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THE ROLE OF KNOWLEDGE AND TECHNOLOGY MANAGEMENT IN IMPROVING THE QUALITY OF BUSINESS 4.0 PRODUCTS

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Abstract: *The purpose of the article is to determine the role of knowledge and technology management in improving the quality of business 4.0 products. Based on statistics for 63 countries in 2022, as well as knowledge and technology, an econometric model of product quality management in business 4.0 has been constructed. The model revealed, along with the contradictory influence of knowledge on the quality of business 4.0 products, a reliable and consistent pattern of systematic growth in the quality of business 4.0 products as industrial designs by origin, as well as the growth of production and export complexity increase. A scenario analysis of the prospects for improving product quality in business 4.0 depending on knowledge and technology management was conducted. The author's forecast for the "Decade of Action" (until 2030) showed that the most promising and preferred of the alternatives considered is the scenario of the development of technically complex products with advanced industrial design in business 4.0. The main conclusion is that the key factor of a new type of business – business 4.0, which was formed under the influence of the Fourth Industrial Revolution, is technology, while human resources have receded into the background. The theoretical significance of the results is due to the fact that they revealed the prospects for improving the competitiveness of business 4.0, for which it is recommended to reduce the share of human-intensive economic processes and proportionally increase the share of automated processes. The originality of the research lies in reconsideration of the importance of such factors of production as human and technological resources in the conditions of the Fourth Industrial Revolution, taking into account the little-studied experience of a new type of business - business 4.0. Management implications consist in the fact that the article offers an innovative approach to corporate social responsibility, whose efforts are proposed to focus on improving product quality in business 4.0. The author's recommendations contribute to unlocking the potential for improving product quality, as well as increasing the effectiveness of quality management in business 4.0.*

Keywords: *quality, knowledge management (HRM), technology management, quality improvement, business 4.0 products, quality management.*

1. Introduction

Quality largely determines the competitiveness of products. Product quality is always the primary basis of consumer decisions, while price is secondary. In a

progressive society, shopping decisions are in most cases rational, which significantly limits the possibilities of marketing in sales promotion. This is explained by the fact that low-quality products are unattractive to consumers even at a low price because they

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do not satisfy or do not fully satisfy their needs, that is, they are useless (Arsovski 2023).

Marketing tools, including advertising, packaging, promotions and discounts, demonstrated high efficiency at the initial stages of the formation of capitalism due to their novelty. In the conditions of modern capitalism, the effectiveness of marketing has significantly decreased due to the great shopping experience under the strong influence of marketing accumulated by consumers. This means that it is the quality of products that mainly determines its market success, while price and marketing can only reinforce it (Arsovski, Arosvski & Stefanovic 2023).

In this regard, quality management aimed at further improvement of its level is a key management process of modern business. Although the totality of factors of production is important, the ratio of the significance of factors of production for product quality has historically changed under the influence of scientific and technological progress. In the conditions of the agrarian economy, land was a system-forming factor of production, which was crucial for the quality of products.

The first two industrial revolutions contributed to the formation of an industrial economy in which high-precision conveyor production provided not only “economies of scale”, but also a guarantee of high quality products. Therefore, it has displaced manual labor from most production processes. At that time capital – financial resources, technology and equipment – was crucial for the quality of products.

After the Third Industrial Revolution, the knowledge economy and information society were formed, in which the knowledge intensity of economic processes significantly increased (Aparicio et al., 2023; Koster, 2023; Li et al., 2023; Yu et al., 2023). The popularity of eco-friendly (environmentally friendly) business has increased, and although the business as a whole did not

have a strict industry specialization, most of the “green” jobs were created in the service sector, which received a new impetus for its development (Erđiaw-Kwasie et al., 2023; Feng, 2023; UI-Durar et al. al., 2023). In order to attract the best human resources, the business needed to gain a reputation as a responsible employer.

To do this, the business showed high corporate social responsibility, which has become one of the components of product quality that consumers take into account when making purchasing decisions. In the knowledge economy, labor embodying human resources was a key factor in production determining the quality of products.

The Fourth Industrial Revolution brought radical changes to the organization of modern economic systems. Neo-industrialization took place, during which industry 4.0 was formed (Gamalie et al. 2023). High-tech industrial production - business 4.0 – became the driver of economic growth. The problem lies in the uncertainty of how to manage product quality in business 4.0.

On the one hand, business 4.0 is characterized by high innovation activity, and its production processes involve the constant introduction and active use of advanced technologies. In this regard, the knowledge intensity of business processes is high: business 4.0 requires highly qualified personnel who are capable and ready to master breakthrough technologies, their application in professional activities, lifelong learning, creative labor, work in innovative teams and high innovation activity - both individual and collective.

On the other hand, the activity of business 4.0 involves high automation, not only of production, but also of distribution and management business processes. While both human and technological resources are irreplaceable and critically important for the functioning and development of business 4.0, it is unknown what contribution these

types of resources make to the quality of business 4.0 products. This is a gap in the literature.

The need to fill the identified gap is explained by the fact that the uncertainty of the value of human and technological resources prevents the full realization of their potential to improve product quality and reduces the effectiveness of quality management in business 4.0. In attempting to fill the identified gap in the literature, this article aims to determine the role of knowledge and technology management in improving the quality of business 4.0 products.

The originality of the research conducted in this article lies in the fact that it rethinks the importance of such factors of production as human and technological resources in the conditions of the Fourth Industrial Revolution, taking into account the little-studied experience of a new type of business - business 4.0. Due to this, the article reveals a new look at corporate social responsibility, justifying its contradiction in the activities of business 4.0, which is forced to balance between responsibility to employees and responsibility to consumers.

The article suggests an innovative approach to corporate social responsibility, whose efforts are proposed to focus on improving product quality in the context of business 4.0. In this regard, the author's approach is based on considering responsibility to consumers as primary compared to the responsibility of business 4.0 to employees. This makes it possible to increase the efficiency of quality management in business 4.0, as well as redirect the released human resources to alternative, more knowledge-intensive economic processes.

