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Elena G. Popkova · Yulia V. Ragulina
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Industry 4.0: Industrial Revolution of the 21st Century

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Preface

The authors formulate the concept of Industry 4.0 within the modern economic theory and determine the fundamental provisions of the concept of knowledge economy. Also, the scientific and methodological approach to studying Industry 4.0 in the conditions of knowledge economy on the basis of the theory of economic growth is substantiated. The authors determine the main stages of formation of Industry 4.0 and the key indicators of its development and offer the criteria of evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy.

The authors analyze the accumulated experience of formation and development of Industry 4.0 in the economic practice of different countries and systematize successful experience of formation of Industry 4.0. Also, potential future outlines of knowledge economy with developed or dominating Industry 4.0 are determined, and priorities of development of Industry 4.0 in modern economic systems that are characterized by different progresses in the sphere of knowledge economy formation are offered and substantiated.

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Contents

Introduction

The modern global economy is at the threshold of the new industrial revolution, which is proved by a lot of actual tendencies. First, large duration of the global economic crisis of the early twenty-first century and impossibility of overcoming it with the help of the existing possibilities of economic systems shows depletion of the potential of the previous technological model. In the sphere of industrial production, the crisis was first manifested in overproduction of industrial goods and impossibility of selling it in domestic economic systems or in the global markets—which led to massive bankruptcy of industrial companies around the world and increase of protectionist measures from governments of various countries.

Second, according to the modern provisions of the economic theory (in particular, the theory of economic cycles, the theory of crises, the theory of innovations, etc.), overcoming the global crisis requires starting a new wave of innovations. This tendency is supported by intensive progress of a lot of countries in formation of knowledge economy, due to which potential of the global economic system as to its future innovational development is strengthened. Innovations are a generally acknowledged global priority of socioeconomic development.

Third, over the recent decades, scholars from different countries conducted research which resulted in new technologies, most of which are the leading production technologies (technological innovations)—i.e., they are oriented at the real sector of economy. These technologies have to form and stimulate intensive development of new high-tech spheres of industry, but they have not yet been used in practice.

Fourth, at the level of separate companies and even countries, there are initiatives on revolutionary technical modernization that are aimed at achieving unprecedented innovational development. In the conditions of global competition, success of economic subjects and economic systems in the global market could be ensured only by unique competitive advantages. In order to achieve and preserve them, it is necessary to use new technologies that ensure optimization of socioeconomic and business processes.

Technical direction and industrial focus on the viewed tendencies, as well as their aiming at activation of development of high-tech spheres of national economy and starting the process of innovational development of economic subjects and economic systems, formed the hypothesis of this research—industrial revolution of the twenty-first century is Industry 4.0, as it combines the above features and conforms to all actual tendencies in the modern global economy.

The purpose of this book is to verify the offered hypothesis, to determine the potential of Industry 4.0 in starting the new Industrial Revolution in the twenty-first century, and to develop practical recommendations for managing this process.

Part I
Theoretical Concept of Industry 4.0 in Economy

The Notion, Essence, and Peculiarities of Industry 4.0 as a Sphere of Industry

Yakov A. Sukhodolov

Abstract The purpose of this chapter is to study the notion, essence, and peculiarities of Industry 4.0 as a sphere of industry. The methodology of the chapter includes the method of content analysis of scientific literature, systematization and classification of scientific knowledge, and the methods of systemic analysis and structural & functional analysis. The information basis of the research includes the materials of the official normative and legal documents of governments of different countries. The authors systematize and classify the existing knowledge in the sphere of Industry 4.0 and distinguish conceptual approaches to treatment of the notion "Industry 4.0". The authors offer their own definition of the notion "Industry 4.0", in which Industry 4.0 is presented as a new industrial model. As a result, the authors come to the conclusion that Industry 4.0 is a new vector of development of industry, which is presented only in certain developed countries and has a small share of their real sector—but in the future it may lead to gradual modernization of other spheres of industry. This means that Industry 4.0, which is treated as a sphere of industry, possesses a potential for changes of the existing technological mode. The universal character of the new industrial model, offered by Industry 4.0, opens a possibility for new industrial revolution, as a result of which Industry 4.0 will become a new global industrial landmark and standard of development of the real sector of economy of the whole global economic system.

Keywords Industry 4.0 · Sphere of industry · New industrial model
New industrial revolution

1 Introduction

One of the problems that are widely discussed by experts and practitioners in the system of state economic regulators and are studied in scientific circles is economic growth. This issue has many aspects, which led to a large number of conceptual

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approaches. An important peculiarity of solving this problem is the fact that the initiative is traditionally started by scholars, who offer a new approach to management of economic growth, which is reflected in the economic practice of socio-economic systems.

Thus, the scientific substantiation of the possibility and necessity for specialization in industry for supporting high global competitiveness initiated the process of industrialization of economic systems. Scientific arguments in favor of post-industrialization started the mechanism of restructuring of economies of different countries in the direction of increase of the share of service sphere. The following global financial crisis became a reason for reconsideration of the concept of post-industrialization and for emergence of the concept "knowledge economy".

In the dominating scientific paradigm, the key landmark of development of economic systems is sustainability, which has two characteristics—stability and balance. In this chapter, the scientific hypothesis is offered—practical implementation of the principle of sustainable socio-economic development of economic systems envisages foundation on the real sector of economy, which has to show high innovational activity that is ensured by means of creation of innovations in adjacent spheres of national economy—education, science, etc.

Combination of all the above characteristics is achieved in Industry 4.0, which belongs to the real sector of economy and is oriented at innovational methods of industrial production. Intensification of development of Industry 4.0 in modern economic systems will ensure their innovational development, stable economic growth, and balance of the sectorial structure of national economy (simultaneous development of industry and service sphere). The purpose of this chapter is to study the notion, essence, and peculiarities of Industry 4.0 as a sphere of industry.

2 Materials and Method

The methodology of this chapter includes the method of content analysis of scientific literature, systematization and classification of scientific knowledge, the method of systemic analysis, and the method of structural & functional analysis. The performed overview of the normative and legal documents of governments of different countries showed that almost all developed and intensively developing countries pay close attention to formation of Industry 4.0 at the national level.

This is proved by development and adoption of the national industrial strategy "Industry 4.0" in Germany in 2012, which became one of the top-priority national (federal) projects in the sphere of high technologies (Federal Ministry of Education and Research of Germany (BMBF) 2014). In the USA, Industry 4.0 is the key tool of implementing the national strategy of innovational development (US National Economic Council, US Office of Science and Technology Policy 2015) and is considered to be one of the most perspective leading industrial technologies (Executive Office of the President, US National Science and Technology Council 2012). At present, there are various initiatives in the USA for practical implementation of the concept of development of Industry 4.0. In particular, genome of materials (Executive Office of the President, US National Science and Technology Council 2011) and robototronics (US National Science Foundation 2016) is developed, etc.

In the UK, Industry 4.0 is proclaimed to be a leading sphere of industry (UK Department for Business, Innovation & Skills 2010). The measures for development of Industry 4.0 are envisaged in the national project "Eight big technologies" (UK Department for Business, Innovation & Skills 2012). The industrial reform of modern France (2013) also envisages emphasis on Industry 4.0 (Ministère de l'Economie et des Finances 2015). In Japan, development of Industry 4.0 is the top-priority direction of implementing the plan of scientific and technological modernization of the country for the period 2016–2020 (The National Institute for Science and Technology Policy of Japan (NISTEP) 2015). China implements multiple projects for development of industry that are based on the concept of Industry 4.0 (The State Council of China 2015).

3 Results

The scientific term "Industry 4.0" was first introduces in Germany in 2011 at the Hanover fair, where it was used for denoting the transformation process in the global chains of value creation. In the report "The Fourth Industrial Revolution", presented by K. Schwab at the World Economic Forum, it is stated that Industry 4.0 includes business processes in industry that envisage organization of global production networks on the basis of new information and communication technologies and Internet technologies, with the help of which interaction of the production objects is conducted (Schwab 2017).

Scholars from Massachusetts Institute of Technology, Erik Brynjolfsson and Andrew McAfee described Industry 4.0 as a golden age of machine industrial production, organized on the basis of digital technologies and fully automatized (Brynjolfsson and McAfee 2014).

According to the Russian scholar V. N. Knyaginina, the most important specific feature that distinguishes Industry 4.0 from the traditional industrial production is absolute integration (close interconnection) and interactivity (adaptation to the situation in real time) of all production processes of an industrial company, ensured by means of modern digital technologies (Knyaginina 2017).

Russian scholars E. Loshkareva, O. Luksha, I. Ninenko, I. Smagin, and D. Sudakov defined Industry 4.0 as a revolutionary method of organization of industrial production, based on wide digitization and authomatization of production and distribution processes in industry that erases limits between physical objects, turning them into a comprehensive complex system of interconnected and interdependent elements. The experts also distinguish the basic characteristics of Industry 4.0 (Loshkareva et al. 2015):

– transition from manual labor to robototronics, which ensures automatization of all production processes;
– modernization of transport and logistical systems, caused by mass distribution of unmanned vehicles;
– increase of complexity and precision of manufactured technical products, manufacture of new construction materials due to improvement of production technologies;
– development of inter-machine communications and self-management of physical systems, conducted with the help of "Internet of things";
– application of self-teaching programs for provision of constant development of production systems.

As a result of content analysis, systematization, and classification of the existing scientific literature, we distinguished four main conceptual approaches to treatment of the notion "Industry 4.0" (Table 1).

As is seen from Table 1, we distinguish four conceptual approaches to treatment of the notion "Industry 4.0". The socio-oriented approach emphasizes the fact that development of Industry 4.0 strongly influences the modern society and has positive and negative manifestations. On the one hand, Industry 4.0 allows creating new goods, thus stimulating the increase of population's living standards. On the other hand, reduction of human's participation in production processes may lead to mass

Table 1 Conceptual approaches to treatment of the notion "Industry 4.0"

Approach	Treatment of the notion "Industry 4.0"	Representatives of the approach
Socio-oriented approach	Development of Industry 4.0 influences the modern society and has positive and negative manifestations	Longo et al. (2017), De Aguirre (2017), Crnjac et al. (2017), Pereira and Romero (2017)
Competence-based approach	Development of Industry 4.0 requires new competences from a modern industrial specialist	Aranburu-Zabalo et al. (2017), Chiu et al. (2017), Spendla et al. (2017), Nardello et al. (2017)
Production approach	Development of Industry 4.0 means modernization of industry by large-scale authomatization of production processes	Kuo et al. (2017), Plakitkin and Plakitkina (2017), Moeuf et al. (2017), Losch et al. (2017)
Behavioristic approach	Development of Industry 4.0 envisages transition to object-object interaction, i.e., elimination of subject (human) from the system of interrelations of inanimate objects (technical devices)	Brynjolfsson and McAfee (2014), Schwab (2017), Loshkareva et al. (2015), Knyaginina (2017)

Source Compiled by the authors

unemployment, which is a restraining factor on the path of development of Industry 4.0.

The competence-based approach envisages that development of Industry 4.0 requires new competences from a modern industrial specialist. Structural changes—replacement of manual (physical) labor by intellectual—are also accompanied by qualitative changes—servicing self-managed physical production systems requires from a modern industrial specialist possession of new competences, which include knowledge and capability to use new information and communication technologies.

Within the production approach, development of Industry 4.0 means modernization of industry with large-scale automatization of the production processes. Emphasis is made on the organizational component of functioning of industrial companies. The behaviorist approach focuses on the fact that development of Industry 4.0 envisages transition to the object-object interaction, i.e., elimination of the subject (human) from the system of interrelations of inanimate objects (technical devices).

We think that these approaches reflect certain aspects of Industry 4.0, so the existing definitions of the notion "Industry 4.0", which are offered within these approaches, are narrow and do not allow for full reflection of the complexity of this multi-aspect phenomenon.

In order to specify it, we offer the proprietary definition of the notion "Industry 4.0", which is a new industrial model, peculiar for self-organization and self-management of fully automated, self-teaching, and interactive production systems, in which the core is new digital and Internet technologies, and the role of human is limited by their initial start, control, and technical maintenance, which requires from modern industrial specialists new competences and is accompanied by social changes.

According to the offered definition, the essence of Industry 4.0 is shown in Fig. 1.

As is seen from Fig. 1, in the model of Industry 4.0 human (industrial specialist) is outside the production system. This system is formed only of physical objects (FO1, 2,…,n), which in Fig. 1 are shown by geometrical figures of different form and size,

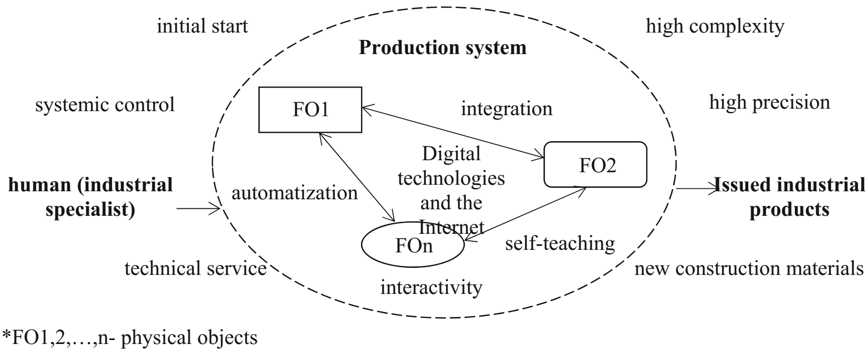

Fig. 1 Industry 4.0 as a new industrial model. *Source* Compiled by the authors

which reflects the possibility and the necessity for interaction (shown by double arrows in Fig. 1) between heterogeneous physical objects within the production system. Physical objects are production equipment that is used in industry.

4 Conclusions

Thus, Industry 4.0 is a new sphere of industry, which appeared as a result of emergence and distribution of new technologies—digital technologies and Internet technologies—which allow developing fully automatized production processes, in which only physical objects that interact without human participation take part. Industry 4.0 creates traditional industrial products and new industrial products, which cannot be manufactured in other spheres of the real sector economy.

The process of formation and development of Industry 4.0 influences all spheres of the economic system, including the social sphere, which is peculiar for substantial changes related to the necessity for adapting human to new conditions of economy. Thus, entrepreneur optimizes business processes, using the possibilities provided by Industry 4.0, and employee (industrial specialist) either masters new competences, which are necessary in Industry 4.0, or looks for a job in another sphere, and consumer masters new industrial products.

While at present Industry 4.0 is a new vector of development of industry, which is represented only in certain developed countries and accounts for a small share of their real sector, in future formation of Industry 4.0 may lead to gradual modernization of other spheres of industry. This means that Industry 4.0, which is treated as a sphere of industry, has a potential for changing the existing technological mode.

Its sectorial belonging is defines not by the issued products but by organization of the production process. Universality of the new industrial model, which is offered by Industry 4.0, enables production of any industrial product. This opens a possibility for new industrial revolution, as a result of which Industry 4.0 is to become a new global industrial landmark and standard by which the real sector of economy of the whole global economic system will be developing.

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Genesis of the Revolutionary Transition to Industry 4.0 in the 21st Century and Overview of Previous Industrial Revolutions

Ulyana A. Pozdnyakova, Vyacheslav V. Golikov, Irina A. Peters and Irina A. Morozova

Abstract Genesis of the revolutionary transition to Industry 4.0 in the 21st century is was formed in the conditions of past industrial revolutions in the 19–20th centuries, which were accompanied by rise of production powers and deep transformation of the whole system of public production. Over the last three decades of the 19th century, the volume of global industrial production grew by three times. Modern history and economics distinguish three large qualitative leaps in the history of humanity—three revolutions in productive powers of society and structures of society. However, technologies change very quickly, creating new challenges in distribution of inter-sectorial and inter-country connections, as well as in the structure of labor resources and education, which stimulates emergence and formation of a new revolutionary stage of transition of countries to "Industry 4.0". The authors analyze historical and economic tendencies of development of the modern economic society, related to "digitization" of economy and society, including development of clever services, clever data, cloud technologies, digital networks, digital science, digital education, and digital environment for living, in view of previous industrial revolutions on the path of the revolutionary transition to Industry 4.0 in the 21st century.

Keywords Industrial revolution · Industry 4.0 · Industry · Production · IT industry · Digital economy

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1 Introduction

According to statistics of the American economist W. Rostow, beginning of the 20th century marked the domination of industrial production: while in 1870 its share constituted 19.5%, in 1900 it was 58.7% (1913—100%). Due to growth of production and development of transport, turnover of the global trade increased by three times. In order to explain the causal factors that constitute the essence of genesis of global revolutionary transitions, it is necessary to determine the role of these revolutions in the historical context.

A well-known philosopher and sociologist of the 20th century Alvin Toffler distinguished three "waves" in developed society: agrarian revolution, transition to industry, and transition to society that is based on knowledge.

Professor of social sciences Danial Bell, who is known also as one of the leading American intellectuals of the post-War period, distinguished the following industrial revolutions: steam engine and railroad transport (late 18th century); electrification, division of labor, and mass production (late 19th century); electronics, IT industry, and automatized production (late 20th century).

Despite the differences in formulation of the names of these periods, it is obvious that each of them became a basis for step like growth in developed society; at that, specific time periods, character, scale, and depth of these changes are different in various countries.

2 Materials and Methods

The Neolithic Revolution created productive economy; the Industrial Revolution led to transition from agrarian society to industrial society; the continuing Technological revolution leads to transition from industrial society to service society. All these processes took place differently in different countries and regions—however, their character was global.

The term "industrial revolution" means quick and step like character of changes that took place at the brink of 18–19th centuries in England and then in other countries of Europe. This notion was first used by the French economist Jérôme-Adolphe Blanqui in 1830s. Since 1840s, it was widely used by Marxists: in the first volume of "Capital. Critique of Political Economy", Karl Marx analyzed revolutionary changes of production means that became a foundation of capitalism. Among non-Marxists, the notion "industrial revolution" was recognized in late 19th century under the influence of lectures on the Industrial Revolution of the English historian Arnold Joseph Toynbee. The term "Industrial Revolution" was further developed by F. Engels in his work "The Condition of the Working Class in England (1845) and later works of the founders of Marxism-Leninism, in which the essence of the Industrial Revolution is viewed as the phenomenon that took place in all countries during transition of capitalism from the manufacture stage to the higher stage of industrial capitalism.

Together with narrow treatment of industrial devolution as the event related only to genesis of capitalism, there are wider treatments, in which industrial revolution is any deep changes in the industrial sphere and revolutionary changes in tools and organization of production, which led to transition from pre-industrial to industrial society. The followers of this approach distinguish more than three industrial revolutions. However, such wide treatment is not widely recognized.

However, revolutionary changes influenced not only productive powers: they led to changes in the social structure of society. Replacement of manufacture by factory led to the most important shifts in ratio of social classes. Vladimir Lenin emphasizes that the Industrial Revolution was a "steep and quick transformation of all public relations under the influence of machines"; this transformation "is called in economics the Industrial Revolution".

In mid-18th century, English capitalism entered a new stage. There were all necessary preconditions for transition from the manufacture level of development of capitalism to the factory level: peasants lost their land and craftsmen could not compete with manufacture, went bankrupt, and became hired labor. These processes led to formation of large masses of workers who has to sell their workforce. On the other hand, large money was accumulated with certain persons and robbery of colonies provided inflow of new capitals. "Wealth that was received outside of Europe with robbing and enslaving the natives and murders went to the mother country and turned into capital" (K Marx, "Capital, V. I, p. 757.). These capitals were an important source of England's industrialization, for they allowed England to be the first country to perform the Industrial Revolution.

3 Results

The First Industrial Revolution, which ensured transition from manual labor to machine labor, continued for many decades. It is connected to invention of steam engine in the 17th century—but the process of transition from manufactures to factories continued in developed countries in 18–19th centuries. The Industrial Revolution influenced not only the development of science and technology but also the change of the structure of society, urbanization, and emergence of new specialties. Thus, the First Industrial Revolution began in England (late 18th–early 19th century): England's leadership in external trade due to colonies and accumulation of capital changed the society, making trade and industry its new basis. These changes took place in France and Belgium in 1830s–1860s, and in Germany (due to its division in early 19th century)—in 1850–1873. 1860–1870 became the period of capitalistic reforms in Russia (due to large territory, small density of population, and geo-strategic vulnerability), but transition to industrial society started only in early 20th century. Ta that, so called modernization influenced only the spheres and sectors of economy that stimulated the increase of the state's power.

The Second Industrial Revolution was connected to electrification and organization of conveyor production in the 20th century—cars and then other products.

Labor efficiency grew and approaches to corporate management changes. The consequences of the Industrial Revolution were manifested only in the second half of the 19th century. 1850s–1860s were the period of mastering of achievements of the Industrial Revolution and preparation of conditions for transition of the countries of the West to a new level of development. Fernand Braudel denotes this period as an important stage in development of the Western society: "Since mid-19th century… we enter a new age: centennial tendency…—is a tendency for simultaneous rise of the number of population, prices, GNP, and wages, broken only by random short cycles—as of "constant growth" were promised to use forever".

Thus, in early 20th century countries of the West had the industrial economic systems that was based on new technologies and dynamic economic growth. The main consequences of the technological changes of late 19th century were formation of wise industrial society and capitalism's entering the new monopolistic stage of development.

The Western society acquired such form as a result of acceleration of technical progress and new technological revolution, which is known in the modern historical literature as the Second Industrial Revolution. Socio-economic development of the Western society in the studied period took place under the sign of cardinal changes, caused by the Second Industrial Revolution.

The peculiarities of the Second Industrial Revolution are as follows:

1. Qualitative transformation of the technical and technological base of industry: heavy industry's acquiring leading positions (spheres of group "A"), which determined the fate of the country's economy, and creation of the system of large machine production.
2. Quick growth of the role of fundamental science in transformation of the technological base of production: based on scientific inventions, new spheres formed, which were very important in economy (electric engineering, motor industry, oil processing, etc.). Production became a technological application of science.
3. Change of the energy base of production: transition to a new fuel and energy source—electricity and oil products.
4. Deep changes in the technical and organizational system: growth of concentration of production and centralization of capital, creation of joint-stock companies and monopolies, and increase of the level of collectivization of labor.
5. Quick growth of labor efficiency, increase of total effectiveness of reproduction, and growth of population's living standards.
6. Qualitative changes in structure and level of qualification of work force, increase of the number of scholars, engineers, and technicians who are involved in the production process.
7. Cheapening and expansion of nomenclature and increase of quality of a lot of products.
8. Increase of contradictions of technical progress: economic crises became more destructive, labor intensity grew, social problems aggravates, and new technical achievements were widely used for creation of the means for annihilation of humans.

The key role in the Second Industrial Revolution belonged to cardinal changes in the sphere of energy: steam was replaced by electricity. The revolutionary changes were started in 1867 by E. Siemens inventing the first electric generator (dynamo). Other inventions followed: in 1879, the American inventor T. Edison created incandescent-filament lamp, and in 1882 he participated in construction of the first electric plant for public use, and in 1896—the first hydroelectric power station (on the Niagara River). Creation of power lines that allowed transferring energy to large distances was very important. One of the first power lines (Miesbach–Munich) was constructed in 1882 by Marcel Deprez. However, the main invention was an economic and relative simple method of transferring electric energy with three-phase alternating current. He designed and constructed in 1891 the first line Laufen–Frankfurt. This invention began wide electrification of industrial production, transport, and households. Usage of electricity started a revolution in the global economy. It became a basis of the electro technical sphere, which became basic in the production complex.

In the conditions of industrialization, development of the information network was very important. Telegraphy communications was founded in 1830s and became very popular. In 1850s, transcontinental telegraph lines appeared due to underwater communication cables. In 1866, the regular telegraph line was established between Europe and America. In 1876, the Scot A. Bell invented the first telephone in the USA, and 1878 saw the creation of the first telephone station. In 1890s such stations appeared all over the world. In late 19th century, the Russian scholar A. Popov and Italian radio engineer Marconi invented radio, which was soon recognized all over the world. In 1890s, G. Marconi invented wireless telegraph, and in 1901 he held a radio session across the Atlantic Ocean. These inventions became an impulse for development of mass communication means.

The developed information network was necessary and was created for organization of sales of the growing volumes of products. Starting from the second half of the 19th century, advertising began to be developed—it was also distinguished into a separate sphere of economy. Professional advertising offices were created, and advertising became a necessary means of selling mass products. A lot of its types were created with advertising: margarine, drugs, cigarettes, and make up began to be widely used in the age of advertising. This business was quickly developing in the USA—in mid-19th century it possessed effectives means of influencing the consumer. In 1910, 4% of national income was spent for this sector. Due to advertising, Coca Cola, Kodak, Camel, and Levi's became the leaders in the national market, and the global economic expansion of the leading American companies began. Development of communication and information means led to unification of all five parts of the world into a single global economic system. Thus, interdependence and interaction of all regions of the world grew, which created preconditions for development of the integration processes in the global economy.

The Second Industrial Revolution entered the sphere of everyday life, changing and simplifying the life of a Western person. According to Eric Hobsbawm: "…thia was the time when telephone and wireless telegraph, phonograph, cinema, cars, and airplanes became part of the life, let alone such achievements of science and technology that entered everyday life as vacuum cleaner (1908) or aspirin (1899), which turned out to be the most universal medicine of all ever invented by human. It is necessary to remember the most useful machine of all times—bicycle, which advantages were recognized at once and everywhere".

Development of industrialization led to serious financial problems: the need for investments grew very quickly. Due to this, the countries of the West created a stable and networked credit and financial system after the Second Industrial Revolution—which was based on joint-stock banks. They provided short-term and long-term commercial credits, which was especially important for development of heavy industry.

Implementation of new technologies required a scientific approach to management of production and organization of labor. F. Taylor became the "father of scientific management"—he developed the foundations of the theory and practice of engineering sociology, aimed at increase of labor efficiency. The system of F. Taylor was successfully implemented by H. Ford, who applied the first assembly line at his plant in 1913.

In the conditions of new technological revolution, economic underrun threatened national sovereignty of the largest European countries. Due to this, the Second Industrial Revolution in late 19th century led to quick industrialization in the "second wave" countries. Economic development became very quick: national market was formed, networked banking system was formed, new technologies were implemented into industry, and concentration of production reached a high level. Forced modernization was conducted by authorities and had artificial character. This envisaged wide government interferences with the development of economy. The state was the main initiator of structural transformations and the largest investor. A large role in development of industry of the "second wave" countries belonged to foreign capital—primarily, British and French.

The Second Industrial Revolution led to changes in the social sphere. Consumer society formed at this stage—a society oriented at material values and at consumption. Social stratification of the economic type and class social structure of society were established. All usual criteria of status group stratification (way of life, level of education, professional specialization, confessional and national belonging) were secondary as to economic factors and class status.

In early 21st century there appeared a lot of publication on the Third Industrial Revolution. It was based on refusal from using minerals, transition to renewable sources of energy with implementation of computers in production, authomatization, and transition to digital additive production (Kupriyanovsky et al. 2016). Three years ago this revolution was called by The Economist a new industrial age. "Industry 3.0" is based on three principles:

(1) Shift of center of profit from production stages to development and design. A classic example was unequal formation of added value in the chains design—creation and marketing—assembly.
(2) Growth of labor efficiency and, as a result, reduction of blue collars and employees involved in production.

(3) Replacement of traditional centralized models of business by distributed structures and horizontal interaction.

The Third Industrial Revolution included complex deep transformations of systems, structures, institutes, relations, and technologies, which change the means, mechanisms, and content of people's organizing production, exchange, consumption, training, communication, and leisure. The system is primarily the system of labor division and monetary, financial, trade, legal, and information systems. The structures are structures of state and corporate management, international organizations and non-government organizations, including religious ones. The institutes are property, state, business, law, money, trade, norms and standards of production and exchange of goods/services, and intellectual elites and middle class.

Scientific inventions that are generated by private and government organizations turned into new technologies, unique machines, equipment, and devices. Technologies transformed into specific investment and consumer goods and services. New goods and services allow for radical change of the system of international and local labor division. They contradict the old norms and standards of production.

The notion "country of origin" disappears. Scientific laboratories and testing grounds are in one country, design is performed by specialists in another country, assembly is conducted in the third country, and marketing is supervise by completely other people. Financial flows are formed for optimization of tax load. Business in the age of the Third Industrial Revolution does not make people to leave their country in order to be employees of a global or even regional TNC.

Financial system became a global system with tough imperatives for the national and fiscal policy. Competition of legislatures, systems of personal and property security, cultures and traditions, educational systems and systems of healthcare entered tough competition.

Locomotives of the Third Industrial Revolution are a unique class of new entrepreneurs, which is extraterritorial, cosmopolitical, polylinguistic, educated, communicative, and apolitical. Its purpose is the global market. They integrate recent achievements in the sphere of transport and telecommunications for allocation of productions on the basis of recent achievements of science and technology. They outsource services for optimization of tax load and legal consulting. They are a part of existing large TNC and new structures. They represent both developed and developing countries (Ivezic et al. 2016).

