, O140, O240, O520, O570.

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Introduction

The relevance of the chosen topic of the study is explained by the fact that the development of disruptive production technologies is increasingly determining the future of the world as a whole and the European Union and Ukraine in particular. Given the rather ambiguous state of development of the high-tech industry in Ukraine, the problem arises of assessing the peculiarities of the development of foreign trade in high-tech products in the context of the challenges of the new industrial revolution.

Today, society is in the middle of the fourth wave of technological progress: the rise of a new digital industrial technology known as Industry 4.0. Industries 4.0 combining the factors of Smart TEMP (T (technology) – smart technology; E (environment) – smart environment; M (manufacturing) – smart manufacturing; P (products) – smart products), creating new markets and industries that promote productivity growth, increase the competitiveness of individual sectors and national economies.

According to forecasts by 2030, world-renowned institutions (OECD, World Bank) and international industry associations can launch a revolution in industrial production only through the introduction, first and foremost, of high-tech industries, called “breakthroughs”, underlining “breakthroughs”. In assessing the impact of regulatory authorities on the foreign trade of high-tech products in Ukraine, scientists note the possibility of using cause-effect relationships between indicators characterizing the market’s business processes and state regulatory tools that can be quantified (Bacho et al., 2019; Sushchenko & Trunina, 2016; Koval et al., 2019). However, according to the modern classification of the Organization for Economic Co-operation and Development (OECD), high-tech industries include the aerospace industry, the pharmaceutical industry, the production of computers and office equipment, information and communications industry and instrumentation (Emerging Trends Report, 2013).

This revolution is connected with the problem of levelling and improving the EU’s economic performance. The dynamics of Europe’s future development will depend on the quality of its science and technological innovation. Together with the US and Japan, the European Union is now a leading player in innovation and research, accounting for 24% of global R&D spending and 32% of patents in 2015 (Rifkin, 2014). As a result, the urgent task is to study the features of the development of foreign trade in high-tech products of Ukraine in the context of association with the EU and the launch of a new industrial revolution (Labunska et al., 2017; Gryshova et al., 2019).

1. Analysis of recent research

This problem is the subject of study by a number of reputable organizations: UNIDO (2014), OECD (2015), KPMG (2015), MIT (2013), Wilson Centre (2012). Moreover, many researchers have studied this problem, who investigated the issues of development of advanced production technologies and the corresponding structural transformation of exports of leading countries in the conditions of the new industrial revolution.

In the works of scientists Industry 4.0. was studied both in the sectoral and territorial aspects. In terms of Industry 4.0. territorial competitiveness in the EU has a strong regional dimension, which analysis at the national level does not adequately reflect in the EU. Regional competitiveness indicators should stimulate discussion of the harmfulness of competitiveness gaps in the EU's national competitiveness and in which extent appropriate regulation can be eliminated (Annoni & Dijkstra, 2013). The advantages of industry-specific innovation development and the provision of financing for innovation in a competitive environment are proved by Pukala (2019). Matt et al. (2020) opened up the new challenges, opportunities and requirements of Industry 4.0, which have to be examined specifically for SMEs, thus paving the way for the digital transformation of traditional SMEs into smart factories.

Emerson and Movchan (2016) noted that since April 2013 the EU has almost completely opened own market to duty-free imports from Ukraine. However, the technical requirements for entering the EU market are high and rigid, but they are applied in a professional and fair manner without any (unlike other) geopolitical manipulation (Emerson & Movchan, 2016).

Actually based on technical restructuring requirements Yegorov, Odotyuk and Salihova prove the need to strengthen the personnel and technical components of the research process of high technology development in Ukraine, legislative support for the reproduction of highly qualified personnel and attract specialists to carry out scientific and scientific-technical work (Yegorov et al., 2016). At the same time, the research proves that the network organization of modern ecosystems allows you to maintain a dominant position with reduced individual costs, and such a network organization can be used to implement research processes in the production of high-tech products (Mussapirov et al., 2019). And for the proper preparation of human resources, it is necessary to use the current state of reforms in education and make greater use of the potential of regional budgets and educational institutions in Ukraine (Pukala & Petrova, 2019).

Dragan (2012), Rifkin (2014), Ross (2016), and Schwab (2016a) predict the irreversible changes caused by the use of technology from Industry 3.0. and moving to Industry 4.0:

- 1) internet technologies and renewable energy are merging;
- 2) robotics and artificial intelligence, cybersecurity, genomics commercialization will be the most important economic future. At the same time, technology will increasingly allow citizens to express their thoughts, coordinate their efforts in a new way, and possibly circumvent state surveillance, or new surveillance technology will give rise to overly powerful public authorities.

At the theoretical level, an understanding of the Industrial Revolution is offered on the basis of the combination of convergent NBIC technologies with the key factors of SMART TEMP's advanced production system. At an empirical level, analysis of forecasts of the development of scientific, technical and innovative activities of developed countries – technological leaders and developing countries, has established that photonics, biotechnology, nanotechnology, microtechnology, ICT in production systems, advanced materials, additive manufacturing are the most promising for solving global problems, energy and environmental technology (Matyushenko, 2017).

Features of functioning of markets of high technologies and high-tech goods are covered in works of some well-known researchers. Barancheiev and Kleimenov (2001) reveal the

relationship of creating marketing value chains and enhancing the competitive advantages of a company manufacturing high-tech products. Christensen (2020) says that for success it is important to understand what drives customers to make their choice. Usually, all product changes occur through trial and error: functionality is added, the appearance is modified, and then you can only hope that it works. In fact, innovation can be much more predictable, and much more profitable. Therefore, it is necessary to understand the tasks of customers in order to predict the success of innovations in business.

Burnett and Moriarty (1998) focused on the wide range of areas included in marketing communication and the tools and techniques needed to create an integrated approach. International examples acknowledge that integrated marketing communication exists and is practised throughout a global community. Real-world profiles of young executives describe a variety of jobs, career paths, and views on how to get ahead in marketing communication. Chesbrough (2003) argues that in today's dynamically changing market, which is becoming increasingly global, one of the key competitive advantages is the company's ability to creatively innovate, bring them to commercial use and make high profits. Breley (2005) explains how to integrate various strategies for entering the market and development strategies into a series of solutions that reflect the interaction of the international marketing environment, technological forces, strengths and weaknesses of the company. Moreover, the study is truly international and written from the point of view of a company competing in international markets, regardless of country of origin. Features of marketing activity and specificity of application of marketing mechanisms in commodity markets of technological innovations are widely covered in the writings of economists such as Shanklin and Ryans (1984), Stiglitz (2012), Moore et al. (2016) provide an opportunity for researchers to develop working knowledge in the field of data production and interpretation in the context of business and economics, providing practical tools that are necessary for making informed business and economic decisions.

Paterson (2010) develops a new, critical approach to global environmental politics and argues that the major power structures of world politics are deeply problematic in ecological terms and that they cannot be easily used to resolve major environmental challenges such as global warming. Instead of simply advocating the construction of new international institutions to respond to such challenges, therefore, he argues that the use of new technologies and the construction on their basis of alternative social and political structures is necessary.