The goal defined the logic and structure of the article, in which the introduction is followed by a literary review. It describes the theoretical basis of the study and forms its conceptual apparatus, analyzes the identified gaps, raises a research question and hypothesis. Then the materials

(empirical base) and methodology of the study are described.

Further, in the results section, the following two tasks of this study are consistently solved: 1) to create an econometric model of product quality management in business 4.0 based on knowledge and technology; 2) to identify alternative scenarios for improving product quality in business 4.0 depending on knowledge and technology management. In conclusion, the obtained results are compared with the literature. In this section, conclusions are drawn, their significance and limitations are noted, and prospects for further scientific research are also outlined.

2. Literature Review

2.1 Theory

The theoretical basis of this research is the concept of product quality management in business. In their work, Zaid and Sleimi (2023) justified the significant impact of total quality management on business sustainability, and they also identified the mediating role of “green” supply chain management practices to improve product quality in business. Wang et al. (2021) have developed an innovative business model of quality management taking into account the product lifecycle based on the Internet of Things.

In turn, Putra et al. (2022), using the example of business in FinTech, proved the important contribution of quality management to the manifestation of business ethics, operational efficiency and business sustainability. To improve the quality of products in FinTech, these authors suggested paying attention to the question of cyber risk management. Švikruhová et al. (2021) proved the important contribution of quality management systems to ensuring high business efficiency.

The object of study in this article is business 4.0, which is understood as a business specializing in high-tech industries in the

context of industry 4.0 based on advanced technologies and automation tools. Specific issues of product quality management in business 4.0 are disclosed in the available following literature.

Zimon et al. (2022) justified the necessity to integrate product quality management into the supply chain in the era of industry 4.0. Karanina et al. (2022) proved the significant contribution of quality management in industry 4.0 to improving economic security and sustainable business development in the post-crisis period.

Rey Sánchez et al. (2022) substantiated the increased importance of quality management for the business of industry 4.0 due to the high-tech nature of its products. This was also proved by Nguyen et al. (2021) in their work justifying the increased influence of quality management on the business efficiency of manufacturing firms in industry 4.0. A significant number of the above publications allows us to determine the degree of elaboration of the problem of this study as high, which indicates its reliable theoretical basis.

2.2 Gap analysis, research question and hypothesis

The conducted literature review revealed a high degree of elaboration of quality management issues in business, but insufficient knowledge of the experience and features of this management in the practice of business 4.0. The available works disclose the essence and specifics of the quality of business 4.0 products, which simultaneously meets both the requirements of high technologies and the international standard ISO 9001 (Canbay and Akman, 2023; Maganga and Taifa, 2023; Saihi et al., 2023). At the same time, the role of production factors, in particular, human and technological resources, in shaping the quality of business 4.0 products is poorly studied and uncertain, which acts as a gap in the literature.

In order to fully unlock the potential of business 4.0 development and improve the quality of its products, this article attempts to fill the identified gap in the literature and find an answer to the following research question. RQ: What role does knowledge and technology play to improve the quality of business 4.0 products? The economic meaning of the RQ is to figure out how to manage product quality in business 4.0 activities – with a focus on knowledge or technology.

In the available literature, it is widely believed that in the conditions of industry 4.0, knowledge still plays a key role in improving the quality of products in business (as well as after the Third Industrial Revolution before the onset of the Fourth Industrial Revolution). Thus, Gharieb (2022), Lin et al. (2023), Yan et al. (2023) consider human resources, i.e. knowledge as a key factor of production that determines the quality of products. According to the works of Balouei Jamkhaneh et al. (2022), Khmour et al. (2021), the role of human resources in product quality management is to design and manufacture products in knowledge-intensive workplaces.

As noted in the works of Al-Dmour et al. (2021), Farida et al. (2021), Gambi et al. (2022), the mechanism of product quality management is human resource management (HRM). Albloushi et al. (2023), Yan et al. (2023) see the optimal way to improve the quality of products through the individualization of products and a creative approach to its production. According to Dwidienawati et al. (2022), Ladogina et al. (2022), the essence of the approach to corporate social responsibility is the priority of responsibility to employees, which is both a component of quality and a factor that strengthens customer loyalty. At the same time, responsibility to consumers is achieved including through responsibility to employees.

Nevertheless, despite a significant number of

published works on this topic, the scientific argumentation of the contribution of knowledge and technology to ensure the quality of business 4.0 products is incomplete and not strong enough, which leaves the question (RQ) open. In contrast to the above literature Thach et al. (2021), which noted the increased importance of technology under the influence of the Fourth Industrial Revolution, this article puts forward hypothesis H that technology plays a more important role than knowledge in improving the quality of business 4.0 products. To test this hypothesis, the article performs economic and mathematical modeling of the impact of knowledge and technology on product quality in business 4.0.

3. Materials and methodology

The methodology of testing the hypothesis is based on the use of economic and mathematical apparatus. The information and empirical base of this study is the WIPO’s statistical data for 2022 (2023) as one of the most authoritative and reliable sources of international statistics on the topic of knowledge management, innovation and technology in modern business in the digital economy and industry 4.0.

To achieve this goal, the article sets and consistently solves the following three research tasks. The first task is to create an econometric model of product quality management in business 4.0 based on

knowledge and technology. The following control variables are used in the study. The resulting variables that allow quantifying the quality of business 4.0 products are the following:

- ISO 9001 quality certificates/bn PPP\$ GDP ($Q_{b4.0(1)}$);
- High-tech manufacturing, % ($Q_{b4.0(2)}$).

The following are the factor variables characterizing knowledge management in business 4.0:

- Knowledge-intensive employment, % ($K_{b4.0(1)}$);
- Research talent, % in businesses ($K_{b4.0(2)}$).