The Fourth Industrial Revolution is the stage of formation of the German concept "Industry 4.0". Its implementation determined the very fact of existence of German industry against the background of the global movement of production to Asia and other developing countries. The key driver of "Industry 4.0" is increased integration of "cyber physical systems" into factory processes. Production capacities start interacting with manufactured goods and adapting to new needs of consumers. At that, the whole stages of production are formed without human participation and will be deepened in this direction. This is the production part of Internet of things, which quickly enters the life of consumer society.

The Fourth Industrial Revolution, known as "Industry 4.0", emerged in Western countries in 2011 as a project (initiative) aimed at increase of competitiveness of the processing industry (Lu et al. 2016). Specialists offered integrating into industrial processes so called "cyber physical systems", or automatized machines and processing centers, connected to the Internet. The purpose is to created such systems that would allow machines to changes production models if the necessity arises.

4 Discussion

New relations of the age of the Third Industrial Revolution are relations between new entrepreneurs with traditional participants of the old age market: national business, old TNC, national states, and international organizations. How they will work, how they will pay taxes, whether they will be under a certain global government, who will inspect them—all these questions will get answers very soon. New relations will be built between innovational entrepreneurs and old intellectual elite and opinion makers (religious organizations, academics, lecturers, experts, etc.). Despite the fact that realia of the Third Revolution are not that popular, a new "revolutionary situation" appeared—the German concept "Industry 4.0".

Germany is the global example and leader in the sphere of transition to the concept "Industry 4.0". This notion appeared in Germany. The concept "Industry 4.0" was developed by the Ministry of science and education of Germany. In 2012, the government published new strategy of development of industry under the name "Platform Industry 4.0". The concept "Industry 4.0" is based on the concept "Internet of things (and services)". It envisages that each physical object or "thing" (e.g., machine, component, or final product) is equipped with built-in digital technology that allows interacting with other objects and humans. At present, according to the surveys, half of industrial companies of Germany are involved into this process, at least at the level of development of new business concepts. Each fifth company uses the components of "clever factory" in production. German industrialists and government plan to develop first working production lines this year, and by 2030 Germany should have the system of Internet industry.

In the concept "Industry 4.0", not only objects, but also machines, assembly lines, and whole factories are unified into a network. Certain factories have the blanks marked with RFID, which transfer the necessary information to the assembly robot. Stock of resources is tracked. The industrial technology Just-in-Time was considered to be the leading one, but very soon the need for this approach and the corresponding specialists will disappear. At that, customization becomes usual, and each item could be produced at factory for an individual customer (Final report of the Industrie 4.0 Working Group, ACATECH 2013).

Apart from Germany, a lot of countries took the path of the concept "Industry 4.0". The USA created a non-commercial consortium Industrial Internet.

All this is very important for development of economy in Russia due to the following reasons:

(1) The structure of employment will change radically. While the Third Industrial Revolution took jobs from a lot of specialists, the fourth wave will continue this tendency. A lot of workers control the work of machines and computers in the autonomous regime. The new Industrial Revolution will allow the machines to act without human interferences.
(2) The Fourth Industrial Revolution will influence distribution of roles between countries. Russia has fallen behind during the Soviet time, and only recently has reduced the gap in certain directions (Ingemansson 2016).

5 Conclusions

It is impossible to change culture settings of the new generation at the stage of revolutionary transition to Industry 4.0, but it is possible to make the advantages the continuation of its drawbacks: this requires emphasis on unique production.

In order to stimulate the increase of the number of people who are inclined to conduct unique production, it is necessary to start from the educational sphere. Apart from studying modern technologies, it is necessary to preserve simple skills, which were passed from generation to generation in the past. At present, there are no lessons of manual training in school—during which children can machine a metal item, etc. It is impossible to become an engineer only on the basis of books. A professional engineer has to have spatial imagination and physical feeling of any item. It is important to support and develop science, and competitive advantages will be based on new inventions and new technologies.

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Fundamental Differences of Transition to Industry 4.0 from Previous Industrial Revolutions

Elena G. Popkova, Yulia V. Ragulina and Aleksei V. Bogoviz

Abstract The purpose of this chapter is to determine fundamental differences of transition to Industry 4.0 from previous industrial revolutions. The methodology includes structural & functional analysis, comparative analysis, induction, deduction, formalization, etc. These methods are used for determining similarities with previous industrial revolutions and peculiarities of the future Fourth Industrial Revolution. The authors prove that transition to Industry 4.0 is a new industrial revolution, which is shown by the attributes that are a sign of all industrial revolutions: change of the type of technological mode as a result of mass implementation of accumulated industrial innovations and systemic transformations in industry, which results in deep changes in logistics and manufactured products. At the same time, the Fourth Industrial Revolution is unprecedented and possesses a whole range of peculiarities, as compared to previous industrial revolutions. It envisages full elimination of human from the production system, ensuring absolute automatization of the production process, simultaneous combination of formation of global industrial networks with elimination of negative social consequences, changes the essence of industrial patents, and creates a possibility for quick change of direction of industrial production's specialization.

Keywords Industry 4.0 · Industrial revolutions · Real sector of economy · The fourth industrial revolution

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1 Introduction

The new industrial revolution, which is expected by the whole global society, as it is to become the means of overcoming the consequences of the global recession and a catalyzer of the new wave of economic growth, is not due for quite some time, but it could be described conceptually even now.

In order to reduce the risk component that accompanies any evolutional and revolutionary changes of economic systems, it is necessary to compare the Fourth Industrial Revolution to three previous revolutions. This will allow minimizing or eliminating possible mistakes and maximizing the effectiveness of this revolution, increasing the positive effect and reducing negative side effects (externalities).

A hypothesis is offered that transition to Industry 4.0 envisages deep changes in the system of industry, which are similar to the changes that accompanied previous industrial revolutions. However, transformations in the real sector of economy that are related to transition to Industry 4.0 are so strong and unprecedented that the new industrial revolution fundamentally differs from previous industrial revolutions. The purpose of this chapter is to determine essential differences of transition to Industry 4.0 from previous industrial revolutions.

2 Materials and Method

Industrial revolutions, as specific economic phenomena, are studied and described in multiple scientific works, among which are Khan (2017), Huberman et al. (2017), Kitsios et al. (2017), Ragulina et al. (2015), Bogoviz et al. (2017), Bogdanova et al. (2016), Popova et al. (2016), Kuznetsov et al. (2016), Kostikova et al. (2016), and Simonova et al. (2017). Transition to Industry 4.0 is studied as the Fourth Industrial Revolution in the publications Agamuthu (2017), Thayer (2017), Pirvu and Zamfirescu (2017), Li et al. (2017), Caruso (2017), etc.

Methodological basis of this research, aimed at provision of verification of this hypothesis, includes various scientific methods, which are traditionally used within the systemic approach—structural & functional analysis, comparative analysis, induction, deduction, formalization, etc. These methods are applied for determining common features with previous industrial revolutions and essential peculiarities of the Fourth Industrial Revolution.

3 Results

All industrial revolutions have common features that allow defining them as revolutions, not simple evolutional changes in industry. A generalized model of the

Industrial Revolution, which emphasizes its peculiarities, is presented graphically in Fig. 1.

As is seen from Fig. 1, a precondition for emergence of any industrial revolution is accumulation of a sufficient volume of completely new technologies of industrial production (industrial technological innovations). In the process of accumulation of these technologies, evolutional development of the real sector of economy takes place (in Fig. 1 it is shown by growing parabola in lower left part of the graph).

When these technologies reach some threshold number and receive necessary development, which prepares them for implementation (practical application) into industrial production, the process of transition from quantity to quality is started. The philosophical basis of this process is set in the works of Georg Wilhelm Friedrich Hegel on materialistic dialectics, which were developed in the works of F. Engels, who formulated the Law of transformation from quantity to quality. In synergy, these transitions take place in the bifurcation points (critical states of the system).

This transition marks the start of the industrial revolution, which is systemic transformations in industry. This causes the need for new infrastructure and presents serious challenges for the state (growth of expenditures for modernization of the real sector economy) and society (mastering of new industrial products, increase of qualification of industrial specialists, etc.). A new technological mode is established in the course of the industrial revolution—i.e., transition to completely new technologies of industrial production. Reorganization of production and mass modernization of technologies and equipment leads to growth of efficiency of industrial production.

As a result, in the real sector of economy, which is treated as an economic system in this research, synergetic effect appears—which is caused by reduction of the volume of consumed resources and energy (economy of resources and energy) with

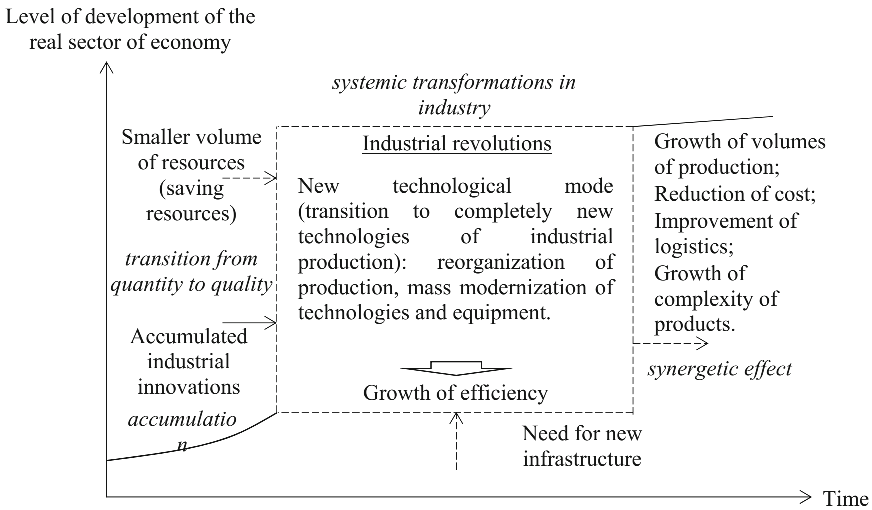

Fig. 1 Generalized model of the industrial revolution. *Source* Compiled by the authors

simultaneous growth of the volumes of industrial production, reduction of cost by means of achievement of the “scale effect”, improvement of logistics (increase of the speed of transportation of intermediary and final industrial products, reduction of probability of products’ defects, possibility of transportation of large items, etc.) and growth of complexity (increase of quality: precision, reliability, sustainability to temperature changes and improvement of technical characteristics) of issued industrial products.

The final result of industrial revolution is transition to a new level of development (new quality of growth) of the real sector of economy. The essence and key parameters of three previous and the Fourth Industrial Revolution according to the offered generalized model of the Industrial Revolution are shown in Table 1.

Table 1 The essence and key parameters of three previous and the Fourth Industrial revolution

Parameters	The industrial revolution			
	First	Second	Third	Fourth
Time frame	18th–early 19th century	Late 19th–early 20th century	Second half of the 20th century	21st century
Accumulated industrial innovations	Production of cast iron, steam engines, and textile industry	Production of high-quality steel, distribution of railroads, electricity, and chemicals	Renewable sources of energy, digital technologies, network organization of business processes	Internet of things, robototronics
Type of technological mode	Industrial production	Conveyor production	Global production on the basis of digital technologies	Fully automatized production
Required new infrastructure	Industrial equipment	Conveyor equipment, railroads	Digital equipment, global infrastructure	High-speed Internet, robotized equipment
Essence of systemic transformations in industry	Formation of industrial production	Formation of conveyor production	Formation of global production on the basis of digital technologies	Formation of fully automatized production
Efficient changes in logistics	Steam transport	Railroad transport	Buildings that generate electric energy, electric, hybrid, and other transport means	Exoskeleton, manipulators, Robototronics
Efficient changes in products	Cast iron products	Steel products	Computer products	New construction materials

Source Compiled by the authors

As is seen from Table 1, timeframes of the First Industrial Revolution covered the 18th–early 19th centuries. Accumulated industrial innovations, which led to this revolution, included technologies of cast iron production, steam engines, and technologies of textile industry.

In the process of the First Industrial Revolution, the industrial technological mode was formed, which replaced manual labor. This requires a new infrastructure—industrial equipment. The essence of systemic transformations in industry, which took place in the course of this revolution, is brought down to formation of industrial production as such. The resulting changes in logistics consist in emergence of steam transport, in products—in manufacture of cast iron products.

The Second Industrial Revolution took place in late 19th–early 20th centuries and was caused by accumulated technological innovations in industry—technologies of production of high-quality steel, railroads, electricity, and chemicals.

As a result of this revolution, conveyor production was formed, which required such objects of infrastructure as conveyors, railroads, etc. The essence of systemic transformations in industry consists in formation of conveyor production. Logistical changes are caused by distribution of railroad transport, in products—by manufacture of steel products.

The second half of the 20th century marked the Third Industrial Revolution, caused by the technologies that allowed accumulating and using renewable sources of energy, digital technologies, and the network organization of business processes. The type of technological mode that appeared was the global (network) production on the basis of digital technologies. This required digital equipment and global infrastructure.

The essence of systemic transformations in industry is brought down to formation of global production on the basis of digital technologies. As a result, there appeared buildings that generate electric energy, electric, hybrid, and other transport means, and production of computer products became possible.

The Fourth Industrial Revolution is expected in the 21st century. It will take place as a result of development of such technologies as Internet of things, robototronics, etc. Fully automatized production is the type of technological mode that will establish in the course of this revolution. This will require such infrastructure as high-speed Internet networks, robotized equipment, etc.

The essence of systemic transformations in industry consists in formation of fully automatized production. The expected resulting changes in logistics include exoskeleton, which is put on a human and which increases human's physical possibilities; manipulators, which allow for remote control for industrial objects; robototronics, which allow transporting heavy loads to large distances. Resulting changes products include new construction materials, which production was impossible in the past (optical fiber, nanomaterials, etc.).

The above essential characteristics of the process of transition to Industry 4.0 allow defining it as a new industrial revolution and reflect its similarity (common essential features) to three previous industrial revolutions. However, the Fourth Industrial Revolution is expected to become an unprecedented phenomenon in development real sector of economy. Its following differences from the previous industrial revolutions are distinguished.

The most important difference of transition to Industry 4.0 from previous industrial revolutions is elimination of human from the production process. While previous industrial revolutions allowed for certain reduction of human's participation (industrial specialist) in the production process, with preservation of his important role in the work of the production system, the new industrial revolution will lead to human's elimination from the production system. This will require reconsideration of the essence of this system's work, as it will turn from socio-technical into fully technical system. Artificial intelligence allows for full elimination of mistakes caused by "human factor", thus ensuring rationalization and optimization of all business processes.

Another difference is revolutionary change of not only separate but all business processes of an industrial company. The capabilities of artificial intelligence allow for deep change, modernization, and optimization of all components of the production and distribution system, including logistics, management, marketing, etc.

For example, it is possible to simplify and accelerate deals due to full automatization of the process of development of products and its manufacture. With receipt of order from a customer, it is possible to develop a technical solution (project, draft, etc.) and create an initial model with 3D printer by the order from the computer, and then the project is passed to production and the necessary volume of products is created automatically. Thus, human does not participate in any of the above operations.

Another difference is caused by the possibility for simultaneous usage of the possibilities of globalization and minimization of negative social consequences. Industry 4.0 envisages global interaction of companies. Computers, which are controlled by AI, can exchange the incoming information in real time via the Internet, this passing orders into production.

During the previous industrial revolutions, optimization of production was accompanied by negative social externalities that were connected to reduction of the population's living standards of the territories on which the industrial companies were located and to negative influence of production on these companies' employees.

Full authomatization of production with a possibility for remote control by human isolates humans from the production process, thus eliminating negative social consequences. The companies of Industry 4.0 could be placed on uninhabited areas (mountains, far North, etc.), without doing any damage to health of employees or the population.

The differences also include the change of the essence of industrial patents. While during the previous industrial revolutions the essence of patenting was brought down to hiding the technologies—so that rivals could not learn how to use them for manufacture of products (industrial samples were not allowed into the hands of rivals, for the technologies of production was secret)—now all information will be available on the Internet and will become generally accessible. That's why patents have to protect the rights of their owners only legally, bereaving the rivals of the legal possibility to use them, despite awareness of all details.

Another difference is the possibility for quick change of the direction of specialization of industrial production. All previous industrial revolutions envisaged complication of production systems (increase of scale and complexity of equipment), which made them less flexible and mobile. At that, industrial equipment was manufactured at separate industrial companies and was transferred to manufacturers of industrial products through B2B markets.

Companies of Industry 4.0 can produce the necessary equipment and industrial products. This allows for quick re-orientation of production in case of an order for another industrial product, with development of the corresponding technical project and creation of the required equipment for its implementation. As humans do not participate in the production process, high mobility is achieved due to the possibility for quick re-orientation of machines.

Based on the above, we compiled a general model of development of industrial production with revolutionary stages and their differences (Fig. 2).

As is seen from Fig. 2, the Fourth Industrial Revolution has more peculiarities and more serious transformations of production systems.

18th – early 19th century, the First Industrial Revolution

Peculiarities:
- formation of industrial production;
- distribution of steam transport;
- start of cast iron production.

Late 19th – early 20th century, the Second Industrial Revolution

Peculiarities:
- formation of conveyor production;
- distribution of railroad transport;
- start of steel production.

Second half of the 20th century, the Third Industrial Revolution

Peculiarities:
- formation of global production based on digital technologies;
- construction of buildings that generate electric energy and electric, hybrid, and other transport vehicles;
- start of computer production

21st century, the Fourth Industrial Revolution

Peculiarities:
- formation of fully automatized production; elimination of human from the production process;
- revolutionary changes of all business processes of industrial company;
- emergence of a possibility of simultaneous usage of globalization and minimization of negative social consequences;
- change of the essence of industrial patents;
- possibility of quick change of specialization of industrial production.

Fig. 2 A general model of development of industrial production with revolutionary stages and their differences. *Source* Compiled by the authors

4 Conclusions

It is possible to conclude that the offered hypothesis was proved—transition to Industry 4.0 is a new industrial revolution, which is confirmed by the attributes that accompany all industrial revolutions. They include the change of the type of technological mode as a result of mass implementation of accumulated industrial innovations and systemic transformations in industry, which results in deep changes in logistics and manufactured products.

At the same time, the expected Fourth Industrial Revolution is unprecedented and possesses a lot of peculiarities as compared to previous industrial revolutions. It envisages full exclusion of human from the production system, ensuring absolute automatization of the production process, combination of development of global industrial networks with elimination of negative social consequences, change of the essence of industrial patents, and creation of a possibility for changing specialization of industrial production.

Therefore, the Fourth Industrial Revolution opens possibilities for development of economic systems of the future, in which modernization of the real sector will be followed by deep changes of the revolutionary character in all spheres and subsystems of national economy.

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Industry 4.0 and Closed-Loop Economy in the Context of Solving the Global Problems of Modern Times

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1 Megatrends of Development of Globalization Processes

Evolution of the global economic system reached the stage when at the global level and at the level of separate national economic public reproduction is transformed into single global economic space, based on the process of globalization. Essential features of the globalization processes are expressed in stage-by-stage formation of the single information space by integration, diffusion of computer and information technologies, which cover the multi-aspect world environment, and in development of scientific and technological radical, optimizing, and modifying innovations, which have the potential scale of implementation. The multi-aspect globalization, which shows regularities of establishment by mega-trends, started the changes in the business environment and outlined its vector of development.

Appearance of scientific studies that outlined megatrends as the main directions of evolution of the modern world is related to the name of J. Naisbitt, who in the work "Megatrends and Global Paradoxes" (Naisbitt 1994) determined transition from industrial society to the society based on formation and dissolution of information.

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J. Naisbitt distinguished ten main megatrends that determine the dominating position of new society:

1. Transformation of industrial society into information society.
2. Movement to the balance "high-tech—moral comfort".
3. Globalization of the world economy: from the global economy to global investments.
4. Transformation of society that is content with fleeing stimuli into society that is oriented at long-term achievements.
5. From centralization to decentralization (construction bottom-up).
6. Realization of benefit of self-help, rather than support from the institutes.
7. Accessibility and speed of dissolved information led to emergence of corporation of participation.
8. Development of entrepreneurial environment is related to formation of network structures.
9. Migration—reality of today's life.
10. Transition to society with multiple choice and multi-variant behavior.

Scientific studies of manifestations of global megatrends and main trajectories of evolution of global development were conducted by other scholars as well (Shakleina and Baykov 2013; Bakas 2009).[1] The key tendencies of manifestation of trends are connected to industrialization on the basis of implementation of innovational solutions.

Each megatrend has its vector of specific manifestation of mega tendencies, which are born in a separate macro-economic systems or at a certain level of economic relations, which generate events along the chain: breakthrough—technological leadership—institutional and organizational development—information society.

Analysis of megatrends in the context of future moving forces specifies implementation of epochal innovations, which are peculiar for:

- humanization of technologies (informatization of production, intellectual functions of labor resources, expansion of production of high-tech products, artificial intelligence, robototronics);
- ecologization of technologies (wasteless technologies of extraction, processing, and transportation of resources, reduction of emissions into atmosphere, production of renewable types of energy);
- globalization of technologies (global markets of innovational products, сырья, clusters of new technologies).

On the whole, the studies show the following processes that determine megatrends of the modern global evolution (Fig. 1).

A moving force of megatrends of globalization processes are Internet space, industrial Internet, software, intellectual automatized systems, tools of virtual environments and cloud technologies, biotechnologies, and artificial intelligence.

[1] Aburdene, Patricia. Megatrends 2010. New ed.—Hampton Roads Publishing Company. New York.—248 p.

Fig. 1 The processes that determine megatrends of the modern global evolution

Megatrends of development of globalization processes determine the peculiarities of formation of national economy of each country and trends of development of the global economy on the whole, which characterize the changing world. The world is developing under the influence of long-term transformations of the global economic systems and the factors that define the modern economic tendencies. Megatrends of economic development are manifested in change of the demographic situation, growth of global trade, formation of a new model of consumption, change of qualitative content of resources, growth of need for them with reducing natural stock, influence of human activities on ecology, and appearance of new technologies (Fig. 2).

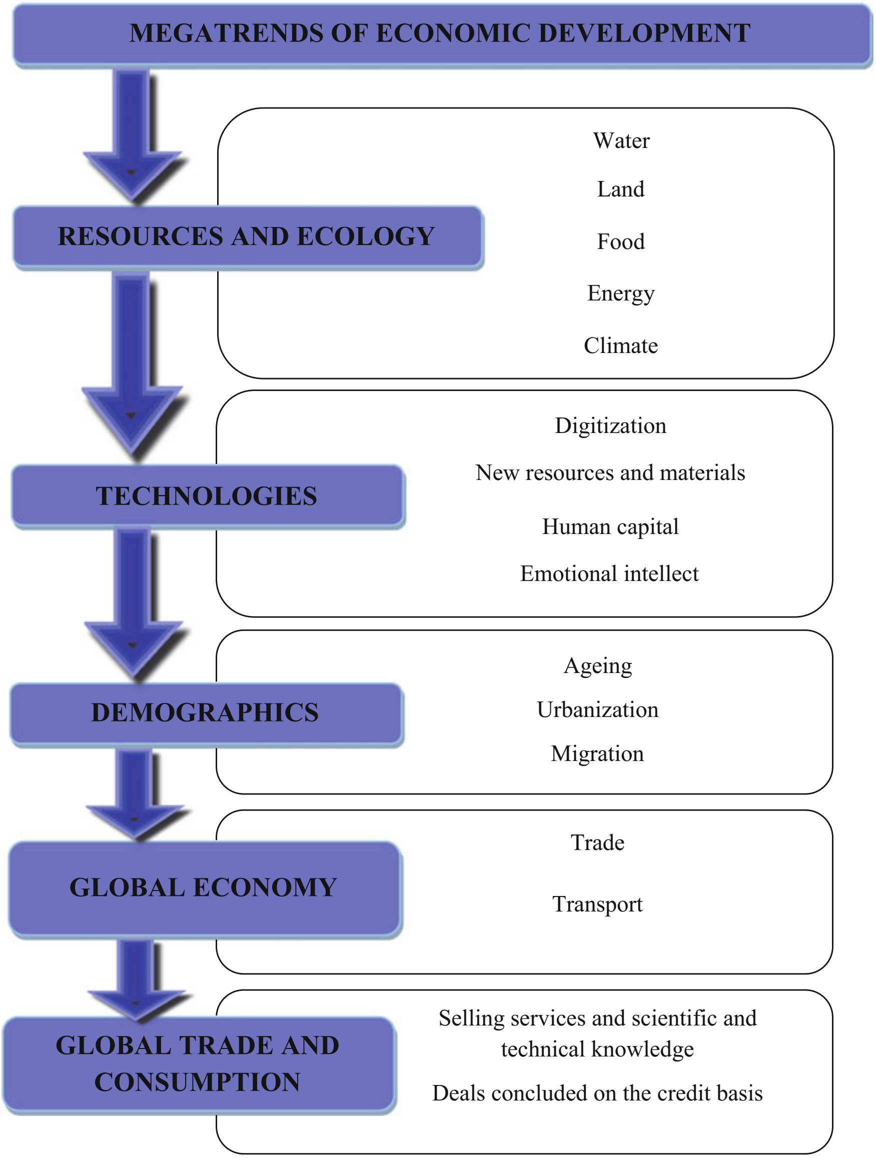

Fig. 2 Megatrends of economic development

As of now, the megatrend of development in leading countries of the world is the new wave of industrialization that influences formation of new paradigms and algorithms. Thus, in the USA it is re-industrialization, which covers the industrial foundation of basic and infrastructural spheres, development of IT technologies in favor of communications; in Europe—the Fourth Industrial Revolution (Industry

4.0), which envisages digitization of all assets that participate in the chain of value creation; in Japan—Industrial Intelligence, which means digitization of all processes and stages of production and robotization of production processes.

2 Closed-Loop Economy as a Model of Industry 4.0 Development

The term "cyclic (or circular) economy" was introduced by economists Pearce and Turner in 1989. They used the studied of the American economist Kenneth Ewart Boulding, who viewed closed economy as a precondition of supporting the sustainability of human existence on the Earth (Ghisellini et al. 2015a). The authors stated that the environment performed three economic functions: provision of resources, supporting life, and storing waste. At that, each function has its cost. So the planet pays with the necessity to solve the following problems:

– reduction of natural resources and growth of their price;
– aggravation of the conditions of existence of population of the Earth, consisting in lack of resources and growth of the number of natural catastrophes;
– accumulation of gigantic volumes of waste that pollute environment.

All these problems are interconnected and to solve them it is necessary to reduce negative influence on the environment by means of increase of feedback from usage of existing resources by reducing their losses and using repeatedly in the production cycle.

Since the beginning of the new millennium, the global economy has been in the Fourth Industrial Revolution, for which the term "Industry 4.0" was introduced. It was formulated at the Hanover Fair in 2011 "for denoting the process of deep transformation of global chains of value creation" (Schwab 2016).

Industry 4.0 is based on development of digital technologies, which enter all spheres of human activities. On the one hand, this means that digitization of economy allows increasing effectiveness of managerial and production processes. On the other hand, development of Industry 4.0 will requires and will allow for effective usage of all resources.

Thus, at the verge of these two global processes, the current necessity and conditions for implementation of closed-loop economy formed. Despite the fact that certain countries have already tried to implement closed economy, the start of its quick development is connected to the activities of the fund of Ellen MacArthur. During her voyages, she saw the problem of pollution of the global ocean and limitation of resources.

On September 25, 2015, the UN General Assembly adopted the Resolution "Transforming our world: the 2030 Agenda for Sustainable Development Until

2030", which formulated 17 goals.[2] It is possible to distinguish two main directions: first—provision of the whole population of the Earth with resources, sufficient for their normal existence; second—rational production and consumption.

In the conditions of growth of the planet's population and reduction of all types of resources, only implementation of closed-loop economy will allow achieving the goals that were set by the UN.

In December 2015, the European Commission adopted the plan of actions for transition to cyclic economy until 2019. It envisages that such model becomes a basis of the strategy of sustainable development of the EU and envisages development of the corresponding state regulation. The documents contains five directions: production and utilization of plastic items, construction and demolition of buildings, waste of food products, minerals, and agro-products.[3]

Thus, there are preconditions for implementation of closed-loop economy in the world. They consist of the chains of factors that approach the critical state of the environment and economy:

– growth of industry—growth of industrial waste—pollution of the environment (water-air-soil);
– development of consumption—growth of consumer waste;
– development of society of consumption—excessive consumption that leads to formation of excesses—impossibility of full usage of all property and throwing out "unused" goods;
– depletion of resources—increase of their cost—growth of expenditures of manufacturers;

and, on the other hand, the factors that create conditions for solving problems:

– appearance of economic and effective technologies of waste processing;
– increase of interest of the public in active participation in preservation of the Earth for descendants;
– development of communication and logistical technologies that allow coordinating the actions of a lot of participants.

