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DISCLOSURE OF THE EXPORT POTENTIAL OF HIGH-TECH ENTERPRISES IN THE CONTEXT OF INDUSTRY 4.0 THROUGH QUALITY MANAGEMENT

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Quality 4.0, Quality Management 4.0, Export Potential, High-Tech Enterprises, The Economic Cycle of Industry 4.0, Neomercantilism 4.0, Bridging the Digital Divide, Digital Management Information Systems, Industrial and Manufacturing Engineering 4.0.

A B S T R A C T

The motivation for this research was the desire to strengthen the scientific and methodological base to reduce the global digital divide. The purpose of the article is to develop a new approach to the disclosure of the export potential of high-tech enterprises. For this purpose, the article examines the dynamics of high-tech exports in 2007-2021 in a complete sample of countries for which the World Bank keeps statistical records, and substantiates a weak relationship of high-tech exports with economic growth, but a strong relationship with quality 4.0 using the method of correlation analysis. Based on data for 2021 from a sample of the top 20 digital economies that most actively use a set of technologies for quality management 4.0, it has been proved that industrial and manufacturing engineering 4.0 makes a greater contribution to the disclosure of the export potential of high-tech enterprises than digital management information systems. The theoretical significance lies in the fact that the scientific concept of neomercantilism 4.0 has been developed to explain the essence of international trade in the context of industry 4.0; the economic cycle of industry 4.0 has been proposed and its difference from the usual economic cycle has been substantiated to explain the dynamics of change and high-precision forecasting of high-tech exports. The practical significance is due to the fact that the developed new approach to the disclosure of the export potential of high-tech enterprises describes more objectively and makes it possible to predict the dynamics of changes in high-tech exports with greater accuracy, and also provides wider use of the advanced capabilities of industry 4.0 to modernize the development of high-tech industries and strengthen their global digital competitiveness.

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1. INTRODUCTION

Globalization is one of the key characteristics of the modern economic landscape. The level of globalization has been increasing intensively over the past five decades and has now become so high that almost all countries are integrated into a single global economic system. Thus, according to the KOF Swiss Economic Institute (2023), the globalization index has increased from 38.2 de facto points and 35.26 de jure points in 1970 to 57.63 de facto points and 63.69 de jure points by 2020. In an open environment, the development of the economy and entrepreneurship is largely determined by the degree of their involvement in international trade. This is confirmed by the fact that, according to the World Bank (2023a), exports of goods and services have increased 2.26 times over the past fifty years from 12.8% of GDP in 1970 to 28.9% of GDP in 2021. Taking into account the context of globalization, the Fourth Industrial Revolution involves the development of high-tech enterprises of industry 4.0 through increasing their export activity. In order to successfully compete with multinational corporations – giants of industry 4.0, which optimize production and sales operations with the help of global supply chains, international business networking and benefit from "economies of scale", national high-tech enterprises must increase their presence on the world stage by diversifying suppliers and expanding sales markets.
The problem lies in the fact that the existing approach to unlocking the export potential of high-tech enterprises offers an insufficiently reliable description and does not give an accurate forecast of the dynamics of changes in high-tech exports, and also does not fully use the advanced capabilities of industry 4.0 to modernize high-tech industries and strengthen their global digital competitiveness.

The severity of the problem is evidenced by the strong differentiation of both the volume and the share of high-tech exports in industrial exports - according to World Bank statistics (2023c), its variation increased from 88.45% in 2007 to 98.47% in 2021. Moreover, in 2011, it generally tends to increase. This indicates the existence of a serious and deepening digital divide as a modern form of global inequality at the country level (Popkova, 2022).

Thus, the motivation for conducting this research was the desire to strengthen the scientific and methodological basis for reducing the global digital divide. The purpose of the article is to develop a new approach to the disclosure of the export potential of high-tech enterprises. The chosen goal implies the need to formulate and solve four research tasks in this article. The first task is to study the dynamics of high-tech exports, to determine its relationship with economic growth.

The second task is to compare alternative mechanisms of quality management 4.0 – digital management information systems and industrial and manufacturing engineering 4.0 – from the standpoint of their contribution to the disclosure of the export potential of high-tech enterprises.

The third task is to determine the prospects for unlocking the export potential of high-tech enterprises in Russia with increasing the quality through the improvement of industrial and manufacturing engineering 4.0. The fourth task is to develop a mechanism for unlocking the export potential of high-tech enterprises through quality management using industrial and manufacturing engineering 4.0.

The originality of the research and its contribution to the literature consists in the development of the scientific concept of neomercantilism 4.0, as well as in the substantiation of the economic cycle of industry 4.0. The practical significance is due to the fact that the proposed authors' approach to the disclosure of the export potential of high-tech enterprises involves reliance on a new mechanism for quality management 4.0 - the transition from digital management information systems to industrial and manufacturing engineering 4.0.

2. LITERATURE REVIEW OF THE EXISTING APPROACH TO THE DISCLOSURE OF THE EXPORT POTENTIAL OF HIGH-TECH ENTERPRISES

2.1. Neomercantilism 4.0: A new concept of international trade in the context of industry 4.0

The fundamental basis of this research is the scientific provisions of the Theory of International Trade. This theory has its roots in mercantilism as the first economic school that emerged against the background of Great Geographical Discoveries and the formation of manufactories. In this regard, the evolution of the theory of international trade was influenced by two key factors: globalization and industrial revolutions. This evolution is reflected in Table 1 through the prism of the concepts of mercantilism.

As shown in Table 1, under early mercantilism, globalization was interpreted as a threat to national security. The vision of an optimal balance of international trade assumed a positive monetary balance. The way to achieve it was monetarism: stimulating input and limiting output cash flow. The essence of import regulation was its restriction, which was accompanied by the risk of shortage.

Table 1. Evolution of the theory of international trade through the prism of the concepts of mercantilism

Areas of difference between the concepts	Concepts of mercantilism		
	Early mercantilism	**Late mercantilism**	**Neomercantilism 4.0**
Interpretation of globalization	threat to national security	threat to domestic entrepreneurship	opportunity for economic development
Vision of the optimal balance of international trade	positive money balance	active trade balance	a significant share (priority of development) of high-tech exports in the structure of foreign trade
The way to achieve an optimal balance of international trade	monetarism: stimulating input and limiting output cash flow	protectionism: high rates of import customs duties (import restrictions)	strengthening the global digital competitiveness (development of high-tech exports)
The essence of import regulation	import restriction	import substitution	proactive import substitution in industry 4.0

Source: developed by the authors.

Under late mercantilism, globalization was interpreted as a threat to domestic entrepreneurship. The vision of an optimal balance of international trade assumed an active trade balance. The way to achieve it was protectionism: high rates of import customs duties (import restrictions). The essence of import regulation was import substitution.

In the context of industry 4.0, a new concept of international trade has emerged – neomercantilism 4.0 (Popkova et al., 2021). It assumes a fundamentally different interpretation of globalization – it is perceived no longer as a threat, but as an opportunity for economic development (Carrasco and Tovar-García, 2021). The vision of an optimal balance of international trade implies a significant share (priority of development) of high-tech exports in the structure of foreign trade (Wang et al., 2022). The way to achieve it is to strengthen the global digital competitiveness (development of high-tech exports) (Bala Subrahmanya, 2022).