The factor variables characterizing technology management in business 4.0 are the following:

- Industrial designs by origin/bn PPP\$ GDP ($T_{b4.0(1)}$);
- Production and export complexity ($T_{b4.0(2)}$).

The values of all variables are taken in scores from 1 to 100 (best) for data comparability. To conduct the study, a sample was formed from 63 countries of the world, for which a complete (without gaps in individual indicators) statistics of the specified indicators for 2022 are available. The factual base of the study is available in the public repository of Mendeley Data in open access. The research model has the following form:

$$\left\{ \begin{array}{l} Q_{b4.0(1)} = a_1 + b_{k11} * K_{b4.0(1)} + b_{k12} * K_{b4.0(2)} + b_{t11} * T_{b4.0(1)} + b_{t12} * T_{b4.0(2)}, \\ Q_{b4.0(2)} = a_2 + b_{k21} * K_{b4.0(1)} + b_{k22} * K_{b4.0(2)} + b_{t21} * T_{b4.0(1)} + b_{t22} * T_{b4.0(2)}; \\ Q_{b4.0(1)} = a_3 + b_Q * Q_{b4.0(2)}. \end{array} \right. \quad (1)$$

The advantage of the research model (2) is that it reveals not only the dependence of business 4.0 product quality indicators on factor variables, but also the interdependence of quality indicators. Model (1) takes into

account the influence of high-tech manufacturing on ISO 9001 quality certificates. This is an advantage of model (1) in comparison with existing similar models, in which the causal relationships of

the formation of the quality of business 4.0 products are not fully and accurately identified.

The proposed hypothesis H can be considered proven if both industrial designs by origin and production and export complexity together have a stronger impact on ISO 9001 quality certificates and high-tech manufacturing than knowledge-intensive employment and research talent. In mathematical terms, the condition for proving hypothesis H is the situation in which $(bt_{11}+bt_{12}) > (b_{k11}+b_{k12})$ and simultaneously $(bt_{21}+bt_{22}) > (b_{k21}+b_{k22})$. Only reliable regression models are used as the evidence base of the hypothesis and during the research. Their reliability is checked using correlation coefficients, Fisher's F-Test.

The second task is to identify alternative scenarios for improving product quality in business 4.0, depending on knowledge and technology management. To do this, using the Monte Carlo simulation model (1), predictive scenarios are constructed that reflect the values and probability of changes in the quality of business 4.0 products with a corresponding change in the influence of knowledge factors and technology factors.

Taking into account arithmetic averages and standard deviations, 100 random numbers are generated, representing forecasts of changes in factor variables in the "Decade of Action" (until 2030). Histograms of the normal distribution of the obtained forecast values are constructed. The predicted values of the factor variables are substituted into the regression equations in the model (1). Three alternative scenarios are constructed.

First: the scenario of the development of knowledge-intensive and creative productions of unique, but technically simple products of business 4.0. In this scenario, the highly probable predictive values of knowledge-intensive employment and research talent are considered. They significantly exceed their corresponding values for 2022. At the same time, the values

of industrial designs by origin and production and export complexity remain at the level of 2022.

Second: the scenario of the development of production of technically complex products with advanced industrial design in business 4.0. In this scenario, the highly probable forecast values of industrial designs by origin and production and export complexity are considered. They significantly exceed their corresponding values for 2022. At the same time, the values of knowledge-intensive employment and research talent remain at the level of 2022.

Third: the scenario of expanding business 4.0 sectors and diversifying high-tech industries with the release of both knowledge-intensive and technically complex products with advanced industrial design. This scenario considers highly probable forecast values of knowledge-intensive employment and research talent, industrial designs by origin and production and export complexity. They significantly exceed their corresponding values for 2022. Scenario analysis makes it possible to develop a promising approach to corporate social responsibility in the context of business 4.0 with an emphasis on improving product quality. At the same time, a set of author's recommendations for improving the quality of business 4.0 products is compiled.

4. Results

4.1 Product quality management model in Business 4.0 based on knowledge and technology

As part of the first task of the study, a regression analysis of statistics from the materials of the author's dataset was carried out to build an econometric model of product quality management in business 4.0 based on knowledge and technology. This made it possible to refine the research model (1) and obtain the following system of equations:

$$\left\{ \begin{array}{l} Q_{b4.0(1)} = -28,7366 - 1,0218 * K_{b4.0(1)} + 0,2552 * K_{b4.0(2)} + 0,1264 * T_{b4.0(1)} + 1,6150 * T_{b4.0(2)}; \\ Q_{b4.0(2)} = -2,7364 + 0,1861 * K_{b4.0(1)} - 0,0649 * K_{b4.0(2)} + 0,0018 * T_{b4.0(1)} + 0,7478 * T_{b4.0(2)}, \quad (2) \\ Q_{b4.0(1)} = 7,1569 + 0,6256 * Q_{b4.0(2)}. \end{array} \right.$$

According to the system of equations (2), with an increase in research talent by 1 point, high-tech manufacturing decreases by 1.0218 points, and ISO 9001 quality certificates increases by 0.1861 points. With an increase in knowledge-intensive employment by 1 point, high-tech manufacturing increases by 0.2552 points, and ISO 9001 quality certificates decreases by 0.0649 points.

With an increase of industrial designs by origin by 1 point, high-tech manufacturing increases by 0.1264 points, and ISO 9001 quality certificates increases by 0.0018 points. With an increase in production and export complexity by 1 point, high-tech manufacturing increases by 1,6150 points, and ISO 9001 quality certificates increases by 0.7478 points. Regression statistics for the system of equations (2) are given in Tables 1-3.