Ramaswamy et al. (2017) said that the erosion of US manufacturing isn't a foregone conclusion. The decade ahead – with increased demand, new technology, and value chain optimization – will give the sector a chance to turn around. The United States could take advantage of rising demand and new Industry 4.0 technologies to revitalize its entire manufacturing sector. The key priorities will be raising productivity in the nation's supplier base, broadening participation in exports, ramping up a national program, and making the long-term investment needed to upgrade plants and equipment for digital readiness.

At the same time, all these studies do not provide a clear methodology for assessing the development of foreign trade in high-tech goods, the nomenclature of which can significantly change under the influence of the key growing technologies of Industry 4.0.

Kyzym and Matyushenko (2014), Khaustova (2015) – emphasize that Ukraine buys more in EU countries than sells. Over the last 17 years, the negative balance has increased almost tenfold with a sixfold increase in turnover. But in that period of research, scientists have not yet set the task of strengthening the stimulation of the export of high-tech products, mainly ways of integration of Ukrainian manufacturers of existing industries are considered (Kyzym & Matyushenko, 2014). And it is precisely for calculating the priorities of Industry 4.0 that the advantages and disadvantages in shaping the economic policy are determined, for which purpose the methodology for assessing and analyzing the export potential of Ukraine proposed by Melnik is used (Melnik, 2008).

However, in the conditions of the new industrial revolution, the problem of the development of foreign trade in high-tech products in Ukraine needs further study, taking into account the association with the EU.

The purpose of the investigation is to evaluate the development of trade in high-tech Ukrainian products in the context of association with the EU and the launch of a new industrial revolution.

2. Methodology

In the process of researching the export of products of high-tech industries of the EU and Ukraine within the framework of a comprehensive approach, such general scientific methods of cognition as induction and deduction, analysis and synthesis, methods of generalization of theoretical and factual material, by comparison, qualitative and quantitative economic-statistical analysis, as well as comparative analysis are used. To identify prospects for the development of trade in high-tech goods, a mathematical model using correlation-regression analysis was constructed (Cook & Seiford, 2009).

Following the developments of the Organization for Economic Cooperation and Development, in cooperation with Eurostat (2005), a final list of high-tech products produced by high-tech industries was agreed. Thus, based on the Standard International Trade Classification (United Nations, 2006), the following product groups are appropriate for the high-tech industries, which should be classified as high-tech (subject to the limitation of calculations by the three-digit level of product subgroups and certain simplifications) OECD (2011), Eurostat (n.d.a, n.d.b, n.d.c):

- Aerospace industry (792 – aircraft and accessories, spacecraft and launch vehicles, spare parts; 714 – non-electric engines (jet, gas turbines, etc.));
- Pharmaceutical industry (541 – medical and pharmaceutical products other than medicines; 542 – medicines (including veterinary medicines));
- Office equipment industry (751 – Office equipment; 752 – electronic computers for data processing; 759 – parts and accessories (not housing caps, packing box, etc.) for machines 751 and 752));
- Telecommunication equipment industry (761 – TVs; 762 – radios; 763 – Recording and reproducing apparatus, video recording apparatus; 764 – telecommunications equipment, spare parts, accessories to 76);
- Instrument making (774 – electromedical and radiological apparatus; 776 – thermionic devices, circuits, transistors, cathodes, diodes and the like; 871 – optical instruments

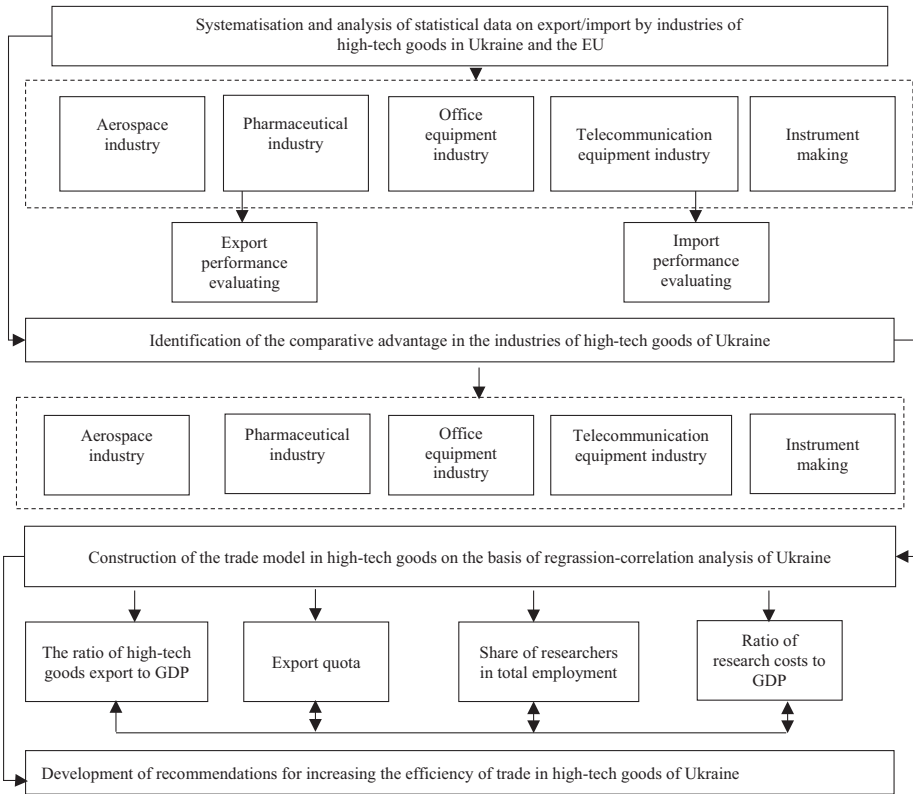


Figure 1. Scheme of research on trade in high-tech products of Ukraine with the European Union (source: own scheme of research)

and apparatus; 872 – Instruments and appliances for medical and veterinary sciences; 873 – meters and counters; 874 – instruments, apparatus for measuring, checking, analyzing and checking).

In Figure 1 shows a scheme of research of trade in high-tech products of Ukraine and the EU.

