International Journal for Quality Research 15(4) 1061–1080
ISSN 1800-6450

Denis E. Matytsin[1]
Ekaterina P. Rusakova

Article info:
Received 15.09.2020
Accepted 25.01.2021

UDC – 005.336.3
DOI – 10.24874/IJQR15.04-03

STRATEGY OF QUALITY MANAGEMENT IN INDUSTRY 4.0 AND FORMATION OF COGNITIVE ECONOMY BASED ON INDUSTRIAL AND MANUFACTURING ENGINEERING IN THE RUSSIAN FEDERATION AND COUNTRIES OF THE EU

Abstract: *The purpose of this paper is to develop a program-target strategy of quality management in Industry 4.0 and formation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU. Originality of this research consists in the following. Firstly, the authors specify the essence, distinguish and determine the elements of quality in Industry 4.0, offer estimate indicators and use them to perform a polycriterial evaluation of quality in Industry 4.0, and determine and substantiate the sources of its increase in the Russian Federation and countries of the EU. Secondly, the authors study and prove the strong influence of the factors of industrial and manufacturing engineering on successes in formation of cognitive economy in the Russian Federation and countries of the EU and determine the perspectives of optimizing the influence of these factors of in the interests of formation of cognitive economy. Thirdly, the specifics of causal connections of quality management in Industry 4.0 in countries of Western and Eastern Europe are determined, due to which this research has high empirical value, for its allows developing the specific programs of development of Industry 4.0 in countries of Europe in view of their specific features. Fourthly, the issues of quality management in Industry 4.0 and formation of cognitive economy based on industrial and manufacturing engineering are studied consistently, due to which a general program-target strategy for the Russian Federation and countries of the EU is developed.*

Key words *Quality; Strategy; Industry 4.0; Cognitive Economy; Russian Federation; European Union; Industrial and Manufacturing Engineering.*

1. Introduction

The perspectives of development of the modern economic systems are connected to transition to Industry 4.0. This is proved by most countries of the world adopting and starting the strategies of digital modernization of economy and transition to Industry 4.0. Ministry of Digital Development, Communications and Mass

[1] Corresponding author: Denis E. Matytsin
Email: gimchp@volsu.ru; Dmatytsin@ya.ru

Media (Russia) (2020) adopted the program "Digital economy of the Russian Federation". The European Commission (2020) started the program "Europe investing in digital: the Digital Europe Programme".

Transition to Industry 4.0 is performed in the interests of creation of a cognitive economy – a socio-economic system in which knowledge is assigned large value, which creates market stimuli for the increase of human potential, and competition in entrepreneurship takes place at the level of information, knowledge and technologies, with creation of conditions for knowledge exchange, implementation of innovations, and implementation of human potential. The advantages of cognitive economy are high and sustainable global competitiveness, reduced cyclicity, stable economic growth, and higher living standards and quality of life of the population.

Though the course at transition to Industry 4.0 does stimulate the formation of cognitive economy, a serious barrier on this path is insufficient manageability of Industry 4.0 and the chaotic character of its development. The reason is that transition to Industry 4.0 is considered to be a goal in itself. Though implementation of the leading technologies in state management, society, and business allows strengthening the positions of national entrepreneurship in the world markets of high technologies and increasing the economy's global competitiveness, it does not ensure the targeted internal socio-economic transformations in the economic system.

To build a cognitive economy, it is necessary to ensure high quality in Industry 4.0, which will stimulate positive influence of the factors of industrial and manufacturing engineering on economy. The following research gaps hinder the achievement of this in the practice of modern economic systems.

1st gap: insufficient elaboration of the scientific and methodological issues of quality measuring and management in Industry 4.0. There are a lot of indicators for measuring progress in Industry 4.0, which include the level of development and accessibility of digital infrastructure and activity of breakthrough technologies implementation.

The issues of quality are not studied enough during research and management of Industry 4.0 – though, like any innovations, it envisages certain risk and does not guarantee any advantages. While there are a lot of global reports on the level of development of Industry 4.0 (e.g., World Digital Competitiveness Report, published annually by IMD (2020)), there is no clear vision of quality in Industry 4.0. Due to this, companies of Industry 4.0 do not adopt growth of quality in corporate plans, and state regulators have to use general indicators, ignoring quality.

2nd gap: uncertainty of the causal connections of influence of the factors of industrial and manufacturing engineering on economic systems and the requirements to influence of these factors for creation of cognitive economy. The factors of industrial and manufacturing engineering are achievements in Industry 4.0, which stimulate social transformations and ensure the transition to information society, support the implementation of breakthrough technologies in the practice of entrepreneurship, and ensure the transition of economy to the next (fourth) technological mode.

The concept of cognitive economy is developed separately from Industry 4.0. Separate management of Industry 4.0 and the process of transition to cognitive economy is an "institutional trap" (ineffective institution) of the modern economic systems. Certain initiatives on development of intellectual capital (increase of educational level, investment in R&D, and final innovations) lead to fragmentary, intermediary results – full-scale creation of cognitive economy is possible only in case of targeted and high-precision management

of the factors of industrial and manufacturing engineering, but there are no scientific and methodological tools for this.

This paper aims to fill these gaps and to develop a program-target strategy of quality management in Industry 4.0 and formation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU. The following hypothesis is offered: in the Russian Federation and countries of the EU, the factors of industrial and manufacturing engineering have strong influence on progress in formation of cognitive economy, but the influence of these factors is not optimal due to imperfection of quality management in Industry 4.0.

Originality – uniqueness and significance for economics and economic practice – of this research consists in its following advantages (as compared to the competing works). Firstly, the authors specify the essence, distinguish and determine the elements of quality in Industry 4.0, offer estimate indicators and use them to perform a polycriterial evaluation of quality in Industry 4.0, and determine and substantiate the sources of its increase in the Russian Federation and countries of the EU. Secondly, the authors study and prove the strong influence of the factors of industrial and manufacturing engineering on successes in formation of cognitive economy in the Russian Federation and countries of the EU and determine the perspectives of optimizing the influence of these factors of in the interests of formation of cognitive economy. Thirdly, the specifics of causal connections of quality management in Industry 4.0 in countries of Western and Eastern Europe are determined, due to which this research has high empirical value, for its allows developing the specific programs of development of Industry 4.0 in countries of Europe in view of their specific features. Fourthly, the issues of quality management in Industry 4.0 and formation of cognitive economy based on industrial and manufacturing engineering are studied consistently, due to which a general program-target strategy for the Russian Federation and countries of the EU is developed, in which a synergetic effect is obtained, ensuring high effectiveness of the managerial measures. Introduction is followed by literature overview (including gap analysis), and description of research materials and methods.

Then, research results are described: 1) Causal connections of quality management in Industry 4.0 in the Russian Federation and countries of the EU; 2) Experience and perspectives of creation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU; 3) Program-target strategy quality management in Industry 4.0 and formation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU. Conclusions sum up this research.

2. Literature Review

The theoretical basis of this research is formed of the published works which are divided into four thematic blocks. 1st block: Industry 4.0 as a vector of development of the digital economy and a source of growth and global competitiveness of economic systems – studied in the works Popkova (2020) and Gomes and Cardoso, (2020).