Table 1. Regression analysis of the dependence of high-tech manufacturing on knowledge and technology factors in 2022

<i>Regression statistics</i>						
Multiple R	0,7810					
R-Square	0,6100					
Adjusted R-square	0,5831					
Standard Error	14,6025					
Observations	63					
<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	4	19345,293	4836,3	22,681	2,582*10 ⁻¹¹	
Residual	58	12367,435	213,23	1		
Total	62	31712,728	16			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t-Stat</i>	<i>P-Value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Y-intercept	-2,7364	6,7014	-0,4083	0,6845	-16,1506	10,6779
Research talent, % in businesses	0,1861	0,1014	1,8349	0,0716	-0,0169	0,3891
Knowledge-intensive employment, %	-0,0649	0,1154	-0,5625	0,5759	-0,2959	0,1661
Industrial designs by origin/bn PPP\$ GDP	0,0018	0,0792	0,0225	0,9821	-0,1568	0,1604
Production and export complexity	0,7478	0,1487	5,0281	0,0000	0,4501	1,0455

Source: calculated and compiled by the autor.

According to the results from Table 1, the change in high-tech manufacturing in 2022

by 78.10% is determined by the influence of knowledge and technology factors. The

significance $F=2,582 \cdot 10^{-11}$, therefore, the regression equation under consideration corresponds to a significance level of 0,01. At this level of significance, at $k_1=4$ and at $k_2=63-4-1=58$, the tabular $F=3,6611$. The

observed $F=22,6811$ – it exceeds the tabular one. Consequently, Fischer’s F-test has been passed and the equation is credible and reliable at a significance level of 0,01.

Table 2. Regression analysis of the dependence of ISO 9001 quality certificates on knowledge and technology factors in 2022

<i>Regression statistics</i>						
Multiple R	0,3176					
R-Square	0,1008					
Adjusted R-square	0,0388					
Standard Error	70,8307					
Observations	63					
<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	4	32633,4631	8158,36	1,626	1	0,1799
Residual	58	290985,525	5016,99			
Total	62	323618,988	5185,48			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t-Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Y-intercept	-28,7366	32,5057	-0,8840	0,380	-93,8039	36,3307
Research talent, % in businesses	-1,0218	0,4919	-2,0772	0,042	-2,0065	0,0371
Knowledge-intensive employment, %	0,2552	0,5598	0,4559	0,650	-0,8653	1,3757
Industrial designs by origin/bn				0,743		0,8957
PPP\$ GDP	0,1264	0,3843	0,3290	0,743	-0,6429	0,8957
Production and export complexity	1,6150	0,7214	2,2386	0,029	0,1709	3,0591

Source: calculated and compiled by the autor.

According to the results from Table 2, the change in ISO 9001 quality certificates in 2022 by 31.76% is determined by the influence of knowledge and technology factors. The significance $F=0,1799$, therefore, the regression equation under consideration corresponds to a significance

level of 0,20. At this level of significance, at $k_1=4$ and at $k_2=63-4-1=58$, the tabular $F=1,5495$. The observed $F=1,6261$ – it exceeds the tabular one. Consequently, Fischer’s F-test has been passed and the equation is credible and reliable at a significance level of 0,20.

Table 3. Regression analysis of the dependence of ISO 9001 quality certificates on high-tech manufacturing in 2022

<i>Regression</i>

<i>statistics</i>						
Multiple R	0,1958					
R-Square	0,0384					
Adjusted R-square	0,0226					
Standard Error	71,4266					
Observations	63					
ANOVA						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	1	12411,3682	12411,3682	2,4328	0,1240	
Residual	61	311207,620	5101,764			
Total	62	323618,988				
	<i>Coefficien ts</i>	<i>Standard Error</i>	<i>t-Stat</i>	<i>P-Value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Y-intercept	7,1569	20,4477	0,3500	0,7275	-33,7308	48,0447
High-tech manufacturing, %	0,6256	0,4011	1,5597	0,1240	-0,1764	1,4276

Source: calculated and compiled by the autor.

According to the results from Table 3, the change in ISO 9001 quality certificates in 2022 by 19.58% of high-tech production is determined by the influence of high-tech manufacturing. The significance $F=0,1240$, therefore, the regression equation in question corresponds to a significance level of 0,15. At this level of significance, at $k_1=1$ and at $k_2=63-1-1=61$, the tabular $F=2,1254$. The observed $F=2,4328$ – it exceeds the tabular one. Consequently, Fischer’s F-test has been passed and the equation is credible and reliable at a significance level of 0,15.

Thus, the ratio of regression coefficients turned out to be as follows: $(b_{t11}+b_{t12}) > (b_{k11}+b_{k12})$, $(0,1264+1,6150) > (-1,0218+0,2552)$, $1,7414 > -0,7666$. And simultaneously $((b_{t21}+b_{t22}) > (b_{k21}+b_{k22}))$, $(0,0018+0,7478) > (0,1861-0,0649)$, $0,7496 > 0,1212$. This proves the hypothesis H and confirms that industrial designs by origin and production and export complexity together have a stronger impact on ISO 9001 quality certificates and high-tech production than knowledge-intensive labor and scientific talent.

4.2 Scenario analysis of prospects for improving product quality in business 4.0 depending on knowledge and technology management

As part of the second task of the study, alternative scenarios for improving product quality in business 4.0 were identified depending on knowledge and technology management based on the model (2). Using the Monte Carlo method, predictive scenarios were constructed reflecting the values and probability of changes in the quality of business 4.0 products with a corresponding change in the influence of knowledge factors and technology factors. Taking into account arithmetic averages and standard deviations, 100 random numbers representing forecasts of changes in factor variables in the "decade of action" (until 2030) were generated. For knowledge-intensive employment, the arithmetic average was 44,63 points, the standard deviation was 28,97 points. For research talent, the arithmetic mean was 51,54 points, standard deviation: 21,21 points.

For industrial designs by origin, the arithmetic mean was 23,87 points, standard

deviation: 24,85 points. For production and export complexity, the arithmetic mean was 58,18 points, standard deviation: 18,96 points. Histograms of the normal distribution

of the obtained forecast values are constructed in Fig. 1.