That is, protectionism has been replaced by free trade, in which state regulation of the economy is aimed not at import, but at export. The essence of import regula tion is in a proactive import substitution in industry 4.0 - introducing innovations to gain unique competitive advantages, creating new high-tech markets, as well as establishing technological leadership (Sepehrdoust et al., 2021).

Thus, the literature review shows that the general issues of international trade have been studied in sufficient detail and reflected in a large number of published sources. Nevertheless, it remains unclear to what extent the existing approach to unlocking the export potential of high-tech enterprises corresponds to the concept of neomercantilism 4.0 - uncertainty on this issue is a gap in the literature that this article seeks to fill.

2.2. Determinants of high-tech export in the context of industry 4.0

Despite the general upward trend, international trade in a market economy develops cyclically. The growth of high-tech exports has a positive impact on the functioning and development of socio-economic systems. The decline in high-tech exports is a crisis of the digital economy, accompanied by a slowdown in the pace of scientific and technological progress. Therefore, the scientific study of the issues of forecasting and preventing the decline of high-tech exports is of high theoretical and practical importance. This raises the following research question. ***RQ$_1$**: What is the determinant of high-tech export?*

Industrial revolutions accelerated the pace of economic growth and determined its new drivers. The first two industrial revolutions contributed to the increase of production capacity in industry and provided primary industrialization. The phenomenon of the industrial boom was formed under their influence; its essence consists in the industrial growth of the economy. The third industrial revolution contributed to the formation of a post-industrial (service) economy, the growth of which was due to the service sector

Under the influence of the Fourth Industrial Revolution, secondary industrialization is taking place, high-tech economic growth acts as a new driver of economic development. Its essence lies in the use of high technology. The previously narrow industry specialization has been replaced by economic diversification – high-tech economic growth is achieved both in industry and in the service sector (Navarro Zapata et al., 2023; Popkova, 2019).

Thus, a series of industrial revolutions has established a clear relationship between the development of high-tech industries and economic growth (Ekanayake et al., 2023; Popkova and Sergi, 2022; Popkova, 2023). In this regard, the existing literature sources, such as El Ghak et al. (2021), Li et al. (2021), Löfsten et al. (2022), Sojoodi and Baghbanpour (2023) indicate economic growth as a determinant of high-tech export. That is, it is assumed that high-tech export is superimposed on the overall economic cycle. The economic recovery contributes to the growth of high-tech exports, and the economic crisis, accordingly, slows down high-tech exports.

However, from the standpoint of the proposed concept of neomercantilism 4.0, high-tech export depends on the success of proactive import substitution, that is, on digital competitiveness and, therefore, should not have a quantitative (from the standpoint of economic growth), but a qualitative dimension. Based on the works ofAbreo et al. (2021), Bustaman et al. (2022), Mamed'yarov (2021), Nouira and Saafi (2022), Wu and Hong (2023), , which note the important role of quality in the export of high-tech products, this article puts forward ***the hypothesis H_1*** *that quality 4.0 acts as a determinant of high-tech export*. In this regard, high-tech export is determined by its own economic cycle of industry 4.0.

To test the hypothesis put forward, the article analyzes the relationship of trends in high-tech export with the dynamics of economic growth, which makes it possible to identify whether the trends in high-tech export superimpose on the standard economic cycle or has its own cyclicity.

2.3. Critical analysis of the existing mechanism of quality management 4.0 using digital management information systems

The specifics of quality 4.0, as well as the issues of its measurement and achievement, have been thoroughly worked out and highlighted in the published works of Handayani et al. (2022), Matytsin and Rusakova (2021), Sharma (2023), Woźniak et al. (2022), Zimon et al. (2022). At the same time, the existing literature does not reveal the cause-and-effect relationships of the use of specific technologies for quality 4.0. This raises the following research question. ***RQ_2****: What should be the mechanism of quality management 4.0 in order to fully disclose the export potential of high-tech enterprises?*

The established approach to the disclosure of the export potential of high-tech enterprises, which is currently being implemented, is based on such a mechanism of quality management 4.0 as digital management information systems (Fig. 1).

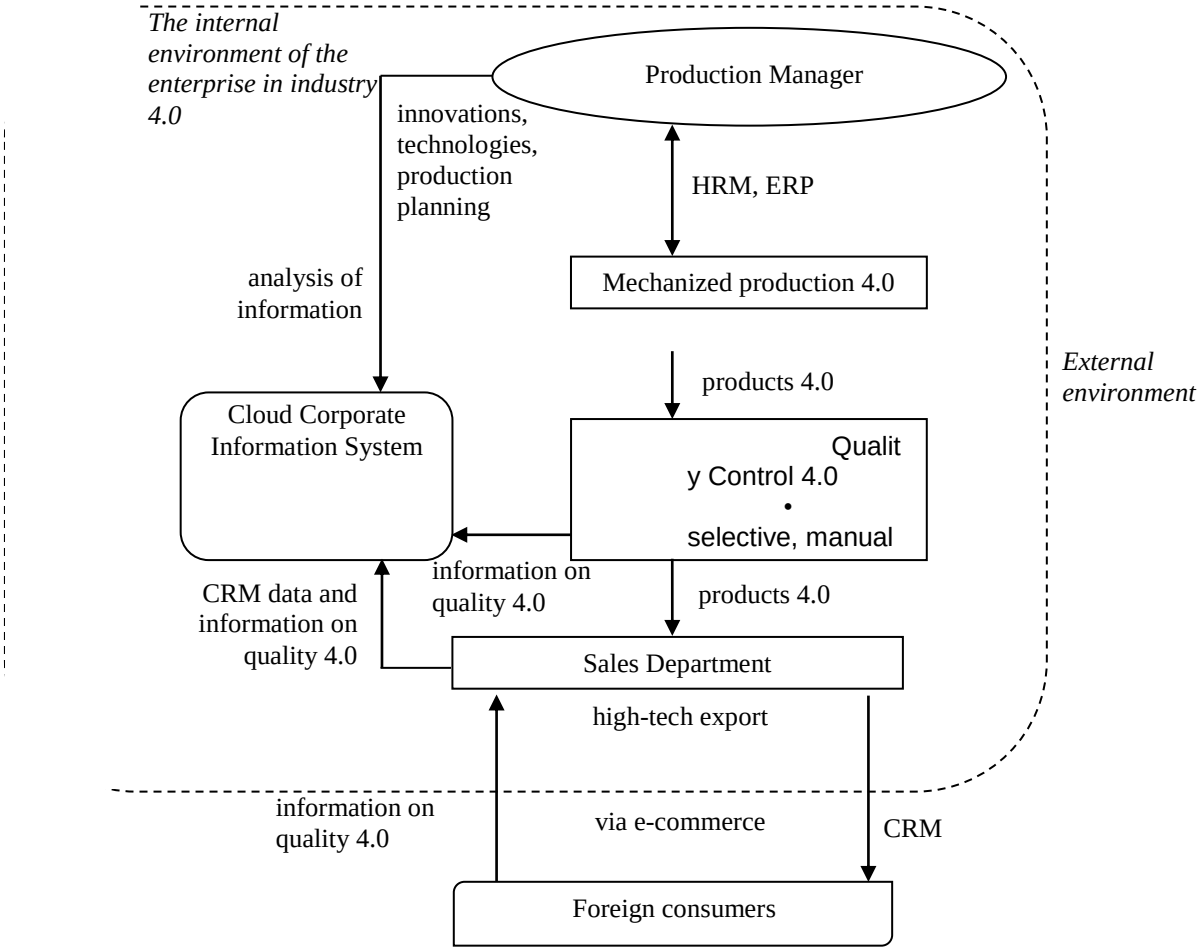

Figure 1. The existing mechanism of quality management 4.0 using digital management information systems
Source: developed by the authors.