To study the main comparative advantages of high-tech trade in Ukraine, it is proposed to use such methodology and to analyse the following indicators (Caves et al., 1982):

- 1) the ratio of goods exports to *GDP* or export quota of the country;

$$Q_e = \frac{E}{GDP} \times 100\%, \quad (1)$$

where E – total export of the country for a certain year; GDP – the gross domestic product of the country for the relevant year;

- 2) the ratio of exports of high-tech goods to the country's *GDP*;

$$QE_{HQ} = \frac{E_{HQ}}{GDP} \times 100\%, \quad (2)$$

where E_{HQ} – total exports of high-tech goods for a certain year; GDP – the gross domestic product of the country for the relevant year;

- 3) the ratio of the employees number involved in the implementation of scientific research and development to the employment of the country's population:

$$\frac{\text{HTSemployees}}{\text{Occupiedpopulationofthecountry}} \times 100\% ; \quad (3)$$

- 4) the ratio of the research cost to the GDP of the country calculated respectively as:

$$\frac{\text{RDexpenses}}{\text{GDPofthecountry}} \times 100\% ; \quad (4)$$

- 5) the indicator of the relative (comparative) advantage of the country by commodity group is an indicator that reflects the country's relative superiority in the export of a particular product group, or whether its partners benefit from this advantage:

$$KP_{ij} = \ln [(Ex_{ij}/Im_{ij}) / (Ex_i/Im_i)], \quad (5)$$

where KP_{ij} is an indicator of the comparative advantage of the i -th country for the j -th commodity; Ex_i , Im_i – export and import of the second country; Ex_{ij} , Im_{ij} – export and import of j -th goods of the countries.

3. Results of research

The World Bank annually generates a country rating on two indicators: (1) a country's R&D spending on *GDP*; (2) the ranking of countries by the volume of high-tech exports in the structure of industrial exports of the country (The World Bank, n.d.c). These indicators highlight how much countries are earning on their innovative products and the return on investment in research and innovation. Indices of expenditure on *GDP* research and high-tech exports of EU and Ukraine for 2005–2015 are given in Appendix, Tables A1, A2.

According to the World Bank's (n.d.a, n.d.b, n.d.c, n.d.d) rating, Sweden (with an average of 3.4% of *GDP*) spend the most on science and research among EU countries, followed by Finland, Austria, Denmark and Germany, with almost 3%. Countries such as Latvia, Romania and Cyprus have the lowest funding rates (about 0.5% of *GDP*). The EU average is about 2% of *GDP*.

Malta (~ 30%), Ireland (~ 27%), France (~ 27%), United Kingdom (~ 21%), Germany (~ 17%) have the highest indicators of high-tech exports of all industrial exports of the analyzed countries. The EU average is around 17%. At the same time, Ukraine spends 0.7% of *GDP* on science (which is much less than in developed countries), and exports of high-tech products account for ~ 6–7% of industrial exports.

In 2016, high-tech exports totalled the EU \$ 16.3 billion, equivalent to 16.3% of total EU exports for the year. However, the EU has recorded a deficit in high-tech trade as imports amounted to about 22 billion euros more than exports (Eurostat). Germany accounts for over a quarter of all high-tech exports, and three countries – Germany, the Netherlands and France – account for more than 50% of all high-tech EU exports. This situation shows that the contribution of individual countries to the export of high technology is absolutely uneven.

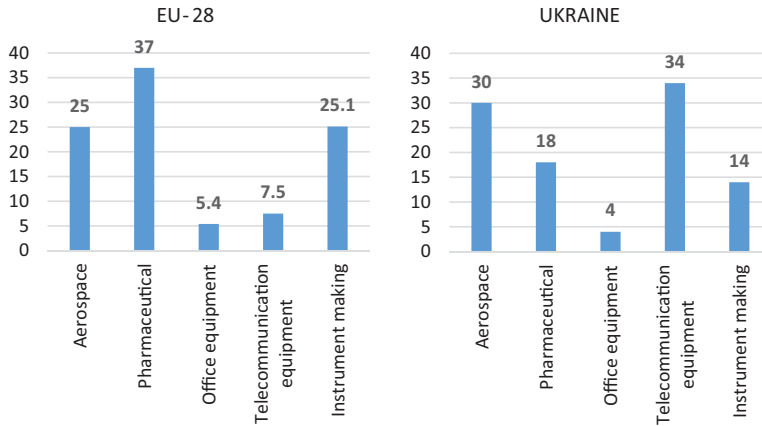


Figure 2. Comparison of export structure of high-tech products of EU-28 and Ukraine in 2018 (source: United Nations Commodity Trade Statistics Database, n.d.)

Table 1. Volume of export-import of high-tech products of Ukraine in 2018 (source: United Nations Commodity Trade Statistics Database, n.d.)

Branch	Export, million US\$	Imports, million US\$	Balance, million US\$
Aerospace	361,353	108,865	252,488
Pharmaceutical	218,668	2031,169	-1812,501
Office equipment	44,354	821,664	-777,31
Telecommunication equipment	402,492	1551,141	-1148,649
Instrument making	164,867	1785,025	-1620,158
Total	1191,734	6297,864	-5106,130

In Figure 2 the structure of exports of high-tech products of EU-28 and Ukraine in 2018 is shown. The leading position in the structure of exports of EU countries is made by telecommunication equipment – 34%, and in Ukraine, these products occupy the second-place – 19%. In 2018, Ukraine made the largest exports of aerospace products – 56%, and in the EU structure, these products ranked second among high-tech industries – 30%. Office equipment is the lowest in the structure of both Ukrainian and European exports – only 3% and 4% respectively.

Table 1 shows the structure and volume of export-import of high-tech products of Ukraine in 2018 according to UNcomtrade data. To determine the components of high-tech products, the International Standard Trade Classification (ISTC) was taken as the basis (United Nations Commodity Trade Statistics Database, n.d.; Official site of the State Statistics Service of Ukraine, n.d.).

According to the data in the above table, it is worth noting that exports of high-tech goods groups are significantly lower than their imports and their balance in 2018 is -5106,130 mil-

lion US\$. If we analyze in detail the structure of export and import of high-tech goods of Ukraine in 2018, it can be noted that only the products of the aerospace industry are characterized by a positive balance of \$ 252,488 million US\$. Thus, Ukraine is today, first and foremost, an importer in the world market of high-tech products, because foreign trade in high-tech goods is characterized by low shares of high-tech goods in total exports and a large negative balance.

The main reason for Ukraine's low presence in the world market for high-tech products and the tendency for its further decline is the outdated structure of production, which in turn is a consequence of the low level of R&D expenditures in Ukraine and the decline in innovation activity of Ukrainian enterprises (The Global Competitiveness Report 2016–2017 (Schwab, 2016b)).

Let us evaluate the comparative advantages and export performance indicators of the main industries of high-tech products of Ukraine using the methodological approach outlined above in terms of:

- 1) the ratio of goods exports to GDP or the country's export quota;
- 2) the ratio of exports of high-tech goods to the country's GDP;
- 3) the ratio of the number of employees involved in the implementation of research and development to the employed population of the country;
- 4) the ratio of research expenditures to the country's GDP;
- 5) an indicator of relative advantage or comparative advantage.

The calculations used foreign trade indicators for the major high-tech industries of Ukraine in 2011–2015, given in Table 2.

1. The ratio of a country's export to GDP or an export quota showing the established output and exports of certain goods. Indicators in the dynamics of Ukraine's GDP and Ukraine's exports (Table 3) were used for the calculations.

Figure 3 shows that Ukraine's export quota does not exceed 52.6% and has an average of 46.5%, which indicates a certain impact of exports on Ukraine's GDP.

Table 2. Dynamics of foreign trade in high-tech goods of Ukraine for 2011–2018, mln. US\$. (source: United Nations Commodity Trade Statistics Database, n.d.)