Sivathanu and Pillai (2018) introduce the notion “smart HR 4.0” and determine how industry 4.0 is disrupting HR. Flores et al. (2020) study the notion “Human Capital 4.0” and compile a typology workforce competencies for Industry 4.0. Rana and Sharma (2019) substantiate the emerging human resource management practices in Industry 4.0. Verma et al. (2020) note that Industry 4.0 changes the future of HR management. Ragulina (2019) points out the vivid influence of education on production placement in the agro-industrial complex in

the conditions of Industry 4.0. Ghobakhloo (2018) considers the future of manufacturing industry and presents a strategic roadmap toward Industry 4.0.

2nd block: quality in Industry 4.0, the certain elements of which are studied in the works Gritsuk et al. (2020), and Inshakova et al. (2019). Within this block, Behmer and Jochem (2019) offer a scientific and methodological approach to organizational planning for quality management in the digital age. Grandinetti et al. (2020) notes that the Fourth industrial revolution, digital servitization and relationship quality in Italian B2B manufacturing firms influence the quality of interrelations in B2B Italian production companies.

Khin and Ho (2019) determine the connection between digital technology, digital capability and organizational performance and point out a mediating role of digital innovation. Ansong and Boateng (2019) think that surviving in the digital era is a complex task and offer business models of digital enterprises in a developing economy. Martínez-Climent et al. (2019) note digital transformations and value creation in international markets. Stuart (2017) thinks that machine knowledge predetermines digital transformations of the sciences and humanities. Hoerlsberger (2019) studies innovation management in the digital world.

3rd block: essence and foundations of the concept of cognitive economy, its basic principles, priorities, and manifestations, and experience of its formation. Hoe (2017) studies the problem "thinking about how to think" and determines cognitive skills to stay relevant in a digital economy. Nguyen et al. (2019) points out the role of cognitive proximity on supply chain collaboration for radical and incremental innovation, performing a study of a transition economy.

Singh and Giacosa (2019) determine cognitive biases of consumers as barriers in transition towards circular economy. Ahmadi and Taghizadeh (2019) present a gene expression programming model for economy growth using knowledge-based economy indicators. Martínez-Climent (2020) draws a connection between Knowledge, business and innovation and substantiates a perspective model of economy and sustainability of future growth. Degelsegger-Márquez et al. (2018) draw a connection between regional knowledge economies and global innovation networks (by the example of Southeast Asia).

Paoloni et al. (2019) study crowdfunding as a new collaborative process in the knowledge economy. Szelagowski and Berniak-Woźny (2019) deem it necessary to adapt business process management maturity models to the context of the knowledge economy. Gangi (2017) notes the role of entrepreneurship education and training on creation of the knowledge economy (studying Qatar's leap to the future). Chilton and Jung (2018) note the applicability of growth machine theory to the knowledge economy (performing a social network analysis of Chattanooga's civic infrastructure).

4th block: specifics of the digital economy and Industry 4.0 in the Russian Federation and countries of the EU, which are studied in the works Inshakova et al. (2018), Popkova et al. (2020) and Popkova et al. (2017). Within this block, Tsourgiannis and Valsamidis (2019) study digital marketing in tourism and explain why Greek tourists use digital marketing applications like Airbnb. Wentrup et al. (2019) think that Uberization in Paris is the issue of trust between a digital platform and digital workers. Dellermann et al. (2017) thinks that innovation risk in digital business models is especially high (by the example of German energy sector).

Thus, as a result of the performed literature review, it is possible to conclude that there are a lot of works on this issue. However, the performed gap analysis shows that the studied problem remains unsolved due to two research gaps. 1st gap: deficit of research developments in the sphere of quality

management in Industry 4.0.

2nd gap: insufficient elaboration and the lack of evidentiary support for the influence of factors of industrial and manufacturing engineering on formation of cognitive economy. In order to fill these gaps, we study the process of quality management in Industry 4.0, its consequences for industrial and manufacturing engineering, and contribution to formation of cognitive economy in the Russian Federation and countries of the EU.

3. Materials and methodology

This research is built on the basis of the hypothetical and deductive principle. The economic & mathematical essence of the formulated hypothesis consists in the following: in the Russian Federation and countries of the EU, the factors of industrial and manufacturing engineering have a close and positive connection with manifestations of cognitive economy, but their influence is contradictory, which is shown not only by positive but also negative correlation and regression dependence of the corresponding indicators.

To achieve the largest applied significance and highest detalization of this work, we selected countries with different geographical location as research objects: countries of Eastern Europe and Western Europe. To characterize the received selection, let us consider the values of digital competitiveness index in countries of Eastern and Western Europe in 2020 (as a result of 2019), according to the IMD report (Figure 1).

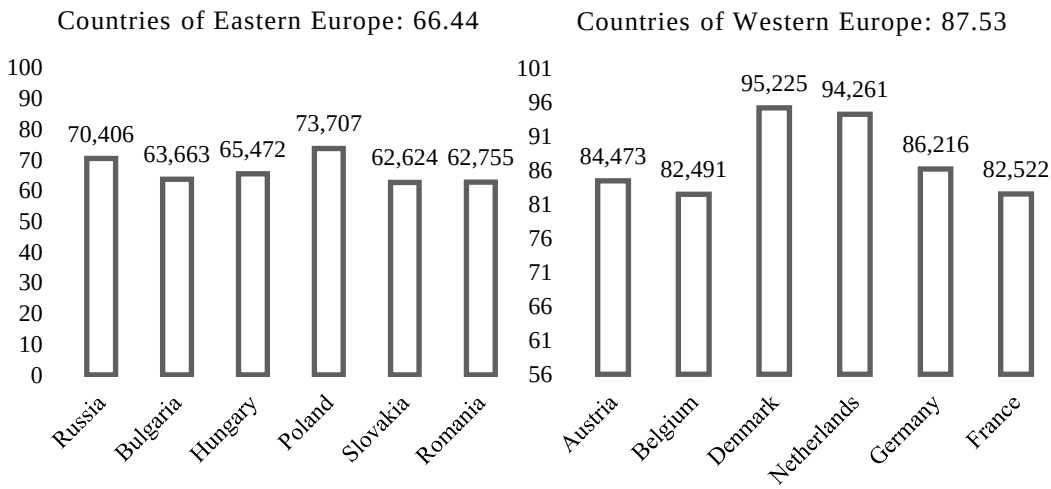

Figure 1. Digital competitiveness index in countries of Eastern and Western Europe in 2020, points 1-100.

Source: compiled by the authors based on IMD (2020).

As shown in Figure 1, the values of digital competitiveness index in countries of Eastern Europe in 2020 are rather equal. The highest values of this index are observed in Poland (73.707 points) and Russia (70.406 points). In countries of Western Europe, there are vivid differences in the level of their digital competitiveness, which is the highest in Denmark (95.225 points) and the Netherlands (94.261 points), and the lowest in Belgium (82.491 points). On the whole, among the selected countries of Western

Europe, the level of digital competitiveness is higher (87.53 points on average) as compared to countries of Eastern Europe (64.44 points on average). This confirms the necessity to study these geographically separate groups of countries in a separate way during research of Industry 4.0.