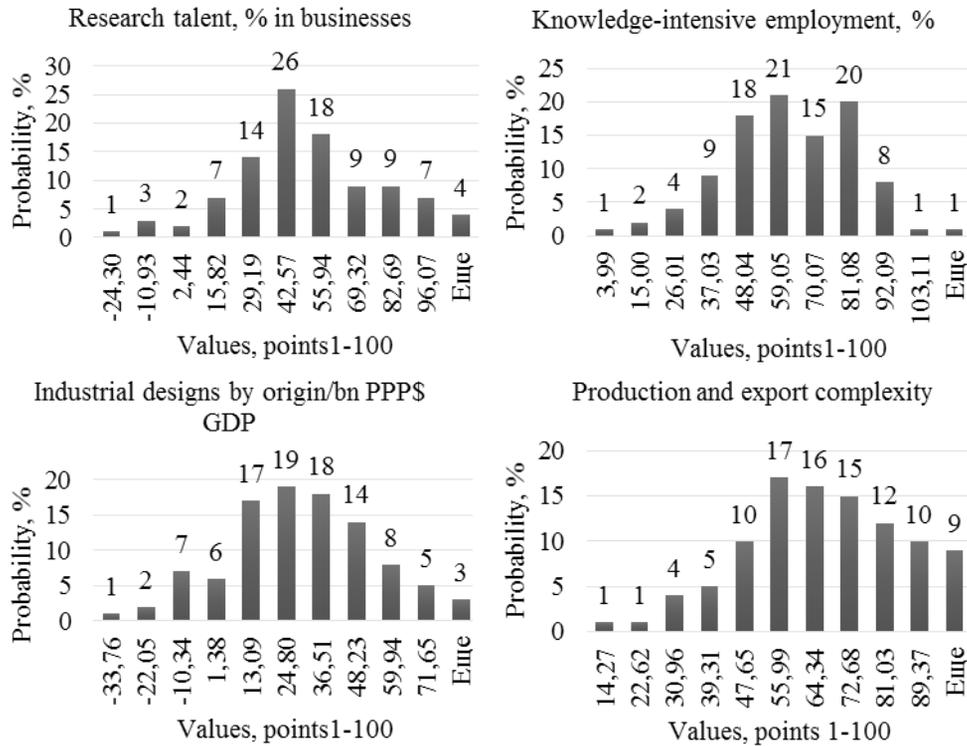


Figure 1. Histograms of the normal distribution of the predicted change in the level of development of knowledge and technology in the “Decade of Action”

Source: calculated and constructed by the author.

During the scenario analysis, the values of factor variables predicted in Fig. 1 are substituted into the regression equations in the model (2). As a result, three alternative scenarios are obtained (Fig. 2-4). The predicted values for the ISO 9001 quality certificate (from and to) are obtained taking into account their dependence on various factors in the model (2).

First: the scenario for the development of knowledge-intensive and creative productions of unique, but technically simple

products in business 4.0 (Fig. 2). This scenario considers highly probable forecast values significantly exceeding their values in 2022 for knowledge-intensive employment (an increase of 85,27% from 44,63 points in 2022 to 82,69 points with a probability of 20%) and research talent (an increase of 57,30% from 51,54 points in 2022 to 81,08% with a probability of 30%). At the same time, the values of industrial designs by origin (23.87 points with a probability of 70%) and production and export complexity (58.18 points with a probability of 69%)

remain at the level of 2022.

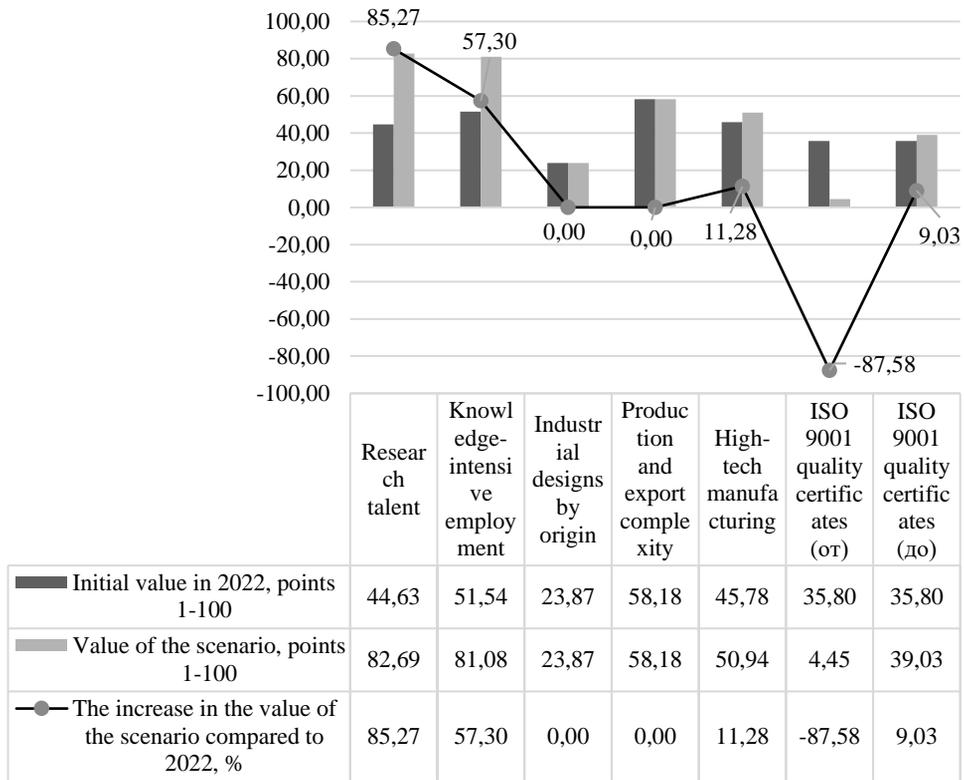


Figure 2.Scenario for the development of knowledge-intensive and creative productions of unique, but technically simple products in business 4.0

Source: calculated and constructed by the author.