Industry	Export, mln. US\$								Imports, mln. US\$							
	2011	2012	2013	2014	2015	2016	2017	2018	2011	2012	2013	2014	2015	2016	2017	2018
Aerospace	1103	1857	1364	1155	857	478	437	361	192	231	150	127	89	80	56	108
Pharmaceutical	201	259	270	266	162	188	196	219	2948	3374	3177	2553	1435	1675	1836	2031
Office equipment	57	66	55	43	43	47	50	44	383	431	460	495	416	598	738	822
Telecommunication equipment	573	761	616	511	289	322	354	402	1540	1630	1623	1155	910	1034	1378	1551
Instrument making	307	318	312	251	171	163	173	165	1227	2263	1824	883	609	827	1130	1785
Total	2241	3261	2617	2226	1522	1198	1210	1191	6290	7929	7234	5213	3459	4214	5138	6297

Table 3. Output data for calculating the export quota of Ukraine for 2011–2018 (source: United Nations Commodity Trade Statistics Database, n.d.)

Indexes	2011	2012	2013	2014	2015	2016	2017	2018
GDP of Ukraine, billion US\$	163,160	175,781	183,310	133,503	91,031	93,356	112,190	130,832
Exports of Ukraine, billion US\$	81,280	62,254	78,744	64,873	47,880	46,023	53,867	59,149
Population of Ukraine, million people	45,706	45,593	45,489	45,271	45,154	45,005	44,831	44,622
Results of calculation of export quota	49,816	35,415	42,957	48,593	52,598	49,298	48,014	45,210

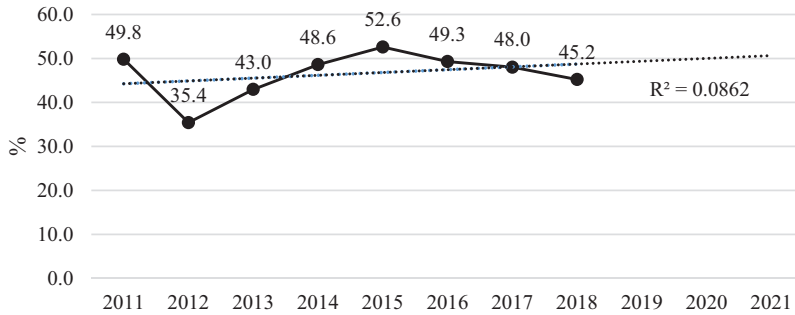


Figure 3. Dynamics of changes in Ukraine's export quota (source: United Nations Commodity Trade Statistics Database, n.d.)

2. The ratio of exports of high-tech goods to the GDP of Ukraine. The initial data and calculation results are given in Table 4.

Table 4. Output data for calculating the ratio of exports of high-tech goods to the GDP of Ukraine (source: United Nations Commodity Trade Statistics Database, n.d.)

Indexes	2011	2012	2013	2014	2015	2016	2017	2018
GDP of Ukraine, billion dollars USA	163,160	175,781	183,310	133,503	91,031	93,356	112,190	130,832
Exports of high-tech products of Ukraine, billion US\$	2,241	3,260	2,618	2,225	1,523	1,198	1,210	1,191
Results of calculating the ratio of export of high-tech products to GDP of Ukraine, %	1.37	1.85	1.43	1.67	1.67	1.28	1.08	0.91

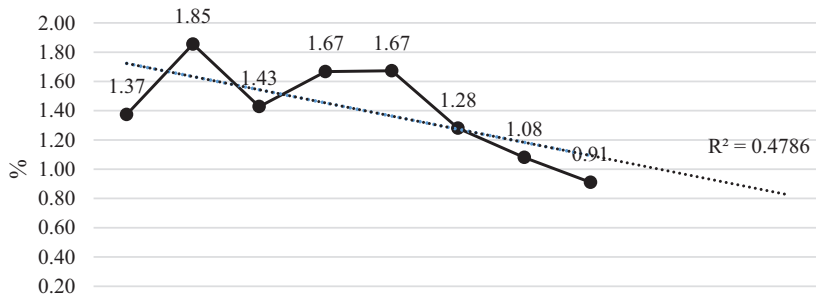


Figure 4. Dynamics of changes in the ratio of exports of high-tech goods to the GDP of Ukraine (source: United Nations Commodity Trade Statistics Database, n.d.)

Figure 4 shows that the export quota of high-tech products of Ukraine does not exceed 1.85% (in 2012) and has an average of 1.41%, which indicates that the export of high-tech products has little impact on the GDP of Ukraine and requires the introduction of effective measures to expand the export quota high-tech products in the country’s economy.

3. The ratio of the number of employees involved in the implementation of research and development to the employed population of working age. The initial data and the calculation results are given in Table 5.

Table 5. Output data for calculating the employees’ number ratio involved in the implementation of research and development to the occupied population. (source: United Nations Commodity Trade Statistics Database, n.d.)

Indexes	2011	2012	2013	2014	2015	2016	2017	2018
The number of employees involved in the implementation of research and development, thousand people	175.3	164.3	155.4	136.1	122.5	97.7	94.3	88.1
Employed population of able-bodied age, thousand persons	19231.1	19261.4	19314.2	18073.2	16276.9	16276.9	16156.4	16360.9
Results of the calculation of the ratio of the number of employees involved in innovation activity to the employed population of working age, %	0.91	0.85	0.80	0.75	0.75	0.60	0.58	0.54

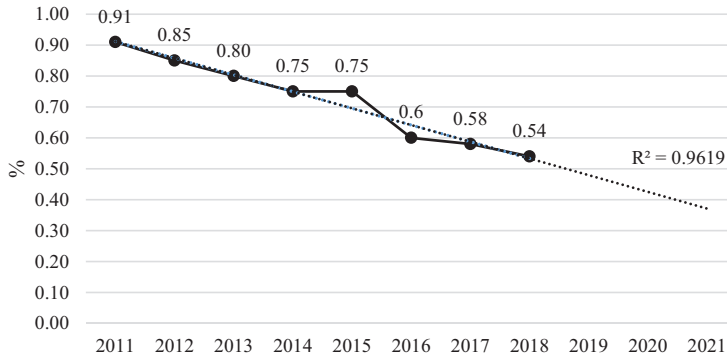


Figure 5. Dynamics of the ratio of the number of employees involved in an innovative activity to the employed population of working age (source: own calculations based on Official site of the State Statistics Service of Ukraine, n.d.)

Figure 5 shows that the number of employees involved in the implementation of research and development decreases every year, as does the overall employment of the population due to the social, political and economic situation in the country. It is also a consequence of the low level of R&D expenditures in Ukraine and the decrease in innovation activity of Ukrainian enterprises.

4. The ratio of research expenditures to the country's GDP. This indicator indicates the return on investment in research and innovation in the country. The output is given in Table 6.