When studying the causal connections of quality management in Industry 4.0 in the Russian Federation and countries of the EU we use correlation analysis. We determine the connection (correlation dependence) between the elements of quality in Industry 4.0 and potentially significance sources of quality growth. Elements of quality in Industry 4.0 are distinguished according to World Digital Competitiveness Report 2019, prepared by IMD (2020), as a source of the most complete and reliable empirical data on the topic of Industry 4.0:

- IT & media stock market capitalization as a manifestation of their competitiveness and effectiveness, achieved by means of high quality of products;
- Internet retailing as a manifestation of distribution networks' quality, the highest level of which is reached on the Internet; Agility of companies as a manifestation of taking into account the individual needs of consumers and of the changes in general market consumer preferences, which leads to growth of quality in the aspect of improved satisfaction of the needs;
- Knowledge transfer as a manifestation of use of leading knowledge and technologies during product manufacture;
- Cyber security as a manifestation of safety of products of Industry 4.0 in the aspect of personal data protection;
- Sofware piracy as a manifestation of reliability of products of Industry 4.0 in the aspect of its continuous work.

The following potentially significant sources of quality growth in in Industry 4.0 are distinguished here:

- Index of economic freedom – as the indicator of influence of state regulation on quality (calculated by The Heritage Foundation (2020));
- Globalization index – as the indicator of influence of international competition on quality (calculated by KOF (2020));
- Total investment - as the indicator of influence of resource provision on quality (calculated by International Monetary Fund (2020);
- Social entrepreneurship index – as the indicator of influence of corporate social responsibility on quality (calculated by Institute of Scientific Communications (2020b) and presented in social entrepreneurship ranking as a part of the dataset "Social Entrepreneurship in the World Economy: a Path from Virtual Scores to Big Data – 2020".

The data are grouped depending on the geographical location of the studied countries (Table 1).

As the elements of quality in Industry 4.0 are available in IMD materials in the form of rating, they are measured in positions (the lower the value, the better). Contrary to them, for the sources of quality growth the following is true: the higher, the better. That's why a proof of the direct connection between indicators is negative values of correlation coefficients.

Table 1. Elements and sources of quality in Industry 4.0 in the Russian Federation and countries of the EU in 2020.

Geographical location	Country	Elements of quality in Industry 4.0, positions 1-63						Sources of increase of quality in Industry 4.0			
		IT & media stock market capitalization	Internet retailing	Agility of companies	Knowledge transfer	Cyber security	Sofware piracy	Index of economic freedom, points 1-100	Globalization index, points 1-100	Total investment, % of GDP	Social entrepreneurship index, points 1-100
Countries of Eastern Europe	Russia	43	41	60	57	44	53	61.0	72.45	21.189	61.147
	Bulgaria	36	50	56	55	46	50	70.2	80.78	22.227	35.763
	Hungary	31	37	50	39	51	27	66.4	84.98	21.277	34.373
	Poland	35	33	17	38	40	36	69.1	81.33	20.735	46.651
	Slovakia	29	36	22	34	13	30	66.8	83.72	23.763	34.700
	Romania	47	40	43	50	32	51	69.7	79.74	25.329	38.515
Countries of Western Europe	Austria	39	17	15	12	5	6	73.3	82.86	24.111	51.643
	Belgium	32	11	39	16	33	13	68.9	86.84	24.339	45.772
	Denmark	45	4	6	8	17	8	78.3	88.26	20.962	55.713
	Netherlands	8	6	10	2	8	13	77.0	90.71	21.806	67.478
	Germany	9	13	36	10	26	8	73.5	88.60	19.348	
	France	25	14	55	26	22	20	66.0	87.25	21.813	61.140

Source: compiled by the authors based on IMD (2020), Institute of Scientific Communications (2020b), International Monetary Fund (2020), KOF (2020), The Heritage Foundation. (2020).

Correlation analysis is used for studying the experience and perspectives of formation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU. Dependence of each sign of cognitive economy (separately) on the whole totality of the factors of industrial and manufacturing engineering is determined and presented in the form of regression equation. The factors of industrial and manufacturing engineering are the indicators from IMD Ranking (2020):

- Robots in Education and R&D;
- World robots distribution;
- Use of big data and analytics.

The signs of cognitive economy are the following indicators:

- Innovation index, available in the materials of the data set "Big Data of the Modern Global Economy: Digital Platform for Data Mining – 2020" Institute of Scientific Communications (2020a);
- Human development index, from Institute of Scientific Communications (2020a);
- Hi-tech export, according to World Bank (2020).

These indicators and their symbols for further analysis are shown in Table.

Table 2. Signs of cognitive economy and potentially influencing factors of industrial and manufacturing engineering in the Russian Federation and countries of the EU in 2020.

Geographical location	Country	Factors of industrial and manufacturing engineering, positions 1-63			Signs of cognitive economy		
		Robots in Education and R&D	World robots distribution	Use of big data and analytics	Innovation index, points 1-100	Human development index, points 1-100	High-technology exports, % of manufactured exports
		x_1	x_2	x_3	y_1	y_2	y_3
Countries of Eastern Europe	Russia	8	34	31	37.62	0.824	10.963
	Bulgaria	49	45	38	40.35	0.816	10.267
	Hungary	31	26	50	44.51	0.845	17.538
	Poland	16	21	27	41.31	0.872	10.099
	Slovakia	29	37	33	42.05	0.857	10.629
	Romania	36	35	34	36.76	0.816	11.074
Countries of Western Europe	Austria	10	23	41	50.94	0.914	11.638
	Belgium	18	24	35	50.18	0.919	11.946
	Denmark	25	30	17	58.44	0.930	13.889
	Netherlands	27	18	10	61.44	0.933	22.677
	Germany	2	5	46	58.19	0.939	16.368
	France	5	8	53	54.25	0.891	25.920

Source: compiled by the authors based on IMD (2020), Institute of Scientific Communications (2020a), World Bank (2020).

4. Results

4.1 Causal connections of quality management in Industry 4.0 in the Russian Federation and countries of the EU

For determining the causal connections of quality management in Industry 4.0 in the Russian Federation and countries of the EU, let us use the results of correlation analysis, which is performed based on the data from Table 1 (Figures 2-7).

As shown in Figure 2, IT & media stock market capitalization in countries of Eastern Europe grows in case of increase of economic freedom (correlation -9.30%) and globalization (-72.44%), and also in case of outflow of investments from economy (34.48%) and decrease of corporate social responsibility (49.70%). In countries of Western Europe, IT & media stock market capitalization grows in case of decrease of economic freedom (1.90%) and outflow of investments from economy (48.20%), and also in case of globalization (-62.80%) and development of social entrepreneurship (-72.32%).