As seen in Fig. high-tech manufacturing increases by 11,28% (from 45,78 points in 2022 to 50,94 points) in the scenario under consideration. ISO 9001 quality certificates ranges from 4,45 points (-87,58% compared to 2022) to 69,03 points (+9,03% compared to 2022). The projected systematic growth in quality is $(11,28-87,58+9,03)/3=-22,42\%$. The cumulative probability of this scenario is: $(20+30+70+69)/4=47,25\%$.

Second: the scenario of the development of production of technically complex products with advanced industrial design in business 4.0 (Fig. 3). This scenario considers highly

probable forecast values significantly exceeding their values in 2022: industrial designs by origin (an increase of 102,09% from 23,87 points in 2022 to 48,23 points with a probability of 30%) and production and export complexity (an increase of 39,26% from 58,18 points in 2022 to 81,03% with a probability of 31%). At the same time, the values of knowledge-intensive employment (44,63 points with a probability of 80%) and research talent (51,54 points with a probability of 70%) remain at the level of 2022.

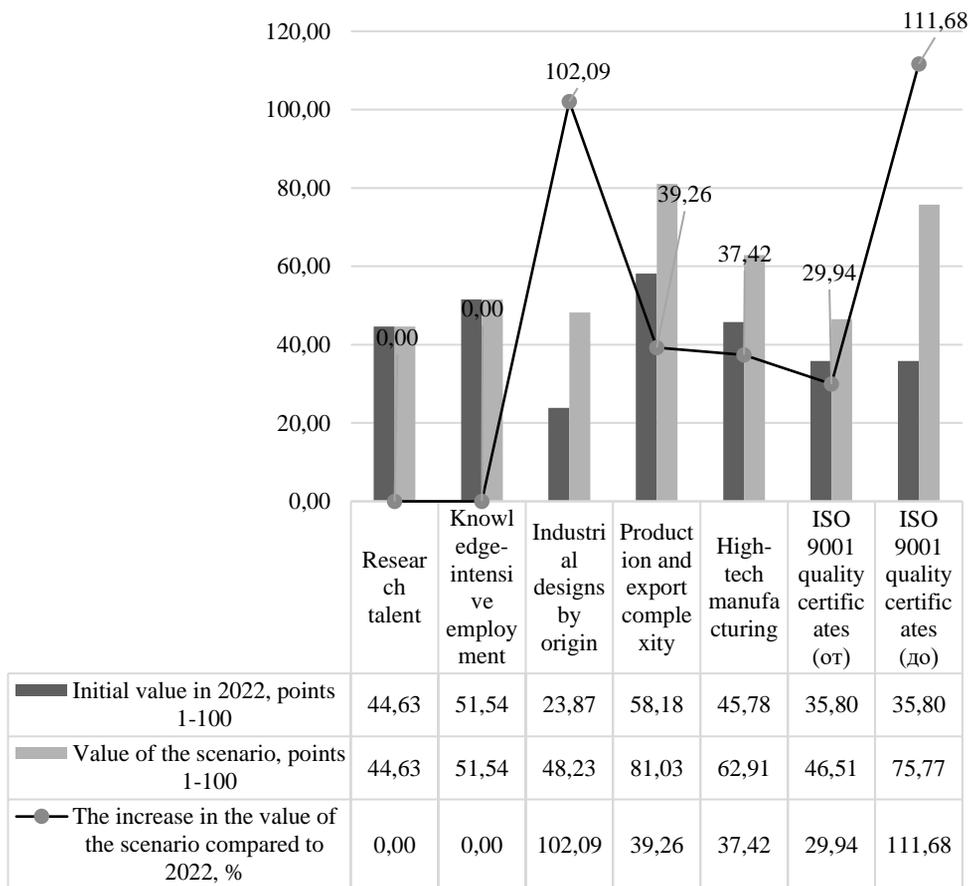


Figure 3. Scenario for the development of production of technically complex products with advanced industrial design in business 4.0

Source: calculated and constructed by the author.

In the scenario under consideration, high-tech manufacturing increases by 37,42% (from 45,78 points in 2022 to 62,91 points), as can be seen from Fig.3. ISO 9001 quality certificates range from 46,51 points (+29.94 compared to 2022) to 75,77 points (+111,68% compared to 2022). The projected systematic growth in quality is $(37,42+29,94+111,69)/3=59,68\%$. The cumulative probability of this scenario is: $(30+31+80+70)/4=52,75\%$.

Third: the scenario of expanding the range of business 4.0 and diversifying high-tech

industries with both knowledge-intensive and technically complex products with advanced industrial design (Fig. 4). This scenario considers highly probable predictive values of knowledge-intensive employment (82,69 points with a probability of 20%) and research talent (81,08 points with a probability of 30%), industrial designs by origin (48,23 points with a probability of 30%) and production and export complexity (81,03 points with a probability of 31%), significantly exceeding their values in 2022.