As we can see in Figure 6 expenditure on R&D in Ukraine is on average 0.61% of GDP and tends to decline. As a result of such financial support, science in Ukrainian society plays predominantly cognitive and sociocultural functions, because it is known from the world practice that the possibility of the influence of science on the level of economic development arises if its financing exceeds 0.9% of GDP.

Table 6. Output data to calculate the ratio of research costs to the GDP of the country (source: Scientific and innovative activity of Ukraine, n.d., The World Bank, n.d.)

Indexes	2011	2012	2013	2014	2015	2016	2017	2018
GDP of Ukraine, billion dollars USA	163.160	175.781	183.310	133.503	91.031	93.356	112.190	130.832
Research expenditures, billion dollars USA	1.204	1.322	1.397	0.868	0.560	0.451	0.503	0.616
Results of the calculation of the ratio of the cost of research to the GDP of the country, %	0.738	0.752	0.762	0.650	0.615	0.483	0.448	0.471

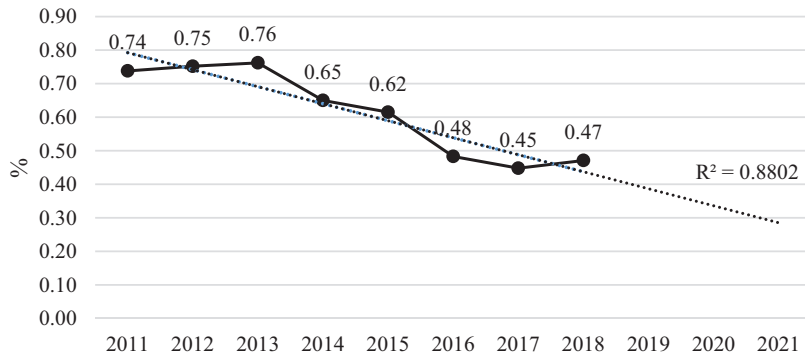


Figure 6. Dynamics of the ratio of research expenditures to the country's GDP (source: own calculations based on Scientific and innovative activity of Ukraine, n.d.)

5. Indicator of the revealed relative (comparative) advantage of Ukraine in high-tech industries. The results of the calculation of the formula for comparative advantage for Ukraine by major high-tech industries of Ukraine in 2011–2015 are given in Table 7.

Table 7. The value of the comparative advantage for Ukraine by the main high-tech industries in 2011–2018 (source: United Nations Commodity Trade Statistics Database, n.d.)

	2011	2012	2013	2014	2015	2016	2017	2018
Aerospace	1.87	2.55	2.40	2.28	2.30	1.92	2.20	1.38
Pharmaceutical	-2.56	-2.10	-2.27	-2.19	-2.15	-2.06	-2.09	-2.05
Office equipment	-1.78	-1.41	-1.92	-2.38	-2.23	-2.41	-2.54	-2.75
Telecommunication equipment	-0.86	-0.30	-0.77	-0.75	-1.11	-1.04	-1.21	-1.18
Instrument making	-1.26	-1.50	-1.57	-1.19	-1.23	-1.49	-1.73	-2.21

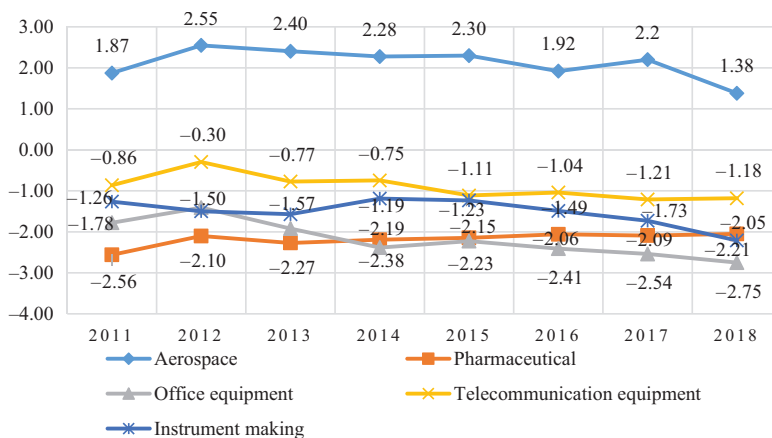


Figure 7. Ukraine's comparative advantages in major high-tech industries (source: own calculations based on The World bank, n.d.)

As can be seen from Figure 7, the comparative advantage for the aerospace industry is the highest (2.55 in 2012) but tends to decline. Telecommunication equipment has the second place in terms of the indicator of the revealed relative advantage in the export of high-tech goods of Ukraine (−0.30 in 2012), but as for other industries, this indicator is negative and shows that the comparative advantage in the export of these goods has foreign partners. At the same time, the realized export potential of the aerospace industry is several times higher than the potential of other industries. Only the instrument industry has a tendency to increase comparative advantage, which is associated with significant efforts to reform and increase investment in the industry in recent years.

The average comparative advantage figures calculated for five groups of high-tech goods in Ukraine for the period 2011–2018 are shown in Figure 8 and also indicate a significant comparative advantage in the export of aerospace.

As shown by the calculations, relatively small comparative competitive advantages in the markets of foreign countries among high-tech products of Ukraine have only aircraft, spacecraft and their parts.

However, today the state of the aerospace industry is characterized by the presence of systemic problems associated with adaptation to market conditions, fierce competition in the world market against the background of low demand for a domestic and significant shortage of working capital of enterprises.

The purpose of the simulation is to establish and characterize the relationship between the following factors: export quota; the share of high-tech exports in total industrial exports; GDP research and development costs; the share of scientists in the total employment of the population, and the identification of the impact of these indicators on foreign trade in high-tech goods of our country. Based on the table of baseline data for these indicators in the period 2014–2018 (Table 8). A correlation analysis was conducted, the results of which are presented in Table 9.

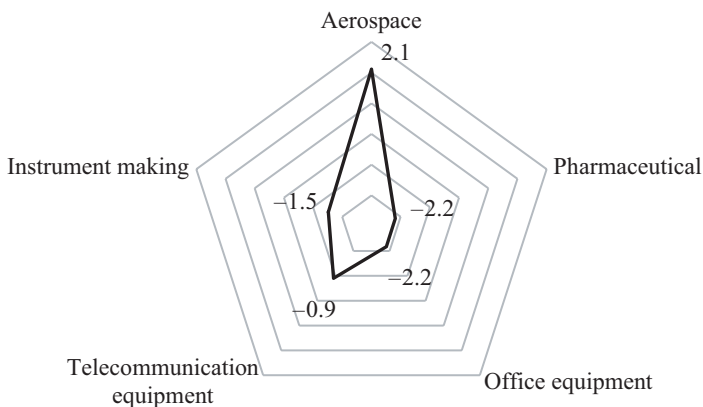


Figure 8. Average values of comparative advantage indicators for Ukraine by major high-tech industries in 2011–2018 (source: own calculations based on Scientific and innovative activity of Ukraine, n.d.)

Table 8. Output data for modelling of foreign trade of high-tech goods of Ukraine in the period of 2014–2018 (source: own calculations based on Scientific and innovative activity of Ukraine, n.d.)