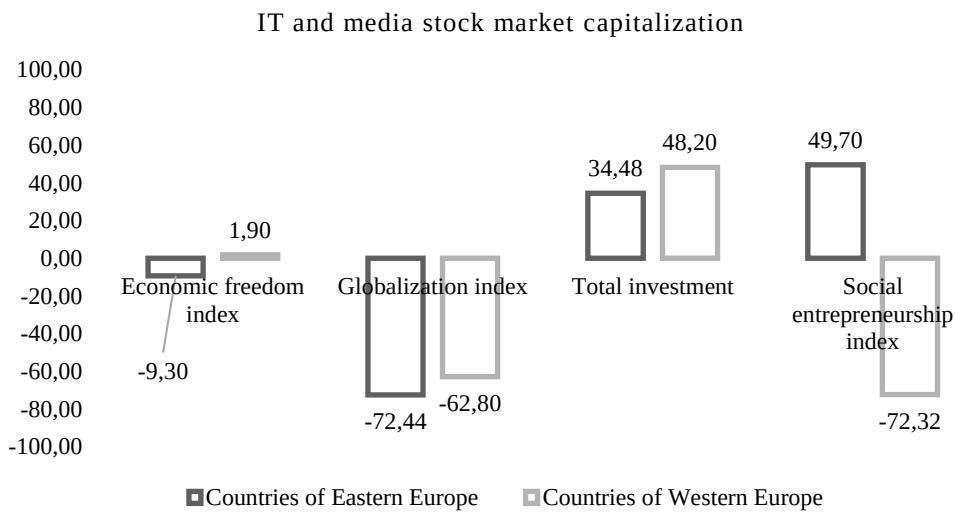

Figure 2. Correlation between IT & media stock market capitalization and the sources of quality in Industry 4.0, %.
Source: calculated and compiled by the authors.

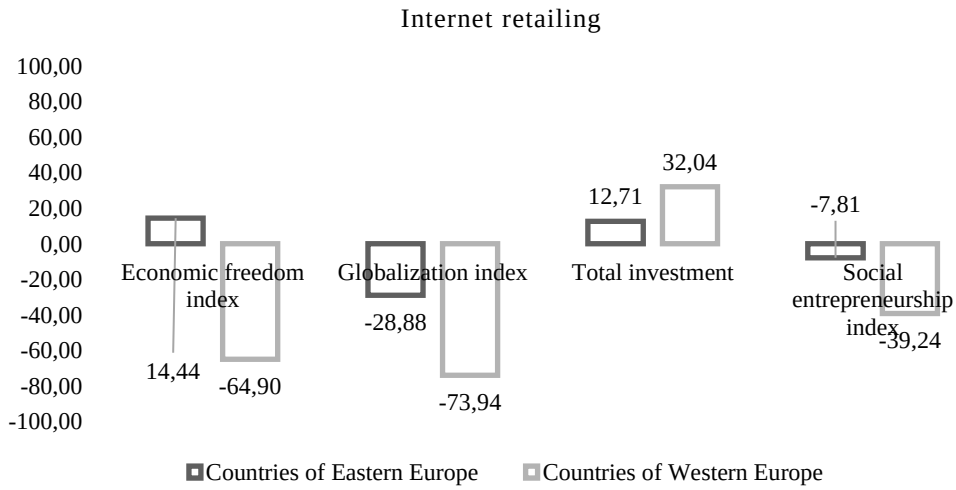

Figure 3. Correlation between Internet retailing and the sources of quality in Industry 4.0, %.
Source: calculated and compiled by the authors.

As shown in Figure 3, Internet retailing in countries of Eastern Europe develops in case of reduction of economic freedom (14.44%) and outflow of investments from economy (12.71%), as well as in case of globalization (-28.88%) and development of social entrepreneurship (-7.81%). In countries of Western Europe, Internet retailing develops in case of increase of economic freedom (-64.90%), globalization (-73.94%), development of social entrepreneurship (-39.24%), and outflow of investments from economy (32.04%).

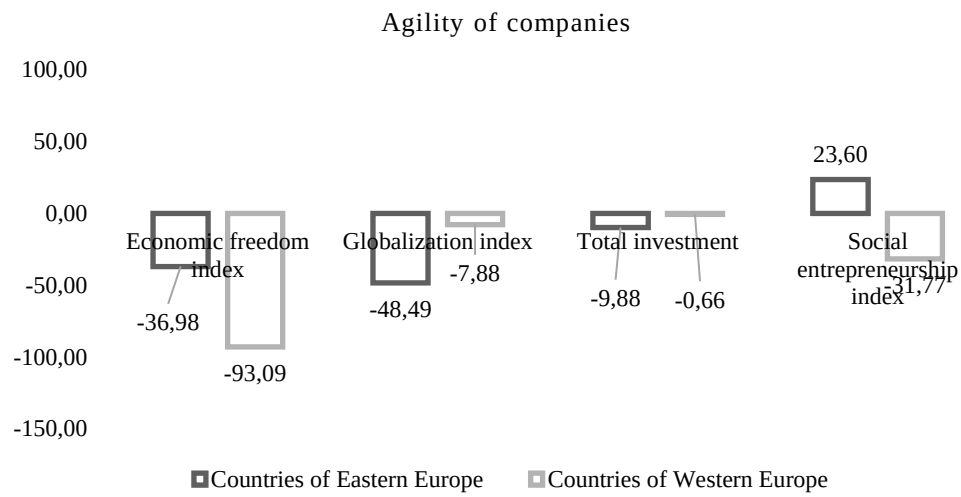

Figure 4. Correlation between agility of companies and the sources of quality in Industry 4.0, %.
Source: calculated and compiled by the authors.

As shown in Figure 4, agility of companies in countries of Eastern Europe grows in case of increase of economic freedom (-36.98%), globalization (-48.49%), and inflow of investments in economy (-9.88%), and also in case of reduction of corporate social responsibility (23.60%). In countries of Western Europe, agility of companies grows in case of increase of economic freedom (-93.09%), globalization (-7.88%), inflow of investments in economy (-0.66%), and development of social entrepreneurship (-31.77%).

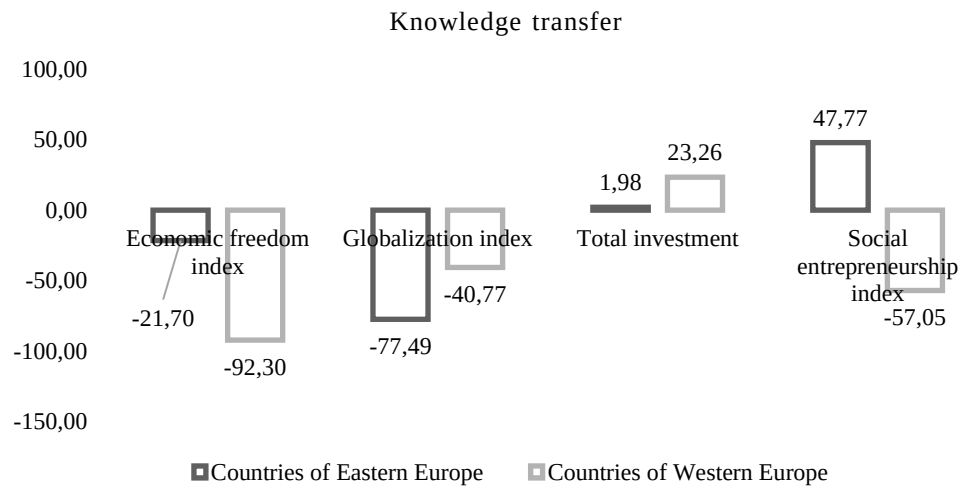

Figure 5. Correlation between knowledge transfer and the sources of quality in Industry 4.0, %.
Source: calculated and compiled by the authors.