The mechanism shown in Fig. 1 assumes that quality management 4.0 is carried out by a production manager who selects suitable innovations (Al-Shami et al., 2022), debugs technologies and plans production. Using HRM (Wang et al., 2022) and ERP (Kitsantas, 2022) technologies, he manages mechanized production 4.0, in which most production operations are carried out by employees using digital technologies and equipment. Quality control 4.0 is selective and manual, carried out using HRM and involves the transfer of information to a cloud-based corporate information system (Moudud-Ul-Huq et al., 2020).

The sales department carries out high-tech exports through e-commerce (Cassia and Magno, 2022) и CRM (Suoniemi et al., 2022). Foreign consumers transmit information about quality 4.0 to this department; this information is fragmentary and is manually transmitted to the cloud corporate information system. The production manager analyzes the information contained in this system and makes management decisions based on it. A critical analysis of the existing mechanism of quality management 4.0 has revealed a number of disadvantages of digital management information systems, including:

- the significant influence of the "human factor" on quality management 4.0;
- insufficiently complete and subjective quality control 4.0, which is not covered by automation and therefore accompanied by a high risk of delivery to the market of products of unfair quality (defective);
- lack of coordination of the corporate information system, which makes it difficult to process, analyze and consider data when making management decisions;
- imperfection of marketing communications due to insufficient concretization of consumer claims to quality 4.0 due to the lack of opportunities for reliable identification of each individual product;
- the insecurity of digital management information systems from cybernetic threats from the external (market) environment of the industry 4.0 enterprise, and therefore the insufficient stability and reliability of this system, as well as the high risk of loss of competitive advantages.

Industrial and manufacturing engineering 4.0 acts as an alternative to the described mechanism. The main technologies of quality management 4.0 in this alternative mechanism are Big Data (Del Vecchio et al. 2022), Internet of Things (IoT) (Haghnegahdar et al., 2022), artificial intelligence (AI) (Aminabadi et al., 2022), RFID (Naciri et al., 2023), cybersecurity (data encryption, biometrics) (Ribas Monteiro et al., 2023).
Some conceptual and applied issues, as well as some advantages of this mechanism are reflected in the available publications of Dafflon et al. (2021), Gupta et al. (2022), Parvanda and Kala (2023), Zhao et al. (2023). Based on this, ***the hypothesis H_2*** is put forward *that the mechanism of industrial and manufacturing engineering 4.0 allows improving quality 4.0 to a greater extent than the mechanism of digital management information systems.* To determine whether the disadvantages of the existing mechanism mentioned above are overcome in an alternative mechanism, this article compares the contribution of technologies of quality management 4.0 in digital management information systems (ERP, CRM, cloud services, electronic sales, innovation, HRM) with the contribution of technologies of industrial and manufacturing engineering 4.0 (Big Data, IoT, AI, RFID, cybersecurity) in high-tech export.

3. MATERIALS AND METHODOLOGY

To clarify the cause-and-effect relationships of the disclosure of the export potential of high-tech enterprises in the context of industry 4.0 through quality management, the following four tasks are set and consistently solved using appropriate methods in this article.

The first task is to study the dynamics of high-tech export, to determine its relationship with economic growth. Based on a complete sample of 266 countries, which are statistically recorded, the annual growth rate of high-tech exports (% of manufactured exports) (World Bank, 2023c) for 2007-2021 is determined using the trend analysis method. The correlation analysis method is used to identify the correlation coefficients of high-tech exports with GDP growth (annual %) (World Bank, 2023b) in each year of the specified time period. Statistical data are given in the appendix to this article: the sheet "Sample 1" of the Microsoft Excel file.

The second task is to compare alternative mechanisms of quality management 4.0 – digital management information systems and industrial and manufacturing engineering 4.0 – from the standpoint of their contribution to the disclosure of the export potential of high-tech enterprises. Based on statistical data from the National Research University Higher School of Economics (2023) on the sample of the top 20 digital economies that most actively use a set of quality management technologies 4.0, the article provides a correlation analysis of the relationship of high-tech exports with the use of various quality management technologies 4.0. Statistical data are given in the appendix to this article: the sheet "Sample 2" of the Microsoft Excel file.

Correlation coefficients are calculated separately for high-tech export of goods and services. The hypothesis H_1 will be considered proven if at least some correlation coefficients of high-tech export with the use of various technologies of quality management 4.0 exceed the

coefficient of its correlation with the rate of economic growth in 2021. This will mean that quality 4.0 determines high-tech export to a greater extent than economic growth.

The hypothesis H_2 will be considered proven if the arithmetic mean of the correlation coefficients of high-tech export with industrial and manufacturing engineering 4.0 technologies (Big Data, IoT, AI, RFID, cybersecurity) exceeds the arithmetic mean of the correlation coefficients of high-tech export with technologies of quality management 4.0 with the use of digital management information systems (ERP, CRM, cloud services, electronic sales, innovation, HRM). This will mean that the mechanism of industrial and manufacturing engineering 4.0 enables to improve quality 4.0 to a greater extent than the mechanism of digital management information systems.

In order to determine strict regularities using the regression analysis method, the authors determine the dependencies of high-tech export of goods and services (separately) on technologies of quality management 4.0, with which they have demonstrated the closest relationship (with which the correlation coefficients are the highest). The reliability of regression models is tested using correlation analysis, Fisher's F-test and Student's t-test.

The third task is to determine the prospect of revealing the export potential of high-tech enterprises in Russia while increasing quality through the improvement of industrial and manufacturing engineering 4.0. To do this, the maximum values among the top 20 digital economies that most actively use the set of technologies for quality management 4.0 are substituted into the obtained regression models. The trend analysis method is used to determine the increase in the obtained values of indicators compared to their values in Russia in 2021. The fourth task is to develop a mechanism for revealing the export potential of high-tech enterprises through quality management using industrial and manufacturing engineering 4.0. The mechanism reveals automation objects (business operations), the environment of quality management 4.0, as well as technological support for each of the areas of quality management 4.0 (planning, organization, control, promotion). Using the method of comparative analysis, the authors' mechanism is compared with the existing mechanism and the advantages of the new mechanism are substantiated.

4. RESULTS

4.1. Dynamics of high-tech exports and its relation to economic growth: the economic cycle of industry 4.0

The solution of the first task of the study, namely, to determine whether economic growth determines high-tech exports, the dynamics of high-tech exports has been studied and its relationship (correlation) with economic growth has been determined based on a complete sample of 266 countries, for which statistics were maintained (World Bank (2023b, 2023c) during 2007-2021. The arithmetic averages of high-tech exports and the growth rate of the global economy in 2007-2021 are calculated and presented in Fig. 2.