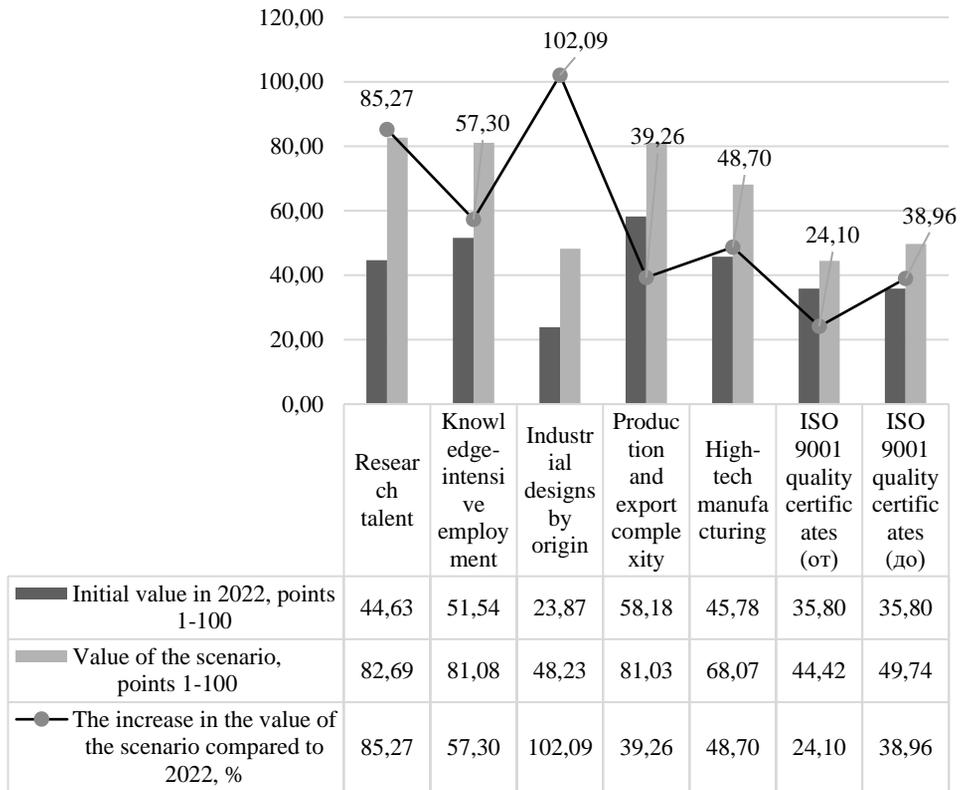


Figure 4. Scenario of expanding the sectors of business 4.0 and diversification of high-tech industries

Source: calculated and constructed by the author.

Fig. 4 shows that high-tech manufacturing increases by 48.70% (from 45,78 points in 2022 to 68,07 points) in the scenario under consideration. ISO 9001 quality certificates ranges from 44,42 points (+24,10% compared to 2022) to 49,74 points (+38,96% compared to 2022). The projected systematic growth in quality is $(48,70+24,10+38,96)/3=37,25\%$. The cumulative probability of this scenario is: $(20+30+30+31)/4=27,75\%$.

Thus, the most promising and preferred of the alternatives considered is the scenario for the development of technically complex products with advanced industrial design in business 4.0, as it provides the greatest systematic benefits for the quality of business 4.0 products (59,68%) with the highest probability (52,75%).

5. Discussion

The contribution of the article to the literature consists in the development of scientific provisions of the concept of product quality management in business by clarifying the cause-effect relationships of this management in business 4.0. The contribution of the article to the literature consists in the development of scientific provisions of the concept of product quality management in business by clarifying the cause-effect relationships of this management in business 4.0. The new scientific results obtained are compared with the existing literature in Table 4.

Table 4. Comparison of the obtained new scientific results with the existing literature

Criterion of comparison	Existing literature	New scientific results obtained in the article
Socio-economic environment	information society and knowledge economy with services as a vector of economic growth (Aparicio et al., 2023; Koster, 2023; Li et al., 2023; Yu et al., 2023)	industry 4.0 with high-tech industry as a vector of economic growth
The subject of quality management	business as an abstract category without strict industry specialization (Erdiaw-Kwasie et al., 2023; Feng, 2023; Ul-Durar et al., 2023)	business 4.0 specializing in high-tech industry
The factor of production that determines quality	human resources: knowledge (Gharieb, 2022; Lin et al., 2023; Yan et al., 2023)	technologies
The role of human resources in product quality management	designing and manufacturing of products in knowledge-intensive workplaces (Balouei Jamkhaneh et al., 2022; Khdour et al., 2021)	maintenance of “smart” machines at automated workplaces, where AI designs products and robots produce them
Product quality management mechanism	human resource management (Al-Dmour et al., 2021; Farida et al., 2021; Gambi et al., 2022)	automation of high-tech industries
Ways to improve product quality	individualization of products, creative approach to its production (Albloushi et al. (2023), Yan et al. (2023)	standardization of products, guaranteeing its template high quality
The essence of the approach to corporate social responsibility	the priority of responsibility to employees, which is a component of quality and a factor in strengthening customer loyalty (responsibility to consumers is achieved including through responsibility to employees) (Dwidienawati et al., 2022; Ladogina et al., 2022)	the priority of responsibility to consumers

Source: developed and compiled by the author.

Unlike Aparicio et al. ((2023), Koster (2023) Li et al. (2023), Yu et al. ((2023) the article proves that the socio-economic environment of business 4.0 is the information society, and the knowledge economy with services and industry 4.0 with high-tech industry act as a vector of economic growth. In contrast to the position of such researchers as Erdiaw-Kwasie et al. (2023), Feng (2023) Ul-Durar et al. (2023), the article substantiates that the subject of quality management in the conditions of the Fourth Industrial Revolution is not business as an abstract category without strict industry specialization, but business 4.0, specializing in high-tech industry.

Unlike Gharieb (2022), Lin et al. (2023), Yan et al. ((2023) the article proves that the key factor of production determining the quality of business 4.0 products is not human resources (knowledge), but technology. In

contrast to the position expressed by Balouei Jamkhaneh et al. (2022), Khdour et al. (2021), the article substantiates that the role of human resources in product quality management is not in the design and production of products in knowledge-intensive workplaces, but in the maintenance of “smart” machines in automated workplaces where artificial intelligence (AI) designs products, and robots produce them. Unlike Al-Dmour et al. (2021), Farida et al. (2021), Gambi et al. (2022) the article proves that the mechanism for managing the quality of business 4.0 products should be based not on human resource management, but on the automation of high-tech industries. Contrary to the opinion of such scientists as Albloushi et al. (2023), Yan et al. (2023), the article offers a new vision of the way to improve product quality – not through the individualization of products and a creative

approach to its production, but through the standardization of products, guaranteeing its high quality.