2.1 Evolution of the Essence of the Notion "Closed-Loop Economy"

The notion "closed-loop economy" replaced linear economy. Linear economy envisages the following cycle: extraction—production—distribution—consump-

[2]Resolution of the UN General Assembly dated September 25, 2015 "Transforming our world: The 2030 Agenda for Sustainable Development Until 2030" [E-source]—https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/285/75/PDF/N1528575.pdf. Open Element (Accessed: 29.01.2018).

[3]How closed cycles of production and consumption bring waste down to zero. Ъ-Online—URL: https://finance.rambler.ru/news/2016-12-16/kak-zamknutye-cikly-proizvodstva-i.html (Accessed: 30.01.2018).

tion—waste (losses). Closed-loop economy envisages transformation (partial or full) of waste into resources.

"Closing" of economy was first viewed primarily as processing of production waste and consumption. At that, it was conducted regardless of both sources.

At the same time, manufacturers developed two directions of increase of effectiveness of using resources:

1. Reduction of expenditures of resources in the process of production. It could be achieved by means of:
   - application of resource- and energy-saving technologies;
   - reduction of defects;
   - reduction of losses;
2. Receiving income at the post-production stage. For this, it is possible to use:
   - further processing of waste and emissions for receiving a product for sale;
   - extraction and usage of resources that are among emissions;
   - collection and processing of used products for compensation of part of resources;
   - repeated usage of emissions of heat energy and water.

However, while the first direction belongs to "saving production", the second is a variant of closing economy.

Initially, these two direction were developing simultaneously. The higher level of development of closed-loop economy is unification of these two approaches, when both the final product and the production process are designed for maximizing the level of usage and repeated involvement of resources at a company. At present, closed-loop economy is a whole philosophy that required deep changes of organization of production of goods and their usage. At the stage of design of product and the process of its production, it is necessary to plan effective usage of all resources and security for the environment. That is, the goal is to prevent, not to fight the consequences.

2.2 The Main Provisions of Closed-Loop Economy

The main principle of implementation of this model of economy is provision of maximum effectiveness of each process in the products of service's life cycle, so management of waste becomes one of the top-priority directions.[4] This type of economy is characterized by "3R"—Reduce, Reuse and Recycle: optimization of the production process, repeated or joint usage of product, and processing of waste (Ghisellini et al. 2015b).

[4]Gerasimenko D., Nikolaeva I. Circular economy in Russia in the context of the Goals of sustainable development of the UB and the Year of Ecology [E-source]. URL: https://www.ictsd.org/bridges-news/ (Accessed: 21.01.2018).

The Center of European Political Studies in the July 2016 report "Cyclic Economy in Europe, from resource effectiveness to platforms for exchange of knowledge: opinion of the CEPS" distinguished three bases of closed economy, which declare its target advantages (Taranic et al. 2016):

1. Favorable influence on the environment. More efficient usage of resources leads to reduction of waste and emissions;
2. Economy by means of reduction of usage of resources. Reduction of materials expenditures, caused by increase of material- and energy-effectiveness of production, and reduction of payments for emissions and utilization of waste;
3. Creation of new markets and, therefore, jobs, which is connected to development of the following spheres of activities:
   - organization of collection and sorting of waste;
   - development of technologies for processing of waste and wasteless production;
   - coordination of joint usage of goods, etc.

Money flows from the resource spheres will be moving into these spheres.

In the report by McKinsey&Company "Closed economy: movement from theory to practice" (The Circular Economy 2016) there are six actions that have to be performed for transforming the existing economy into closed:

- regenerate. Transition to renewable sources of energy and materials: supporting and restoring the eco-system;
- share. Maximization of usage of goods by means of joint usage, repeated usage, and maintenance;
- optimize. Increasing the efficiency and effectiveness of production, excluding waster and production chains, increasing the effect by means of analysis of big data and automatization;
- close the chain of resources. Providing maximum repeated usage of materials;
- virtualize. Transition to digital carrier and online access;
- change. Replacing old materials with leading renewable resources, applying new technologies—e.g., 3D printing.

Also, the CEPS distinguishes eight blocks on which closed-loop economy is built (Taranic et al. 2016):

1. Industrial symbiosis. Two concepts are distinguished. The first one includes the classical physical exchange between industrial objects with materials, energy, water, and side products. The second concept is based on achievements of the digital era and is characterized by exchange of knowledge that stimulates the development of joint innovations.
2. Resource effectiveness. Reduction of consumption of material resources and negative influence on the environment.
3. Renewable energy and energy efficiency. Reduction of consumption of mineral fuel and implementation of alternative sources of energy.
4. Biological products. It is necessary to reduce the usage of pesticides and chemical fertilizers, which have negative influence on the state of soil and food products.

At the same time, it is necessary to pay attention to possibility of reduction of food waste and their processing.
5. Increase of products' life cycle. Development of products with a possibility of replacement of broken elements and their modernization.
6. Saving on provision. It is necessary to sell goods as services, renting or leasing them—which allows increasing the useful effect from usage of a product item.
7. Saving on joint usage. Consumer can unite into groups for reducing the costs of product's usage; development of network technologies expands these possibilities.
8. Saving on creation of platforms of exchange of information and implementation of direct interaction between sellers and buyers at the global scale.

According to these blocks, experts distinguish five business models of closed economy (Lacy and Rutqvist 2015):

1. The model of circular supplies, based on expansion of usage of renewable, processed, and compostable resources;
2. The model of restoration of resources, which envisages usage of innovational technologies for restoring resources from waste;
3. Extending the life cycle of products by means of maintenance, restoration, and modernization;
4. The model of joint usage, in which favorable effect from the product is maximized by means of involvement of several consumers;
5. The model of product as a service, in which manufacturer provides product to the consumer for temporary usage, preserving the ownership right and responsibility for further application.

2.3 Participants of the Process of Development of Cyclic Economy

Application of turnover of resources is possible within a separate company. This will be effective in vertically integrated companies that unify consecutive links of the technological chain. Within vertically integrated company it is possible to coordinate "inputs" and "outputs" of the stages of resources' processing and organization of closing of flows of heat energy and water. The company will thus save on material expenditures.

As for the companies of small and medium business, they have to unify according to the technological chain, in order to optimize the materials and energy flows.

However, regardless of the size of the company, implementation of intersectorial cooperation may be more effective. In this case, there are more alternatives for application of production waste.

Companies can implement such business models of closed-loop economy as the model of circular supplies and restoration of resources.

Consumers are also involved into closed-loop economy in terms of collection and sorting of consumer waste. Evolution of understanding the role of consumers led to emergence of such models as:

- joint usage, when the product is passed from consumer to consumer, fully satisfying the needs with lower aggregate level of consumption;
- extension of life cycle, which envisages preferring maintenance and modernization of existing of product to purchasing the new product.

As a result, fighting the manifestation of waste as such begins.

Coordination of actions of manufacturers and consumers allowed for implementing the model of product as a service.

2.4 Who Should Initiate Implementation of Closed-Loop Economy?

Two moving forces—state and large companies (especially, vertically integrated companies).

A prominent economist in the sphere of cyclic economy Walter Stachel gave an interview to UNIDO in Russia and pointed put state's support in the form of changes of the taxation system by means of implementing socially responsible taxation as a very important aspect (Closed-Loop Economy 2013).

Firstly, it is necessary to shift taxation from renewable resources to non-renewable resources. Secondly, to cancel value added tax for operations within closed economy, as a result of which processing and involvement of resources into repeated usage take place, as added value in this case is absent.

He criticized the measures that stimulate acceleration of utilization of durable goods, when certain sums are paid for refusing from a car that is ten years old and more and purchasing a new car. In this case, additional consumption stimulates growth of economy against the background of growth of spending of resources, which is not a part of the concept of closed economy.

We think that the state, apart from implementing taxation that motivates implementation of closed usage of resources, has to provide support in the following directions:

1. Organization and stimulation of scientific research aimed at development of the processes of involvement of waste into new production;
2. Material (not only tax, but also grants and subsidies) stimulation of implementation of business-models of closed economy;
3. Organization of educational work among population and entrepreneurship on explaining the principles of closed economy and the necessity for its application and expected positive effects;
4. Formation of infrastructure that has to ensure:

– interaction between business and science in the issues of development of technologies of closed economy;
– training of personnel.

The companies have to refuse from the model of maximization of profit in the current period in favor of strategic orientation at increase of effectiveness of using all resources and reduction of negative influence on environment by means of formation of closed materials flows.

The population, in its turn, should be "open" for active participation in the processes of "closing".

However, not all manufacturers are interested in population's reducing consumption in favor of the ecological component. On the contrary, they stimulate increase of needs. That's why closed-loop economy will be popular only under the condition of excess of benefits from its implementation over the incomes that are generated in linear economy.

3 Sectorial Concepts of Implementation of Closed-Loop Economy

In June 2017, the World business council for sustainable development presented a guide for transition to closed-loop economy (CEO Guide to the Circular Economy), which contains the modified model of circular economy of the Ellen MacArthur Fund and description of business models and technologies that stimulate implementation of circular economy (Tables 1 and 2) (CEO Guide to the Circular Economy 2017).

One of the top-priority directions of closed-loop economy, which determines the possibility of implementation of its principles, is rational management of waste of production and consumption. At that, the concept of closed-loop economy goes beyond the limits of possibilities of processing of waste, envisaging the directions of increase of effectiveness of using resources.

Preconditions and possibilities of transition to closed loop economy in the Russian Federation could be analyzed according to the data of the official statistics (Table 3).[5] In the context of the concept of circular economy, management of waste could be characterized by the indicator of their usage and decontamination, as well as the share of decontaminated and used waste in the aggregate volume of waste per year (Fig. 3).

As is seen from the data of Table 3, the volume of waste in Russia growth annually by 8%, and over the recent six years this indicator grew by 45%. At that, a positive tendency of secondary usage and decontamination of production waste has been outlined.

[5]Data of the Federal State Statistics Service. [E-source]. URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/environment/.

Table 1 Business models and technologies that are offered by Accenture for implementation of cyclic economy (CEO Guide to the Circular Economy 2017)

Business models	Technologies
1. "**Circular supplies**": usage of renewable sources of energy and bio- and fully recycled resources for replacing toxic resources and resources with one life cycle 2. "**Restoration of resources**": obtaining useful resources from materials, side products, or waste 3. "**Extension of product's life cycle**": extension of product's life cycle by maintenance, modernization, and re-selling, as well as rationalization 4. "**Joint usage platform**": cooperation of product's users and stimulation of joint usage, access, or possession for increase of coefficient of product's usage 5. "**Product as service**": provision of paid access to product and preservation of property right, for internalization of advantages of cyclic efficiency of resources	1. **Digital technologies**, e.g., Internet of Things, big data, blockchain, and RFID (radio frequency identification) will help companies to track resource and to control utilization and volumes of waste 2. **Physical technologies**, e.g., 3D print, robototronics, energy accumulation, module technology of design, and nanotechnologies help companies to reduce production and material expenditures and reduce influence on environment 3. **Biological technologies**, i.e., bio-energy, bio-materials, hydroponics, and aeroponics help companies to refuse from minerals

Table 2 The matrix of application of business models according to the stages of the circular economy chain (CEO Guide to the Circular Economy 2017)

Business model / Link of the circular economy chain	"Circular supplies"	"Extension of product's life circle"	"Platform of joint usage"	"Restoration of resources"	"Product as service"
Production and processing	✓				✓
Selling and re-selling		✓			✓
Usage and joint usage			✓		✓
Maintenance and reorientation		✓	✓		✓
Return				✓	✓
Restoration and repeated processing	✓			✓	✓

Table 3 Emergence, usage, decontamination, and placement of production and consumption waste in the RF, million tons (see Footnote 3)

Indicator	2003	2004	2005	2006	2007	2008	2009
Emergence of production and consumption waste—total	2613.5	2644.3	3035.5	3519.4	3899.3	3876.9	3505.0
Including hazardous[a]	287.3	142.8	142.5	140.0	287.7	122.9	141.0
Usage and decontamination of production and consumption waste—total	1342.7	1140.9	1265.7	1395.8	2257.4	1960.7	1661.4
Placement of production and consumption waste at the objects belonging to the company—total	1747.2	2316.0	2077.3	2732.5	2782.8	2517.3	2334.2
Including in places of							
Storing	1385.6	1866.0	1670.9	2189.1	1746.1	1868.5	1650.6
Burial	361.6	450.0	406.5	543.4	1036.8	648.9	683.6
Indicator	2010	2011	2012	2013	2014	2015	2016
Emergence of production and consumption waste—total	3734.7	4303.3	5008	5152.8	5168.3	5060.2	5441.3
Including hazardous[a]	114.4	120.2	113.7	116.7	124.3	110.1	98.3
Usage and decontamination of production and consumption waste—total	1738.1	1990.7	2348	2043.6	2357.2	2685.1	3243.7
Placement of production and consumption waste at the objects belonging to the company—total	2227.5	2584.4	2912.0	4897.7	2951.4	2333.1	2620.8
Including in places of							
Storing	1634.5	1919.4	2109	4071.8	2426.2	1978.1	2105.3
Burial	593.0	665.0	777.3	814.9	524.5	354.6	503.8

[a]Production and consumption waster of I–IV classes of hazard for environment. According to Article 4.1 of the Federal law dated June 24, 1998 N 89-FZ "Regarding production and consumption waste", depending on the level of negative influence on the environment, waste is divided into five danger groups: I—very hazardous waste; II—highly hazardous waste; III—moderately hazardous waste; IV—low hazard waste; V—virtually non-hazardous waste

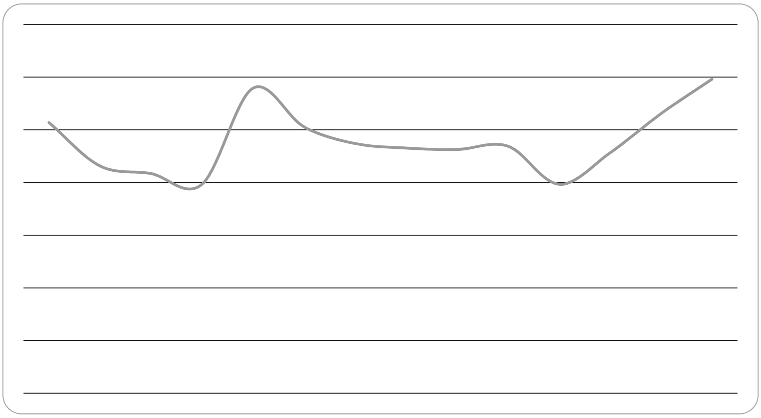

Fig. 3 Share of used and decontaminated waste in the RF per year, %

The sectorial structure of waste management could be characterized by relative indicators that are calculated on the basis of the data of the Federal Service for Supervision of Natural Resource Usage on emergence, usage, decontamination, transportation, and placement of production and consumption waster according to the form 2-TP (waste) (Table 4).[6]

The "leaders" of negative influence on environment in the form of waste formation are agriculture, minerals extraction, and processing production.

The largest share of manufactured waste (in view of accumulated waste at the beginning of the year and manufactured waste during the year) accounts for: coal production (54.3%), metal ores production (10.3%)—against 0.02% during oil and natural gas production; metallurgical production (6.6%), production of textile items (9.5%), production of chemicals and chemical products (0.7%), plant production and cattle breeding (0.1 and 0.05%, accordingly).

It is obvious that the provided data do not reflect the class of hazed of waste, accounting of which can significantly change the results of analysis with qualitative evaluation.

For preliminary evaluation of the effect from implementation of managerial mechanisms of transition to cyclic economy for the spheres of the Russian industry and types of economic activities, it is possible to use the results of analysis given in the report of McKinsey "Closed-loop economy: transition from theory to practice" (Table 5) (The Circular Economy 2016).

The most vivid representative that implements the principles of closed-loop economy in Russia is a vertically integrate company SIBUR Holding PJSC, which has six production areas and which manufactures products of the petrochemical complex: caustic soda, polystyrene, polypropylene, polyethene, polyethyleneterephthalate, etc.

[6]According to this form, all types of production and consumption waste, except for radioactive, are subject to accounting.

Table 4 Management of production and consumption waste as to types of economic activities in the RF in 2016 (see Footnote 4)

Types of economic activities	Share in the volume of waste as of beginning of the year, %	Share in the volume of waste that is formed during the year, %	Share in the volume of used and decontaminated waste (including by other organizations), %	Share in the volume of waste as of year-end, %
A—Agriculture, hunting, fishing, and fishing industry	0.008	0.905	1.318	0.010
B—Extraction of minerals	75.941	86.814	87.515	76.124
C—Processing production	19.898	10.095	8.087	19.738
D—Provision of electric energy, natural gas, and steam; air conditioning	2.141	0.377	0.115	2.103
E—Water supply, water discharge, organization of collection and utilization of waste, activities for liquidation of pollution	0.228	0.132	0.772	0.247
F—Construction	0.001	0.388	0.540	0.001
G—Wholesale and retail, repair of motor vehicles and motorcycles	0.000	0.139	0.186	0.006
H—Transportation and storing	0.001	0.055	0.293	0.001
I—Activities of hotels and public catering companies	0.000	0.008	0.002	0.000
J—Activities in the sphere of information and communication	0.000	0.005	0.152	0.000
K—Activities in finance and insurance	0.000	0.002	0.000	0.000
L—Activities on operations with real estate property	0.029	0.061	0.031	0.028
M—Activities of professional, scientific, and technical type	0.010	0.324	0.454	0.012
N—Activities of administrative type and corresponding additional services	0.003	0.010	0.012	0.003

(continued)

Table 4 (continued)

Types of economic activities	Share in the volume of waste as of beginning of the year, %	Share in the volume of waste that is formed during the year, %	Share in the volume of used and decontaminated waste (including by other organizations), %	Share in the volume of waste as of year-end, %
O—State management and provision of military security; social provision	0.000	0.007	0.005	0.000
P—Education	0.000	0.016	0.004	0.000
Q—Activities in the sphere of healthcare and social services	0.000	0.008	0.004	0.000
R—Activities in the sphere of culture, sport, organization of leisure and entertainment	0.002	0.017	0.052	0.003
S—Provision of other types of services	0.000	0.011	0.014	0.000
U—Activities of exterritorial organizations and bodies	1.739	0.625	0.445	1.725

The main resource base for production of petrochemical products by the holding is residual stock of oil and natural gas companies. These include oil-dissolved gas (side product of the oil industry) and liquid hydrocarbon feedstock, including broad fraction, LPG, and naphtha (residual stock of the gas producing industry).

The main model of closed-loop economy, which is implemented by SIBUR, is presented in Fig. 4.

One of the main products of SIBUR is polyethyleneterephthalate, which is widely used in other spheres: production of plastic bottles, civil engineering, medicine, food industry, machine building, and light industry.

As is seen from Fig. 4, transition from traditional natural resources (timber, cuttings) to usage of innovational materials (polymers) will allow reducing consumption of energy, technological losses, and production waste and increasing the duration of usage of finished product—polymer products.

As was mentioned in the scientific article of D. Y. Dunov “Closed-loop economy” (Dunov 2017), wide usage of polymer allows for 100% recycling of plastic waste and receipt of useful products. Thus, one ton of plastic bottles waste may provide:

(1) car covers for 200 cars;
(2) 800 m^2 of sailcloth;
(3) furniture cloth for 200 sofas;
(4) 400 sleeping bags;
(5) insulation for 750 winter coats;
(6) 4300 m^2 of road materials;

Table 5 Evaluation of potential level of income from implementing the concept of cyclic economy

Economic activities	Code of OKVED[a]	Processing	Joint usage	Optimization	Cycling	Virtualizaiton	Exchange
Activities in the sphere of information and communication	J	Low	Medium	Medium	Low	**High**	Low
R&D; other professional, scientific and technical activities	M	Low	Medium	Medium	Low	**High**	Low
Education	P	Low	Medium	Medium	Low	**High**	Low
Activities in the sphere of healthcare and social services	Q	Low	Medium	Medium	Low	**High**	Low
Administrative activities and corresponding additional services	N	Low	Medium	Medium	Low	**High**	Low
Activities in the sphere of art; organization of leisure and entertainment	R	Low	Medium	Medium	Low	**High**	Low
Financial activities and insurance	K	Low	Medium	Medium	Low	**High**	Low
Activities in the sphere of law and financial accounting; activities of main departments, consulting on the issues of management	M	Low	Medium	Medium	Low	**High**	Low
Wholesale and retail	G	**High**	**High**	Medium	Medium	**High**	Medium
Production of timber and paper products, printing	C	**High**	**High**	Medium	Low	**High**	Low
State management and provision of military security; social provision	O	Low	**High**	Medium	Medium	**High**	Medium
Activities for operations with real estate	L	Low	**High**	Medium	Low	Medium	Low
Production of textile, clothes, leather, and corresponding products	C	**High**	**High**	Medium	Low	Medium	Medium
Construction	F	Low	**High**	Medium	**High**	Medium	Medium
Production of transport vehicles (car building industry)	C	Low	**High**	Medium	**High**	**High**	Medium
Production of furniture	C	**High**	**High**	Medium	Medium	Low	Low

(continued)

Table 5 (continued)

Economic activities	Code of OKVED[a]	Processing	Joint usage	Optimization	Cycling	Virtualizaiton	Exchange
Water supply and water discharge, organization of collection and utilization of waste	E	**High**	Medium	Medium	Low	Low	Medium
Production of electric equipment; computers, electronic and optimal items	C	Low	Medium	Medium	**High**	Medium	Medium
Production of machines and equipment	C	Low	Medium	Medium	**High**	Medium	Medium
Production of rubber and plastic items; final metal items	C	Medium	Medium	Medium	**High**	Low	**High**
Transportation and storing	H	Low	Medium	Medium	**High**	Low	**High**
Agriculture, forestry, fishing and fishing industry	A	**High**	Low	Medium	Low	Low	**High**
Production of food products and tobacco products	C	**High**	Low	Medium	**High**	Low	**High**
Mining operations and development of quarries	B	Low	Low	Medium	**High**	Low	**High**
Provision of electric energy, natural gas, and steam; air conditioning	D	**High**	Low	Medium	Medium	**High**	**High**
Production of coke and oil products, chemical products	C	Low	Low	Medium	Medium	Low	**High**
Production of pharmaceutic products, medical chemical products, and medical herbal products	C	Medium	Low	Medium	Medium	Low	Medium
Activities of hotels and companies of public catering	I	Medium	**High**	Medium	Medium	**High**	Low

[a]OK 029-2014 (KDES Ed. 2). Russian Classification of Economic Activities (Adopted by the Decree of the Federal Agency for Technical Regulation and Metrology dated January 31, 2014 N 14-st) (edited on September 08, 2017)

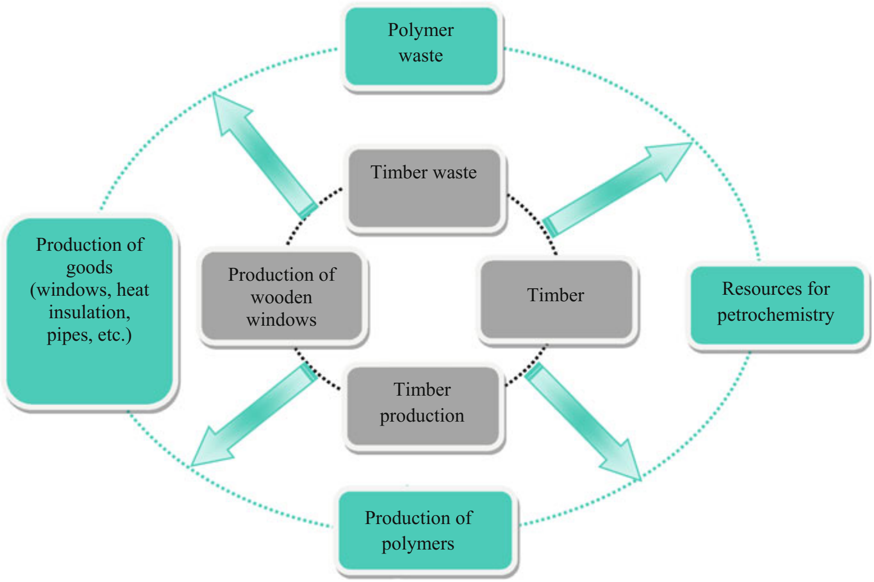

Fig. 4 The model of closed-loop economy that is implemented by SIBUR Holding PJSC

(7) 450 m^2 of carpets.

At present, the main leaders for recycling of polyethyleneterephthalate are Japan (78% of recycling of plastic waste) and China (83% of recycling of plastic waste).

Thus, SIBUR Holding PJSC is the largest Russian integrated gas processing and petrochemical company and built its business model according to the principles of cyclic economy, which will allow reaching sustainable development in future.

4 Methodological Approaches to Evaluation of Effectiveness of Closed-Loop Economy

The main concept of closed-loop economy is increase of effectiveness of company's activities by means of growth of profit from using secondary technological processes that are aimed at further processing of side products, and production waste and by means of reduction of expenditures for consumption of electric energy and increase of duration of usage of recycling products.

Thus, for example, for petrochemical and chemical complexes of industry, the main parameters of closed-loop economy are the following indicators:

(1) Saving materials and energy expenditures by means of using innovational technologies that are aimed and resource- and energy-saving;

(2) Increase of usage of multi-component resources by means of involving into the production process the residual stock and production waste, which will ensure growth of profit from implementation of products obtained from secondary products of recycling;
(3) Reduction of expenditures for utilization, burial, and neutralization of production waste.

Based on the principles of effectiveness, i.e., ratio of receive financial result to expenditures or used resources, a set of estimate indicators for evaluation of effectiveness of closed-loop economy is offered—they characterize the company's activities' effectiveness in the conditions of complex usage of multi-component resources, effectiveness of implementation of processes of secondary recycling, and usage of production waste.

A short characteristics of the offered estimate indicators in closed-loop economy of a company.

1. Profitability of complex production (R_k) characterized relative economic effect in the form of growth of profit from selling the products that are received as a result of complex usage of resources (primary and recycling of multi-component resources) to cost of multi-component resources or expenditures for it. The formula for calculating this indicator has the following form:

$$R_k = \frac{\left(\sum_{i=1}^{n} P_i \times Q_i\right) - Z_o}{\sum_{j=1}^{m} Q_j^* \times P_j^*} \tag{1}$$

where

I type of product of complex production (main product, side product);
j type of used resource and materials for manufacture of products of complex production;
Q^* volume of spent multi-component resources;
P^* purchasing price for multi-component resources or expenditures for its production;
P selling price for products that are received as a result of complex usage of multi-component resources;
Q volume of products that are received as a result of complex usage of multi-component resources;
Z_0 expenditures of the single technological process for processing of multi-component resources, as a result of which the main products and secondary products were received.

2. General profitability of sales (R_s), which characterizes effectiveness of sales of all products received as a result of implementation of the processes of initial processing and recycling of multi-component resources and production waste in the company. The formula for calculating total profitability of sales has the following form:

$$R_s = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} B_i} \tag{2}$$

where

P profit from selling the products that are received as a result of primary processing and recycling of multi-component resources and production waste;
B volume of sales in cost expression for the products that are received as a result of main processing and recycling of multi-component resources and production waste (revenues from selling products);
i type of issues products that are received as a result of processing of multi-component resources and production waste.

3. Total profitability of manufacture of products of complex production and products of their processing (Ro), characterizes the share of receive profit from selling the products, received as a result of complex usage of resource and production waste to total expenditures for production of products in the company. This indicator helps to provide general economic evaluation of rational and effective usage of resource, labor, fuel & energy, and financial resources in the company. The formula of calculating this indicator has the following form:

$$R_o = \frac{\sum_{i=1}^{n} (P_i - Z_i) \times Q_i}{\sum_{i=1}^{n} Z_i \times Q_i} \tag{3}$$

where

P selling price for products that are received as a result of complex usage of resources and production waste;
Q volume of sales of products that are received as a result of complex usage of resources and production waste;
Z total expenditures for production and selling of products (full cost), received as a result of complex usage of resources and production waste;
i type of products that are received as a result of complex usage of resources and production waste;
n volume of products that are received as a result of complex usage of resources and production waste;

4. Coefficient of effectiveness of usage of waste and residual stock (side product) of complex production (C_{wst}), characterizes the relative economic effect in the form of growth of profit from selling products that are received as a result of recycling of products of complex production and production waste to expenditures for utilization, burial, and neutralization of production waste. This coefficient is calculated according to the formula:

$$C_{wst} = \frac{E}{Z_l} = \frac{\sum_{j=1}^{k} (P_j - Z_{pj}) \times Q_j + (P_o - Z_{po}) \times Q_o}{\sum_{i=1}^{s} Z_{yi} \times Q_{wst} + L} \tag{4}$$

where

E absolute effect from usage of waste and residual stock of complex production;
Z_l total expenditures of the company for decontamination of environment from waste from complex production and side productions;
P_j selling price for j-th type of product, which is manufactured of production waste;
Z_{pj} production cost of the item of j-th type of product, manufactured of production waste;
Q_j natural volume of manufactured j-th type of product of production waste;
P_o selling price for residual/side products (products, received as a result of complex usage of resources);
Z_{po} production cost of the item of residual/side products that are received as a result of complex usage of resources;
Q_o volume of manufactured residual product/side product in natural expression;
Z_{yi} expenditures for utilization (neutralization) of the item of i-th type of waste;
Q_{wst} volume of utilized i-th type of waste in the natural expression;
L losses from incomplete usage of side products of complex production and production waste of the company;
k number of products that are manufactured of waste of complex production;
s volume of waste;

On the whole, synergetic economic effect is achieved by means of provision of growth of consolidated net profit of the company as a result of organization of production processes that are based on the principles of closed-loop economy, wide usage of the products that the company receives as a result of the single technological process, and by means of implementing the innovational technological processes that are aimed at processing of production waste and receipt of new useful products.