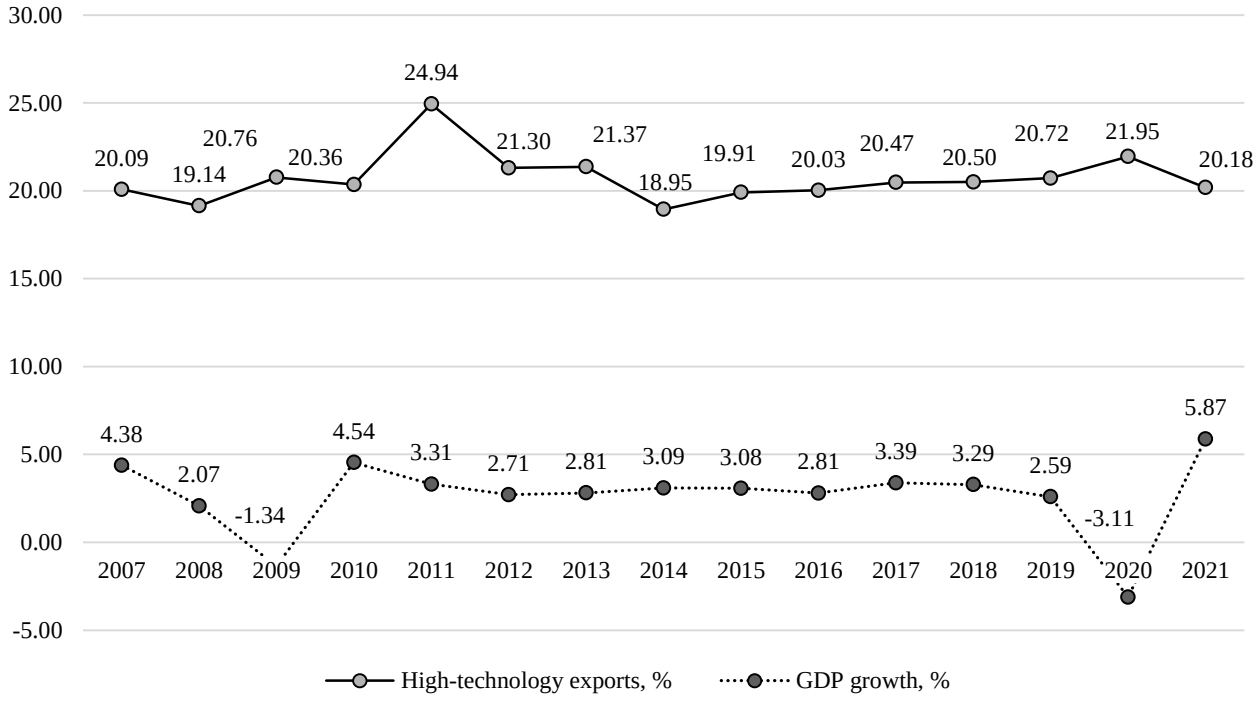

Figure 2. Arithmetic averages of high-tech exports and the growth rate of the global economy in 2007-2021, %
Source: calculated and constructed by the authors.

As can be seen from Fig. 2, there is a lack of visual connection between high-tech export trends and economic growth trends. So, for example, against the background of a decline in economic growth (-1.34%) in 2009, there was an increase in high-tech exports from 20.36% in 2010 to 24.94% in 2011. Similarly, amid a decline in economic growth (-3.11%) in 2009, there was an increase in exports of high-tech products from 20.72% in 2019 to 21.95% in 2020. At the same time, against the background of the bottom of high-tech exports in 2014 (18.95%), the economic growth rate increased from 2.81% in 2013 to 3.09% in 2014. To obtain more accurate evidence, it is advisable to refer to the results of trend analysis of high-tech export and correlation analysis of its relationship with economic growth in 2007-2021. (Fig. 3).

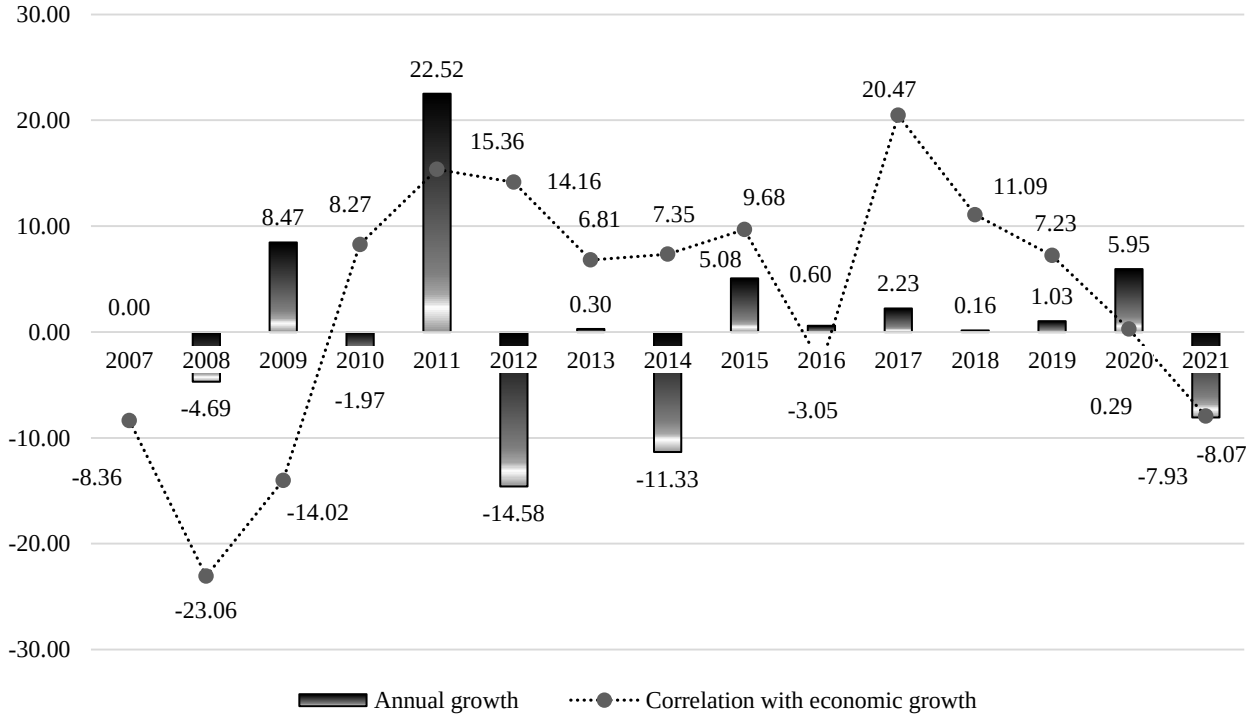

Figure 3. Trend analysis of high-tech exports and correlation analysis of the relationship of high-tech exports with economic growth in 2007-2021, %

Source: calculated and constructed by the authors.