Years	Export quota, %	Export ratio high-tech products to industrial country export, %	Ratio of R&D expenditures to GDP of the country, %	Ratio of number of scientific and technical staff to the able-bodied population, %
	Y	X ₁	X ₂	X ₃
2014	48.593	7.530	0.650	0.753
2015	52.598	8.524	0.615	0.753
2016	49.298	7.218	0.483	0.600
2017	48.014	6.252	0.448	0.584
2018	45.210	5.406	0.471	0.538

Table 9. Correlation dependence of 4 indicators across Ukraine (source: own calculations based on Scientific and innovative activity of Ukraine, n.d.)

	Export quota, % (Y)	The ratio of exports high-tech products up to industrial exports, % (X ₁)	The ratio of R&D expenditure to GDP, % (X ₂)	The ratio of the number of scientific and technical staff to the able-bodied population, % (X ₃)
Export quota, % (Y)	1.000			
The ratio of exportshigh-tech products for industrial exports, % (X ₁)	0.950	1.000		
Ratio of R&D expenditure to GDP, % (X ₂)	0.564	0.766	1.000	
The ratio of the number of scientific and technical staff to the working population, % (X ₃)	0.746	0.887	0.958	1.000

The close relationship between the indicators and the share of high-tech exports can be explained by the impact of side factors, namely the rate of decline in exports that continues as a result of the political and economic crisis, and the depreciation of the hryvnia (according to Tables 10–12).

As can be seen from the Table 9, the coefficient of the export quota (0.950) and the ratio of the number of scientific and technical staff to the working population of the country (0.887) is the largest factor in the ratio of the export of high-tech products to the industrial exports of the country. In addition, a very close direct link is found between the cost of research and development and the share of scientists in the total employment of the population (0.958). In other words, the more the state spends its money on R&D and the more scientific and technical staff in the country, the more exports of high-tech products will be in Ukraine.

The next step in the analysis is to calculate the regression. Consider the Y factor of the ratio of high-tech exports to industrial exports of the country and see what other coefficients

Table 10. Characteristics of the tightness of the link between the indicators (source: own calculations based on Scientific and innovative activity of Ukraine, n.d.)

Indicators	Symbolic correlation value	Correlation coefficient value	Communication characteristic tightness
Export quota, % The ratio of high-tech exports to industrial, %	$Y \leftrightarrow X1$	0.950	The connection is very tight
Export quota, % Ratio of R & D expenditures, % of GDP	$Y \leftrightarrow X2$	0.564	Medium tightness relationship (moderate)
Export quota, % The ratio of the number of scientific and technical staff to the able-bodied population, %	$Y \leftrightarrow X3$	0.746	Relationship is tight (strong)
The ratio of high-tech exports to industrial, % Ratio of R & D expenditures, % of GDP	$X1 \leftrightarrow X2$	0.766	Relationship is tight (strong)
The ratio of high-tech exports to industrial, % The ratio of the number of scientific and technical staff to the able-bodied population, %	$X1 \leftrightarrow X3$	0.887	The connection is very tight
R & D expenditures, % of GDP: The share of scientists in the total employment of the population	$X2 \leftrightarrow X3$	0.958	The connection is very tight

Table 11. Matrix of output data ratio of high-tech exports to industrial exports of the countries under consideration and Ukraine, % (source: United Nations Commodity Trade Statistics Database, n.d.)

Years	Ukraine	Germany	Poland	Romania	EU
	Y	X1	X2	X3	X4
2013	6.711	17.386	8.850	7.364	17.493
2014	7.530	17.280	10.250	8.387	17.404
2015	8.524	17.893	11.018	9.415	18.009
2016	7.218	18.064	11.037	10.392	18.215
2017	6.252	15.902	10.894	9.823	16.689

Table 12. The results of the factor regression analysis of the high-tech exports share in the industrial sector (source: United Nations Commodity Trade Statistics Database, n.d.)

	Germany	Poland	Romania	EU
R-square	0.497	0.110	0.008	0.471
F	2.963	0.372	0.024	2.670
Significance F	0.184	0.585	0.886	0.201
Coefficient a	-5.142	4.032	6.663	-10.250
Standard error, a	7.205	5.289	3.770	10.713
Coefficient b	0.716	0.309	0.064	0.996
Standard error b	0.416	0.506	0.412	0.610
P-value, a	0.527	0.501	0.175	0.409
P-value, b	0.184	0.585	0.886	0.201

of the considered and how they affect it. In this case, we consider the impact of export quota indicators (X1), the ratio of researchers to the country’s population (X2), and the ratio of R&D expenditures to country’s GDP (X3), and the ratio of high-tech exports to country exports (B).

To complete the study, a multivariate regression analysis of the impact of all three factors on the (B) share of high-tech exports in industrial was conducted. In Table 13 presents the results of a multivariate regression analysis of the impact of all three factors on the share of high-tech exports in industrial.

Table 13. Results of multivariate regression analysis

R-square	0.98010
F	16.41689
The significance of F	0.17902
The coefficient of Y	-12.75732
Standard error, Y	5.52315
The coefficient of X1	0.36408
Standard error X1	0.15787
The coefficient of X2	5.99830
Standard error X2	10.59619
The coefficient of X3	-1.86226
Standard error, X3	12.03845

The R-squared value describes the degree of accuracy of the process model description. R-square –0.98010, or 98.01%. In our case, the degree of approximation is high and it can be concluded that these factors have a significant impact on the level of high-tech exports in Ukraine. Then the regression equation takes the form:

$$Y = -12,75732 + 0,36408X_1 + 5,99830X_2 - 1,86226X_3. \tag{6}$$

Next, we calculate the correlation-regression model and find out the degree of dependence of the high-tech export indicator of Ukraine on the same indicator of other countries. We selected Germany, Poland, Romania and the EU as a whole for analysis. Table 13 shows the output matrix of this metric.

Table 14 shows the correlation between the ratio of high-tech exports to industrial exports of the countries under consideration and Ukraine.

Table 14. Correlation of high-tech ratio indicator exports to the industrialexports of the countries under consideration and Ukraine

	Ukraine (Y)	Germany (X1)	Poland (X2)	Romania (X3)	EU (X4)
(Y)	1.000				
(X1)	0.705	1.000			
(X2)	0.332	0.010	1.000		
(X3)	0.090	0.007	0.931	1.000	
(X4)	0.686	0.978	0.177	0.204	1.000

The calculations show that a strong direct link is a factor in the share of high-tech exports in industrial exports found between almost all countries, as all countries are important trading partners for each other. However, a moderate inverse relationship exists between the selected countries and Romania and a weak inverse between Romania and the EU (0.204). This means that only in the case of reduced exports of high-tech products to other countries will Romania have a chance to increase its share of high-tech exports. The reliability of these calculations is also underlined by the results of the regression analysis was presented in Tables 11–12.