As shown in Figure 5, knowledge transfer in countries of Eastern Europe grows in case of increase of economic freedom (-21.70%) and globalization (-77.49%), as well as in case of outflow of investments from economy (1.98) and reduction of corporate social responsibility (47.77). In countries of Western Europe, knowledge transfer grows in case of increase of economic freedom (-92.30%), globalization (-40.77%), and development of social entrepreneurship (-57,05%), as well as outflow of investments from economy (23.26%).

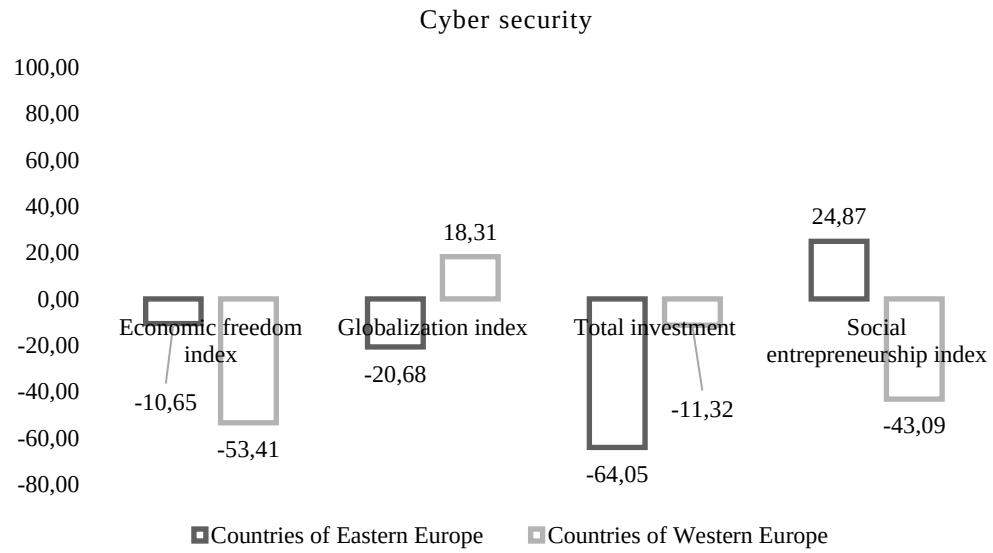

Figure 6. Correlation between cyber security and the sources of quality in Industry 4.0, %. Source: calculated and compiled by the authors.

As shown in Figure 6, cyber security in countries of Eastern Europe grows in case of increase of economic freedom (-10.65%), globalization (-20.68%), and inflow of investments in economy (-64.05%), as well as reduction of corporate social responsibility (24.87%). In countries of Western Europe, cyber security grows in case of increase of economic freedom (-53.41%), inflow of investments in economy (-11.32%), and development of social entrepreneurship (-43.09%), as well as de-globalization (18.31%),

As shown in Figure 7, quality of software piracy grows in case of economic freedom (-8.28%) and globalization (-80.37%), as well as outflow of investments from economy (21.55%) and reduction of corporate social responsibility (49.96%). In countries of Western Europe, quality of software piracy grows in case of increase of economic freedom (-68.01%), but also in case of de-globalization (30.84%), outflow of investments from economy (6.15%), and reduction of corporate social responsibility (1.78%).

Averaged correlation between the elements of quality and the sources of quality in Industry 4.0 is shown in Figure 8.

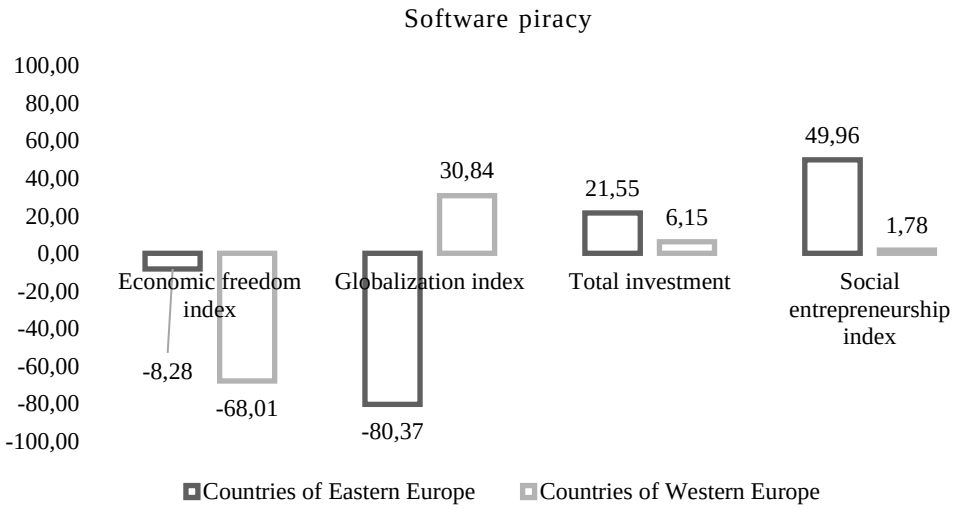

Figure 7. Correlation between software piracy and the sources of quality in Industry 4.0, %.
Source: calculated and compiled by the authors.

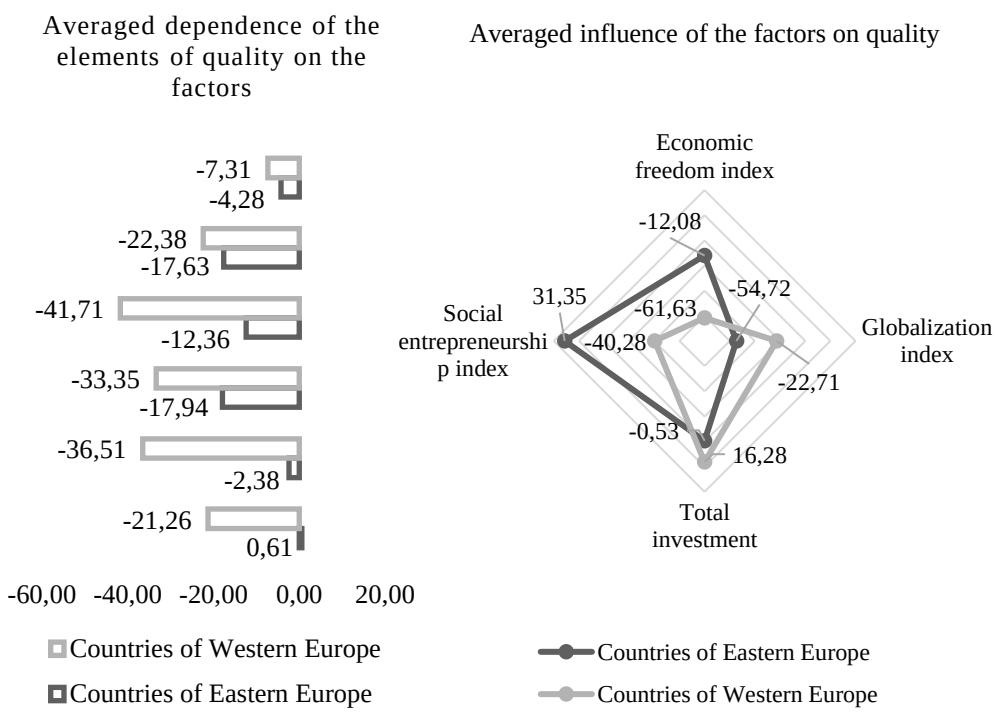

Figure 8. Averaged correlation between the elements of quality and the sources of quality in Industry 4.0, %.
Source: calculated and compiled by the authors.