As can be seen from Fig. 3, the peak of growth in high-tech exports occurred in 2011 (22.52%), and the bottom was in 2012 (-14.58%). In both of these periods, the correlation of high-tech export with economic growth was positive, but small (15.36% and 14.16%, respectively). In five of the fifteen calendar years considered, the correlation was negative and was -8.36% in 2007, -23.06% in 2008, -14.02% in 2009, -3.05% in 2016 and -7.93% in 2021. The maximum value of the correlation coefficient was observed in 2017, when it was 20.47%.

4.2. Disclosure of the export potential of high-tech enterprises through quality management 4.0: digital management information systems vs industrial and manufacturing engineering 4.0

To solve the second task of the study, aimed at determining to what extent quality 4.0 determines high-tech export, and which technologies play a key role in this, the authors compare alternative mechanisms of quality management 4.0 – digital management information systems and industrial and manufacturing engineering 4.0 – from the standpoint of their contribution to the disclosure of the export potential of high-tech enterprises. Based on a sample of the top 20 digital economies that most actively use a set of technologies for quality management 4.0, a correlation analysis of the relationship of high-tech export with the use of various technologies for quality management 4.0 was carried out (Fig. 4).

As shown in Fig. 4, exports of high-tech goods has demonstrated a positive relationship with the use of such technologies of quality management 4.0 as RFID technologies (64.09%), Big Data (8.27%) and ERP technologies (29.68%). Exports of high-tech services demonstrated a positive relationship with the use of such technologies of quality management 4.0 as biometrics (51.37%), tools for data encryption (28.68%), AI (10.09%), IoT (21.79%), Big Data (48.35%), HRM (ICT specialists: 32.29%), innovation activity (16.70%), cloud services (22%) and CRM (15.48%). The average correlation of high-tech exports with alternative mechanisms of quality management 4.0 is calculated in Fig. 5.

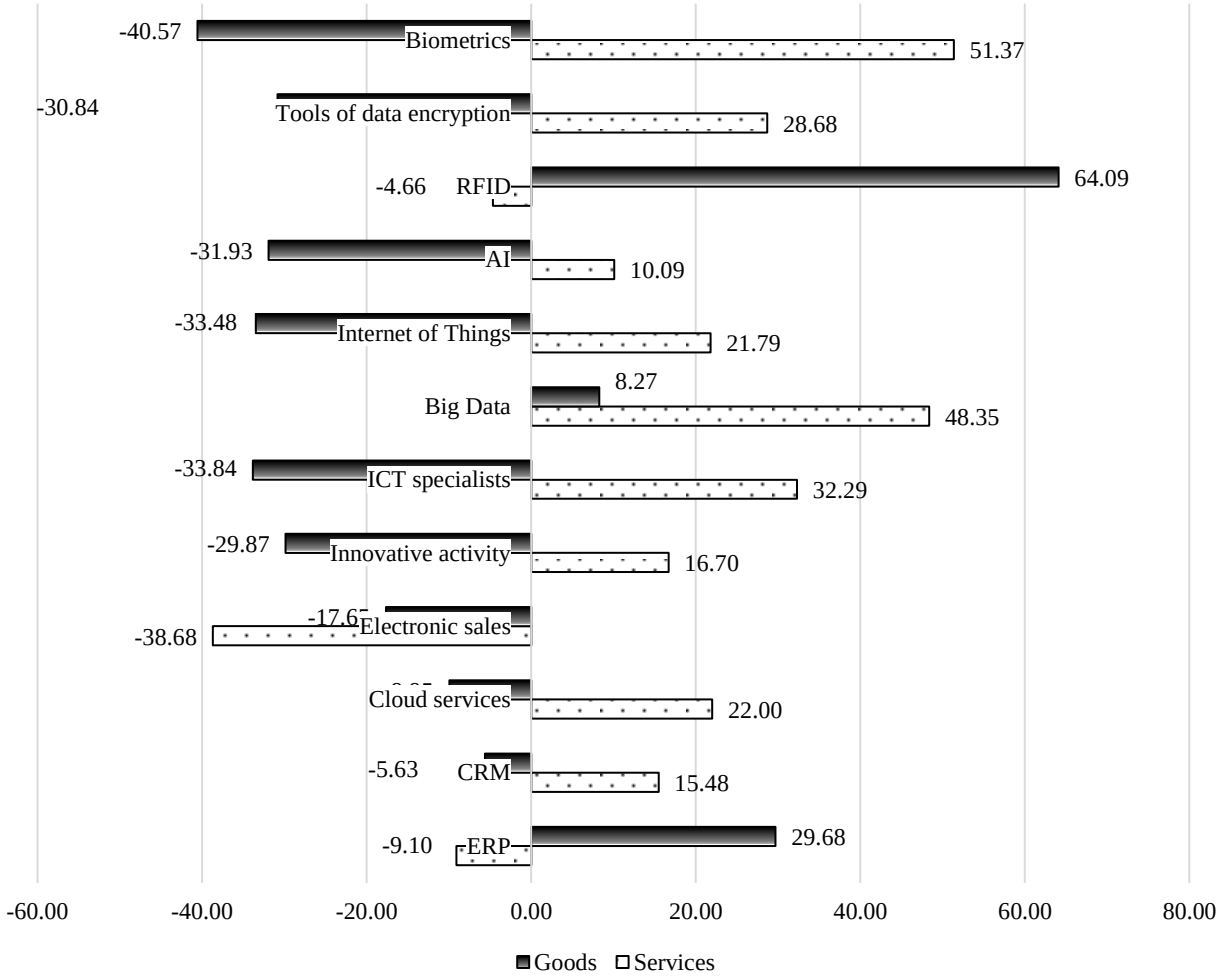

Figure 4. Correlation analysis of the relationship of high-tech exports using various technologies of quality management 4.0, %

Source: calculated and constructed by the authors

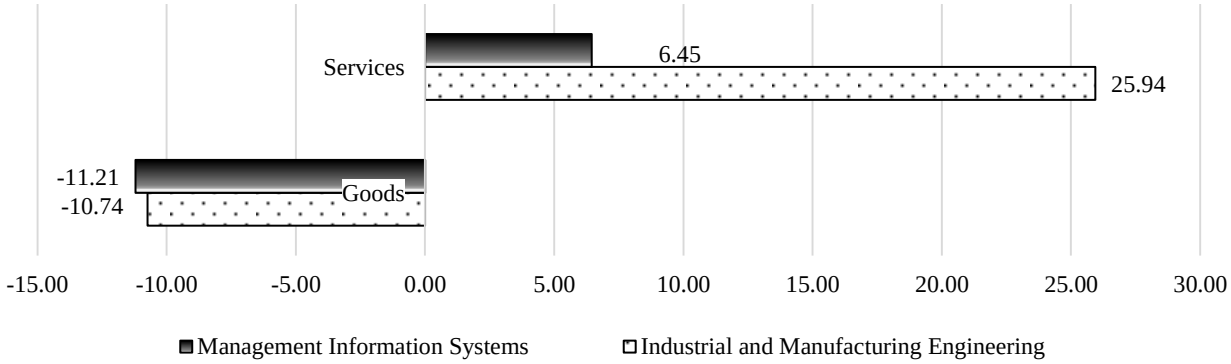

Figure 5. Average correlation of high-tech exports with alternative mechanisms of quality management 4.0, %

Source: calculated and constructed by the authors.