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Part II
Development of Industry 4.0 in the Conditions of Knowledge Economy

The Fundamental Provisions of the Concept of Knowledge Economy

Pavel T. Avkopashvili, Andrey A. Polukhin, Sergey V. Shkodinsky and Andrey L. Poltarykhin

Abstract The purpose of this chapter is to study the fundamental provisions of the concept of knowledge economy. The authors use the systemic and dynamic approaches to studying socio-economic phenomena and processes. Also, the method of analysis of causal connections, the method of comparative analysis, induction, deduction, formalization, etc. are used. The authors conduct comparative analysis of knowledge economy and other types of economy, study the essence of the process of transition to knowledge economy through the prism of evolution of modern economic systems, and present a conceptual model of knowledge economy. As a result, the authors substantiate the evolutional point of view that treats knowledge economy as a pinnacle of the evolutional path of modern economic systems. The authors show that uniqueness of knowledge economy consists in the fact that it places human capital into the center of economic system, which allows satisfying public material needs and

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implementing the existing human potential (labor, intellectual, and innovational) of development, thus satisfying non-material needs of employees. This takes knowledge economy to the pinnacle of the evolutional path of modern economic systems.

Keywords Concept of knowledge economy · Knowledge · Human capital
Evolution of modern economic systems

1 Introduction

In the post-crisis global economy, a new strategic course of development of chosen —formation of knowledge economy. Striving to quickly overcome the consequences of the global economic depression and to prevent its emergence in the mid-term, an effort has been made for cardinal change of the approach to management of economic systems. The basis of the concept of knowledge economy as an economic system that shows high level and rate of socio-economic development with a sustainable trajectory.

According to the general global trend and the advantages of knowledge economy, a lot of countries have already began to form it. At that, the concept of knowledge economy is insufficiently elaborated from the scientific point of view. In particular, there are no factual data on the conditions required for formation of knowledge economy, as well as the factors of its development. The academic society does not have a common opinion as to the role of knowledge economy in the process of development of modern economic systems.

Thus, the followers of the evolutional approach are sure that knowledge economy is a new modern stage in developed economic systems. It takes into account the actual peculiarities of economic practice and offers the tools for solving the existing problems. Representatives of the revolutionary approach state that knowledge economy announced the revolutionary breakthrough of modern economic systems that envisages their transition to a completely new quality of economic growth and social development.

The purpose of this chapter is to study the fundamental provisions of the concept of knowledge economy. The working hypothesis is the evolutional point of view that treats knowledge economy as a pinnacle of the evolutional path of modern economic systems, as it corresponds to expectations of the relative character of sustainability and prevention of global crises in future.

2 Materials and Method

The theoretical and methodological foundation of studying and measuring the progress in the sphere of formation of knowledge economy from the positions of the evolutional approach are set in scientific works of such scholars as Popkova et al.

(2015), Skiter et al. (2015), Dong et al. (2016), Kwon (2016), etc. This approach emphasizes the priority of formation of knowledge economy for achievement of sustainability (Ahmed 2017) and stability of growth and development of modern economic systems (Amavilah et al. 2017; Bogoviz et al. 2017). At that, the key role belongs to education (Chen 2016), entrepreneurship (Parahina et al. 2014), and innovations (Kuznetsov et al. 2016; Sibirskaya et al. 2017; Bogoviz and Mezhov 2015).

Conceptual issues of studying knowledge economy through the prism of the revolutionary approach are viewed in the publications of such authors as Antony et al. (2017), Momeni et al. (2017), Galkina et al. (2016), Lundgren and Westlund (2017), Pagano and Rossi (2017), Rodríguez-Pose and Wilkie (2016), Švarc and Dabić (2017), etc. According to this approach, it is considered that knowledge economy allows modern economic systems to perform a breakthrough in growth of efficiency (Nunes 2016) and to provide unprecedented growth of countries with developing economy, thus leveling disproportions in the modern global economic system (Hadad 2017; Polyakov 2017).

The performed overview of existing publications on the topic of knowledge economy showed insufficient elaboration of its basic principles and peculiarities, which does not allow providing substantial scientific proofs in favor of one of the existing approaches. This actualizes further scientific research in the sphere of development of the fundamental provisions of the concept of knowledge economy.

The authors use the systemic and dynamic approaches to studying socio-economic phenomena and processes and the methods of analysis of causal connections, comparative analysis, induction, deduction, formalization, etc.

3 Results

In order to determine the conceptual peculiarities of knowledge economy, let us perform its comparative analysis with other types of economy—pre-industrial, industrial, and post-industrial (Table 1).

As is seen from Table 1, each of the consecutive stages of economy is characterized by own specific peculiarities. Thus, a precondition for transition from pre-industrial economy to industrial economy was the First Industrial Revolution, to post-industrial economy—the Second Industrial Revolution, and to formation of knowledge economy—the Third Industrial Revolution.

Change of the types of economies was accompanied by transformation of public and technological modes. Pre-industrial economy corresponded to agrarian society, industrial economy—to industrial society and initial four technological modes, post-industrial economy—service society and the fifth technological mode, and knowledge economy—information society and the sixth technological mode.

The main vector of development (the key sphere of national economy) of pre-industrial economy was agrarian sector (agriculture), industrial economy—indus-

Table 1 Comparative analysis of knowledge economy and other types of economy

Criteria of comparison	Pre-industrial economy	Industrial economy	Post-industrial economy	Knowledge economy
The Industrial Revolution, which was an impulse for formation of this type of economy	–	First industrial revolution	Second industrial revolution	Third industrial revolution
Public mode	Agrarian society	Industrial society	Service society	Information society
Technological mode	–	First–Fourth	Fifth	Sixth
The main vector of development of economy (key sphere of the national economy)	Agrarian sector (agriculture)	Industrial sector (industry)	Service sphere (service)	High-tech spheres
Dominating type of entrepreneurship	Agricultural business	Industrial business	Service business	Venture business
The most valuable type of capital	Material capital (land)	Labor capital	Technological capital	Human capital

Source Compiled by the authors

trial sector (industry), post-industrial economy—service sphere, and knowledge economy—high-tech spheres.

In pre-industrial economy, the dominating type of entrepreneurship was agricultural business, for which the most valuable aspect of material capital (land); in industrial economy—industrial business, for which labor capital was most important; in post-industrial economy—service business, which valued technological capital the most; in knowledge economy—venture business, for which the most important aspect was human capital.

Thus, it is possible to see evolutional development of the types of economy. Despite the existence of the above specific peculiarities, knowledge economy does not have cardinal differences from other types of economy. In other words, in order to substantiate the revolutionary approach, it is necessary to compare knowledge economy, which possesses unique features, to traditional forms of economy that possess common features. However, knowledge economy has the similar features with previous types of economy, and it is impossible to generalize historical experience of economic development before the emergence of knowledge economy—which is a proof of correctness of the evolutional approach.

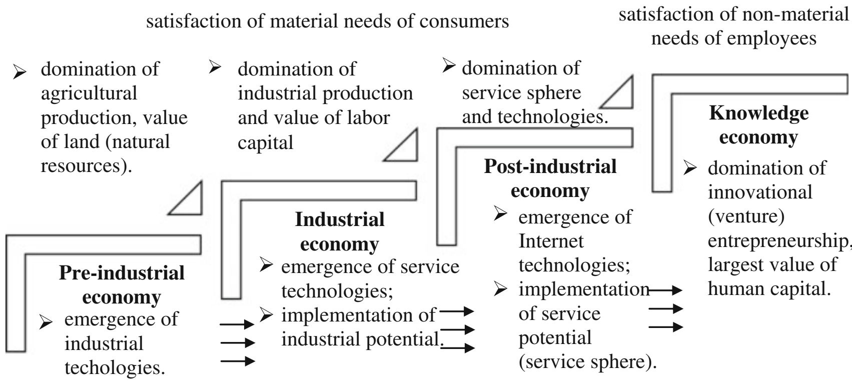

Fig. 1 The essence of the process of transition to knowledge economy through the prism of evolution of modern economic systems. *Source* Compiled by the authors

The essence of the process of transition to knowledge economy through the prism of evolution of modern economic systems is shown in Fig. 1.

As is seen from Fig. 1, industrial economy was peculiar for domination of agri-economic production. Emergence of industrial technologies was an impulse for formation of industrial economy. It was peculiar for domination of industrial production. With emergence and distribution of service technologies and implementation of industrial potential, transition to post-industrial economy took place, in which service sphere dominated.

Appearance of Internet technologies and implementation of service potential (service sphere) led to emergence of knowledge economy. It is dominated by innovational (venture) entrepreneurship and innovational potential is realized. As in the conditions of knowledge economy human capital is valued and favorable conditions are created for opening human potential, material and non-material needs of consumers are satisfied, which allows defining knowledge economy as a pinnacle of the evolutional path of modern economic systems.

Based on the above, a conceptual model of knowledge economy is presented (Fig. 2).

As is seen from Fig. 2, human cpaital is the basis of knowledge economy. It consists of labor capital (mechanic, routine labor), intellectual capital (professional competences—knowledge, skills—oh human, not related to innovational activities, and the results of innovational activities—know how, patents, etc.), and innovational capital (professional competences—knowledge, skills—of human, related to innovational activities and used for creation of innovations—new knowledge, technologies, etc.).

Human capital acquires and uses material and financial capital and creates and develops technological capital, which leads to creation and translation of knowledge in economy. This stimulates establishment and development of venture entrepreneur-

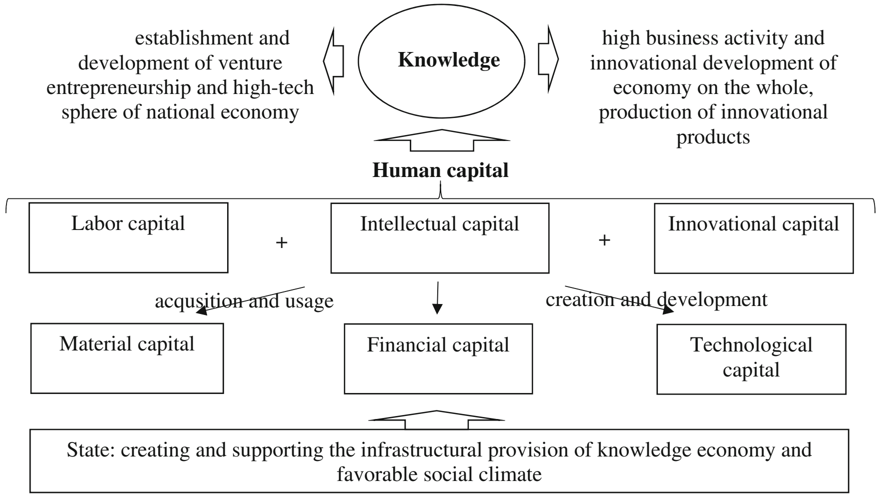

Fig. 2 The conceptual model of knowledge economy. *Source* Compiled by the authors

ship and high-tech spheres of national economy, as well as high business activity and innovational development of economy on the whole.

Like any economic system, knowledge economy functions in a certain legal environment, and the state plays an important role in the process of its formation. In the aspect of knowledge economy, the role of the state is to create and support the infrastructural provision of knowledge economy, including normative and legal (institutional), material and technical, and other provision, as well as favorable social climate, which supports the process of formation of knowledge economy.

4 Conclusions

Thus, as a result of the research, the offered hypothesis was proved. Knowledge economy should be studied from the positions of the evolutional approach, as it does not possess revolutionary features that distinguish it from other types of economy, each of which possesses unique characteristics and is within the general classification of these types.

Uniqueness of knowledge economy consists in the fact that it place human capital into the center of the system, which allows satisfying public material needs and implementing the existing potential of human (labor, intellectual and innovational) development, thus also satisfying non-materials needs of employees. This puts knowledge economy at the pinnacle of the evolutional path of modern economic systems.

The viewed fundamental provisions of the concept of knowledge economy form the theoretical basis for its scientific research. However, methodological aspects of its qualitative and quantitative evaluation and practical aspects of formation of knowledge economy in modern economic systems remain without attention. Studying these aspects is a perspective direction for further scientific works in continuation of this chapter.

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Preconditions of Formation and Development of Industry 4.0 in the Conditions of Knowledge Economy

Elena G. Popkova

Abstract The purpose of the chapter is to determine and analyze preconditions for formation and development of Industry 4.0 in the conditions of knowledge economy by the example of modern Russia. For evaluating the level and character of influence of the process of formation of knowledge economy on the possibilities of formation and development of Industry 4.0, the author uses the method of correlation analysis. The objects of analysis include the index of knowledge economy according to the World Bank and the indices that indirectly characterize the possibilities and perspectives of establishment and development of Industry 4.0—index of innovational development of economy according to the INSEAD and WIPO and the index of development of information and communication technologies according to the International Telecommunication Union. The values of these indices are studied in dynamics of several years—2013–2017. The additional methods of research that are used for evaluation of the growth rate of the values of these indices are horizontal and trend analysis. As a result, the authors proved that in the conditions of knowledge economy the preconditions of formation and development of Industry 4.0 appear. Therefore, in the interests of formation of Industry 4.0 and stimulation of business activity in this sphere it is necessary to develop knowledge economy, which is a platform for new industrial revolution. This shows that knowledge economy and Industry 4.0 develop not in the parallel way but are a single system—i.e., they are mutually supportive processes. Based on the results of the performed complex analysis, the second potential scenario is determined, at which during the initial stage of establishment of knowledge economy it is a platform for starting business activity in Industry 4.0, but then Industry 4.0 comes to the foreground, which is en inseparable component and basic criterion for defining the economic system as knowledge economy.

Keywords Industry 4.0 · Knowledge economy · Innovational development
Information and communication technologies · Modern russia

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1 Introduction

Knowledge economy is a perspective scientific phenomenon, as it stimulates the change of conditions for economy and establishment of new status quo in national economic systems and in the global economy system on the whole. These changes could have contradictory consequences. On the one hand, like any innovation, they may lead to violation of balance in economic systems and cause an economic crisis or the whole wave of crises, leading to the global economic recession, which could be overcome only after final adaptation of economic subjects to new conditions.

On the other hand, knowledge economy opens new possibilities for development of modern economic systems. Depending on the approach to usage of these possibilities, they may ensure growth of the values of socio-economic indicators with preservation of the existing social and technological mode or stimulate the change of this mode and transition of economic systems to a new trajectory of development. Thus, actuality of studying the issue of management of transformation process that are started in modern economic systems due to their transition to knowledge economy grows.

In the interests of provision of sustainable development of the global economy and economic systems, which are parts of it, and according to the new provisions of the Theory of economic cycles, the second variant of usage of possibilities of development of these systems in the conditions of knowledge economy, related to starting the wave of innovations, is preferable. This will allow accelerating the process of overcoming the consequences of the recent global economic crisis and preventing new crises. The working hypothesis is the idea that in the conditions of knowledge economy there appear preconditions for formation and development of Industry 4.0, as a perspective vector of implementation of the above preferable scenario of events. The purpose of the work is to verify this hypothesis—determine and analyze the preconditions of formation and development of Industry 4.0 in the conditions of knowledge economy by the example of modern Russia.

2 Materials and Method

For evaluation of the level and character of influence of the process of formation of knowledge economy on the possibilities for formation and development of Industry 4.0, the author uses the method of correlation analysis. The objects for analysis are the index of knowledge economy according to the World Bank and the indices that indirectly characterize the possibilities and perspectives of establishment and development of Industry 4.0—index of innovational development of economy according to the INSEAD and WIPO and the index of development of information and communication technologies according to the International Telecommunication Union.

The values of these indices are studied in dynamics of several years—2013–2017. The additional research methods that are used for evaluating the growth rate of these

Table 1 Dynamics of values of the index of innovational development of economy, development of information and communication technologies and knowledge economy in Russia in 2013–2017, points

Indices	Values of indices for year				
	2013	2014	2015	2016	2017
Index of innovational development of economy	37.2	39.1	39.3	38.5	38.8
Index of development of information and communication technologies	5.71	6.87	6.91	6.91	7.07
Index of knowledge economy	5.78	6.96	6.99	6.85	6.9

Source compiled by the authors based on: INSEAD and WIPO (2017), International Telecommunication Union (2017), The World Bank Group (2017)

indices are horizontal (ratio of the indicator's value in current year to its value previous year) and trend analysis (ratio of the indicator's value in current year to its value in basic year). Dynamics of the values of these indicators in modern Russia are given in Table 1.

The theoretical basis of the research includes fundamental and applied studies in the sphere of knowledge economy—in particular, the works (Galkina et al. 2016; Rychalovska 2016; Liargovas and Repousis 2015; Andrés et al. 2015; Nour 2015; Ragulina et al. 2015; Bogoviz et al. 2017; Bogdanova et al. 2016), and Industry 4.0, among which are Santos et al. (2017), Tupa et al. (2017), Wanyama (2017), Nunes et al. (2017), Crnjac et al. (2017), Popova et al. (2016), Kuznetsov et al. (2016), Kostikova et al. (2016), and Simonova et al. (2017).

3 Results

As a result of the analysis, the following results were obtained (Table 2).

As is seen from Table 2, in 2013–2017 the growth rate of the studied indicators is almost equal. In 2017, the value of the index of innovational development of the Russia's economy grew by 4%, as compared to 2013, the value of the index of development of information and communication technologies—by 24%, and the index of knowledge economy—by 19%. The key factor of these changes was the selected political course at modernization of the Russia's economy.

Correlation of the values of the index of innovational development of the Russia's economy (dependent variable) with the index of knowledge economy (independent variable) constitutes 92.92%, and of the index of development of information and communication technologies (dependent variable)—96.07%. Graphic interpretation of the performed analysis with the help of the regression curve is given in Fig. 1.

The obtained data allow concluding that in the conditions of knowledge economy, innovational development of the Russia's economy takes place and new possibili-

Table 2 Results of horizontal, trend, and correlation analysis of the indicators

Indicators	Results of analysis of indicators					
	2014/2013	2015/2014	2016/2015	2017/2016	2017/2013	R^2
Index of innovational development of economy	1.05	1.01	0.98	1.01	1.04	92.92%
Index of development of information and communication technologies	1.20	1.01	1.00	1.02	1.24	96.07%
Index of knowledge economy	1.20	1.00	0.98	1.01	1.19	–

Source Calculated by the authors

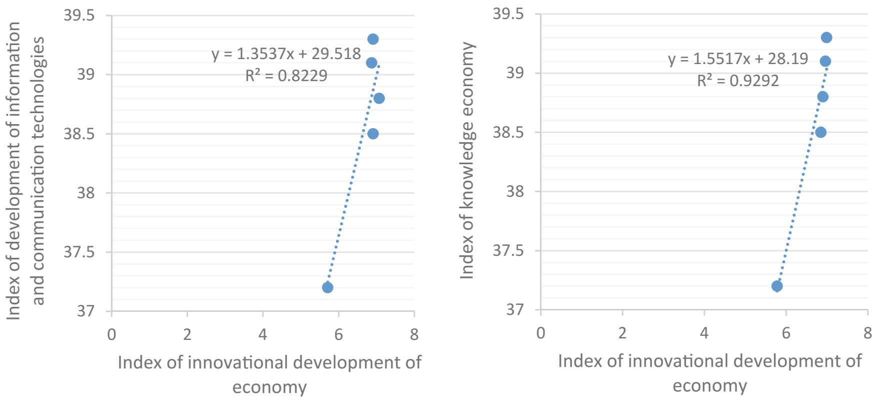

Fig. 1 Regression curve that reflects dependence of the index of innovational development of the Russia's economy on the index of knowledge economy and the index of development of information and communication technologies. *Source* Compiled by the authors

ties open for distribution and application of new information and communication technologies. This creates favorable conditions for formation and development of Industry 4.0. A qualitative analysis has been performed—it allowed determining the following preconditions of formation and development of Industry 4.0 in the conditions of knowledge economy.

The first precondition is related to the fact that in the conditions of knowledge economy the value of mind as a key economic resource grows. As mind could be human and artificial, the interest to artificial mind grows—for it is not sufficiently studied, but it is a perspective vector of growth of knowledge economy. Computer intelligence possesses advantages as compared to human intelligence—expanded possibilities for high-precision and complex quantitative analysis and high speed of processing of information.

Mind—as a carrier of the existing and a source of new knowledge—is the central link in the economic systems, which is in the conditions of knowledge economy. Human mind is a basis for artificial intelligence, but in perspective it becomes primitive and does not allow satisfying growing demands of society and business in solving complex tasks. Artificial intelligence appears on its basis and provides more possibilities, allowing reducing the risks and eliminating errors of human mind, thus optimizing everyday, production, and managerial processes in a socio-economic system.

The second precondition is transition of human society to a higher level in the Pyramid of needs. Before the establishment of knowledge economy, economic systems were forcedly oriented at satisfaction of primary (material) needs. In the conditions of knowledge economy, the role of non-material needs grows—in self-expression, creation and implementation of innovations, etc. Industry 4.0 allows satisfying not only growing non-material needs but also the preceding material ones.

Automatization and resulting optimization (increase of precision, reduction of expenditures, etc.) of business-processes allow increasing efficiency with reduction of consumption of all types of resources, thus stimulating the solution of such global problems as famine and deficit of mass consumer goods. That's why Industry 4.0 is a logical continuation of knowledge economy. In addition to this, increase of satisfaction of primary (material) needs will lead to growth of demands of a higher level—non-material—thus creating preconditions for further development of Industry 4.0.

The third precondition is growth of demand for Industry 4.0. As is expected, in the conditions of knowledge economy the level of awareness of human society will grow, which will lead to reconsideration of values and the course of strategic socio-economic development of economic systems. Increase of corporate social responsibility of business, reduction of risk component in economy, increase of social justice, and other positive changes, related to development of knowledge economy, will allow preventing future crises of economic systems.

In the conditions of stability, demand and volumes of accessible resources for development of innovational spheres of the national economy, such as Industry 4.0, will grow. Redistribution of efforts of society and business for highly-productive and perspective spheres of economy will raise the interest to Industry 4.0, which occupies an important position among these spheres. Industry 4.0 could become a vector of development of knowledge economy and the most important attribute of assigning economic systems to knowledge economy. The viewed preconditions are shown in Fig. 2.

As is seen from Fig. 2, transition of the modern economic system to knowledge economy leads to increase of demand for Industry 4.0 and creates favorable conditions for its development. Turning to economic experience of modern Russia, it is possible to see that despite the potential interest in formation and development of Industry 4.0 for quick overcoming of crisis and increase of the global competitiveness of economy, the possibilities for its formation are not favorable enough.

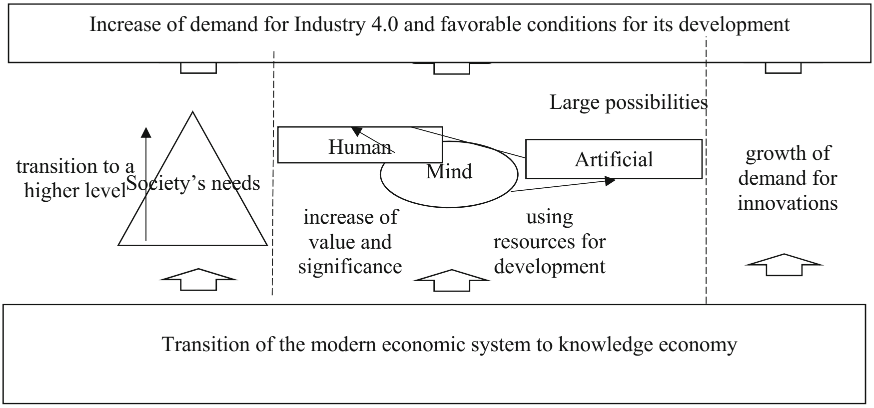

Fig. 2 Preconditions of formation and development of Industry 4.0 in the conditions of knowledge economy. *Source* Compiled by the authors

Firstly, in the conditions of economic recession, accompanied by violation of external business connections, the resources of economic systems are concentrated on restoration of entrepreneurial activity and development of import substitution. That's why necessary resources for starting the process of development of Industry 4.0 are not accessible. Secondly, the value of intellectual capital in economy is not sufficiently high and is behind other types of capital, primarily material and financial capital. This hinders the implementation of the investment and innovational projects for creation of artificial intelligence.

The performed qualitative and quantitative analysis allows supposing that further development of knowledge economy will stimulate reduction and further elimination of these barriers on the path of establishment of Industry 4.0 and formation of favorable conditions for its development.

4 Conclusions

Concluding the above, it should be noted that in the conditions of knowledge economy there emerge the preconditions for formation and development of Industry 4.0, which proves the offered working hypothesis of this research. Therefore, in the interests of formation of Industry 4.0 and stimulation of business activity in this sphere it is necessary to develop knowledge economy, which is a platform for the new the industrial revolution. This shows that knowledge economy and Industry 4.0 develop not in the parallel way but are a single system—i.e., they are mutually supporting processes.

Based on the results of the performed complex analysis, we determined the second potential scenario, at which at the initial stage of formation of knowledge economy it is a platform for starting business activity in Industry 4.0, but after that Industry 4.0 comes to the foreground, which becomes an inseparable component and the basic criterion for defining the economic system as a knowledge economy.

That is, this research determines strong and direct connection between knowledge economy and Industry 4.0, but the character of their interconnection is beyond the limits of performed scientific work, as up to this time there is not enough practical experience in the sphere of development of knowledge economy and Industry 4.0 for detailed study of their interdependence. Overcoming this limitation of the performed research and deep study of mutual influence of knowledge economy and Industry 4.0 are a perspective direction for future scientific research.

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The Role and Importance of Knowledge Economy as a Platform for Formation of Industry 4.0

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Abstract Purpose: The purpose of the chapter is to substantiate the "knowledge economy" as the basis for the formation and development of Industry 4.0, which is characterized by the solution of the tasks of increasing competitiveness through the strengthened integration of "cyber physical systems". Methodology: The methodological basis for the study of the role of education in the development of Industry 4.0 is the fundamental monographic work devoted to the theoretical and practical aspects of the transition to a new type of society development. The authors studied the basic elements of the knowledge economy: the institutional structure; an innovative system; education and training; information infrastructure. Particular attention is paid to education. Result: The authors reasoned that under the conditions of the transition from the "knowledge economy" to Industry 4.0, the content of the concept "human capital" is transformed. The result of the research was the differentiation of human capital into three types: "traditional", "convertible" and "creative." The latter is characterized by knowledge and skills in the advanced fields; the permanence of continuing education and knowledge updating; the ability to set tasks independently; ability to switch to various activities; high professional autonomy. It is the creative human capital that plays the role of the accelerator in the process of becoming and spreading Industry 4.0. In the process of analyzing the peculiarities of the "knowledge economy" development, their natural evolution has been revealed, which, if replaced, on the basis of the principle of continuity, will lead to the establishment of industry 4.0. There are no clear boundaries between the selected stages, but the employment structure of the population can serve as one of the criteria for determining the transition to Industry 4.0. It is concluded that the Russian education system's desire to implement the tasks to ensure the transition to Industry 4.0 was reflected in the emergence of a new integrated function in higher education—the innovative-intellectual one, and the higher school itself is justified as a component of an economic system that has the potential to provide a multiplicative knowledge increment due to the presence of specific features. Conclusions: The characteristic feature of Industry 4.0 is the determining role of the effectiveness of information exchange organization. If

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for the "knowledge economy" the structure of the technological mode of production can be schematically represented as "information + knowledge + innovation", in Industry 4.0 it is—"human intelligence + new information technologies + information + innovations". The knowledge economy is a type of economy characterized by the duration and formation staging, the distinguishing feature of which is the predominant role of metamorphosis: "information–knowledge–innovative knowledge," where the creativity of an individual and the formation of human capital are the qualitative basis of the good. Proceeding from the fact that the development of Industry 4.0 is characterized by the use of high-tech electronics and equipment, the widespread introduction of Internet technologies, the actual task is the adaptation of the education system to the requirements of the stage of society development. Under the circumstances, only accumulated knowledge will contribute to the development of Industry 4.0. and its safe development.