The results of the scenario analysis make it possible to propose a promising new approach to corporate social responsibility in the context of business 4.0 with an orientation towards improving product quality.

The essence of the approach to corporate social responsibility is fundamentally different from the position of such researchers as Dwidienawati et al. (2022), Ladogina et al. (2022), who defend the priority of responsibility to employees. In this case, it is a component of quality and a factor in strengthening customer loyalty (responsibility to consumers is achieved including through responsibility to employees).

The author's approach assumes the priority of the responsibility of business 4.0 to consumers. For the practical implementation of the developed approach, the following set of author's recommendations for improving the quality of business 4.0 products is proposed:

- increase of industrial designs by origin by 102,09% compared to 2022 to 48,23 points;
- increase in production and export complexity by 39,26% compared to 2022 to 81,03%.
- maintaining knowledge-intensive employment (44,63 points) and research talent (51,54 points) at the level of 2022.

6. Conclusion

According to the results of the conducted research, the identified gap in the literature has been filled and the scientific argumentation of the contribution of knowledge and technology to ensuring the quality of business 4.0 products has been strengthened, the importance of human and technological resources in improving the

quality of business 4.0 products has been clarified. The following results have been obtained:

1. An econometric model of product quality management in business 4.0 based on knowledge and technology has been constructed. The model revealed the contradictory influence of knowledge on the quality of business 4.0 products. Thus, research talent, instead of increasing, leads to a decrease in high-tech manufacturing. Similarly, knowledge-intensive employment reduces ISO 9001 quality certificates instead of increasing.

At the same time, a reliable and consistent pattern of systematic growth in the quality of business 4.0 products was revealed as industrial designs by origin, as well as the growth of production and export complexity increase. Thus, the ratio of the regression coefficients turned out to be as follows: $(bt_{11}+bt_{12}) > (bk_{11}+bk_{12})$, $1,7414 > 0,7666$ simultaneously with this $(bt_{21}+bt_{22}) > (bk_{21}+bk_{22})$, $0,7496 > 0,1212$.

This proved the hypothesis H and confirmed that industrial designs by origin and production and export complexity together have a stronger impact on ISO 9001 quality certificates and high-tech manufacturing than knowledge-intensive employment and research talent.

2. A scenario analysis of the prospects for improving product quality in business 4.0 depending on knowledge and technology management was conducted. The author's forecast for the "Decade of Action" (until 2030) showed that the scenario of the development of knowledge-intensive and creative productions of unique, but technically simple products in business 4.0, instead of increasing, can systematically reduce the quality of business 4.0 products by 22,42% with a probability of 47,25%. The scenario of expanding the sectors of business 4.0 and diversifying high-tech industries with the release of both knowledge-intensive and technically complex products with advanced industrial

design makes it possible to systematically improve the quality of business 4.0 products by 37,25% with a probability of 27,75%.

The most promising and preferred of the alternatives considered in the article is the scenario for the development of technically complex products with advanced industrial design in business 4.0, since this scenario provides the greatest systematic benefits for the quality of business 4.0 products (59,68%) with the highest probability (52,75%). In this scenario, business 4.0 actively develops advanced technologies, but pays secondary attention to knowledge and In this scenario, business 4.0 actively develops advanced technologies, but pays secondary attention to knowledge and refuses to use insignificant human resources.

The main conclusion based on the results of the study is that the key factor of a new type of business – business 4.0, which was formed under the influence of the Fourth Industrial Revolution, is technology, while human resources have receded into the background. The theoretical significance of the results of the study lies in the fact that they contribute to rethinking the role of knowledge and technology management in improving the quality of business 4.0 products. In this regard, it is necessary to reduce the share of human-intensive economic processes and, accordingly, increase the share of automated processes to increase the competitiveness of business 4.0.

The practical significance of the research lies in the fact that the proposed new approach to corporate social responsibility in the context of business 4.0, provided that it is focused on improving product quality, allows balancing the interests of the management (managers, shareholders, investors, etc.) of business 4.0 and consumers of its products. The system-forming element in this case is the improvement of product quality. The author's approach takes into account the changed trend of consumer consumption preferences, which is due to the fact that consumers of products in business 4.0 are

more interested in improving their technical properties than in the responsibility of business 4.0 as an employer.

Management implications are that the proposed recommendations make it possible to improve the practice of product quality management in business 4.0. The author's recommendations contribute to unlocking the potential for improving product quality, as well as increasing the effectiveness of quality management in business 4.0.

The social significance of the results obtained lies in the fact that they support the systematic practical implementation of such Sustainable Development Goals (SDGs) as SDG8 and SDG9 through the improvement of knowledge and technology management in business 4.0, provided that better product quality is set as a priority. The author's conclusions and recommendations strengthen the scientific and methodological basis for accelerating the pace of high-tech economic growth, innovation and neo-industrialization based on business 4.0 due to the most complete use of its potential in the field of product quality improvement.

In conclusion, it should be noted that the results obtained are limited by the focus on improving product quality, while the implications for business 4.0 workers and the labor market remained beyond the scope of the study. A new approach to corporate social responsibility in the context of business 4.0 with an emphasis on improving product quality provides benefits for the management of business 4.0 and for consumers of its products.

However, a decrease in the knowledge intensity of production may be accompanied by a decrease in jobs, which may reduce the role of sellers in the labor market and increase the unemployment rate. Therefore, corporate governance measures aimed at improving the quality of business 4.0 products should be implemented in parallel with public administration measures aimed at creating new jobs in knowledge-intensive

sectors of the economy (for example, in the service sector), stabilizing the labor market and social support. Based on this, it is

proposed to devote future research to the elaboration of these measures as a continuation of the topic of this article.

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