As shown in Figure 5, the average correlation of high-tech exports by mechanisms of quality management 4.0 with industrial and manufacturing engineering 4.0 is higher (25.94% with services and -10.74% with goods) than with digital management information systems (6.45% with services and -11.21% with goods).

To identify the precise regularities, the authors used the regression analysis method to determine the dependence of exports of high-tech goods (Table. 2) and services (Table 3) from the technologies of quality management 4.0, with which they have demonstrated the closest relationship (with which the correlation coefficients are the highest).

Table 2. Regression analysis of the dependence of the quality of exported goods in industry 4.0 on the use of RFID technologies

Regression Statistics						
Multiple R	0.6409					
R-Square	0.4107					
Adjusted R-Square	0.3780					
Standard Error	28063.2945					
Observations	20					
ANOVA						
	Df.	SS	MS	F	Significance F	
Regression	1	9881090244.44	9881090244.44	12.5466	0.0023	
Residual	18	14175873008.50	787548500.47			
Total	19	24056963252.95				
Parameters of the regression model						
	Coeffi-cients	Standard Error	t-Stat	P-Value	Lower 95%	Upper 95%
Y-intercept	-4943.1143	10641.3069	-0.4645	0.6478	-27299.67	17413.44
RFID	2341.6665	661.0910	3.5421	0.0023	952.77	3730.567

Source: calculated and compiled by the authors.

Based on the results from Table 2, the following regression equation is obtained:

$$Exp_{htg}=-4943.1143+2341.6665RFID, \quad (1)$$

where Exp_{htg} – exports of high-tech goods, %;
RFID – the share of organizations using RFID technologies, %.

Equation (1) indicates that the exports of high-tech goods grow by 2341.6665% with an increase of 1% in the share of organizations using RFID technologies. The correlation of the quality of exported goods in industry 4.0 with the use of RFID technologies is 64.09%. Fischer's F-test and Student's t-test have been passed at a significance level of 0.01.

Table 3. Regression analysis of the dependence of the quality of exported services in industry 4.0 on the use of Big Data and biometric technologies

Regression Statistics						
Multiple R	0.6471					
R-Square	0.4187					
Adjusted R-Square	0.3504					
Standard Error	26194.9118					
Observations	20					
ANOVA						
	df	SS	MS	F	Significance F	
Regression	2	8403636642.73	4201818321.36	6.1236	0.0099	
Residual	17	11664947858.07	686173403.42			
Total	19	20068584500.80				
Parameters of the regression model						
	Coeffi-cients	Standard Error	t-Stat	P-Value	Lower 95%	Upper 95%
Y-intercept	-22974.53	13057.11	-1.7595	0.0965	-50522.64	4573.57
Big Data	1842.00	865.59	2.1280	0.0483	15.78	3668.23
Biometrics	2203.62	947.40	2.3260	0.0326	204.78	4202.46

Source: calculated and compiled by the authors.

Based on the results from Table 3, the following regression equation is obtained:

$$Exp_{hts}=-22974.53+1842.00BD+2203.62BM \quad (2)$$

where Exp_{hts} – exports of high-tech services, %;
BD – the share of organizations using Big Data technologies, %.
BM – the share of organizations using biometric technologies, %.

Equation (2) indicates that the exports of high-tech services rise by 1,842.00% with an increase of 1% in the share of organizations using Big Data technologies The exports of high-tech services grow by 2203.62% with an increase of 1% in the share of organizations using biometric technologies. The correlation of the quality of exported services in industry 4.0 with the use of RFID technologies was 64.71%. Fischer's F-test and Student's t-test have been passed at a significance level of 0.01.

Thus, the results obtained indicate that many correlation coefficients of high-tech exports using various technologies of quality management 4.0 (for example, the correlation of exports of high-tech services with biometrics was 51.37%, the correlation of exports of high-tech goods with RFID technologies was 64.09%) exceed the correlation coefficient of high-tech exports with the rate of economic growth in 2021 (-7.93%). This makes it possible to conclude that quality 4.0 determines high-tech export to a greater extent than economic growth, and proves the hypothesis H_1.

The results also indicate that the arithmetic mean of the correlation coefficients of high-tech exports with technologies of industrial and manufacturing engineering 4.0 (Big Data, IoT, AI, RFID, cybersecurity: on average for goods and services: 7.60%) exceed the arithmetic mean of the correlation coefficients of high-tech exports with technologies of quality management 4.0 at digital management information systems (ERP, CRM, cloud services, electronic sales, innovation, HRM: on average for goods and services: -2.38%). This leads to the conclusion that the mechanism of industrial and manufacturing engineering 4.0 improves quality 4.0 to a greater extent than the mechanism of digital management information systems, and proves the hypothesis H_2.

4.3. The prospect of revealing the export potential of high-tech enterprises in Russia while increasing quality through the improvement of industrial and manufacturing engineering 4.0

To solve the third task, which is to determine the prospects for revealing the export potential of high-tech enterprises in Russia while increasing quality through the improvement of industrial and manufacturing engineering 4.0, the maximum values among the top 20 digital economies that most actively use the set of technologies for quality management 4.0 are substituted in the obtained regression models (1) and (2). Using the trend analysis method, the authors determine the increase in the obtained values of indicators compared to their values in Russia in 2021 (Fig. 6).

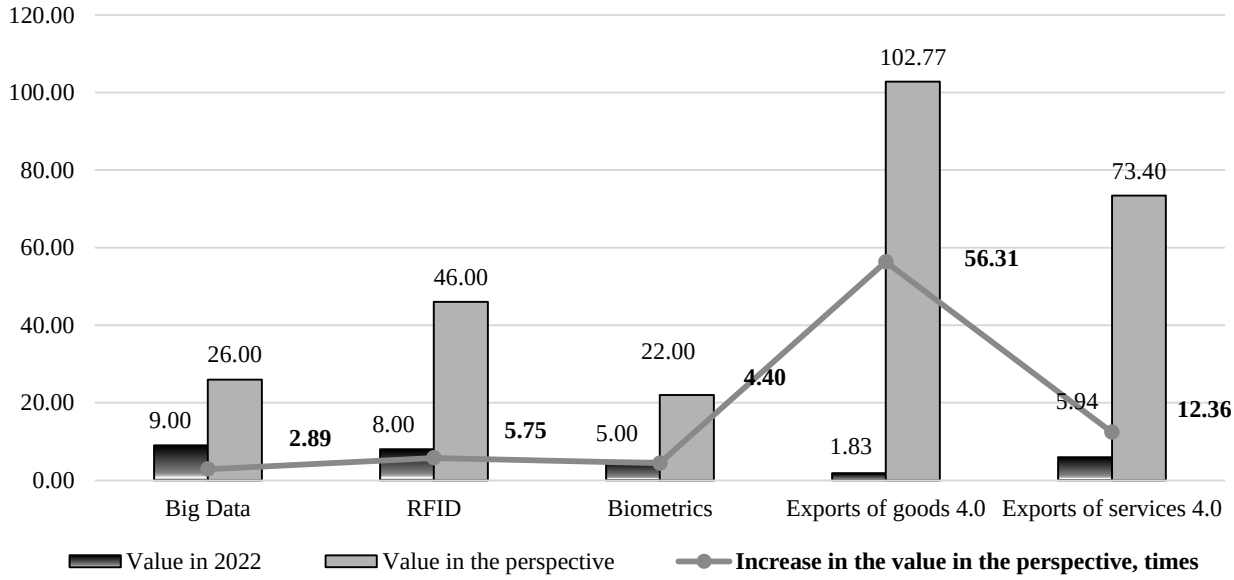

Figure 6. The prospect of revealing the export potential of high-tech enterprises in Russia while increasing quality through the improvement of industrial and manufacturing engineering 4.0

Source: calculated and compiled by the authors.