Keywords Industry 4.0 · Education · System of education
Functions of education

1 Introduction

The current stage of management is characterized as a transition to Industry 4.0. The fourth the Industrial Revolution, better known as Industry 4.0, derives its name from the initiative of the year 2011, headed by businessmen, politicians, and scientists, who identified it as a means of increasing the competitiveness of Germany's manufacturing industry through the enhanced integration of "cyber physical systems." Development of the theory of Industry 4.0 is a relatively new direction of economic science. Despite the different approaches to designating the stages of its formation, all scientists admit that the basis of the current stage of economic development is the increment of information and knowledge. Education, which forms human capital at various levels of management, under the conditions of Industry 4.0 acts as a dominant factor in the development of both the individual and the economic system as a whole (Melikhov 2010). However, in order to use the full potential of Industry 4.0, changes in the labor market are needed in accordance with changing requirements and, as a result, in learning concepts, since it is people that are the key to success.

2 Methodology

The methodical basis for the study of the role of education in the development of Industry 4.0 is the fundamental monographic work devoted to the theoretical and practical aspects of the transition to a new type of development of society; research of economists on the problems of the formation and development of the knowledge economy; scientific articles and applied developments of domestic and foreign scientists on the issues under study. The methodological basis of the research is the dialectical approach, which involves considering the knowledge economy as a stage in the development of Industry 4.0. The authors used a set of general scientific approaches: hypothetical-deductive, abstract-logical, structurally-functional, complex and systemic ones.

3 Results

3.1 "Knowledge Economy" and Its Characteristics

The greatest interest in the study of the transition of the national economy to Industry 4.0 is evoked by a doctrine emphasizing the special role of knowledge and denoting society as "the knowledgeable", "society knowledge". It is in this connection that many researchers consider the "knowledge economy" as the basis for the development of Industry 4.0. For the first time the role of knowledge was announced by Machlup (1966) in 1962. He put forward the idea that the most important branch of the economics is education, versatility of which manifests itself in its connection with production, science, the labor market, information, its storage and distribution. This is confirmed by the fact that 90% of the knowledge available in human civilization has been obtained during the last 30 years.

The term "knowledge economy" is used to determine the type of economy in which knowledge plays a decisive role, and the creation and use of knowledge becomes a source of growth, a factor that determines the competitiveness of companies, regions and countries. In modern economic literature, the definition proposed by the World Bank experts is most often used, according to which the knowledge economy should be understood as an economy that creates, disseminates and uses knowledge to accelerate its own growth and increase competitiveness.

In modern conditions of management, knowledge on the recommendation of a number of scientists (Gavrilova et al. 2016) is generally accepted as:

- direct result of activity;
- product of direct final consumption;
- factor of production, used in the production of economic goods;
- the subject and means of distribution and/or transactions in the market;
- a means of accumulating intellectual information;—means of management activity;
- a way of uniting society and the reproduction of public institutions.

In this regard, it is useful to distinguish the following basic elements of the knowledge economy:

1. Institutional structure. The institutional structure is based on the creation of certain economic incentives and institutional nature that support the widespread dissemination and effective application of local and global knowledge in all

spheres of the economic life of society. In this regard, attention should be paid to the existing education system, which can be characterized as an institutional mechanism that continuously generates and transfers knowledge to succeeding generations.

2. Innovative system. Under the conditions of the innovation system, effective organizational forms and business environment are created that encourage innovation and entrepreneurship, cover commercial structures, scientific and research centers, universities and other institutions working to develop global knowledge and, at the same time, transforming themselves in accordance with local requirements, apply knowledge for the production of innovative products, services and ways to implement business operations.
3. Education and training. This element is designed to form a society of qualified, dynamic and creative people with the prospects of getting decent education and lifelong learning for all members of society. The higher school plays a special role in this process. It is important to note the characteristic features of higher education in relation to other educational and scientific systems and in relation to economic complexes in general, identified by Melikhov (2009), which determine the role of this institution in the formation of the innovative and intellectual stage of development of the postindustrial society.

High school—is a unique system that simultaneously reproduces: the source of knowledge; the carrier of knowledge; object and subject of knowledge;

Higher school is a system that gives a strongly marked integral national economic effect from its activities, not reducible to a local economic effect;

Higher school—is a monopolist in the field of activity, a pure monopolist—in the field of education and oligopolist—in the field of science. And this means that in case of disintegration it has no adequate substitute;

The time lag for the formation of the potential of higher education is long. It requires the efforts of several generations of teachers and scientists.

As it can be seen from the list of properties above, they are possible only in a system that has an innovative type of development. The possibility of acquiring many of the listed properties by the system is associated with the active use of the transformative possibilities of self-development factors. Such a situation is possible only with the development and stability of intra-system innovation processes.

4. Information infrastructure. The process of creating a dynamic infrastructure, as well as a competitive, innovative, information economic space provides a variety of effective and competing services and tools for a wide range of social activities. This process is carried out not only in high-tech format—such as the Internet and mobile communications, but also radio, television and a variety of media, computer technologies and other means for storing, implementing operations and applying information, including a large set of communication services.

Table 1 The characteristics of the different types of human capital

"Creative" human capital	"Convertible" human capital	"Traditional" human capital
The skills of creative labor: – Knowledge and skills in the advanced fields – Permanent training and updating of knowledge – The ability of the employee to independently set ourselves objectives – The ability to switch to different types of activities – High professional autonomy – intuition	The skills of mixed labor: – Skills of working with IT – Readiness "lifelong learning" – Communication skills; – Teamwork – The ability to solve problems – Adaptability	The skills of template labor: – Specialization of work – Mobility, willingness to learn new operations, functions
Factors of change human capital: – Specialization and individualization of the labor activity – Informatization of labor relations – Network connections – Technological progress – Tolerance social environment for innovators – Susceptibility of the economy to innovations – Labour mobility		

3.2 Knowledge Economy as the Basis for Development of Industry 4.0

The formation of an economy of a new level implies the accumulation of a labor resource and entails its transformation into human capital (Bondarskaya 2014). Under knowledge economy conditions, human capital is a dynamic process of expanded reproduction. The authors made the assumption that under the conditions of transition from the knowledge economy to Industry 4.0, the content of the concept of "human capital" itself is transformed, which is due to the functional division of labor in industry 4.0 conditions (Kolesnichenko et al. 2017). The result of the research was the differentiation of human capital into three types: "creative", "convertible" and "traditional" (Table 1).

The authors reasoned that the process of constantly updating the implicit knowledge of the individual (experience, skill, culture of professional thinking, intuition) is considered as a key characteristic of human capital, which is the result of the synthesis of genetic heredity, education and acquired life experience. Creative human capital plays a role of an accelerator in the process of development and spreading of Industry 4.0 in overcoming the systemic backwardness of some territories, since it carries within itself the subject potential of renewing the entire structure of the economic process, and also ensures the formation of fundamentally new combinations involving all the other factors of the production function.

Table 2 Stages of the knowledge economy evolution

No.	Stage	General characteristics
1.	Information economy	The basis for the efficiency of the economy functioning is the availability of information, which makes it possible to make decisions on the number and structure of the use of production factors (which increase their effectiveness)
2.	Intellectual economy	The basis for the functioning of the economy is knowledge (primarily in such dynamically developing industries as financial, consulting and other professional services). At the same time, the economic implementation of this resource is built on completely different factors, in comparison with material ones. Information becomes not just the main economic resource, but represents the physical commodity on the market
3.	Intellectual-innovative economy	The basis of the functioning of society is not simple, but expanded reproduction of knowledge, the ability to innovate in the creation of products, the development of goods and services that meet the unique needs of individual customers, the involvement of customers in the production process, as their knowledge becomes part of the product specification. The production of new information is a creative process and therefore it is unique and non-reproducible

The study of creativity as a resource reallocation factor led to the conclusion that the measuring instruments of creative human capital should be sought not in the indicators of economic activity, the degree of specialization of production, etc., but among the characteristics of the creative behavior of skilled workers.

In addition, the authors, in the process of analyzing the features of the "knowledge economy" development, have revealed their regular evolution, which, if replaced by one another on the basis of the principle of continuity, will lead to the establishment of Industry 4.0 (Table 2).

From the economic point of view, they represent a single society, characterized as a knowledge economy (Fig. 1).

There are no clear boundaries between the selected stages, but the employment structure of the population can serve as one of the criteria for determining the transition to Industry 4.0. All these societies are closely interrelated and include one another.

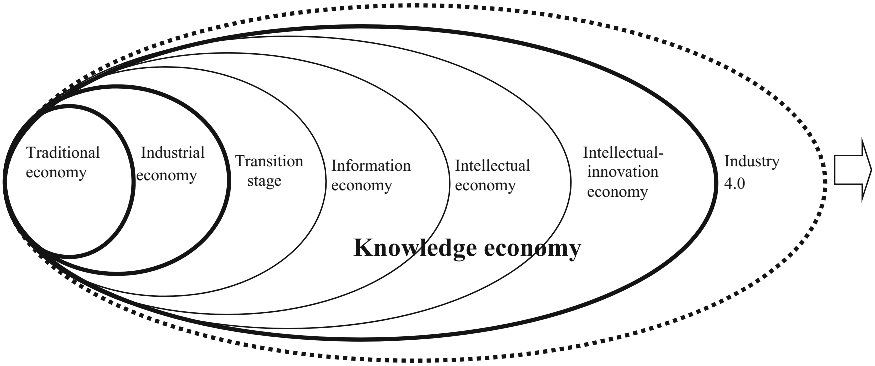

Fig. 1 The evolution of society

The transition from the innovation-intellectual stage to industry 4.0 is characterized not so much by changes in the technosphere. The use of "smart technologies" can change the concept of human labor itself. Machines are able to perform monotonous actions with much greater efficiency and with much less errors.

Transition to Industry 4.0 will be associated with solution of the tasks related to the implementation of skills, creativity, management of smart enterprises through the Internet. It is a question of Egorova et al. (2002) unique abilities of a person not just to reproduce, transform knowledge, but also to create new knowledge.

3.3 Readiness of the Russian Education System to Form Industry 4.0

In the opinion of Silantieva (2009), the assertion that the Russian higher school is called upon to train specialists getting ahead of the practice needs is axiomatic. If a university graduate does not correspond to the level reached by the practice, it cannot be a carrier of progress. Short-sighted short-term saving on education and training of specialists, allegedly in the interests of production, turns into difficulties in production, first of all, in the development of society as a whole. Moreover, the needs of modern production require, in training a specialist with higher education, to shift the emphasis from qualification to competence (Sutyagin et al. 2017). In the most diverse spheres of activity, it is increasingly necessary not to qualify, but competence that can be viewed as a kind of amount of skills inherent in the individual and including qualifications in the strict sense of the word, skills of professional and social communication, initiative, ability to make responsible decisions.

In modern conditions of managing it is already impossible to accumulate knowledge and, using methodical innovations, easily broadcast it, supplementing it only from time to time. Thus, changing the requirements for training highly qualified specialists automatically entails the problem of adequate staffing of the educational process, which in many cases means its radical transformation. The aspiration for such an implementation was reflected in the emergence of a new integrated function in higher education—an innovative intellectual one, which includes a number of components:

– innovation-venture, that is, associated with the introduction of innovative products created by the university, into specific economic practices;
– entrepreneurial, that is, associated with the development of the economic independence of the university, the ability to profitably and competitively promote the results of its educational, scientific and production activities in the regional, federal and international markets;
– educational accompanying of the educational career, that is, associated with the development of the continuing education system and the inclusion of service blocks in it to enhance professional skills;
– creative, that is, associated with the development of creative abilities of society members;
– cluster, that is, associated with the positioning of the university as an ideological development center.

Thus, in the context of providing a transition to Industry 4.0, higher education is substantiated as a component of an economic system that has the potential to provide a multiplicative increase in knowledge due to the presence of specific features (a unique system that provides extended reproduction of sources, carriers, objects and subjects of knowledge; open-closed system, a system that gives an integral national economic and socio-economic effect from its activities, a monopolist in the field of activity). The desire to carry out the existing potential is defined as a new function—innovative-intellectual one.

4 Conclusions

Based on the content selection and analysis of these stages of society development, the following conclusions can be made:

First, the characteristic feature of industry 4.0—is the determining role of the effectiveness of the information exchange organization. The organization and implementation of the information transfer is fundamentally different from the movement of material goods. Thanks to modern telecommunication facilities, such transportation is carried out almost instantaneously and with minimal human participation. Thus, low costs and high economic efficiency of information exchange are a powerful stimulating factor for the economic development of Industry 4.0. In the industrial society, the structure of the technological mode of production can be schematically represented as the "physical and mental abilities of a human + machine + natural factor + electricity" (Thevenot 1997), in the knowledge economy—it is "information + knowledge + innovation", and in industry 4.0—it is "human intelligence + the latest information technology + information + innovation”. The development of Industry 4.0 is associated with the modernization of the society, that is, with the processes of informatization and digitization, with changes in governance, with the growing role of science and education, with the rationalization of thinking as the consequences of the scientific and technological revolution.

Secondly, the knowledge economy is a type of economy characterized by the duration and staging of formation, the distinguishing feature of which is the predominant role of metamorphosis: “information–knowledge–innovative knowledge,” where the creativity of an individual and the formation of human capital are the qualitative basis of the good.

Thus, on the basis of the content selection and analysis of the stages of society development, the following conclusion can be made: industry 4.0 is a type of economy characterized by the duration and staging of formation, the distinguishing feature of which is the predominant role of information technology. To obtain maximum efficiency and benefit from the Industrial Revolution, global unification is necessary, which is not confined to the framework of a particular industry. Therefore, the primary task is the development of common standards, protocols and cyber platforms.

One of the most serious problems of “Industry 4.0” is security. The combination of industrial systems and the Internet makes them vulnerable to cybercrime. By remotely affecting processes and software, you can intervene in production processes or completely stop them, paralyzing production with all the ensuing consequences. And the more enterprises will be involved in “Industry 4.0”, the more topical this problem will become.

Under the circumstances, only accumulated knowledge will contribute to the development of Industry 4.0. and its safe development.

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Part III
Methodology for Analysis and Evaluation of Industry 4.0 in the Conditions of Knowledge Economy

Industry 4.0 as a New Vector of Growth and Development of Knowledge Economy

Aleksei V. Bogoviz

Abstract The purpose of the work is to study the possibilities of formation of Industry 4.0 as a new vector of growth and development of knowledge economy by the example of modern Russia and to develop recommendations for their practical implementation. For this, the method of dynamics (horizontal and trend) analysis of time rows and correlation analysis are used. The indicator of development of knowledge economy is the corresponding index that is prepared by the World Bank. The vectors of growth and development of knowledge economy are share of innovations-active companies in the structure of entrepreneurship, number of developed completely new leading production technologies, and share of high-tech spheres in economy (as the indicator of development of the sphere of science and education) according to the Federal State Statistics Service. The author shows that knowledge economy, which was developing dynamically at the initial stage of its formation, has slowed down. The existing growth vectors—innovational entrepreneurship, high-tech spheres of economy, and the sphere of science and education—have depleted their potential and cannot ensure its further development. It is necessary to look for such vectors, of which the most perspective is Industry 4.0, as formation of Industry 4.0 leads to growth of knowledge economy: innovational development, increase of the values of indicators of socio-economic development of economic system, and increase of the role of intellectual component of economy—the sphere of science and education.

Keywords Industry 4.0 · Vector of growth · Development of knowledge economy · Innovations · High-tech · Modern russia

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1 Introduction

The wave of the global economic crisis, which influenced the global economy at the beginning of the 21st century, increased expectations as to innovational breakthrough. With deepening of the global economic recession, tension escalated and new hypotheses as to sources of this breakthrough were offered. The most popular objects of scientific discussions on this topic were modern biotechnologies, space technologies, and nano-technologies.

However, there has been no breakthrough in any of the above spheres. Moreover, knowledge economy, which concept became a new landmark for post-crisis global economy, did not justify all its functions. Thus, on the one hand, formation of knowledge economy in modern economic systems allowed diversifying their business activity and increasing their sustainability to cyclic fluctuations of the global economic system.

On the other hand, the largest success in formation of knowledge economy was achieved by developed countries, which increased disproportions in development of the global economic system—instead of their expected leveling. Intensity of innovational development of economic systems, which took the path of formation of knowledge economy, was not sufficiently strong for ensuring the overcoming of the global crisis. This aggravated the problem of search for new vectors of breakthrough innovational growth of the modern global economic system, which developed in the conditions of knowledge economy.

The author offers a hypothesis that the existing vectors of growth of the modern knowledge economy have depleted their potential and cannot ensure its further development. This requires the search for such vectors, of which the most perspective is Industry 4.0. The purpose of this work is to study the possibilities of formation of Industry 4.0 as a new vector of growth and development of knowledge economy by the example of modern Russia and to develop recommendations for their practical implementation.

2 Materials and Method

The modern scientific literature outlines three key vectors of growth and development of knowledge economy, which are studied in multiple works: innovational activity of entrepreneurship (Popkova et al. 2015; Skiter et al. 2015; Parahina et al. 2014) and innovations (Kuznetsov et al. 2016; Bogoviz et al. 2017), R&D activities of scientific and educational establishments (Sibirskaya et al. 2017; Bogoviz and Mezhov 2015; Tyshchenko 2013; Pagano and Rossi 2017) and high-tech sector of economy (Labra et al. 2016; Kaur and Singh 2016; Seddighi 2015; Saruchera et al. 2014; Nyarko 2013).

In order to verify the offered hypothetical statement, the author uses the method of dynamic (horizontal and trend) analysis of time rows and the method of correlation

Table 1 Time rows of the values of indicators of knowledge economy and existing vectors of its development in Russia in 2012–2016

Indicators	2012	2013	2014	2015	2016
Share of innovations-active companies (%)	10.5	11.1	10.9	10.9	11.2
Number of developed completely new leading production technologies	110	135	153	164	175
Share of high-tech spheres in economy (%)	1.2	1.4	1.5	1.6	1.7
Index of knowledge economy, points	5.75	5.78	6.96	6.99	6.85

Source Compiled by the authors based on: The World Bank Group (2017), Federal State Statistics Service (2016)

analysis. The indicator of development of knowledge economy is the corresponding index that is prepared by the World Bank. The vectors of growth and development of knowledge economy are share of innovations-active companies in the structure of entrepreneurship, number of developed completely new leading production technologies and share of high-tech spheres in economy (as indicator of development of the sphere of science and education) according to the Federal State Statistics Service (Table 1).

3 Results

The data from Table 2 show that the annual growth rate of the values of the index of knowledge economy decreases. Thus, while in 2014 its growth constituted 20%, in 2015 it decreased to 0, and in 2016 it became negative, constituting −2%. Analysis of five-year trend shows that growth rate of the values of the index of knowledge economy (19%) is lower than the number of developed completely new leading production technologies (59%) and share of high-tech spheres in the Russia's economy (42%) and slightly exceeds the growth of share of innovations-active companies in the Russian economy.

All existing vectors of knowledge economy are peculiar for downward trend. Correlation (R^2) of values of the index of knowledge economy (dependent variable) with share of innovations-active companies (14%), number of developed completely new leading production technologies (76%), and share of high-tech spheres in economy (69%) is low—which shows weak connection between these indicators.

Thus, the results of the performed analysis showed that potential of the existing vectors of growth of knowledge economy in modern Russia is almost depleted. Based on through study of causal connections of growth and development of knowledge economy the following main features were determined:

Table 2 Results of analysis of dynamics and connection between knowledge economy and existing vectors of its development in Russia in 2012–2016

Indicators	Dynamics and connection of indicators					
	2013/2012	2014/2013	2015/2014	2016/2015	2016/2012	R^2
Share of innovations-active companies (%)	1.06	0.98	1.00	1.03	1.07	0.14
Number of developed completely new leading production technologies	1.23	1.13	1.07	1.07	1.59	0.76
Share of high-tech spheres in economy (%)	1.17	1.07	1.07	1.06	1.42	0.69
Index of knowledge economy, points	1.01	1.20	1.00	0.98	1.19	–

Source Calculated by the authors

- innovational development of economic system, growth of its effectiveness through optimization of business-processes;
- increase of values of the indicators of socio-economic development (GDP and GDP per capita, living standards, etc.);
- increase of value of the intellectual component in economy, development of science and education.

Industry 4.0 stimulates the emergence of the above features in the following way. Firstly, in the conditions of knowledge economy, manual labor is replaced by machine labor (authomatization of business-processes), which leads to increase of the volumes of production with increase of quality of issued products (higher complexity, precision, and technical characteristics) with reduction of its cost and reduction of probability of errors, which leads to reduction of defects. Thus, growth of efficiency is achieved.

Secondly, modernization of technologies and equipment stimulates reduction of resource capacity of economy and reduction of production waste. This increases corporate social and ecological responsibility of entrepreneurial structures, which is one of the most important peculiarities of knowledge economy. This advantages is achieved not only due to elimination of human from the production process and the corresponding optimization but also due to supporting the intellectual efforts of human by efforts of artificial intelligence—as a result of which the speed of development of technologies grows even more.

Thirdly, in the conditions of Industry 4.0, labor intensity of economy reduces with growth of the volume of GDP, GDP per capita, and volume of accessible benefits for each person. This stimulates increase of population's living standards. Growth of social well-being is the most important goal of development of any modern economic systems, especially in the conditions of knowledge economy, which is characterized by human-oriented approach to management of the process of this development.

Fourthly, in Industry 4.0 labor (mechanical, routine) activities of human is replaced by intellectual activities, as automatization of routine (repeated, model) processes takes place. This leads to growth of demand for intellectual activities of human, which artificial intelligence cannot fully replace. This ensures fuller opening of intellectual potential of human and increase of its satisfaction with creativity.

Fifthly, Industry 4.0 envisages increase of intensity of scientific and technical development. In order to preserve competitiveness, modern human has to obtain education and increase the level of qualification. Adaptation to quickly changing conditions in the labor market supposes workers' studying during the whole life. Therefore, the sphere of science and education is constantly developing and plays a very important role in the economic system.

The performed detailed factor analysis of growth and development of knowledge economy allowed determining the following main factors:

– growth of entrepreneurial and innovational activity: knowledge economy envisages high level and growth rate of economy and innovational development of socio-economic system;
– highly-effective application of the corresponding state tools of stimulation of economic initiatives: formation of knowledge economy requires adequate normative and legal provision and state regulation of economic processes;
– high level and rate of development of industrial sectors: the real sector of economy, in which high-tech spheres function, is the basis of knowledge economy.

Formation and development of Industry 4.0 ensure maximum positive influence of these factors on the process of formation of knowledge economy, as it envisages modernization of entrepreneurship and growth of effectiveness of state management of economy, belongs to the real sector, and envisages intensification of development. The conceptual model of Industry 4.0 as a vector of growth and development of knowledge economy is shown in Fig. 1.

As is seen from Fig. 1, Industry 4.0 stimulates achievement of the main goals of knowledge economy and starts the processes that show signs of development of knowledge economy. In modern Russia, these signs are weak, which leads to small rate of development of knowledge economy. In particular, the values of the indicators of socio-economic development have been showing reduction in recent years under the influence of the crisis of the economic systems.

Development of science and education in Russia is predetermined by state support and the system of state order. Though these stimuli allow achieving high values in the sphere of growth of this sphere, they do not ensure the start of the market mechanism, which includes competition of scientific and educational organizations and expansion of flows of private investments in this sphere.

On the whole, effectiveness of the Russia's economic system is high, but intensity of the process of innovational development of this system is moderate due to imbalance of production factors in favor of material resources, to which the opposite category is intellectual resources. Therefore, successful growth of knowledge economy in Russia requires development of Industry 4.0. The following recommendations are thus offered:

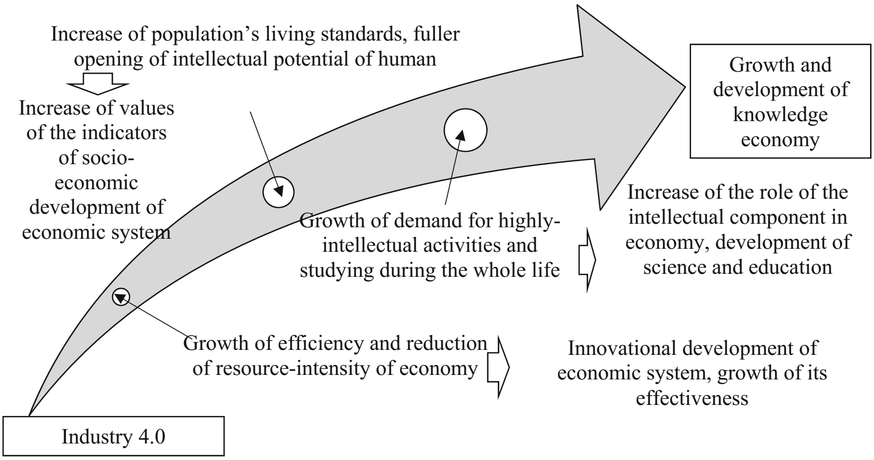

Fig. 1 Model of Industry 4.0 as a vector of growth and development of knowledge economy *Source* Compiled by the authors

– establishment of the course at formation and development of Industry 4.0 in the national strategy of long-term economic growth;
– increase of requirements to effectiveness of entrepreneurial structures that stimulate their demand for products of Industry 4.0;
– expansion of financing of scientific studied, aimed at preparation of technologies that are in the basis of Industry 4.0.

4 Conclusions

It should be concluded that the offered hypothesis was proved—dynamically developing knowledge economy slowed down its growth. This was caused by depletion of the potential of existing vectors of its growth—innovational entrepreneurship, high-tech spheres of economy, and the sphere of science and education. Industry 4.0 is a perspective new vector of growth of knowledge economy, as formation of Industry 4.0 leads to all signs of growth of knowledge economy: innovational development, increase of values of the indicator of socio-economic development of economic systems, and increase of the role of the intellectual component of economy—the sphere of science and education.

Experience of modern Russia—by the example of which this research was performed—could be used for other countries, which shows universal character of the author's conclusions. However, the offered recommendations for practical implementation of the determined potential of Industry 4.0 in stimulation of growth and development of knowledge economy are generalized and are bound to context, which is a certain limitation of the received results. Detalization and universalization of these recommendations leads to perspectives of further scientific research.

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Stages of Formation of Industry 4.0 and the Key Indicators of Its Development

Alexander N. Alekseev, Elena V. Buraeva, Elena V. Kletskova and Natalia A. Rykhtikova

Abstract The purpose of this chapter is to study the main stages of formation of Industry 4.0 and to determine the key indicators of its development at each of them. The authors analyze the process of formation of Industry 4.0 and distinguish the main stages: preparation of the socio-economic system, formation of Industry 4.0 as a sphere of industry and the Industrial Revolution—transition to Industry 4.0. The authors determine the potential barriers on the path of formation of Industry 4.0 at each of the distinguished stages and offer recommendations for overcoming them. The authors also develop and present the system of indicators for monitoring of formation of Industry 4.0, which includes target values of the indicators for transition to the next stage. As a result of the research, the authors make a conclusion that modern economic systems are at different stages of the process of formation of Industry 4.0. Thus, while in developed countries transition to the second stage is close, developing countries have just started the first stage. Therefore, in the scale of the global economic system formation of Industry 4.0 should be forecasted for the long-term.

Keywords Industry 4.0 · Process of development · Stages of formation
Indicators of development

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1 Introduction

Industry 4.0 is not just an actual trend in development of the modern global economy but a perspective direction of its development in future, which stimulates achievement of its strategic goals. Firstly, Industry 4.0 is a tool and vector of growth and development of knowledge economy, which is a landmark for modern economic systems. Knowledge economy is recognized by the academic and expert society as the most optimal type of economic system.

However, the first experience of its formation showed that it is a long and complex process, the main obstacle on the path of which is low effectiveness of the existing tools (growth vectors). Industry 4.0 allows diversifying these tools, thus reducing the risk component of the process of formation of knowledge economy, and increasing its effectiveness due to acceleration of the rate of economic development and reduction of its resource intensity.

Secondly, Industry 4.0 could be viewed as a self-goal, as it stimulates the achievement of sustainable socio-economic development regardless of successfulness of formation of knowledge economy. Industry 4.0 allows for reduction of labor and even intellectual load on a modern human with increase of growth rate of production and innovational development of economic systems. Due to this, growth of effectiveness of economy is achieved through increase of efficiency, reduction of resource intensity, and increase of the level of real income of population.