As shown in Figure 8, the distinguished sources of quality in countries of Eastern and Western Europe positively influence the quality of Industry 4.0. The elements of quality of Industry 4.0 are ordered according to manageability based on the distinguished sources of quality: knowledge transfer (-41.71% and -12.36%, accordingly), agility of companies (-33.35% and -17.94%, accordingly), Internet retailing (-36.51% and -2.38%, accordingly), cyber security (-22.38 and -17.63%, accordingly), IT & media stock market capitalization (-7.31% and -4.28%, accordingly), and software piracy (-21.26% and 0.61%, accordingly). In countries of Western Europe, manageability of quality of Industry 4.0 is much higher (-27.09%) as compared to countries of Eastern Europe (-9%).

Source of quality of Industry 4.0 have different values in the studied groups of countries. In countries of Eastern Europe, they are classified in the descending order by significance: globalization index (-54.72%), index of economic freedom (-12.08%), total investment in economy (-0.53%), and social entrepreneurship index (31.35% – insignificant). In countries of Western Europe, they are classified in the descending order by significance: index of economic freedom (-61.63%), social entrepreneurship index (-40.28%), globalization index (-22.71%), and total investment (16.28% – insignificant).

4.2 Experience and perspectives of formation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU

In order to study the influence of the factors of industrial and manufacturing engineering on formation of cognitive economy in the Russian Federation and countries of the EU in 2020, we perform – on the basis of data from Table 2 – regression analysis for the full selection of countries (Table 3).

Table 3. Regression statistics of the influence of the factors of industrial and manufacturing engineering on cognitive economy formation.

Regression statistics	Innovation index (y_1)	Human development index (y_2)	High-technology export (y_3)	
Multiple R (determination coefficient)	0.8079	0.8199	0.7663	
Significance F	0.0304 significant at the level α=0,05 (0.0304<0.05)	0.0244 significant at the level α=0.05 (0.0244<0.05)	0.0584 not significant at the level α=0.05 (0.0584>0.05)	
Fobs	5.01	5.47	3.79	
Fobs	with k1=m=3, k2=n-m-1=8 Ftabl=4.07			
F-test	Fobs>Ftabl (5.01>4.07) passed	Fobs>Ftabl (5.47>4.07) passed	Fobs<Ftabl (3.79<4.07) not passed	
Constant	72.25	1.02	not significant	22.45
Coefficient with x_1	0.18	-0.0001		0.20
Coefficient with x_2	-0.74	-0.0032		-0.49
Coefficient with x_3	-0.26	-0.0016		0.00

Source: calculated and compiled by the authors.

To substantiate the reliability of the results of regression analysis, let us check whether they conform to the Gauss–Markov theorem. Cross-correlation of the factor variables is below 0.90 in all cases, constituting: r_{x1x2}=0.76, r_{x1x3}=0.25, r_{x2x3}=0.25. Therefore, there are no repeated variables. Multiple R for all three obtained models exceed 0.75, constituting 0.8079, 0.8199, and 0.7663, accordingly – which shows a close connection between the variables. Significance F in the first regression equation constitutes 0.0304 – thus, it is significant at the level α=0.05 (0.0304<0.05); in the second – 0.0244, it is significant at the level α=0.05 (0.0244<0.05); in the third – 0.0584, it is not significant at the level α=0.05 (0.0584>0.05).

The table value of F-test with k1=m=3, k2=n-m-1=12-3-1=8 (where m- number of factor variables, n-number of countries in the selection) Ftabl=4.07. F-test is passed only for the first (Fobs>Ftabl, 5.01>4.07) and second (Fobs>Ftabl, 5.47>4.07) models, but is not passed for the third model Fobs<Ftabl (3.79<4.07). That's why the third model should not be further studied, for it is expedient to acknowledge that high-technology export is not determined by the factors of industrial and manufacturing engineering in the Russian Federation and the EU. Thus, two equations of multiple linear regression remain:

– $y_1=72.25+0.18x_1-0.74x_2-0.26x_3$, according to which innovation index decreases due to robots in science (if it goes up 1 position in rating) by 0.18 points, but grows due to world robot distribution (if it goes up 1 position in rating) by 0.74 points, and due to increase of use of big data and intellectual analytics (if it goes up 1 position in the rating) by 0.26 points;

– $y_2=1.02-0.0001x_1-0.0032x_2-0.0016x_3$, according to which innovation index grows due to robots in science and R&D (if it goes up by 1 position in the rating) by 0.001, world robot distribution (if it goes up 1 position in the rating) by 0.0032, and increase of use of big data and intellectual analytics (if it goes up 1 position in the rating) by 0.0016.

On the basis of the obtained regression models and with the help of complex method, we determine the values of the factor variables, at which manifestations of cognitive economy in the Russian Federation and countries of the EU reach the level of the leaders of global ratings by innovation index (67.24 points – Switzerland) and human development index (0.954 - Norway). The perspectives of cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU in the period until 2024 are shown in Figure 9.

As shown in Figure, for innovation index to grow from 48 points to 67.24 points (by 40.07%) with simultaneous increase of human development index from 0.88 to 0.97 (by 10.39%) in the Russian Federation and countries of the EU in the period until 2024, management of the factors of industrial and manufacturing engineering has to ensure the following: increase of world robot distribution from 25.50th position to 4.84th position (by -81.01%) and growth of use of big data and intellectual analytics from 34.58th position to 19.72nd position (by -42.99%), while robots in education and R&D could remain at the 2020 level (21.33rd position).

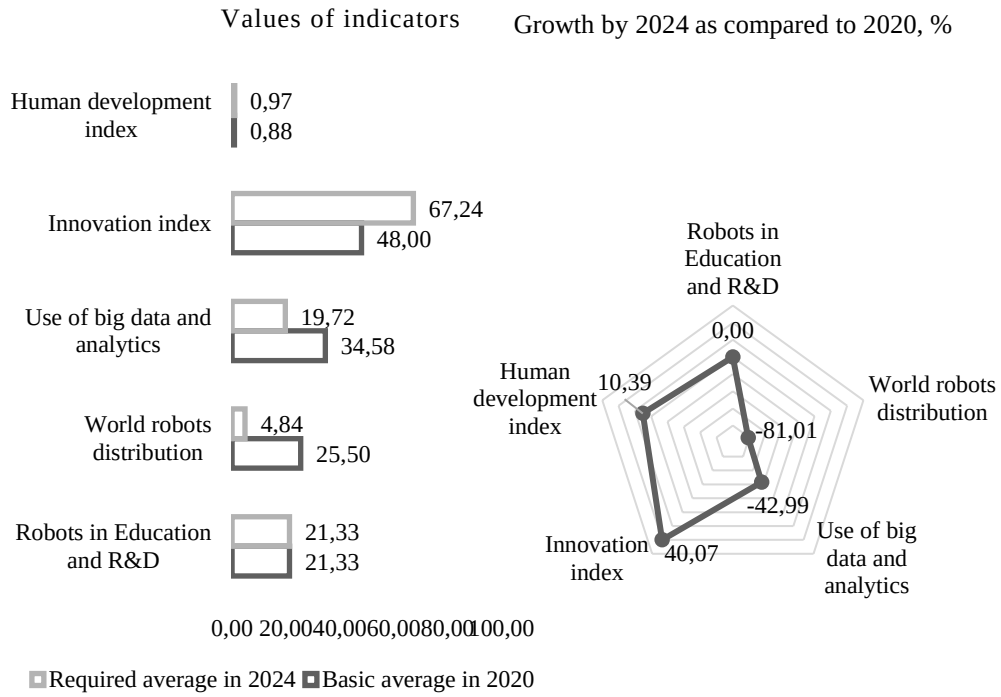

Figure 9. Perspectives of cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU in the period until 2024.
Source: calculated and compiled by the authors.