The perspective shown in Fig. 6 indicates that exports of high-tech goods in Russia will increase by 56.31% (from $1.83 billion in 2021 to $102.77 billion), and exports of high-tech services will increase by 12.36% (from $5.94 billion in 2021 to $73.40 billion) with the growth of share of Russian organizations using Big Data by 2.89% (from 9% in 2021 to 26%), with the growth of the share of Russian organizations using RFID technologies by 5.75% (from 8% in 2021 up to 46%), as well as with the increase in the share of Russian organizations using biometric technologies by 4.40% (from 5% in 2021 to 22%).

4.4. The mechanism for revealing the export potential of high-tech enterprises through quality management using industrial and manufacturing engineering 4.0

As part of the solution of the fourth research task for scientific and methodological support of the fullest disclosure of the export potential of high-tech enterprises, the authors have developed a quality management mechanism using industrial and manufacturing engineering 4.0 (Fig. 7).

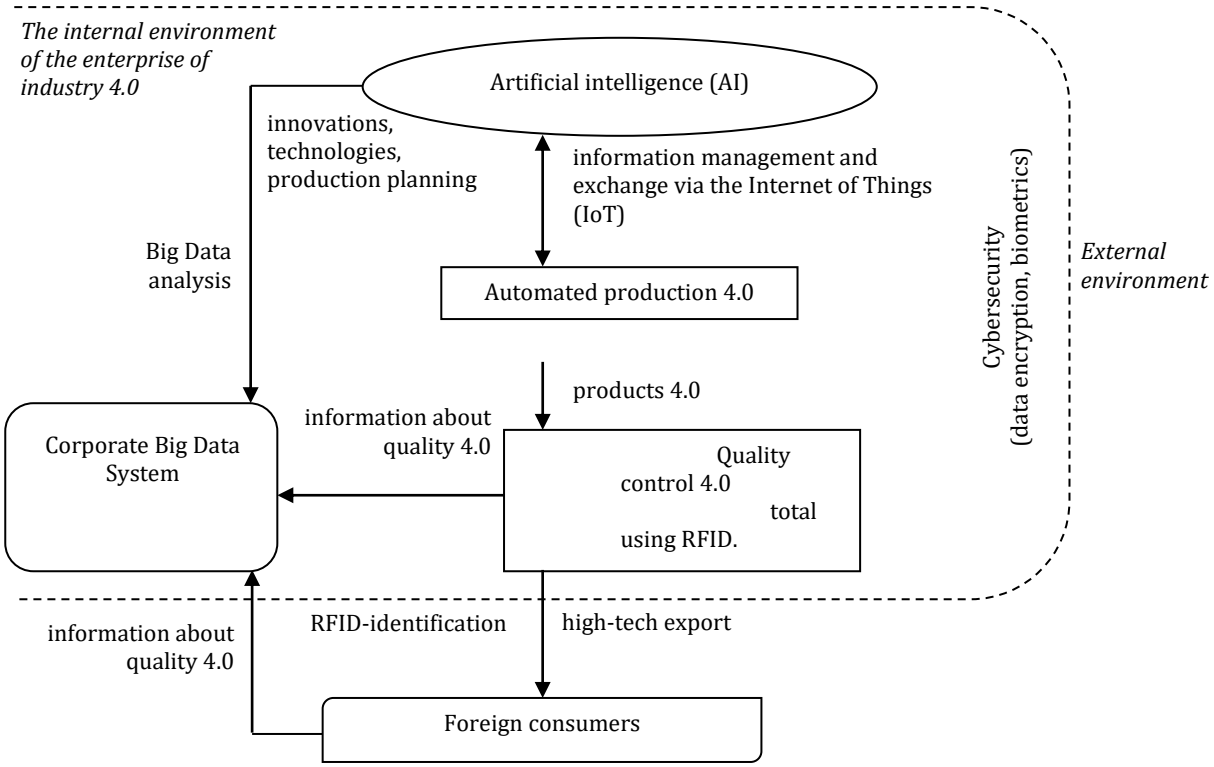

Figure 7. Mechanism for revealing the export potential of high-tech enterprises through quality management using industrial and manufacturing engineering 4.0
Source: developed by the authors.

The mechanism shown in Fig.7 assumes that quality management 4.0 is carried out by artificial intelligence (AI), which selects suitable innovations, debugs technologies and plans production. With the help of the Internet of Things (IoT), it manages and exchanges information with automated (for example, robotic) production 4.0. Quality control 4.0 is excercised using RFID technologies and involves the transfer of information to the corporate Big Data system.

High-tech export is carried out through e-commerce, but it is fully automated. With the help of chatbots and AI consultants, foreign consumers transmit information about the quality of 4.0, which is refined and detailed using RFID technologies, to the corporate Big Data system. AI analyzes the information contained in this system and makes management decisions based on it. Using the method of comparative analysis, the authors' mechanism is compared with the existing mechanism and the advantages of the new mechanism are justified (Table 4).

Table 4. The opposition of alternative mechanisms of quality management 4.0

Areas of difference of mechanisms		**Mechanism of quality management 4.0**		
		Digital management information systems	**Industrial and manufacturing engineering 4.0**	
Essence	Automation objects (business operations)	only management (non-production) operations	both managerial and productive operations	
	Environment of quality management 4.0	social environment with the use of automation tools	technological environment: cyber-physical system	
Technological support for the areas of quality management 4.0	Planning for quality 4.0: innovation management and debugging of technologies	innovations, cloud services	artificial intelligence (AI)	cybersecurity technologies (data encryption, biometrics)
	Organization: production management 4.0	HRM, ERP	Internet of Things (IoT)	
	Control: assessment of product compliance with standards of quality 4.0	HRM	RFID-technologies	
	Promotion: marketing management and sales of products 4.0	CRM, electronic sales	Big Data	

Source: developed by the authors.