Due to the above reasons, the concept of Industry 4.0 is peculiar for high scientific and practical significance. This explains topicality of studying the potential, problems, possibilities, and perspectives of its implementation in the economic practice of modern socio-economic systems. The purpose of this chapter is to study the main stages of formation of Industry 4.0 and to determine the key indicators of its development at each of them.

2 Materials and Method

Despite the relative novelty of the scientific concept of Industry 4.0, it is studied in a lot of works. Thus, E. Loshkareva and her colleagues determine Industry 4.0 as economy of the future, i.e., Industry 4.0 is viewed not as a means of formation of knowledge economy but as its replacement—new independent type of economic systems. The authors note that formation of Industry 4.0 will take place in four consecutive stages (Loshkareva et al. 2017a):

– creation of cyber-physical systems of mass production with minimum participation of human;
– full authomatization of production and everyday non-intellectual processes with the help of blockchain technologies;
– authomatization of intellectual processes with the help of neuron networks;

– full elimination of human from active economic operations with its replacement of new technologies, equipped with artificial intelligence and Internet of Things.

The authors view the process of formation of Industry 4.0 through the prism of digitization of modern socio-economic systems. According to this group of scholars, there's a basis for starting the process of formation of Industry 4.0, as transition from general digitization of external world to digitization of personal space" has been performed—i.e., technologies of virtual reality have entered the modern economic systems so deep that they have distributed to business processes and everyday life.

According to the authors, the next step of digitization and the first stage of formation of Industry 4.0 should be "development of bio- and neuro-interfaces that allow reading and interpreting signals of human brain". The second stage of formation of Industry 4.0 will features "development of Neuro-net, which is a platform for communication between humans and machines on the basis of neuro-interfaces". The third and final stage of formation of Industry 4.0, according to the expert, will be related to "distribution of automatized technologies of management and production of material and digital products" (Loshkareva et al. 2017b).

V.N. Knyaginina raises Industry 4.0 to the level of "top-priority direction of development of the modern Russia's economy until 2024" and divides the process of its establishment into two consecutive stages. The first stage (2018–2020) envisages "starting organizational changes (national standards and normatives) and pilot projects", i.e., implementation of certain initiatives in the sphere of Industry 4.0. The second stage (2021–2024) will feature "transition to action in the regulatory regime in the scale of the whole economy", i.e., coverage by Industry 4.0 of the whole national economic systems (Knyaginina 2017).

Mamedov sees Industry 4.0 as a "new historic level of public production", distinguishing three stages of its formation: mass distribution of computer and Internet technologies, development of creativity of national economy, and formation of inclusive civilization (Mamedov 2017). The authors use the materials of the following works: Lin et al. (2017), Prause and Weigand (2016), Belov (2016), Ganzarain and Errasti (2016), Ragulina et al. (2015), Bogoviz et al. (2017), Bogdanova et al. (2016), Popova et al. (2016), Kuznetsov et al. (2016), Kostikova et al. (2016), Simonova et al. (2017) and Veselovsky et al. (2017).

3 Results

As a result of content analysis of the existing scientific literature and own scientific research, the following stages of formation of Industry 4.0 were determined (Fig. 1).

As is seen from Table 1, the first stage includes preparation of the socio-economic system to future start of business activity in the sphere of Industry 4.0. This stages features implementation of necessary social changes (preparation of society and business), preparation of the institutional platform (restructuring of the government machine and creation of the normative and legal provision of Industry 4.0) and

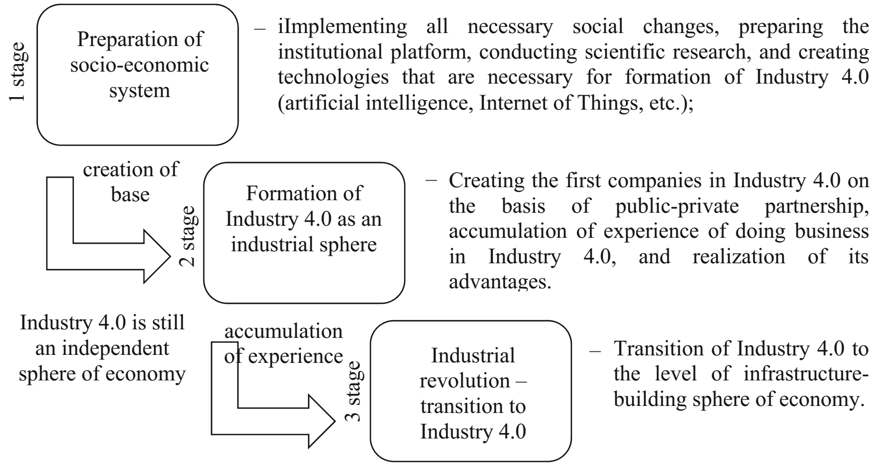

Fig. 1 The process of formation of Industry 4.0 *Source* Compiled by the authors

implementation of scientific research and creation of technologies that are necessary for formation of Industry 4.0 (artificial intelligence, Internet of Things, etc.).

At this stage, the main barriers on the path of formation of Industry 4.0 are public opposition to innovations, which include formation of Industry 4.0, inflexibility of government machine, high duration of modernization of institutes, and high cost and duration of return of R&D projects in the sphere of Industry 4.0. In order to overcome them, it is necessary to increase technological literacy of population, and attract private investors for financing of R&D projects in the sphere of Industry 4.0. When the necessary social, institutional, and technological basis is crated, transition to the next stage takes place.

At the second stage, Industry 4.0 is formed as a sphere of industry. It supposes creation of first companies in Industry 4.0 on the basis of public-private partnership, accumulation of experience of doing business in Industry 4.0, and realization of its advantages. At this stage, the main barriers on the path of formation of Industry 4.0 are underdevelopment of the institute of public-private partnership in modern economic systems and the necessity for large resources for creation of companies in the sphere of Industry 4.0.

Their overcoming requires detailed elaboration of projects for creation of companies in the sphere of Industry 4.0, as the high level of their innovativeness predetermines high risk. When sufficient successful experience of in the sphere of Industry 4.0 is accumulated, transition to the next stage takes place.

The third stage envisages the Industrial Revolution—transition to Industry 4.0. At this stage, Industry 4.0 becomes an infrastructure building sphere of economy. This means that in all other spheres the technologies of Industry 4.0 will be used, which still remain an independent sphere of economy.

Table 1 The system of indicators for monitoring of Industry 4.0 formation

Stages of formation of Industry 4.0	Key indicators of development of Industry 4.0 at each stage	Target value of indicators for transition to the next stage
Preparation of socio-economic system	Level of society's digitization (coverage of population and business with computer and Internet technologies)	Above 90%
	Presence of Industry 4.0 in normative and legal documents of the state	Above 50%
	Total volume (state and private) of financing of scientific research in the sphere of Industry 4.0	More than 5% of GDP
Formation of Industry 4.0 as a sphere of industry	Number of companies in the sphere of Industry 4.0	More than 40% of the whole industry
	Number of digital companies in the service sphere	More than 50% of the whole service sphere
	Ratio of profit to expenditures of companies in the sphere of Industry 4.0	More than 2
	Share of Industry 4.0 in structure of GDP	Above 20%
The Industrial Revolution—transition to Industry 4.0	Level of automatization of non-cognitive business-processes	Above 90%
	Level of automatization of everyday non-cognitive processes	Above 90%
	Level of replacement of cognitive processes (human intellect with artificial)	Above 80%

Source Compiled by the authors

At this stage, the main barriers on the path of formation of Industry 4.0 are complexity and duration of restructuring of business- and everyday processes in the direction of their automatization (replacement of equipment, attraction of resources, development of the work of processes and systems, etc.) and imperfection of technologies of artificial intelligence and Internet of Things (probability of failures in their work, distortion of the set logic, etc.).

Their overcoming requires gradual modernization of economic system, which envisages revolution in the sphere of Industry 4.0 (i.e., revolution is seen not as instantaneous changes but as a deep transformation of the economic system) and constant scientific studies in the sphere of development (improvement of existing and creation of new) technologies in the sphere of Industry 4.0.

The following system of indicators for monitoring of formation of Industry 4.0 is offered (Table 1). The target values are assigned according to the existing concept of Industry 4.0, which is described in literature overview.

As is seen from Table 1, the level of preparation of socio-economic system is evaluated with the help of the level of society's digitization (coverage of population and business by computer and Internet technologies), which should constitute more than 90%; presence of Industry 4.0 in normative and legal documents of the state, which should be above 50%; total volume of state and private financing of scientific research in the sphere of Industry 4.0, which should be above 5% of GDP.

Successfulness of formation of Industry 4.0 as a sphere of industry is evaluated through the prism of the number of companies in the sphere of Industry 4.0, which should constitute more than 40% of the whole industry, number of digital companies in the service sphere (which are digitized in the first turn and participate in GDP production), which should constituted more than 50% of the whole service sphere, ratio of profit to expenditures of companies in the sphere of Industry 4.0, which should constitute more than 2, and share of Industry 4.0 in structure of GDP, which should be above 20%.

Completion of the process of the industrial revolution, which envisages transition to Industry 4.0, is evaluated with the help of the level of authomatization of non-cognitive business-processes, which should constitute more than 90%, the level of automatization of everyday non-cognitive processes, which should be over 90%, and the level of replacement of cognitive processes (human intellect by artificial), which should be above 80%.

The offered system of indicators for monitoring of formation of Industry 4.0 has been developed for the managerial (regulatory) purposes and allows performing precise quantitative evaluation of intermediary successes at each of the distinguished stages of the process of Industry 4.0 formation. Excess of these target values of the described indicators is a signal for transition to the next stage and implementation of the corresponding managerial measures.

In order to prevent crisis of the socio-economic system in the process of managing the formation of Industry 4.0, it is recommended to use high level of regulation of market processes. This measure should not be viewed as an artificial slowdown of the coming revolutionary breakthrough in the sphere of Industry 4.0, as it is aimed for preventing the increase of social opposition to this process and achievement of maximum economic effectiveness by preventing mass bankruptcy of companies in the sphere of Industry 4.0 and in other spheres of economy.

4 Conclusions

The results of the performed research showed the process of formation of Industry 4.0 is linear and envisages consecutive change of three stages: formation of social, institutional, and scientific and technological basis, starting first companies in the sphere of Industry 4.0 and its transformation of one of the main spheres of industry, and revolutionary changes of the socio-economic system and its full transition to development in the conditions of Industry 4.0, which starts performing the infrastructure-building role for all spheres of national economy.

It should be noted that modern economic systems are at the different stages of the process of Industry 4.0 formation. Thus, while developed countries are peculiar for transition to the second stage, developing countries have just started the first stage. Therefore, in the scale of the global economic system formation of Industry 4.0 should be forecasted for the long-term. We do not recommend treating the experience of developed countries in formation of Industry 4.0 as the national model, as this process is under the strong influence of the context and national peculiarities. However, the existing experience should be taken into account during further scientific studies.

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Criteria of Evaluation of Effectiveness of Industry 4.0 from the Position of Stimulating the Development of Knowledge Economy

Tatiana N. Litvinova, Irina A. Morozova and Ulyana A. Pozdnyakova

Abstract The purpose of this chapter is to determine the criteria for evaluating the effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy and to develop methodological basis for this evaluation. As Industry 4.0 is at the stage of formation, the object of evaluation is the process of development of Industry 4.0—i.e., analysis is conducted in dynamics, which allows—at the initial stages of formation of Industry 4.0—conducting evaluation of its effectiveness from the point of view of stimulation of development of knowledge economy. The methodological basis of this research is the classical method of evaluation of effectiveness of socio-economic phenomena and processes. According to this method, effectiveness is determined through finding the ratio of aggregate results to aggregate expenditures for their achievement, including negative "side effects". Based on the classical method of evaluation of effectiveness, the proprietary method of evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy has been developed. This method takes into account the peculiarities of Industry 4.0 and interprets its profits and expenditures through the prism of knowledge economy. The results of the performed research show the potential positive influence of the process of Industry 4.0 formation on development of knowledge economy. The offered methodological recommendations and justified criteria of evaluation of effectiveness of Industry 4.0 from the position of stimulating the development of knowledge economy contribute into formation of methodological basis of studying mutual influence of these phenomena. Advantages of the offered methodological recommendations are their universality—possibility to use them in any economic system; systemic and complex character—consideration of all aspects of potential influence of the process of Industry 4.0 formation on

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development of knowledge economy; vividness and wide possibilities for analysis of causal connections due to the possibility for considering each estimate criterion separately and conducting factor analysis.

Keywords Evaluation of effectiveness · Industry 4.0 · Knowledge economy

1 Introduction

The concepts of Industry 4.0 and knowledge economy have a lot of similarities. Firstly, both these concepts focus on intellectual resources. Secondly, both these concepts envisage large progress in efficiency of economic subjects and economic systems. Thirdly, the key notion, object of study, and strategic landmark of both these concepts are knowledge, which is a complex category that includes the process of realization and perspectives of usage. These and other similarities are a basis for the hypothesis that formation of Industry 4.0 could stimulate the development of knowledge economy.

In the aspect of studying Industry 4.0 as a tool of formation of knowledge economy, development of methodological provision for measuring the influence of the process of Industry 4.0 formation on progress in the sphere of formation of and development knowledge economy is very important. This influence should be viewed through the prism of effectiveness, as it reflects applicability of the tool to achievement of the set goal. Thus, criteria of measuring the intensity of the process of development of Industry 4.0 should be adapted to evaluation of its effectiveness from the point of view of stimulating the development of knowledge economy.

The purpose of this chapter is to determine the criteria for evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy and to develop the methodological basis of this evaluation. As Industry 4.0 is currently at the stage of its formation, the object of evaluation is the process of development of Industry 4.0—i.e., analysis is conducted in dynamics, which allows—at the initial stages of formation of Industry 4.0—evaluating its effectiveness from the point of view of stimulating the development of knowledge economy.

2 Materials and Method

The theoretical basis of the research includes multiple publications of modern authors which describe methodological approaches to evaluation of efficiency and successfulness of progress in formation and development of Industry 4.0. One of these approaches is measuring the level of transition of economic subjects (primarily, industrial companies) to Industry 4.0. It is described in the works Ballo et al. (2017), Chang et al. (2017), Cotet et al. (2017), and Gökalp et al. (2017).

Another approach is related to determining the level of correspondence of modern economic systems to the principles of Industry 4.0. It is presented in the works Jentsch et al. (2013), Majeed and Rupasinghe (2017), Queiruga-Dios et al. (2017), and Santos et al. (2017).

Despite a large number of scientific studies and publications that are devoted to methodological issues of measuring progress in formation of Industry 4.0, both distinguished approaches are oriented at studying Industry 4.0 without connection to knowledge economy. Thus, development of methodological recommendations for complex study of these phenomena and, in particular, evaluation of effectiveness of progress in Industry 4.0 formation from the point of view of stimulating the development of knowledge economy requires further scientific research, which is done is this chapter.

The methodological basis of new research is the classic method of evaluation of effectiveness of socio-economic phenomena and processes. According to this method, effectiveness is determined through finding the ratio of aggregate results (profits) to aggregate expenditures for their achievement, including negative "side effects". Interpretation of the results of evaluation of effectiveness is conducted in the following form: the larger the value of the received product, the better.

Therefore, increase of effectiveness requires maximization of profits and minimization of expenditures. At that, equality of received product 1 is treated as "zero effectiveness", i.e., profits equal expenditures, and performed efforts for their achievement are not expedient. Accordingly, if received product is below 1, effectiveness is negative. This means that expenditures exceed profits, so efforts have to be ceased.

If the received product exceeds 1 (the larger the better), effectiveness is positive, and performed efforts are justified, so they should be continued. The most important successful application of this method is compatibility of data, i.e., their ratio to general time period (as a rule, calendar year) and commonness of measuring units. At that, indicator of effectiveness is measures in shares of one, i.e., they are not assigned with additional measuring units, applied to estimate criteria.

3 Results

Based on the described classic method of evaluation of effectiveness, the authors develop a method of evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy. This method takes into account peculiarities of Industry 4.0 and interprets its profits and expenditures through the prism of knowledge economy. The following formula is used for that:

$$\begin{aligned} CE_{ind\_4.0/ke} = {} & (\Delta N_{ci} + \Delta N_{ci} * \Delta N_{sii} * D_{ind\_4.0/GDP} * D_{dcs/s} * \Delta S_{ind./conv.}) \\ & /(\Delta KI{*}\Delta S_{int./mat} * \Delta S_{art./hum.}) \end{aligned} \tag{1}$$

where $CE_{ind.4.0/ke}$—coefficient of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy;

N_{ci}—number of created innovations in the process of development of Industry 4.0;

N_{ii}—number of implemented innovations in the process of development of Industry 4.0;

S_{ii}—share of implemented innovations (ratio of the number of implemented innovations to the number of created innovations) in the process of development of Industry 4.0, %;

$S_{ind.4.0/GDP}$—share of Industry 4.0 in the structure of gross domestic product (GDP) of country (ratio of gross added value that is created within the Industry 4.0 to GDP), %;

$S_{dcs/s}$—share of digital companies in the service sphere of the whole service sphere, %;

$S_{ind./conv}$—share of performed individual orders (ratio of the number of individual orders to mass orders, i.e., to conveyor production) within Industry 4.0, %;

KI—knowledge intensity (ratio of the number of implemented innovations to the volume of production) of Industry 4.0, innovations per unit;

$S_{int./mat.}$—share of intellectual resources in the structure of resources that are used in Industry 4.0 (ratio of intellectual resources to non-intellectual resources), %;

$S_{art./hum.}$—share of artificial intellectual resources in the structure of intellectual resources, used in Industry 4.0 (ratio of artificial resources to intellectual resources), %;

Δ—ratio of the value of this indicator in previous calendar year to its value in this (studied) year.

As is seen from formula (1), the classic formula of evaluation of effectiveness is modified for provision of its applicability to this research. In particular, their ratio to 1 is used for evaluation of expenditures. This is necessary for preservation of the classic essence of evaluation of effectiveness that is related to maximization of profits and minimization of expenditures.

The problem is that from the point of view of stimulating the development of knowledge economy it is expedient to evaluate not only expenditures of various types of resources that are used with development of Industry 4.0, as it is done within the classic method of evaluation of effectiveness of economy's development but expenditures of knowledge (as a result of intellectual activities) and intellectual resources (as sources of intellectual activities).

From the point of view of stimulating the development of knowledge economy, increase of the values of these indicators is a positive value, as it ensures increase of the value of knowledge and intellectual resources in developed economic system. However, from the point of view of expenditures during evaluation of effectiveness, their growth requires negative treatment. In order to eliminate this contradiction, expenditures are given not in the classic stable form but in ratio to 1.

Another modification of the classic formula of evaluation of effectiveness is that instead of absolute values of the indicators of effectiveness, their relative values are used—annual growth. This forced measure is predetermined by the necessity for bringing all indicators to common measuring units, which are shares of 1. This modification does not lead to distortion of the results of evaluation and is possible in this research, as it is aimed at studying dynamic process—development of Industry 4.0 through the prism of knowledge economy.

Let us view the offered criteria for evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in detail. Let us study the criteria for evaluation of results—profits, which are expressed in developed knowledge economy and are received in the process of development of Industry 4.0.

One of these criteria is the number of created innovations in the process of development of Industry 4.0. At present, Industry 4.0 is in the process of its formation. Supporting its theoretical concept, there are a lot of applied technologies that allow implementing its provisions in practice. That's why Industry 4.0 creates a lot of innovations—primarily, leading production technologies. New knowledge and technologies (innovations) are the basis of knowledge economy, which explains the choice of this estimate criterion.

Another criterion is the number of implemented innovations in the process of development of Industry 4.0. Creation of innovations does not guarantee their successful application in practice. Formation of knowledge economy requires implementation of innovations into economic activities. In the context of this research, it is expedient to take into account the innovations that are implemented within Industry 4.0. This criterion could be measuresd in natural (number of implemented leading production technologies, number of manufactured innovational products, etc.) or cost expression (aggregate cost of manufactured innovational products)—however, it is necessary to take into account the inflation.

The third criterion is related to the share of implemented innovations. Successful formation and development of knowledge economy requires successful commercialization of innovations and achievement of the fullest usage of new knowledge in economic activities. In order to determine the role of implemented innovations, it is offered to find the ratio of the number of implemented innovations to the number of created innovations in the process of Industry 4.0 development.

The fourth criterion is share of Industry 4.0 in the structure of GDP of the country. Industry 4.0 belongs to the number of high-tech spheres. High share of these spheres in the structure of GDP is a sign of knowledge economy. Therefore, the larger the share of Industry 4.0 in the structure of GDP, the larger the progress in formation of knowledge economy. This share is found through calculating the ratio of gross added value that is created within the Industry 4.0 to GDP.

The fifth criterion is share of performed individual orders within the Industry 4.0. One of the sings of development of knowledge economy is increase of population's living standards. Industry 4.0 opens possibilities for collection and execution of individual orders that are oriented at unique needs of each separate consumer. This allows satisfying the needs of existing demand, thus stimulating living standards. The number of performed individual orders should be viewed in connection to the general structure of performed orders, and their ratio to mass orders should be found for determining the capabilities of Industry 4.0 in this aspect and activity of their usage in dynamics.

Let us also view the indicators of expenditures that are related to development of Industry 4.0 from the point of view of stimulating the development of knowledge economy. The first of them is knowledge intensity. High knowledge intensity is a sign of knowledge economy. That's why it is offered as an estimate criterion as to development of Industry 4.0. Knowledge intensity should be determined by finding the ratio of the number of implemented innovations to the volume of production of goods in Industry 4.0.

The second criterion is related to share of intellectual resources in the structure of resources that are used in Industry 4.0. Th sign of knowledge economy is domination of "knowledge-based" (intellectual) resources in the general structure of resources. Intellectual resources are the results of intellectual activities, i.e., knowledge, namely leading production technologies, know how, etc. In order to calculate this indicator, it is offered to find ratio of intellectual resources to non-intellectual resources, including land (material), financial, labor, and other types of non-intellectual resources.

Th third criterion is share of artificial intellectual resources in the structure of intellectual resources that are used in Industry 4.0. Artificial intelligence is a new form of interpretation and a new source of creation of new knowledge, which emerges and is used in Industry 4.0. This indicator characterizes sources of intellectual activities, so for its measuring the cost of business processes that are conducted on the basis of usage of artificial intelligence should be applied. It is calculated as ratio of artificial resources to human intellectual resources.

4 Conclusions

The results of the performed research confirmed the offered hypothesis on potential positive influence of the process of formation of Industry 4.0 on knowledge economy's development. The offered methodological recommendations and justified criteria of evaluation of effectiveness of Industry 4.0 from the position of stimulating the development of knowledge economy contribute into formation of methodological basis of studying the mutual influence of these phenomena.

Advantages of the offered methodological recommendations are their universal character—possibility to use them in any economic system; systemic and complex character—consideration of all aspects of the potential influence of the process of Industry 4.0 formation on development of knowledge economy; wide possibilities for analysis of causal connections due to the possibility for considering each estimate criterion separately and conduct of factor analysis.

It should be concluded that despite the multiple advantages, the offered formula and criteria for evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy have a serious drawback, which limits the possibilities of their practical application—complexity of collection of initial statistical data. That's why in case of inaccessibility or imprecision of these data for evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy, it is possible to use the classic formula, which calculates ratio of aggregate result of development of Industry 4.0 (volume of production, volume of sales in cost expression, etc.) to expenditures for its achievement (volume of resources that are spent in cost expression).

In order to consider the effect in the sphere of stimulating the development of knowledge economy in this case, it is necessary to use estimate coefficients, which values will increase or decrease the received value of the indicator of effectiveness of Industry 4.0 development. Of course, in this case the results of evaluation will be less informative for further analysis due to unclear structure and less precise due to high share of subjectivism during assigning of values to estimate coefficients. Due to this reasons, development of these formulas is beyond the framework of the research, but probable practical need for them makes them a perspective direction for further scientific studies.

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Part IV
Practical Aspects of Development of Industry 4.0 in Various Economic Systems

Industry 4.0—Transition to New Economic Reality

Stella S. Feshina, Oksana V. Konovalova and Nikolai G. Sinyavsky

Abstract The Fourth Industrial Revolution has already begun. It will lead to maximum consideration of consumers' preferences. The purpose of the chapter is to describe the characteristics of the Fourth Industrial Revolution, make a forecast for the contents of the Fifth Industrial Revolution, and emphasize the fundamental role of Industry 4.0 in economic development of Russia. The conclusions are based on analysis of the trends of the indicators of the technological progress and specific efforts for development of the direction of Industry 4.0.

Keywords Industry 4.0 · New economic reality · Industry · Revolution · Positive effect · Negative effect

JEL Classification Codes O14

1 Introduction

Over the recent centuries, the world has changed a lot, with three industrial revolutions following each other. The first revolution took place in the early 19th century and was related to mass transition from usage of manual labor and muscle force in industry to energy of steam engine. A hundred years later, the second revolution marked the start of mass production due to appearance of conveyor. A large role belonged to development of Taylorism, or scientific organization of labor. 1970s-1980s passed under new vectors of scientific and technological progress—the Third Industrial Revolution. Modern industrial complexes with machines with numeric

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control and robotized production made modern factories uninhabited. As a result, mass products became cheaper, so it was better to buy a new product that to repair the old one. Thirty years later the world is getting ready for the new industrial revolution—Industry 4.0.

The concept "Industry 4.0" was formulated in 2011 by the President of the World Economic Forum in Davos, Klaus Schwab. Its essence consists in quick convergence of cyberphysical systems and factory processes, as a result of which a possibility of production of individual product with necessary functions and options appears—at that, its cost is almost similar to the cost of a mass product (Schwab 2016). At present, the leader of development of Industry 4.0 is Germany, where a place similar to the Silicon Valley is created—Intelligent Technical Systems Ost Westfalen Lippe (Dumitrescu 2012). Similar programs have been started in the Netherlands, France, the UK, Italy, Belgium, etc. Since 2012, a non-profit "Coalition of leaders of clever production" has been working in the USA—it unites business, universities, and government structures.

Industry 4.0 is based on mass distribution and implementation of a lot of new technologies (Table 1), which will lead to global and deep changes in all spheres of society's life (The World Economic Forum, "Deep transformation—technological breakthrough moments and social influence", Research report, International Expert Council of the World Economic Forum on the issues of future program provision and society, November 2015).

According to the data of PwC (Report 2016), manufacturers of industrial products from various countries of the world plan to invest into development of Industry 4.0 $907 billion per year until 2020. The World Bank and General Electric estimate that Industry 4.0 may bring $30 trillion for the global economy.

The global services market, which corresponds to the requirements of Industry 4.0, is estimated at $773 billion, but Russia's share in it is only 0.28%. The key barriers for Russia's transition to Industry 4.0 include low level of digitization and insufficient expenditures of companies for innovations. For example, the share of expenditures for R&D in the budgets of the world leaders on car industry is by six times higher than with Russian companies, and in the telecommunication sphere this gaps is tenfold.

The main stimulus for development of the Russian technologies within Industry 4.0 is the program "Digital economy of the Russian Federation", which defines priorities of national policy and is a basis for creation of the normative base and favorable investment environment. Within the program, it is planned to spend RUB 16 billion for supporting Russian software developers in 2018–2020, of which half accounts for investments from the companies. Regarding the Internet, there's an issue of registration of the Russian standard NarrowBandFidelity (NB-FI). Standardization of protocols of data transfer will allow solving the issue of compatibility of digital systems.