4.3 Program-target strategy of quality management in Industry 4.0 and cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU.

Based on the received results of correlation and regression analysis, we have developed the following program-target strategy of quality management in Industry 4.0 and cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU, which is oriented at the period until 2024 (Figure 10).

As shown in Figure 10, the offered strategy sets before the Russian Federation and countries of the EU two strategic priorities (goals) of cognitive economy formation: acceleration of innovative development and accelerating of human development. The tools for achieving these goals are connected to management of the factors of industrial and manufacturing engineering through worldwide robot distribution and use of big data and intellectual analytics.

Figure 10. Strategy of quality management in Industry 4.0 and cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU.

Source: developed and compiled by the authors.

The management methods envisage increase of quality of Industry 4.0 in view of its elements: increase of knowledge transfer, growth of agility of companies, development of Internet retailing, increase of software piracy, and increase of IT & media stock market capitalization. These tasks are achieved due to using the sources of quality, which, in countries of Eastern Europe, are globalization, economic freedom, and inflow of investments in economy, and in countries of Western Europe - economic freedom, corporate responsibility, and globalization.

5. Conclusion

Thus, the offered hypothesis has been proved. It has been shown that the factors of industrial and manufacturing engineering in the Russian Federation and countries of the EU have positive connection with the manifestations of cognitive economy (27.09% in countries of Eastern Europe and 9% in countries of Western Europe), but their influence is contradictory – which is shown by not only positive but also negative correlation and regression dependence of the studied indicators.

It has been substantiated that the elements of quality of Industry 4.0 have different manageability. The most manageable element is knowledge transfer, which is followed by agility of companies, which is followed by Internet retailing, cyber security and IT & media stock market capitalization. Sofware piracy is least manageable. The sources of quality of Industry 4.0 are different in countries of Western (economic

freedom, corporate social responsibility, and globalization) and Eastern (globalization, economic freedom, inflow of investments in economy) Europe.

Experience of cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU shows that high technology export does not depend on the factors of industrial and manufacturing engineering, which, however, determine innovations and human development. The developed program-target strategy of quality management in Industry 4.0 and cognitive economy formation based on industrial and manufacturing engineering in the Russian Federation and countries of the EU reflects the above conclusions and uses such tools of managing the factors of industrial and manufacturing engineering as world robot distribution and use of big data and analytics.

Contribution of this research to development of economics consists in structuring of the elements of quality of Industry 4.0, substantiating their manageability, and determining the key sources of increase of quality of Industry 4.0 in countries of Western and Eastern Europe. Theoretical significance of the research is also confirmed by proving the important influence of the factors of industrial and manufacturing engineering on manifestations of cognitive economy in the Russian Federation and countries of the EU. Practical significance of the research is due to development of a program-target strategy of quality management in Industry 4.0 and formation of cognitive economy based on industrial and manufacturing engineering in the Russian Federation and countries of the EU in the period until 2024.

Acknowledgements: The work was supported by Russian Science Foundation (project No. 20-18-00314).

References:

Ahmadi, M., & Taghizadeh, R. (2019). A gene expression programming model for economy growth using knowledge-based economy indicators: A comparison of GEP model and ARDL bounds testing approach. *Journal of Modelling in Management*, *14*(1),31-48. https://doi.org/10.1108/JM2-12-2017-0130

Ansong, E., & Boateng, R. (2019). Surviving in the digital era – business models of digital enterprises in a developing economy. *Digital Policy, Regulation and Governance*, *21*(2), 164-178. https://doi.org/10.1108/DPRG-08-2018-0046

Behmer, F. J., & Jochem, R. (2019). Organizational planning for quality management in the digital age. *Business Process Management Journal*, 26(3), 679-693. https://doi.org/10.1108/BPMJ-12-2018-0365

Chilton, K., & Jung, K. (2018). The applicability of growth machine theory to the knowledge economy: Social network analysis of Chattanooga's civic infrastructure. *International Journal of Social Economics*, *45*(4), 582-601. https://doi.org/10.1108/IJSE-10-2016-0293

Degelsegger-Márquez, A., Remøe, S. O., & Trienes, R. (2018). Regional knowledge economies and global innovation networks – the case of Southeast Asia. *Journal of Science and Technology Policy Management*, *9*(1), 66-86. https://doi.org/10.1108/JSTPM-06-2017-0027

Dellermann, D., Fliaster, A., & Kolloch, M. (2017). Innovation risk in digital business models: the German energy sector. *Journal of Business Strategy*, *38*(5),35-43. https://doi.org/10.1108/JBS-07-2016-0078

European Commission (2020). *Europe investing in digital: the Digital Europe Programme.* Retrieved from: https://ec.europa.eu/digital-single-market/en/europe-investing-digital-digital-europe-programme (data accessed: 28.08.2020).

Flores, E., Xu, X., & Lu, Y. (2020). Human Capital 4.0: a workforce competence typology for Industry 4.0. *Journal of Manufacturing Technology Management*, *31*(4), 687-703. \ https://doi.org/10.1108/JMTM-08-2019-0309

Gangi, Y. A. (2017). The role of entrepreneurship education and training on creation of the knowledge economy: Qatar leap to the future. *World Journal of Entrepreneurship, Management and Sustainable Development*, *13*(4), 375-388. https://doi.org/10.1108/WJEMSD-06-2017-0032

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, *29*(6), 910-936. https://doi.org/10.1108/JMTM-02-2018-0057

Gomes, R.F.S. & Cardoso, I.G. (2020). Emerging Technologies Applied to Quality Engineering: Current Scenario and Perspectives, *Proceedings on Engineering Sciences, 2*(3), 295-304, doi: 10.24874/PES02.03.008

Grandinetti, R., Ciasullo, M. V., Paiola, M., & Schiavone, F. (2020). Fourth industrial revolution, digital servitization and relationship quality in Italian B2B manufacturing firms. An exploratory study. *The TQM Journal*, *32*(4), 647-671. https://doi.org/10.1108/TQM-01-2020-0006

Gritsuk, N. V., Gamulinskaya, N. V., & Petrova, E. V. (2020). The innovative approach to managing the product quality in the digital economy: intellectual accounting & audit. *International Journal for Quality Research, 14*(2), 559-576. doi: 10.24874/IJQR14.02-13.