As shown in Table 4, the objects of automation in digital management information systems are only managerial (unproductive) operations, and the objects of automation in industrial and manufacturing engineering 4.0 are both managerial and productive operations. Quality management 4.0 with digital management information systems is carried out in a social environment using automation tools, and quality management 4.0 with industrial and manufacturing engineering 4.0 takes place in a technological environment: a cyber-physical system. The comparative analysis has revealed the advantages of industrial and manufacturing engineering 4.0, including:

- overcoming the "human factor" in quality management 4.0, which is carried out by AI;
- complete and objective quality control 4.0 due to automation;
- a high degree of coherence of the corporate information system (thanks to the use of big data technologies), which simplifies the processing, analysis and accounting of information when making management decisions;
- improved marketing communications by concretizing consumers claims to quality 4.0 with the help of reliable RFID-identification of each individual product;
- the security of the corporate information system from cybernetic threats emanating from the external (market) environment of the enterprise of industry 4.0, and therefore the stability and reliability of this system, the sustainbility of competitive advantages.

5. DISCUSSION

The contribution of the article to the literature is the development of scientific provisions of the Theory of international trade through the development of the concept of neomercantilism 4.0 and its corresponding approach to the disclosure of the export potential of high-tech enterprises. The new approach is reflected in contrast with the existing approach in Table 5.

Table 5. The opposition of alternative approaches to the disclosure of the export potential of high-tech enterprises

Areas of difference in approaches	**The approach to the disclosure of the export potential of high-tech enterprises**	
	The existing approach	**The new approach**
The determinant of high-tech export	economic growth (high-tech export is superimposed on the overall economic cycle) (El Ghak et al., 2021; Li et al., 2021; Löfsten et al., 2022; Sojoodi and Baghbanpour, 2023)	quality 4.0 (high-tech export is determined by the own economic cycle of industry 4.0)
The mechanism of quality management 4.0	digital management information systems (Handayani et al., 2022; Matytsin and Rusakova, 2021; Sharma, 2023; Woźniak et al., 2022; Zimon et al., 2022).	industrial and manufacturing engineering 4.0
Technologies of quality management 4.0	ERP, CRM, cloud services, electronic sales, innovation, HRM (Al-Shami et al., 2022; Cassia and Magno, 2022; Kitsantas, 2022; Moudud-Ul-Huq et al., 2020; Suoniemi et al., 2022; Wang et al., 2022)	Big Data, Internet of Things (IoT), Artificial intelligence (AI), RFID, cybersecurity (data encryption, biometrics)

Source: developed by the authors.

As shown in Table 5, unlike El Ghak et al. (2021), Li et al. (2021), Löfsten et al. (2022), Sojoodi and Baghbanpour (2023), in the new approach, the determinant of high-tech export is not economic growth (high-tech exports are superimposed on the overall economic cycle), but quality 4.0: high-tech export is determined by the own economic cycle of industry 4.0 (the hypothesis H_1 has been proven).

Unlike such authors as Handayani et al. (2022) Matytsin and Rusakova (2021), Sharma (2023), Woźniak et al. (2022), Zimon et al. (2022), in the new approach, the mechanism of quality management 4.0 is based not on digital management information systems, but on industrial and manufacturing engineering 4.0 (the hypothesis H_2 has been proven). In contrast to the position of such authors as Al-Shami et al.,(2022), Cassia and Magno (2022), Kitsantas (2022), Moudud-Ul-Huq et al. (2020), Suoniemi et al. (2022), Wang et al. (2022), the authors' approach involves the use of new technologies of quality management 4.0 in each area of this management.

In the field of planning for quality 4.0, innovation management and debugging of technologies are carried out not with the help of innovation and cloud services, but with the help of artificial intelligence (AI). The organization of production management 4.0 is implemented not with the help of HRM and ERP, but with the help of the Internet of Things (IoT). In the field of control, the assessment of product compliance with standards of quality 4.0 is performed not with the help of HRM, but with the help of RFID technologies. In the field of promotion, marketing management and sales of products 4.0, electronic sales are carried out not with the help of CRM, but with the help of Big Data. In addition, in the new approach, cybersecurity technologies (data encryption, biometrics) are used for the first time in all areas.

6. CONCLUSION

Thus, the main conclusion based on the results of the study is that the full disclosure of the export potential of high-tech enterprises requires the improvement of

practice of quality management 4.0, for which the transition from digital management information systems to industrial and manufacturing engineering 4.0 is recommended. In particular, the following main results are obtained:

1) The export dynamics of high-tech products has been studied, which allowed to substantiate its weak relationship with economic growth (correlation: -7.93% in 2021), but a strong relationship with the quality of 4.0, which averaged 2.61% for goods and services in 2021, and was very high for certain technologies (for example, the correlation of exports of high-tech services with biometrics was 51.37%, the correlation of exports of high-tech goods with RFID technologies was 64.09%);
2) The alternative mechanisms of quality management 4.0 have been compared and based on this it has been proved that industrial and manufacturing engineering 4.0 (average correlation: 7.60%) makes a much greater contribution to the disclosure of the export potential of high-tech enterprises than digital management information systems (average correlation: -2.38%).

Based on the results obtained, the authors have developed a new approach to the disclosure of the export potential of high-tech enterprises, the features of which are: 1) a new determinant: quality 4.0; 2) a new mechanism for quality management: industrial and manufacturing engineering 4.0; 3) new technological support for each of the areas of quality management 4.0 (planning, organization, control, promotion) using Big Data technologies, the Internet of Things (IoT), artificial intelligence (AI), RFID and cybersecurity technologies (data encryption, biometrics).

The new approach eliminates the disadvantages of the existing approach and has a number of advantages, including overcoming the "human factor" in quality management 4.0, full and objective quality control 4.0, consistency and security of the corporate information system from cybernetic threats, improved marketing communications. Due to the mentioned advantages, the authors' approach provides a more complete disclosure of the export potential of high-tech enterprises through quality management using industrial and manufacturing engineering 4.0.

The theoretical significance lies in the fact that the scientific concept of neomercantilism 4.0 has been developed to explain the essence of international trade in the context of industry 4.0; to explain the dynamics of change and high-precision forecasting of high-tech exports, the economic cycle of industry 4.0 has been proposed and its difference from the usual economic cycle has been substantiated.

The practical significance is due to the fact that the developed new approach to the disclosure of the export potential of high-tech enterprises describes more objectively and makes it possible to predict the dynamics of changes in high-tech exports with greater accuracy, and also provides wider use of the advanced capabilities of industry 4.0 to modernize the development of high-tech industries and strengthen their global digital competitiveness.

The managerial significance is expressed in the fact that the transition to the new mechanism of quality management 4.0 recommended in this article opens up a broader prospect for the disclosure of the export potential of high-tech enterprises. This perspective is demonstrated by the example of Russia: it has been shown that quality increase through the improvement of industrial and manufacturing engineering 4.0 (growth in the use of Big Data by 2.89%, RFID technology by 5.75% and biometric technology by 4.40%) will ensure an increase in exports of high-tech goods in Russia by 56.31% and exports of high-tech services by 12.36%.
The social significance of the results of this article is that the developed new approach to the disclosure of the export potential of high-tech enterprises will help to overcome the global digital divide. Consequently, the authors' approach will contribute to reducing the inequality of the countries of the world in the context of the Fourth Industrial Revolution, comprehensively implementing such Sustainable Development Goals (SDGs) as SDG9 and SDG10. Nevertheless, the approach is of a framework nature (which ensures its universality, but, at the same time, is its limitation) and needs to be adapted to the specifics of each individual digital economy – future research should be devoted to this in the continuation of this article.

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