Construction of technological parks contributes into development of Russian technologies. According to the Association of clusters and technological parks, Russia has 125 technological parks in 44 subjects of the RF. Most of them are located in the central part of Russia, with maximum concentration in Moscow. As a rule, the

Table 1 Public, economic, and other effects from implementation and distribution of new technologies within Industry 4.0

Technology	Positive effects	Negative effects
Implanted ad body-carried technologies (digital tattoos, clever pills, clever clothes, etc.)	– Increase of effectiveness during search for missing people; – Selection of individual treatment plan and resulting increase of life span; – Formation of more clear self-sufficiency and cultural changes of personality (so called eternal memory); – Improvement of the quality of decisions; – Recognition of images and accessibility of personal data (anonymous network that will "work within" people)	– Violation of the principles of privacy of life through potential observation; – Reduction of the level of protection of security data, including personal; – escapism and development of dependence; – Increase of the level of dependence of new technologies, distraction (syndrome of attention deficit)
Digital life (digital presence)	– Increase of transparency of business operations; – Acceleration of the rate of information exchange, including exchange of volumes between separate persons and groups of people; – Higher freedom of speech, lower censure; – Increase of effectiveness from provision and usage of government services; – Target advertising for specific groups of consumers; – More valuable information and news for society	– Complication of protection of competitive advantages of business; – Increase of possibilities of personal data theft, including of corporations' personnel; – Aggressive behavior or intimidation online; – Group thinking within interest groups and increase of the level of opinions' polarization; – Dissemination of incorrect information (reputation risks)
Visualization and additional reality	– Quick transfer of information to human for making a decision based on the information, related to navigation, work, and own actions; – Improved capability to perform tasks and produce goods and services with the help of visual additional means; – Providing the handicapped with resources due to which they are able to interact and study the world: move, speak, print	– Mental disorders that lead to accidents; – Traumas from negative effects from entering virtual reality, isolation from reality; – Increased level of dependence and escapism
Distributed calculations (distribution of accessible smart devices)	– Handicapped people receive a possibility to be involved in market economy; – The number of people who are involved in market economy, in remote regions, or in regions with poor infrastructure ("last mile") grows; – Access to educational, healthcare, and government services; – Access to professional knowledge, increase of employment, emergence of new specialties; – Growth of online trade market	– Increase of the number of manipulations and echo-cameras; – Political division; – Closed platforms (i.e., limited areas in the network, only for certain users) do not allow for full access in certain regions and countries
Free data storages	– Data bases of legal systems; – Historical research and accumulated knowledge for teaching in secondary and higher school; – Evaluation of effectiveness of business operations; – Usage and infinite expansion of limits of individual memory of business, verification by errors, eternal memory of business failures with obtaining the experience; – Increase of volumes of created content, joint usage and consumption by intermediaries and interested parties	– Reduction of possibilities of protection of competitive advantages of business – Loss of privacy for everyone

(continued)

Table 1 (continued)

Technology	Positive effects	Negative effects
Internet of Things (clever homes/cities/companies)	– Increase of effectiveness of resources' usage; – Growth of efficiency; – Improvement of living standards; – Influence on the environment; – Reduction of cost of provision of services; – Increase of transparency as to usage and state of resources; – Security (e.g., airplanes, food products); – Increase of effectiveness (logistics); – Increase of demand for storage and width of range; – Shift in labor market and professional knowledge and skills; – Creation of new businesses; – Even difficult application in real time become easy in standard communication networks; – Design of item takes into account the possibility of "digital connection"; – Adding digital services to the main functions of the product; – Digital double provides precise data for constant control, management, and forecasting; – Digital double becomes an active participant of business, information, and social processes; – Objects will react to the environment in the autonomous regime; – Generation of additional knowledge and values, based on connected "clever" items	– Confidentiality; – Loss of jobs for non-qualified workers; – Hacking, security threats (e.g., local energy grid); – Increase of the level of complexity and loss of control/management; – Influence of the value of data in the business model; – Each company is a potential company of software provision; – New businesses; selling data; – Changes of legal framework during determination of confidential and personal information
Dig data	– Improvement and acceleration of decision making; – Increase of the number of decisions made in real time; – Open data for innovations; – Jobs for lawyers; – Elimination of complexities and increase of effectiveness for citizens; – Economy on expenditures; – New categories of jobs	– Loss of jobs; – Threat to preservation of personal information; – Who possesses this algorithm?; – Trust (trusting the data); – Struggle for algorithms
Unmanned cars	– Increase of the security level; – More time for work and (or) content of used data; – Influence on the environment; – Reduction of the level of stress and aggressive driving; – Increase of the level of mobility for old people and the handicapped; – Mastering of electric cars	– Loss of jobs (taxi and truck drivers, car industry); – Changes in insurance and road assistance ("pay more for driving personally"); – Reduction of income from traffic tickets; – Reduction of the number of car owners; – Legal organizations concerned with drivers; – Lobby against automatization (people are not allowed to drive on toll-free roads); – Hacking/cyber attacks
Artificial intelligence	– Rational decisions that are based on data; less subjectivity; – Elimination of "irrational excess"; – Reorganization of obsolete bureaucratic structures; – New and innovational jobs; – Independence from energy resources; – Achievements in medical science, overcoming diseases; – Reduction of expenditures; – Increase of effectiveness; – Reduction of barriers for innovations, possibilities for development of small business, companies-startups (reduction of initial barriers, "software provision as a service" that is applicable to everything)	– Accountability (who is responsible, legal aspects); – Loss of jobs; – Hacking/cybercrimes; – Responsibility and accountability, organization of management; – Going beyond the regular things; – Increase of the level of inequality; – "Conflict with algorithm"; – Existential threat to humanity

(continued)

Table 1 (continued)

Technology	Positive effects	Negative effects
Robototronics and services	– System of supply and logistics, elimination of intermediaries; – More free time; – Improvement of indicators of health (“big data” for r&d achievements in pharmacy); – Larger access to materials; – Replacement of foreign workers by robots	– Loss of jobs; – Responsibility, accountability; – Risk of cyber attacks and hacking
Blockchain and other technologies of distributed register	– More serious financial presents in developing markets after achievement of critical mass of usage of technologies of block chain in financial services; – Elimination of intermediary services in financial institutes due to the fact that new services and methods of values’ exchange are created in block chain; – Quick increase of the number of tradable assets due to the fact that the technology of block chain allows processing all types of values’ exchange; – Better documenting of property in developing markets and the capability to turn everything into tradable asset; – Contracts and legal services are connected to blockchain code, so they are a protected escrow or developed with the help of smart contract program; – Increases transparency due to the fact that block chain is a world accounting book that preserves all transaction	
3D print and 3D production	– Quick development of products; – Reduction of the cycle “development—production”; – Simplicity of production of complex parts (which were impossible to manufacture or they required too much effort); – Growing demand for developers of items; – Usage of 3d print by educational establishments for accelerating the process of learning and understanding; – Democratization of the processes of creation/production (both are limited only by development); – Traditional mass production conforms to challenges, finding the ways to reduce expenditures and the size of minimum series; – Growth of the number of “plans” with open code for printing various items; – Emergence of a new industry for supply of materials for print; – Growth of entrepreneurial possibilities in space; – Favor for ecology from reduction of requirements for transportation	– Growth of the volume of waste and increase of negative influence on ecology; – Creation of anisotropic parts of the item in the process of layer print, which means that such parts will not be equally strong in all directions, which, in its turn, may limit their functionality; – Reduction of the number of jobs in the sphere due to changes in the work cycle; – Primary nature of intellectual property as a source of value in efficiency; – Piracy; – Quality of trade mark and product
3D print and healthcare	– Solving the problem of deficit of donor organs; – Printing prosthesis: replacement of limbs/body parts; – Personalized medicine: 3d print is accepted better when each customer requires an individual version of body part (e.g., a tooth); – Printing rare expensive parts of medical equipment, e.g., sensors; – Printing tooth implants, cardio stimulators, and prefilled syringes for bone fractures in local hospitals instead of importing them, for reducing the cost of surgeries; – Fundamental changes in testing drugs that could be performed with real human objects, in view of accessibility of fully printed organs; – Printing of food products, which raises food security	– Uncontrolled production of body parts, medical equipment, or food; – Growth of the volume of waste and increase of negative influence on ecology; – Main ethical differences regarding printing body parts and bodies: who controls the capability to produce them? who guarantees the quality of body parts? – Lack of stimuli for caring for health: what for if it is possible to replace everything? – Influence of printing of food on agriculture

sphere of specialization of technological park is somehow connected to the region's industrial potential, ensuring maximum synergetic effect. In the structure of Russian technological parks, the most popular specialization in the sphere of information technologies, which corresponds to the general direction of the trend of Russia's development.

Thus, it is expected that Industry 4.0 will have the fundamental influence on the global and Russian economies and will influence all large macro-variables: GDP, investments, consumption, employment, trade, inflation, etc. What will this new economic reality look like? In order to answer this question, let us view historical trends of the main macro-economic indicators.

2 Information and Methods

Several years before the 2008 crisis, growth of the global GDP constituted 4.4% per year in real value (according to the World Bank). After the economic decline, a lot of people expected the economy to return to the previous model of quick growth. However, this did not happen. The global economy slowed down at 2.5% growth rate per year in 2012–2016. There are a lot of explanations of this slowdown of growth: from irrational usage of capital and excessive debt to demographic shift, etc. One of the main factors was "stagnation" of labor efficiency.

Let's take the USA (Fig. 1), where labor efficiency in 1987–1993 grew by 2.8%; in 2000–2007—by 2.6%, and in 2007–2015—by 1.3%. Such decline was caused by reduction of the level of aggregate efficiency of production factors—the indicator that is associated to increase of effectiveness as a result of technological progress. According to the Bureau of Labor Statistics of the USA, growth of aggregate efficiency of production factors for 2007–2014 constituted 0.5%, which is a large reduction as compared to annual growth of 1.4% for 1995–2007.

The thing is that official statistics cannot record real increase of efficiency for consumers by means of technical progress, as growth of value is not reflected in the number of transactions or EBITDA. For example, aggregators of taxi or food delivery are free for consumer, but provide convenience and save time and resources.

Goods and services of Industry 4.0 have higher functionality and quality, but have zero threshold expenditures. Due to digital globalization, the Fourth Industrial Revolution will enable certain people and society to obtain access to required products in all countries of the world. This will lead to increase of demand and economic growth. Also, Industry 4.0 will rise our capability to cope with external negative effects—e.g., ecological problems.

Selling goods in highly-competitive open digital platforms-aggregators and reduction of production costs by means of implementing new technologies should lead to gradual reduction of prices. Figure 2 shows that in real value prices for durable goods (cars, household equipment, furniture) reduced by three times. Non-durable goods (food, clothes, household chemicals, office supplies, etc.) remained at the same price level, as they depend on volatile prices for energy and resources. Prices for services

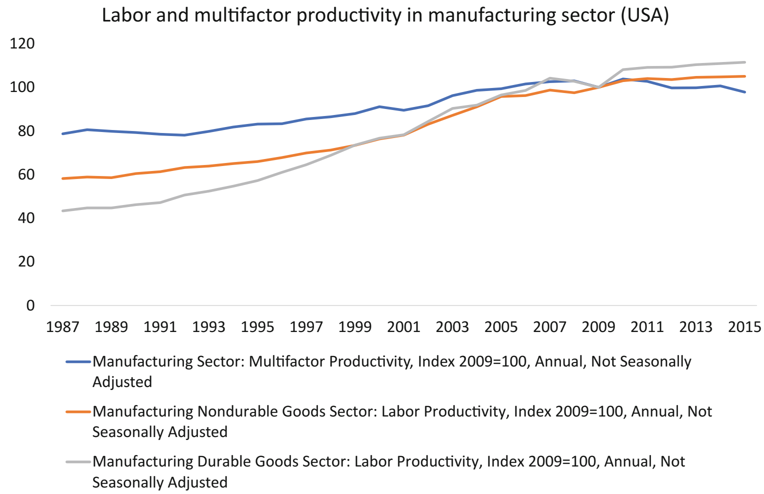

Fig. 1 Dynamics of efficiency of labor and production factors in the USA in 1987–2015 (2009 = 100%) *Source* The Federal Reserve Bank of St. Louis https://fred.stlouisfed.org/series/FREDEconomicData

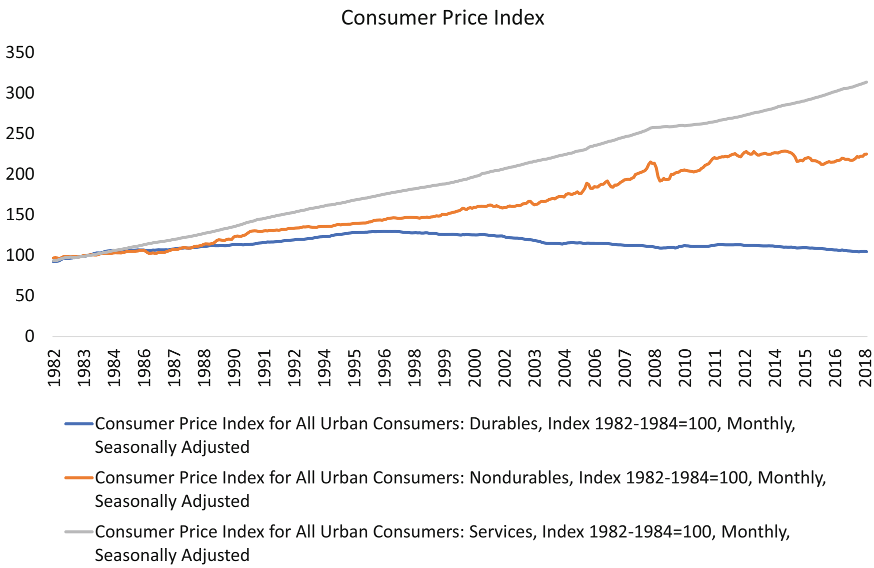

Fig. 2 Index of prices for categories of goods in view of inflation in the USA

grow quicker than inflation. Prices for goods reduce by 4% annually. This means that with preservation of the volumes of production at the same level, industrial countries will be losing 4% of GDP if they do not change the structure of national product formation.

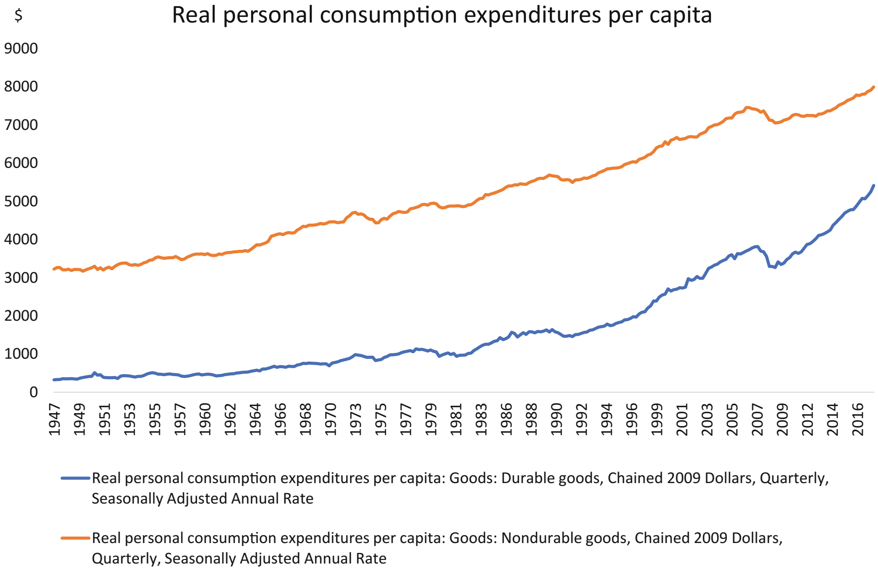

Fig. 3 Real expenditures for personal consumption per capita in the USA, $ *Source* data of the Bureau of Economic Analysis of the USA, https://www.bea.gov

Reduction of prices for goods and increase of revenues led to increase of consumption (Fig. 3). Demand for durable goods grew by ten times for fifty years. Accessibility of goods and services for each person in the world, which is offered by Industry 4.0, will preserve growth of this indicator.

Another important fact is transition of the centers of profit from industrial companies to digital ones. Implementation of new technologies becomes the main articles of expenditures of largest companies. New spheres of Industry 4.0 occupy a large share in formation of GDP of developed countries. Thus, in 2016 the share of digital companies that offer services in the sphere of implementation of new technologies in the American GDP constituted 14%. This indicator will continue growing.

3 Results

Industry 4.0 will preserve the trend of reduction of prices for industrial goods. As a result, marginality of productions will reduce, and centers of profit will move to IT corporations that implement technologies. If the country does not have its own suppliers of technologies, the companies will have to use foreign suppliers. If Russia remains above this technological rivalry and does not take seriously the challenges of the Fourth Industrial Revolution, Russia's GDP will be reducing by 4% per year (according to the rate of prices' reduction). At that, there's a risk to remain at the periphery of new digital markets and become dependent on import of foreign technologies, without which—in the conditions of Industry 4.0—industry will die. As is observed today, well-known companies experience large pressure from new innovational companies from other spheres and countries. The same is true for the countries that do not recognize the necessity for building their own innovational eco-systems in the corresponding way.

4 Discussion

The Fourth Industrial Revolution has already started—but what form will the Fifth Revolution have? The current trends show that prices for goods will continue reducing, and share of digital companies and IT corporations in GDP will continue increasing, as they will become the main centers of cost formation. According to the authors, the next industrial revolution will be related to emergence and distribution of more perfect computation means, which will process large volumes of information instantaneously.

The existing computers have a whole range of drawbacks, the main of which are expensive components and large consumption of electric energy. The concepts of "machines" of future without these disadvantages have already appeared. Thus, for example, bio-engineers have started work on an interesting product—"living" supercomputer, which will obtain energy from adenosine triphosphate, as all normal organisms, and information transfer will be conducted by proteins instead of electrons.

As a result, artificial intelligence will be able to process dig data of not only one company or corporations but the whole spheres. This will lead to global unification of the sphere of production into one interconnected structure. The notion "competition" will disappear—as an ineffective relic of the past. The driver of new economy will become not free market but optimization and "individualization". Advertising will disappear—it will be replaced by automatic recommendation systems that will adapt to the needs and preferences of each person. Larger reduction of expenditures will allow selling products for the lowest process. In a certain sense, new reality will look like communism, which will be "built" by technological progress.

5 Conclusions

We're looking at the origin of the Fourth Industrial Revolution, but it is possible to see its effects in all spheres of society's life—especially, in economy. It is possible to note the following main directions of changes.

1. Self-optimization and self-adaptation of cyber-physical systems" the means of self-optimization and self-adaptation, endogenous adaptation of the system's

goals to changing external influences, which conforms to the tasks of activities and ensures effective correction of the system's behavior. Reliability of such cyber-physical systems will grows substantially, as they will be more reliable against temporary errors.
2. Man-machine symbiosis: growing complexity of intellectual systems set high requirements to natural and intuitively understandable man-machine interfaces. Flexible setting for developer ensures consecutive and well-structured interaction, which supports convenience of usage of technical systems.
3. Intellectual networks (artificial intelligence): intellectual technical networks consist of a lot of closely connected and complex systems which connection leads to global changes in production. Global optimality of production system becomes a result of connection of local decentralized sub-systems.
4. Energy efficiency: cyber-physical systems allow determining and using reserves of economy of electric, heat, and other energy from the stage of design to exploitation, changing the structure of costs along the whole chain of formation of product's cost.

The list of directions of future changes is much larger. It is necessary to expect fundamental changes in all spheres of society's life as a result of mass implementation of new technologies, which consists the basis of "Industry 4.0".

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Successful Experience of Formation of Industry 4.0 in Various Countries

Svetlana V. Lobova, Natalia V. Bykovskaya, Irina M. Vlasova and Olga V. Sidorenko

Abstract The purpose of this chapter is to study successful experience of formation of Industry 4.0 in the countries of the world. As developed countries proclaimed the strategic course at practical implementation of the concept of Industry 4.0 and achieved the highest progress in its formation, they were selected as the objects for this research. According to the criterion of data accessibility and in the interests of coverage of various geographical regions of the world, we selected the USA, the UK, Germany, and Japan. Due to novelty of the concept of Industry 4.0, timeframe of the research covers 2016–2017, which does not allow evaluating the dynamics of progress in formation of Industry 4.0 in detail, but provides sufficient initial statistical and analytical data for studying this process. For that, the methodological recommendations in the sphere of monitoring of the process of Industry 4.0 formation and evaluation of effectiveness of Industry 4.0 from the point of view of stimulation of knowledge economy's formation are used. The methodological basis of the research includes the systemic approach and structural and functional and problem analysis. As a result of the research, the scientific proofs are given for the fact that despite the recent emergence of the concept of Industry 4.0, successful experience of its practical implementation in the countries of the world is already accumulated. Developed countries have already started formation of Industry 4.0, as they possess necessary resources and social platforms. Complex analysis of forecasting data by the example of the USA, the UK, Germany, and Japan shows its high effectiveness from the point of view of stimulating the development of knowledge economy.

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1 Introduction

The concept of Industry 4.0 is attractive for modern economic systems due to two main reasons. The first reason is innovativeness of Industry 4.0. Socio-technological progress has formed preconditions for new industrial revolution, which is expected by the whole global economy.

These expectations are increased by the large duration of the global depression of the early 21st century and striving for quick overcoming of its consequences and transition to a new level and quality of economic growth. There's an opinion in the scientific and political environment that Industry 4.0 has to become a new vector of development of the global economy for future decades, which will ensure its reformation after the recent global crisis and will allow preventing new crises.

The second reason is based on expected high effectiveness of Industry 4.0 and its capability to solve the global problems of modern humanity. Despite the unprecedented level and intensive growth of the volumes of production, the possibilities of modern technologies lag behind the increase of needs of society of consumption, which are largely caused not by physiological (natural) but social issues—i.e., they are created artificially.

Industry 4.0 allows increasing efficiency of economic systems, and, therefore, overcoming total deficit of consumer goods. At that, development of Industry 4.0 is accompanied by reduction of load onto a human, who turns from worker into consumer, and the production functions belongs to automatized production systems that are equipped with artificial intelligence.

However, despite the demand and global recognition of the concept Industry 4.0, initiatives for its practical application are restrained by uncertainty as to possible negative consequences. That's why studying successful experience of formation of Industry 4.0 in countries of the world becomes very important.

2 Materials and Method

As developed countries of the world proclaimed the strategic course at practical implementation of the concept of Industry 4.0 and achieved large progress in its formation, they were selected as objects for the research. According to the criterion of accessibility of data and in the interests of covering different geographical regions of the world, we have selected such countries as the USA, the UK, Germany, and Japan.

Due to novelty of the concept of Industry 4.0, timeframe of the research covers 2016–2017, which does not allow evaluating dynamics of progress in formation of Industry 4.0 in detail but provides sufficient statistical and analytical data for studying this process. For that, the methodological recommendations in the sphere of monitoring the process of formation of Industry 4.0 (Chapter "Industry 4.0 as a New Vector of Growth and Development of Knowledge Economy") and evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy (Chapter "Stages of Formation of Industry 4.0 and the Key Indicators of its Development") are used.

The theoretical and methodological basis of the research includes the systemic approach and structural and functional and problem analysis, as well as scientific research and publications that reflect successful experience of formation of industry 4.0 in various countries, which are systematized according to the selected objects:

– the USA: Mendoza et al. (2018), Reitsma et al. (2017), Cross and Felis (2017), Motesharezadeh et al. (2017), Ebadian et al. (2017);
– the UK: Gavrysh and Boiarynova (2017), Sutton and Sapsford (2016), Song et al. (2015), Tserkovsky et al. (2012);
– Germany: Jakobs et al. (2018), Patalas-Maliszewska and Kłos (2018), Küsters and Praß (2017), Belov (2016), Romberg (2016), Uhlmann (2015);
– Japan: Tokumasu (2017), Ivanov (2018), Takano et al. (2017), Chien et al. (2017), Motesharezadeh et al. (2017).

3 Results

Based on detailed content analysis of the above scientific literature, it was determined that in the studied countries the process of formation of Industry 4.0 is at the initial stage and envisages preparation of their socio-economic systems by implementing the necessary social changes, formation of the institutional platform, conduct of scientific research, and creation of technologies that are necessary for formation of Industry 4.0 (artificial intelligence, Internet of Things, etc.).

In the USA, interest to Industry 4.0 is explained by social goals and changes. Formation of digital society raises demand for further development of innovational technologies, among which robototronics is of the highest interest. At present, the US government has to solve a serious social contradiction related to striving for overcoming the unemployment and become the leader in the global competition of industrial innovations.

In Industry 4.0, this contradiction is solved with the help of creation of highly-intellectual jobs for servicing robototronics, which will allow overcoming the initial unemployment and satisfying the growing needs for opening the creative potential of American workers. Visible results in Industry 4.0 are to be achieved by 2022 (Robotics Tommorrow 2017).

In the UK, close attention in the aspect of strategic management of the process of Industry 4.0 formation is paid to transformation processes in the market. Deep change of consumer expectations and preferences under the influence of the process of development of Industry 4.0 is expected in this country. The 2016 sociological survey of British industrial companies showed that 74% were not ready for transition to Industry 4.0 and experienced serious worries due to its formation.

At the same time, 42% of British companies said that they tracked the course of formation of Industry 4.0 and had high commercial interest in it. In the macro-economic aspect, the UK government expects large growth of the unemployment level (more than by 30%) as a result of formation of Industry 4.0. At the state level there are discussions on "creation of 'New England' in the conditions of the Fourth Industrial Revolution", in which Internet of Things, cyber-physical systems and "clever plants" are to be used.

First successes are expected in the sphere of artificial intelligence and unmanned cars. However, here we speak of long-term forecasts. High expectations of the government regarding unfavorable social consequences (primarily, growth of the unemployment level) and unreadiness of industrial companies cause slow rate of formation of Industry 4.0 in the UK, which will lead to visible macro-economic changes only in 10–20 years (The Telegraph 2017).

In Germany, Industry 4.0 is the basis of the national strategy of development of industry. Germany started implementing this strategy in 2013; by 2025, serious results are expected—increase of gross added value by $14.8 billion in car industry, $23 billion—in machine building, $12.1 billion—in production of electric energy, and 12%—in chemical industry. Germany featured the highest readiness (as compared to other studied countries) for the process of starting Industry 4.0.

The German Government did not stop at compilation of forecasts but set the people who were responsible for practical implementation of specific measures. Thus, the Ministry of Economy and Energy is responsible for stimulating sectorial cooperation during implementing the initiatives in the sphere of Industry 4.0, the Federal Ministry of Education and Science—for stimulating scientific R&D in the sphere of Industry 4.0.

The Federal Ministry of Labor and Social Affairs regulates employment and stimulates increase of living standards of German specialists to the level that is necessary in Industry 4.0. The Federal Ministry of the Interior is responsible for provision of security of data in Industry 4.0, the Federal Ministry of Justice and Consumer Protection—for protection of consumers and confidential information during consumption of products of Industry 4.0, and the Federal Ministry of Transport and Digital Infrastructure—for formation and support for necessary infrastructural provision of Industry 4.0 (Schroeder 2017).

The Japanese Strategy of formation and development of Industry 4.0 is oriented at gaining advantages related to optimization of social systems, business-processes, and production of technologies and equipment, by formation of transport, electric energy, medical, and industrial networks. At that, the main load on formation of Industry 4.0 in Japan is set on private business—the government's national strategy urges companies to develop and adopt long-term strategies of their development (for future 5–10 years) in view of their contribution in formation of Industry 4.0.

Table 1 Results of monitoring of the process of Industry 4.0 formation in different countries in 2017

Stage	Key indicators of development of Industry 4.0 at each stage	Target values (%)	Values of indicators in countries			
			USA	UK	Germany	Japan
Preparation of socio-economic systems	Level of society's digitization (accessibility of Internet technologies)	>90	89	88	85	69
	Presence of Industry 4.0 in normative and legal documents of the state	>50	12	6	30	4
	Total volume of financing of scientific research in the sphere of Industry 4.0	>5 of GDP	0.5	0.3	0.9	0.1

Source Compiled by the authors based on: Pew Research Center (2017), Robotics Tommorrow (2017), The Telegraph (2017), Schroeder (2017), Fujino and Konno (2016)

Japan entered the path of formation of Industry 4.0 later than other studied countries, so in its national strategy of development of Industry 4.0 it uses the initiatives of other countries. The Japanese government set the goal of formation of Industry 4.0 as overcoming other countries and supporting high global competitiveness of its socio-economic systems in the long-term (Fujino and Konno 2016).

The viewed examples of formation of Industry 4.0 in different countries showed that there's successful experience of practical implementation of this concept. However, in order to compile a fuller picture of this experience, let us supplement the performed qualitative analysis with quantitative analysis. For that, let us use Tables 1 and 2, in which—based on preliminary and forecast statistical data—the monitoring of the process of Industry 4.0 formation in different countries in 2017 was performed, and evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in countries of the world in 2017–2022/2025 was conducted.

As is seen from Table 1, according to the level of society's digitization (accessibility of Internet technologies), all studied countries are ready for transition to the next stage of formation of Industry 4.0. A restraining factor is incompleteness of the process of formation of normative and legal provision of Industry 4.0—it is mentioned in certain official documents, as a rule, strategies of economy's development,

Table 2 Evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in different countries in 2016–2022/2025

Type	Indicators of	Values of indicators in modern countries for years							
		USA		UK		Germany		Japan	
		2017	2022	2017	2025	2017	2025	2017	2022
Indicators of result	ΔN_{ci}	70	200	50	250	400	800	50	100
	N_{ci}	30	150	10	100	250	700	5	80
	S_{ii} (%)	43	75	20	40	63	88	10	80
	$D_{ind.4.0/GDP}$ (%)	0	40	0	10	0	50	0	30
	$S_{dcs/s}$ (%)	0	60	0	55	0	50	0	50
	$S_{ind./conv.}$ (%)	30	90	20	70	10	30	5	10
	Result	–	56.70	–	5.39	–	98.43	–	2.16
Indicators of expenditures	KI (pcs/thousand people)	128	1000	137	800	161	1500	211	2000
	$S_{int./mat.}$ (%)	40	70	30	60	25	50	20	65
	$S_{art./hum.}$ (%)	0	10	0	5	0	8	0	3
	Expenditures	–	70	–	24	–	60	–	39
Result	$CE_{ind.4.0/ke}$	–	3969.00	–	129.36	–	5906.25	–	84.24

Source Calculated by the authors based on: Sayer (2017), Robotics Tommorrow (2017), The Telegraph (2017), Schroeder (2017), Fujino and Konno (2016) while other normative and legal documents should be reconsidered in view of actual tendencies in the sphere of Industry 4.0.