Hoe, S. L. (2017). Thinking about how to think: cognitive skills to stay relevant in a digital economy. *Human Resource Management International Digest*, *25*(5), 1-3. https://doi.org/10.1108/HRMID-02-2017-0040

Hoerlsberger, M. (2019). Innovation management in a digital world. *Journal of Manufacturing Technology Management*, *30*(8), 1117-1126. https://doi.org/10.1108/JMTM-12-2019-461

IMD (2020). *World Digital Competitiveness Ranking 2019.* Retrieved from: https://www.imd.org/wcc/world-competitiveness-center-rankings/world-digital-competitiveness-rankings-2019/ (data accessed: 28.08.2020).

Inshakova, A. O., Inshakova, E. I., & Marchukov, I. P. (2019). Participation of international organizations & integration associations in the development of legal regulation of foreign trade in energy resources. *Lecture Notes in Networks & Systems*, *44*, 173-185.

Inshakova, A. O., Uskova, M. S., Dolinskaya, V. V., & Frolova, E. E. (2018). Dynamics of the legislative development of public-private partnership in the sphere of agricultural insurance in Russia & the US. *Espacios*, *39*(28),2-12.

Institute of Scientific Communications (2020a). *Dataset "Big Data of the Modern Global Economy: Digital Platform for Data Mining – 2020".* Retrieved from: https://www.archilab.online/en/data/data-set-on-the-world-economy/sounting-data-set (data accessed: 28.08.2020).

Institute of Scientific Communications (2020b). *Dataset "Social Entrepreneurship in the World Economy: a Path from Virtual Scores to Big Data – 2020": Social entrepreneurship ranking.* Retrieved from: https://www.archilab.online/en/data/entrepreneurship/social-entrepreneurship-ranking (data accessed: 28.08.2020).

International Monetary Fund (2020). *World Economic Outlook Database: Total investment 2020*. Retrieved from: https://www.imf.org (data accessed: 28.08.2020).

Khin, S., & Ho, T. C. (2019). Digital technology, digital capability and organizational performance: A mediating role of digital innovation. *International Journal of Innovation Science*, *11*(2), 177-195. https://doi.org/10.1108/IJIS-08-2018-0083

KOF (2020). *Globalization Index 2019.* Retrieved from: https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html (data accessed: 28.08.2020).

Martínez-Climent, C. (2020). Knowledge, business and innovation. Economies and sustainability of future growth. *International Journal of Entrepreneurial Behavior & Research*, *26*(3), 397-399. https://doi.org/10.1108/IJEBR-04-2020-825

Martínez-Climent, C., Rodríguez-García, M., & Ribeiro-Soriano, D. (2019). Digital transformations and value creation in international markets. *International Journal of Entrepreneurial Behavior & Research*, *25*(8), 1603-1604. https://doi.org/10.1108/IJEBR-11-2019-820

Ministry of Digital Development, Communications and Mass Media of the Russian Federation (2020). *Program "Digital economy of the Russian Federation".* Retrieved from: https://digital.gov.ru/ru/activity/directions/858/ (data accessed: 28.08.2020).

Nguyen, M. A. T., Lei, H., Vu, K. D., & Le, P. B. (2019). The role of cognitive proximity on supply chain collaboration for radical and incremental innovation: a study of a transition economy. *Journal of Business & Industrial Marketing*, *34*(3), 591-604. https://doi.org/10.1108/JBIM-07-2017-0163

Paoloni, P., Paoloni, N., & Modaffari, G. (2019). Crowdfunding as a new collaborative process in the knowledge economy: A literature review. *VINE Journal of Information and Knowledge Management Systems*, *49*(2), 241-255. https://doi.org/10.1108/VJIKMS-12-2018-0118

Popkova, E.G. (2020). A new treatment of quality of goods and services in the conditions of the knowledge economy: opposition of traditions and innovations. *International Journal for Quality Research, 14*(2), 329-346. https://doi.org/10.24874/IJQR14.02-01.

Popkova, E.G., Przhedetsky, Yu V., Przhedetskaya, N.V. & Borzenko, K.V. (Ed.) (2020). *Marketing of Healthcare Organizations: Technologies of Public-Private Partnership.* A volume in the series Popkova, E.G. (Ed.) Advances in Research on Russian Business and Management, Charlotte, NC, USA, Information Age Publishing.

Popkova, E.G., Poluyufta, L., Beshanova, Y., Popova, L.V. & Kolesnikova, E. (2017). Innovations as a basis for marketing strategies of Russian oil companies in the conditions of oil prices reduction. *Contributions to Economics*, (9783319606958), 449-455. https://doi.org/10.1007/978-3-319-60696-5_57

Ragulina, J. V. (2019). Influence of education on placement of production in the AIC in the conditions of Industry 4.0. *On the Horizon*, *27*(3/4), 153-158. https://doi.org/10.1108/OTH-07-2019-0038

Rana, G., & Sharma, R. (2019). Emerging human resource management practices in Industry 4.0. *Strategic HR Review*, *18*(4), 176-181. https://doi.org/10.1108/SHR-01-2019-0003

Singh, P., & Giacosa, E. (2019). Cognitive biases of consumers as barriers in transition towards circular economy. *Management Decision*, *27*(4), 921-936. https://doi.org/10.1108/MD-08-2018-0951

Sivathanu, B., & Pillai, R. (2018). Smart HR 4.0 – how industry 4.0 is disrupting HR. *Human Resource Management International Digest*, *26*(4), 7-11. https://doi.org/10.1108/HRMID-04-2018-0059

Stuart, D. (2017). Knowledge Machines: Digital Transformations of the Sciences and Humanities. *Online Information Review*, *41*(1), 134-134. https://doi.org/10.1108/OIR-12-2015-0377

Szelagowski, M., & Berniak-Woźny, J. (2019). The adaptation of business process management maturity models to the context of the knowledge economy. *Business Process Management Journal*, *26*(1), 212-238. https://doi.org/10.1108/BPMJ-11-2018-0328

The Heritage Foundation. (2020). *2020 Index of Economic Freedom.* Retrieved from: https://www.heritage.org/index/explore?version=452 (data accessed: 28.08.2020).

Tsourgiannis, L., & Valsamidis, S. (2019). Digital marketing in tourism: why Greek tourists use digital marketing applications like Airbnb. *International Journal of Culture, Tourism and Hospitality Research*, *13*(4), 473-486. https://doi.org/10.1108/IJCTHR-03-2019-0043

Verma, A., Bansal, M., & Verma, J. (2020). Industry 4.0: reshaping the future of HR. *Strategic Direction*, 36(5), 9-11. https://doi.org/10.1108/SD-12-2019-0235

Wentrup, R., Nakamura, H. R., & Ström, P. (2019). Uberization in Paris – the issue of trust between a digital platform and digital workers. *critical perspectives on international business*, *15*(1), 20-41. https://doi.org/10.1108/cpoib-03-2018-0033

World Bank (2020*). Indicators: High-technology exports (% of manufactured exports).* Retrieved from: https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS?view=chart (data accessed: 28.08.2020).

Denis E. Matytsin
Volgograd State University,
Volgograd, Russia, e-mail:
dmatytsin@ya.ru,
gimchp@volsu.ru

Ekaterina Rusakova
Peoples' friendship
University of Russia (RUDN
University),
Moscow, Russia,
rusakova-ep@rudn.ru;