4. Results and recommendations

As a result of the analysis of trends in the market for high-tech products, as well as the technological gap between Ukraine and the developed countries of the EU, there is a need to identify priority state actions to support the growth of production of high-tech products in Ukraine.

Firstly, it is necessary to increase the share of investments both from the state and from foreign investors in the fixed capital and the share of the expenses for innovations in the total volume of industrial production, increase of scientific and technical potential, including due to the expansion of state funding of basic science, research and development as well as education. It is important now to improve the business climate in the country and create favourable conditions for attracting foreign investment.

Besides, it is necessary to create an effective system of access to financing, which implies increasing the availability of credit resources for high-tech enterprises by creating special lending programs, improving and updating the legislative and regulatory support of venture funds and crowdfunding platforms.

Secondly, it is necessary to solve the problem of the workforce, namely the “drain of minds”. Unfavourable working conditions lead to the migration of skilled workers to other countries in search of a better life and the possibility of self-realization, leaving their own country without developing its potential. Therefore, the state needs to develop incentive measures to retain specialists at home. First and foremost, it should be the creation of a state program to encourage scientists and researchers through the provision of grants and funding for research projects, awards for achievement.

Third, the government’s important task is to harmonize national standards in high-tech industries with international standards, simplify the certification process for Ukrainian-made products, and simplify the patenting of intellectual property for start-ups and small and medium-sized enterprises, which are a driving force today development of innovations.

Fourth, integration of Ukraine into the world scientific and technical information space is required, which requires deepening of relations between Ukraine and developed countries (in particular, Israel, Canada, China, Korea, USA, Switzerland, Sweden, Japan, etc.) through review and / or signing bilateral agreements on scientific and technical cooperation, as well as facilitating the participation of Ukrainian scientists in international scientific conferences, internships, exchange programs, scientific projects. Most importantly, focus on clearly identifying priorities from Ukraine’s involvement in international integration processes within the

EU, which would first and foremost take into account the orientation of Ukraine’s economy by the high-tech vector (Pagliacci, 2014).

Table 15 presents the author’s recommendations for improving the efficiency of high-tech trade between Ukraine and the EU, taking into account the results of the analysis carried out during the study.

Table 15. The author’s recommendations on the development of high-tech trade between Ukraine and the EU (source: own recommendations)

Metric/type of analysis	The result of the analysis	Recommendations
R&D expenditure,% of GDP	0.471 in 2018 GDP below the EU level (2.05%)	<ol style="list-style-type: none"> 1. Increase R&D expenditure (grants, patents, etc.); 2. Financial support and stimulation of development of production and technological clusters. 3. Creation of “technological infrastructure”; 4. Establishment of specialized universities in enterprises (mutual benefit from the implementation of experimental studies).
High-tech exports, % in industrial	5.4 in 2018 below EU level (7%)	<ol style="list-style-type: none"> 1. Creation of conglomerates based on domestic industrial giants, granting of privileges; 2. Preferential taxation, low-interest long-term credits for exporters and importers of high-tech goods; 3. Initiation of programs for technology exchange, production experience with further development of real projects, calculation of their profitability, implementation in production. 4. Development of own analogues of foreign technologies; 5. Determining the development of high-technology exports by a strategic national priority.
Comparative advantages for groups	2.1 for the aerospace industry	1. To develop export of this high-tech industry in all directions
	-2.2 for pharmaceutical and office equipment	1. It is necessary to constantly reform and increase capital investment in these sectors, as it is promising for Ukraine and has a tendency to grow.
Correlation analysis, ratio of high-tech exports to industrial (X1)	Export quota (Y) – The connection is very tight	<ol style="list-style-type: none"> 1. Increasing the volume of all types of production, especially those for which a comparative advantage is found; 2. Diversification of export markets to reduce dependency and minimize the risk of a sharp drop in exports.
	The ratio of R&D expenditures to GDP (X2) is tight (strong)	<ol style="list-style-type: none"> 1. Increase the cost of research and development (grants, patents, etc.); 2. Financial support and stimulation of development of production and technological clusters.
	The ratio of the number of scientific and technical staff to the able-bodied population (X3) is very tight	<ol style="list-style-type: none"> 1. Creation of “technological infrastructure”; 2. Establishment of specialized universities in enterprises (mutual benefit from the implementation of experimental studies). 3. Increasing the prestige of the profession of a scientist at the expense of decent wages

End of Table 15

Metric/type of analysis	The result of the analysis	Recommendations
Regression analysis, ratio of high-tech exports to industrial exports (Y)	The ratio of researchers to the population of the country (X2)	$Y = -12.75732 + 5.99830 * X2$ 1. Increasing the share of scientists in total employment by 1% will lead to an increase in exports of high-tech products by 5.99%, therefore, it is necessary to ensure an increase in the number of scientists through the creation of university-based research centers directly involved in the implementation of production projects.
	Ratio of R&D expenditure to GDP (X3)	$Y = -12.75732 - 1.86226 * X3$ 1. Increase in R&D expenditures by 1% will result in a 1.86% increase in exports of high-tech products, therefore, effective and efficient public funding programs for R&D need to be developed
Correlation analysis, Ukraine (Y), variables – EU countries	High-tech exports,% in industrial – communication is very close	1. Increasing the competitiveness of Ukrainian goods, starting from state support of exporters by methods approved by international standards, and finishing with the modernization of production; 2. Focus on developing the capacity of such high-tech products as aircraft, aircraft and spacecraft.

Only the combined action of the Ukrainian government, domestic producers and academia can bring Ukrainian high-tech products to a high level of competitiveness.

5. Discussion with the other scientists/papers and prospects for further research

In his work, Kyzym (2011) examined the problems of assessing the readiness of high-tech clusters in Ukraine to trade their products with EU countries, although he assessed the possibility of forming innovative clusters even before the concept of a new industrial revolution appeared. In her work, Haustova (2015) also assessed the possibility of developing trade in products of innovative clusters of Ukraine on the example of enterprises in the electrical industry working in the Kharkov region. However, she did not consider the prospects for developing trade in high-tech products in association with the EU. Yegorov et al. (2016), and Salihova (2012) examined the impact on the foreign trade of Ukraine of the results of the introduction of high technologies in the Ukrainian economy, and also evaluated the development indicators of ICT, biotechnology, nanotechnology, new materials and nuclear technologies. Moreover, in the studies of all these authors, there was no comprehensive analysis of comparative advantages in the trade-in high-tech products of Ukraine and the EU as a whole. Fedulova (2011) also used many indicators to assess the prospects for foreign trade in high-tech products, as well as to justify the national priorities of the country's socio-economic development on an innovative basis, although it determined only the general opportunities for trade in high-tech products of Ukrainian industry without taking into account the factors of the new Industrial Revolution. Duginec (2018) in his work analyzed Ukraine's place in global value chains, in particular, determined the imperative of transformation of foreign

trade flows of the Ukrainian economy, substantiated the need for innovative development of the economy as a competitive advantage in global production, and also simulated the country's participation in global value chains. However, these authors did not have a comprehensive approach to the development of a methodology for studying Ukraine's readiness for innovation in association with the EU.

Therefore, as the prospect of their research, the authors of this article see an assessment of the possibilities for developing foreign trade in high-tech products of Ukraine and the EU within the framework of the formation of common value chains in an association.

Conclusions

The results of the assessment of the state of the high-tech sector of Ukraine's economy in the conditions of the formation of a new industrial revolution and association with the EU allow us to draw the following conclusions:

1. It is revealed that the main trend in the modern world is the transition to a new technological way and convergent technologies, on which the fourth industrial revolution is built. The introduction of advanced technologies in Ukraine is conditioned by the need to increase the competitiveness of domestic producers in foreign and domestic markets in the conditions of deep integration of the country, first of all, with the countries of the European Union, and implementation of the Association Agreement between Ukraine and the EU.
2. The reason for Ukraine's low presence in the world market for high-tech products and the tendency for its further decline is the outdated structure of production, which in turn is a consequence of the low level of R&D expenditures in Ukraine and the decrease of innovative activity of Ukrainian enterprises.
3. Comparative analysis shows that the largest indicator of comparative advantage among high-tech industries is the aerospace industry – (2.55 in 2012). For other industries, this indicator is negative and indicates that foreign partners have a comparative advantage in exporting these goods.
4. The regression analysis shows that export quota (0.950) and the ratio of the number of scientific and technical staff to the working population of the country (0.887) are most influenced by high-tech exports of the country.
5. Given that Ukraine has great export potential and competitive technologies, it is necessary to focus on clearly identifying priorities from Ukraine's involvement in international integration processes within the EU, which would first take into account the orientation of the Ukrainian economy's growth by the high-tech vector.

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Author contributions

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Appendix

Table A1. Expenditures on research activities of EU countries and Ukraine (% of GDP)
(source: author's own elaboration based on The WorldBank)

Country	Year						
	2011	2012	2013	2014	2015	2016	2017
Austria	2.67	2.91	2.95	3.08	3.05	3.13	3.16
Belgium	2.16	2.27	2.33	2.39	2.46	2.55	2.59
Bulgaria	0.53	0.60	0.64	0.79	0.96	0.78	0.75
UK	1.66	1.59	1.64	1.66	1.67	1.68	1.66
Greece	0.67	0.70	0.81	0.83	0.96	0.99	1.13
Denmark	2.94	2.98	2.97	2.91	3.05	3.12	3.06
Estonia	2.31	2.12	1.72	1.43	1.47	1.25	1.29
Ireland	1.56	1.56	1.57	1.50	1.19	1.17	1.04
Spain	1.33	1.29	1.27	1.24	1.22	1.19	1.20
Italy	1.21	1.27	1.31	1.34	1.34	1.37	1.35
Cyprus	0.46	0.44	0.48	0.51	0.48	0.53	0.55
Latvia	0.70	0.66	0.61	0.69	0.63	0.44	0.51
Lithuania	0.90	0.89	0.95	1.03	1.04	0.84	0.89
Luxembourg	1.46	1.27	1.30	1.26	1.28	1.30	1.26
Malta	0.67	0.83	0.77	0.71	0.74	0.57	0.54
Netherlands	1.88	1.92	1.93	1.98	1.98	2.00	1.99
Germany	2.80	2.87	2.82	2.87	2.91	2.92	3.02
Poland	0.75	0.88	0.87	0.94	1.00	0.96	1.03
Portugal	1.46	1.38	1.33	1.29	1.24	1.28	1.32
Romania	0.50	0.48	0.39	0.38	0.49	0.48	0.50
Slovak Republic	0.66	0.80	0.82	0.88	1.17	0.79	0.88
Slovenia	2.42	2.57	2.58	2.37	2.20	2.01	1.86
Hungary	1.19	1.26	1.39	1.35	1.36	1.20	1.35
Finland	3.64	3.42	3.29	3.17	2.89	2.74	2.76
France	2.19	2.23	2.24	2.28	2.27	2.24	2.19
Croatia	0.75	0.75	0.81	0.78	0.84	0.86	0.86
Czech Republic	1.56	1.78	1.90	1.97	1.93	1.68	1.79
Sweden	3.25	3.28	3.30	3.14	3.26	3.27	3.33
EU	1.97	2.00	2.01	2.03	2.04	2.04	2.06
Ukraine	0.74	0.75	0.76	0.65	0.61	0.48	0.45

Table A2. High-tech exports from the EU and Ukraine (% of industrial exports)
(source: author's own elaboration based on The World Bank)

Country	Year						
	2011	2012	2013	2014	2015	2016	2017
Austria	13.26	14.58	15.41	15.53	15.08	14.51	12.87
Belgium	10.55	11.86	12.03	13.36	13.65	13.05	10.70
Bulgaria	7.83	8.05	8.29	7.36	8.19	8.87	9.53
UK	23.58	23.80	23.88	22.47	22.67	23.98	23.03
Greece	11.15	10.06	8.38	11.40	12.81	13.62	11.99
Denmark	15.29	15.84	15.85	15.72	17.19	16.68	13.88
Estonia	22.16	20.45	20.54	23.33	22.44	22.02	17.56
Ireland	24.80	25.48	24.84	24.78	28.20	32.72	29.03
Spain	6.82	7.36	8.08	7.43	7.58	7.45	7.74
Italy	8.07	7.67	7.91	7.82	8.29	8.37	7.91
Cyprus	30.31	16.59	13.08	14.59	13.14	13.43	14.05
Latvia	9.32	11.25	15.22	17.69	18.83	17.14	17.50
Lithuania	10.64	11.06	11.06	11.16	12.81	12.72	12.57
Luxembourg	9.05	8.68	6.85	5.97	7.11	7.97	7.14
Malta	47.55	46.13	38.77	34.78	30.45	21.99	..
Netherlands	25.07	25.50	25.98	25.79	24.15	23.90	22.67
Germany	16.45	17.36	17.39	17.28	17.89	18.06	15.90
Poland	6.62	7.89	8.85	10.25	11.02	11.04	10.89
Portugal	4.11	4.48	4.68	4.86	5.06	5.78	5.96
Romania	11.63	8.13	7.36	8.39	9.41	10.39	9.82
Slovak Republic	7.38	9.58	11.02	11.14	11.15	10.74	11.80
Slovenia	6.21	6.65	6.73	6.41	7.00	7.14	6.50
Hungary	25.15	21.20	19.36	16.68	..	17.47	17.30
Finland	11.11	10.52	9.09	10.13	10.21	10.06	9.56
France	25.32	26.85	27.28	27.61	28.36	28.08	26.09
Croatia	8.72	11.89	12.63	10.55	10.79	14.70	8.80
Czech Republic	18.71	18.59	17.35	17.40	17.79	16.99	17.90
Sweden	18.76	18.00	18.00	17.98	18.13	18.28	15.38
EU	16.94	17.45	17.49	17.40	18.01	18.21	16.69
Ukraine	5.00	6.91	6.71	7.53	8.52	7.22	6.25