A barrier on the path of formation of Industry 4.0 is also deficit of financing of scientific research. In the studied countries, the total volume of this financing does not exceed 1%, which is below the target 5%. The main problem here is high risk component which reduces the commercial attractiveness of scientific research in the sphere of Industry 4.0 for private investors, due to which these studies are financed primarily by the state.

Results of evaluation in Table 2 show that according to existing forecast data, effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in the studied countries will be very high. During evaluation of effectiveness, dynamics of development of Industry 4.0 from 2017 to the year of the forecast of the corresponding countries (2022 or 2025) are evaluated. As is expected, positive effect will exceed expenditures by 4000 times in the USA, by 100 times in the UK, by 6000 times in Germany, and by 100 times in Japan. This ratio is achieved with high positive effect and both in the aspect of results and optimization of expenditures.

4 Conclusions

It is possible to conclude that despite the recent emergence of the concept of Industry 4.0, successful experience of its practical implementation in different countries has already been accumulated. Developed countries were the first to start formation of Industry 4.0, as they possess the necessary resources and social platforms. Complex analysis of forecast data by the example of the USA, the UK, Germany, and Japan shows its high effectiveness from the point of view of stimulating the development of knowledge economy.

The results of the performed research also showed socio-technological readiness of these countries for transition to the next stage of formation of Industry 4.0. This requires modernization of law and strengthening of partnership relations with private business for attracting large volume of investments into financing of scientific research in the sphere of Industry 4.0. We hope that the presented results of quantitative analysis of dynamics and evaluation of effectiveness of Industry 4.0 will stimulate this.

It was also determined that potential social risks that are connected to development of Industry 4.0 could be brought down to minimum. This, worries as to high unemployment level are partially justified—automatization could reduce the need of companies for human resources, but then they will need highly-qualified and innovations-active specialists for servicing automated production systems.

Therefore, it is expedient to start training such specialists beforehand. This task is set on the state, and it is an important component of modern social policy of countries of the world that are aimed at formation of Industry 4.0. Development of strategies of modernization of social policy of different countries according to this priority is a perspective direction for further scientific studies.

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Causal Connections of Formation of Industry 4.0 from the Positions of the Global Economy

Anastasia A. Sozinova

Abstract The purpose of the article is to study causal connections of formation of Industry 4.0 from the positions of the global economy. For collecting precise quantitative proofs of existence of causal connections of Industry 4.0 formation from the positions of the global economy and determining their character and strength, the author uses the method of regression analysis. Consequences of formation of Industry 4.0 for the global economy are determined. For determining the reasons of formation and development of Industry 4.0, the authors apply the method of factor analysis, which, due to absence of statistical data, has qualitative (logical) character. The author also uses the method of scenario analysis for determining further perspectives of development of Industry 4.0 in the global economy and substantiate the most optimal scenario that allows determining the global goals of strategic development of Industry 4.0. As a result, it is substantiated that at the global level Industry 4.0 is a more important economic phenomenon than at the national level. From the positions of the global economy, formation of Industry 4.0 is not just a tool of achievement of strategic goals in the sphere of international marketing and obtaining profit by certain states, but a means of solving the global problems of humanity and achievement of the global economic progress and social well-being.

Keywords Formation of industry 4.0 · Global economy · Differentiation of countries · Unemployment · Developed and developing countries

1 Introduction

At present, Industry 4.0 is viewed as a perspective concept, which is reflected in strategies of long-term development of several countries of the world. Some of them see Industry 4.0 as a perspective direction of application of existing human, intel-

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lectual, and technological capital and opening of potential of development of their socio-economic systems.

Other countries are sure that formation of Industry 4.0 will allow solving their internal socio-economic problems, ensuring highly-efficient jobs, high rate of economic growth, and successful satisfaction of growing public needs with preservation of balance of social ecosystem by means of reducing resource intensity of production (and overcoming of deficit of resources) and reduction of production waste.

Other countries strive to conquer global domination in Industry 4.0, considering this sphere the future vector of development of the global economy and thus ensuring long-term competitiveness of their economic systems. However, in view of the fact that popularity of the concept of Industry 4.0 grows very quickly, it is necessary to expect its practical implementation in leading developed countries in the next ten years and then wide coverage in another ten years.

This explains high topicality of studying causal connections of formation of Industry 4.0, as early determination of possible negative externalities ("side effects"), related to this process, will allow preventing a new global crisis, and determining the factors that stimulate or hinder the development of Industry 4.0 will provide wide possibilities for highly-effect management of this process.

The hypothesis of this work is that at the level of the global economy formation of Industry 4.0 has a role that is different from the national level and acquires a more important meaning, as economic effects are supplemented by social effects. In order to verify this hypothesis, the purpose of the chapter is to study causal connections of formation of Industry 4.0 from the positions of the global economy.

2 Materials and Method

For collecting precise quantitative proofs of existence of causal connections of Industry 4.0 formation from the positions of the global economy and determining their character and strength, the authors uses the method of regression analysis. Consequences of formation of Industry 4.0 for the global economy are determined. The authors determines the direction (+/−) and scale of changes of dependent variables (y) with change of independent variables (x) by 1, by analyzing the value of coefficient m in the model of paired linear regression of the type $y = mx + b$.

The author also evaluates the level of connection of dependence and independent variables by analyzing the value of the coefficient of determination (r^2). As Industry 4.0 is presented in separate countries and is at the initial stage of the process of its formation, statistical data in the sphere of development of Industry 4.0 at the level of the global economy are absent.

That's why independent variables (x) during analysis of regression are indicators that indirectly characterize Industry 4.0. The high-tech character of Industry 4.0 and its stimulation of formation of knowledge economy predetermined selection of such indicators as global coverage of population with higher education, high-tech

Table 1 Dynamics of values

Indicators (measuring units)	2000	2005	2010	2015	2016
Global GDP ($ billion)	33.567	47.429	65.955	74.758	75.845
Global GDP per capita ($)	5486.459	7277.696	9516.347	10,163.9	10,191.31
Global unemployment rate (% of work force)	6.369	6.201	6.082	5.702	5.739
Global coverage of population by higher education (%)	19.036	24.28	29.342	34.983	35.693
High-tech export ($ billion)	1.158	1.586	1.78	2.109	2.147
Number of patents per 1000 people	824.055	966.151	1161.547	1713.208	1862.548
Number of researchers per 1,000,000 people	1081.32	1203.966	1277.569	1326.875	1564.237
Added value in industry (% of global GDP)	30.753	30.121	28.963	29.928	27.145
Differentiation of developed and developing countries according to GDP per capita (%)	3.834	3.922	3.965	4.227	4.401

Source Compiled by the authors based on: The World Bank (2017)

export, patent activity, the number of researchers, and its belonging to the sphere of industry—usage of such indicator as added value in industry.

Dependent variables (y) are social (global unemployment rate and global GDP per capita) and economic (global GDP and differentiation of developed and developing countries according to GDP per capita, calculated as ratio of GDP per capita of developed countries to developing countries) characteristics of the global economic system. Timeframe of the research is 2000–2016. The initial statistical data that are presented in the official statistics of the World Bank are systematized and shown in Table 1.

For determining the reasons of formation and development of Industry 4.0, the author uses the method of factor analysis, which, due to absence of statistical data, has qualitative (logical) character. The author also uses the method of scenario analysis for determining further perspectives of development of Industry 4.0 in the global economy and substantiating the most optimal scenario that allows setting the global goals of strategic development of Industry 4.0.

The theoretical basis of the research consists of scientific studies of modern authors that are devoted to the global aspect of formation of Industry 4.0, which include (Allcock 2016; Brekelmans 2016; Ford, 2016; Hwang 2016; Igor et al. 2016; Kopecká and Soukup 2017; Plakitkin and Plakitkina 2017; Plass 2016; Zhang et al. 2016).

Table 2 Regression and determination of Industry 4.0 as a high-tech sphere with global unemployment rate and differentiation of countries in the global economy in 2000–2016

Dependent variables (y)	Type of connection	Independent variables (x)			
		Global coverage of population by higher education (%)	High-tech export ($ billion)	Number of patents per 1000 people	Number of researchers per 1,000,000 people
Global unemployment rate (% of work force)	m	−0.041	−0.692	−0.001	−0.001
	r^2	0.960	0.941	0.962	0.732
Differentiation of developed and developing countries according to GDP per capita (%)	m	0.030	0.524	0.001	0.001
	r^2	0.846	0.820	0.970	0.898

Source Calculated by the authors

3 Results

The performed regression analysis led to the following results (Tables 2 and 3).

The data of Table 2 show that increase of global coverage of population by higher education by 1% leads to reduction of the global unemployment level by 0.041% of work force (determination—0.960), and increase of the level of differentiation of developed and developing countries according to GDP per capita by 0.030% (determination—0.846).

Increase of the volume of high-tech export by $1 billion leads to reduction of the global unemployment level by 0.692% of work force (determination—0.941) and increase of the level of differentiation of developed and developing countries according to GDP per capita by 0.524% (determination—0.820).

Growth of the number of patents by 1 per 1000 people ensures reduction of the global unemployment level by 0.001% of work force (determination—0.962), and growth of the level of differentiation of developed and developing countries according to GDP per capita by 0.001% (determination—0.970).

Increase of the number of researchers by 1 per 1,000,000 people is accompanied by reduction of the global unemployment level by 0.001% of work force (determination—0.732) and growth of the level of differentiation of developed and developing

Table 3 Regression and determination of Industry 4.0 as a sphere of industry with the global GDP and GDP per capita, and differentiation of countries in the global economy in 2000–2016

Dependent variables (x)	Type of connection	Dependent variables (y)		
		Global GDP ($ billion)	Global GDP per capita ($)	Differentiation of developed and developing countries according to GDP per capita (%)
Added value in industry (% of global GDP)	m	−9.541	−1084.670	−0.132
	r^2	0.529	0.510	0.618

Source Calculated by the authors

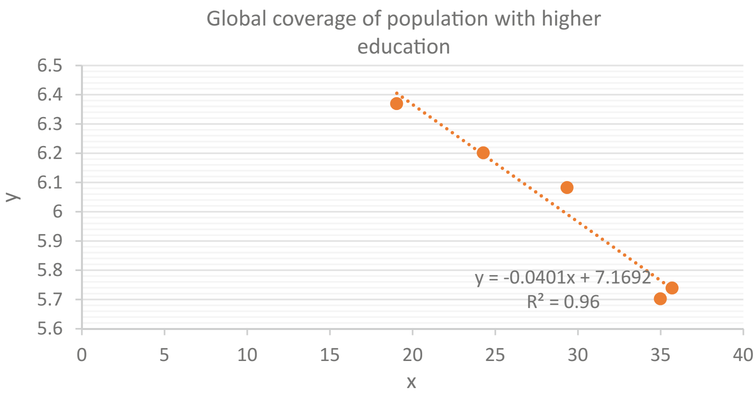

Fig. 1 Line of regression of the global unemployment level of work force from the global coverage of population by higher education. *Source* Compiled by the author

countries according to GDP per capita by 0.001% (determination—0.898). Figures 1, 2, 3, 4, 5, 6, 7, 8 and 9 show evaluation of correlation connections between the studied social and economic indicators.

Therefore, development of high-tech spheres and progress in formation of knowledge economy, provided by formation of Industry 4.0, stimulate visible reduction of the global unemployment level. It is probably caused by the fact that increase of the value of knowledge in society raises the need of population for self-realization, and

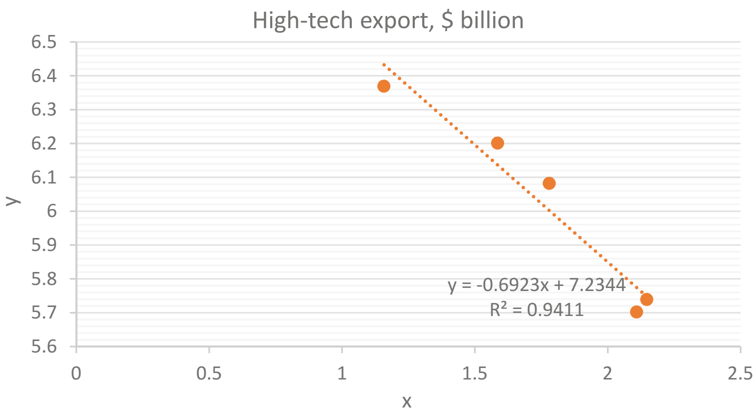

Fig. 2 Line of regression of the global unemployment level of work force from high-tech export. *Source* Compiled by the author

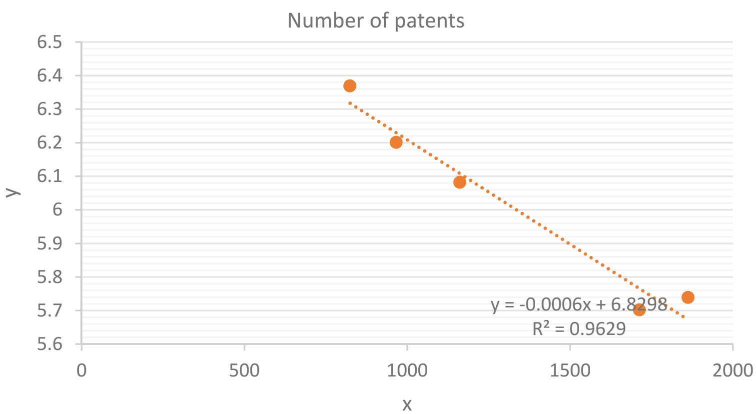

Fig. 3 Line of regression of the global unemployment level of work force from the number of patents. *Source* Compiled by the author

servicing high-tech spheres, despite the high level of their automatization, required highly-qualified specialists, the demand for whom grows with time.

At that, the gap between developed and developing countries grows, as largest successes in developed high-tech spheres and formation of knowledge economy have been achieved by developed countries.

As is seen from Table 3, growth of added value in industry by 1% of global GDP leads to reduction of GDP by $9.542 billion (determination—0.529), global GDP per capita—by $1084.670 (determination—0.510), and reduction of the level of differentiation of developed and developing countries in the global economy—by 0.132% (determination—0.618). Evaluation of correlation connections between the studied social and economic indicators is shown in Figs. 9, 10 and 11.

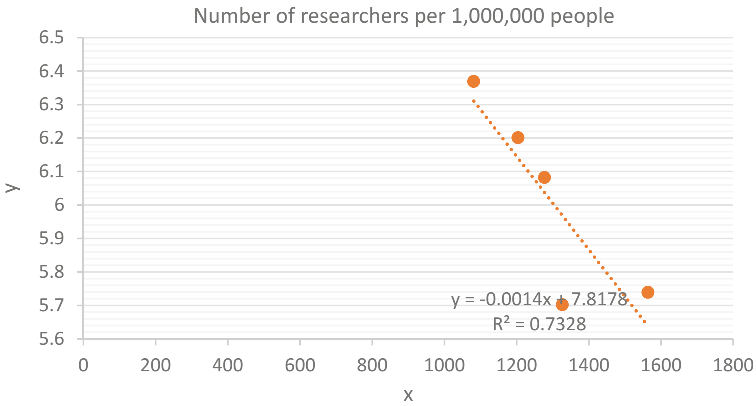

Fig. 4 Line of regression of the global unemployment level of work force from the number of researchers per 1,000,000 people. *Source* Compiled by the author

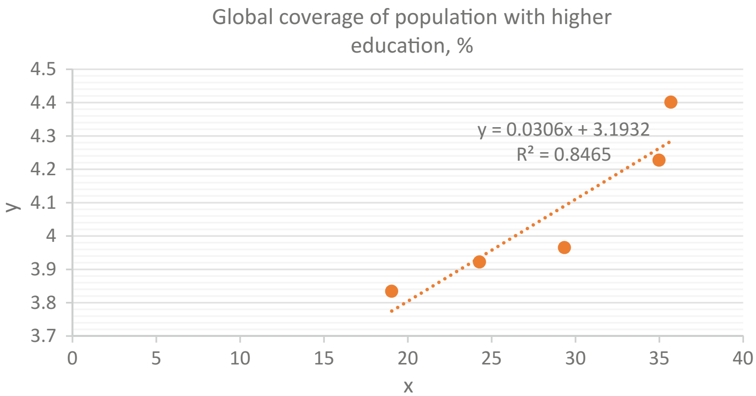

Fig. 5 Line of regression of differentiation of developed and developing countries according to GDP per capita from the global coverage of population by higher education. *Source* Compiled by the author

This means that as a sphere of industry that stimulates it development and increase of its share in global GDP, Industry 4.0 may lead to slowdown of growth rate of the global economy. However, in view of low determination and other features of Industry 4.0—in particular, its high-tech character and stimulation of formation of knowledge economy, they might overcome this negative effect. Also, it is possible to expect positive effect from formation of Industry 4.0, related to reduction of differentiation between developed and developing countries in the global economy.

Based on the determined regression dependencies, the possible scenarios that reflect the perspectives of development of Industry 4.0 from the positions of the global economy in 2035 in the 2016 prices were determined (Table 4).

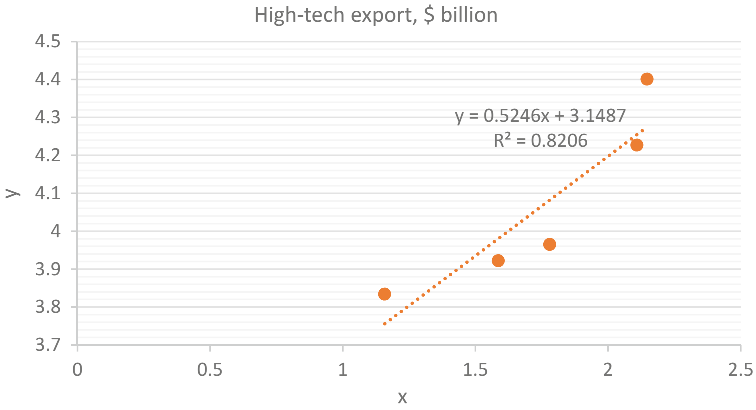

Fig. 6 Line of regression of differentiation of developed and developing countries according to GDP per capita from high-tech export. *Source* Compiled by the author

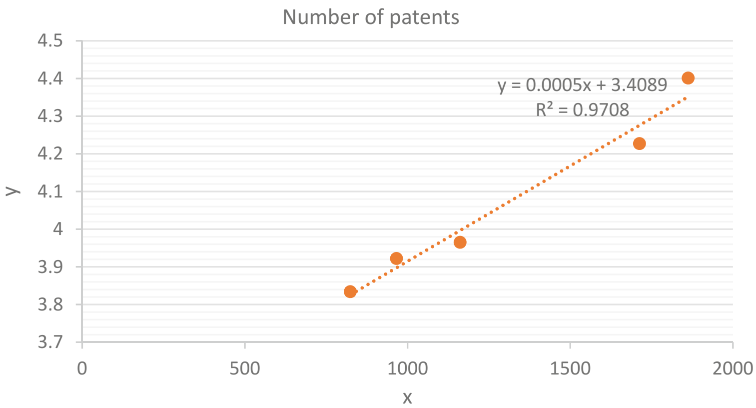

Fig. 7 Line of regression of differentiation of developed and developing countries according to GDP per capita from the number of patents. *Source* Compiled by the author

As is seen from Table 4, four main scenarios of development of Industry 4.0 from the positions of the global economy for 2035 are given. According to the first scenario, Industry 4.0 becomes a prerogative of primarily developed countries and develops as a sphere of industry. The second scenario envisages that Industry 4.0 acquires the infrastructure building role in economies of developed countries. These scenarios envisage formation of Industry 4.0 as a competitive advantage of developed countries as compared to developing countries, increasing the positions of the former in the global area and weakening the positions of the latter.

This will lead to increase of differentiation of developed and developing countries to the level of 5 and 5.5%, accordingly, for the first and second scenarios. At that, the best values of socio-economic indicators are peculiar for the second scenario, as

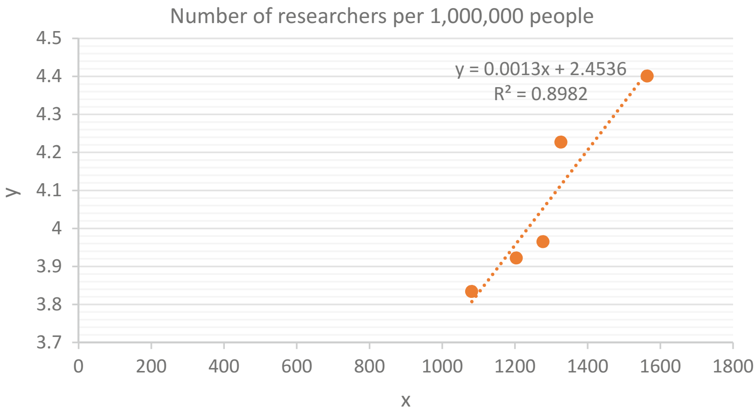

Fig. 8 Line of regression of differentiation of developed and developing countries according to GDP per capita from the number of researchers per 1,000,000 people. *Source* Compiled by the author

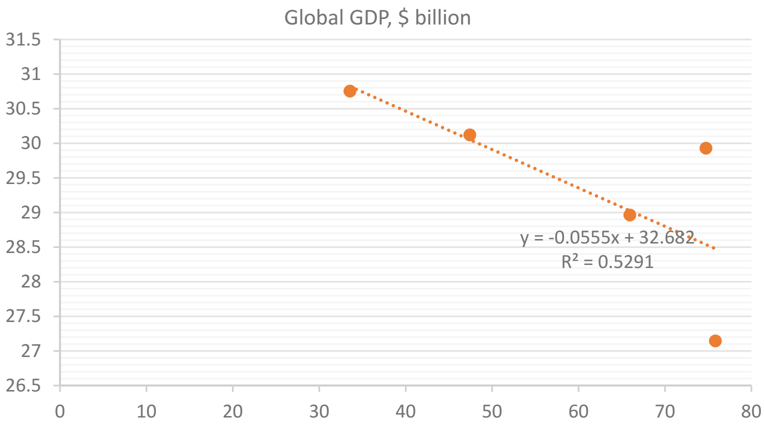

Fig. 9 Line of regression of added value in industry from global GDP. *Source* Compiled by the author

it ensures distribution of positive effects from development of Industry 4.0 for the whole economic system, while the first scenario limits the action of these effects by the sphere of industry.

Despite the fact that Industry 4.0 develops only in developed countries within the first two scenarios, positive effects from its formation are manifested in the whole global economy. They are expressed in reduction of the level of global unemployment to 4.5%, increase of global GDP per capita to $15,000 and global GDP to $110 billion within the first scenario and, accordingly, in reduction of the global unemployment level to 4%, increase of global GDP per capita to $20,000 and global GDP to $150 billion within the second scenario.

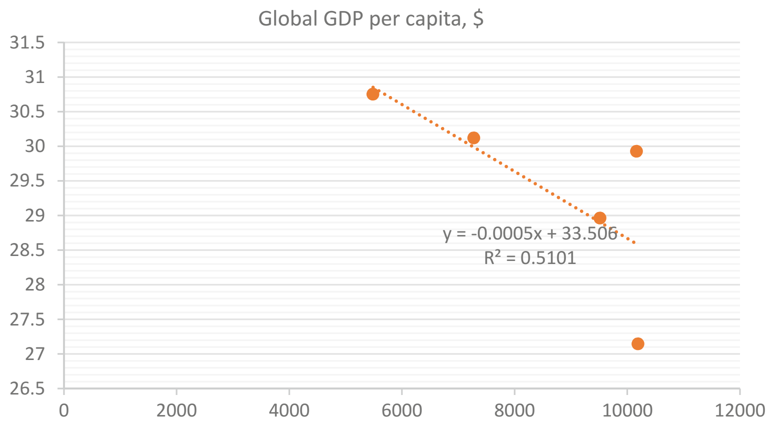

Fig. 10 Line of regression of added value in industry from global GDP per capita. *Source* Compiled by the author

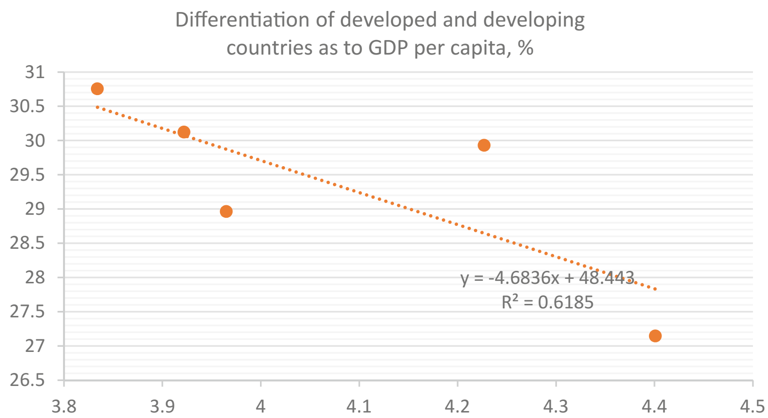

Fig. 11 Line of regression of added value in industry from differentiation of developed and developing countries according to GDP per capita. *Source* Compiled by the author

The third scenario is formation of Industry 4.0 as a vector of development of the global economy with its preserving the roe of a sphere of industry. The fourth scenario is related to assigning Industry 4.0 with the infrastructure building role in the global economy. These scenarios allow maximizing positive socio-economic effects from development of Industry 4.0 at the level of the global economy.

Similarly to the first two scenarios, the most efficient is the fourth scenario, which envisages execution of the infrastructure building role by Industry 4.0.

Within the third and fourth scenarios, Industry 4.0 may become a competitive advantage of developing countries as compared to developed countries or turn into characteristic of all countries of the world that does not provide any advantages. In

Table 4 Results of scenario analysis of perspectives of development of Industry 4.0 from the positions of the global economy in 2035 in the 2016 prices

Indicators	Scenarios and their characteristics according to the corresponding indicators			
	Industry 4.0 develops primarily in developed countries		Industry 4.0 becomes a vector of development the global economy	
	Industry 4.0 develops as a sphere of industry	Industry 4.0 acquires the infrastructure-building role	Industry 4.0 develops as a sphere of industry	Industry 4.0 acquires the infrastructure-building role
Global unemployment rate (%)	4.5	4.0	3.0	2.5
Global GDP per capita ($ thousand)	15	20	25	30
Global GDP ($ billion)	110	150	190	225
Differentiation between developed and developing countries according to GDP per capita (%)	5	5.5	2.5	2

Source Calculated by the authors

any case, this will lead to reduction of the level of differentiation between developed and developing countries to the level of 2.5 and 2%, accordingly, for the third and fourth scenarios.

Positive socio-economic effects from development of Industry 4.0 at the level of the global economy will be expressed within the third scenario in reduction of the global unemployment level to 3%, increase of global GDP per capita to $25,000 and global GDP to $190 billion, and within the fourth scenario in reduction of the level of global unemployment to 2.5%, increase of global GDP per capita to $30,000 and global GDP to $225 billion.

Comparative analysis of the studied scenarios showed that the most preferable (optimal) one is the fourth scenario, which envisages formation of Industry 4.0 in all countries of the world and assigning it with the infrastructure building role in the global economic system, as this scenario ensures maximization of advantages from formation of Industry 4.0 from the positions of the global economy.

Based on deep qualitative analysis of the accumulated experience in formation of Industry 4.0, the peculiarities of all developed countries that achieved largest successes in this process were determined; they are the key factors of the process of formation of Industry 4.0:

- progressive public mode: inclination of society and business for innovational development and readiness for acceptance of accompanying risks;
- formed knowledge economy: high value, accessibility, and mass coverage of population by higher education, conduct of leading scientific research that allow developing technologies in the sphere of Industry 4.0;
- accessibility of financial resources: sufficient financial provision for quick and successful modernization of economy, by formation of Industry 4.0;
- readiness of a social system; formed digital society, in which digital and Internet technologies are widely used.

Successful practical implementation of the above optimal scenario of development of Industry 4.0 from the positions of the global economy may require management of these factors for achieving their most favorable influence on economic systems of developing countries. This will allow eliminating disproportions in socio-economic conditions of developed and developing countries and ensuring equal possibilities in formation of Industry 4.0.

4 Conclusions

Thus, the offered hypothesis has been proved—it has been determined at the global level Industry 4.0 is a more important economic phenomenon that at the national level. From the positions of the global economy, formation of Industry 4.0 is not just a tool of achieving the strategic goals in the sphere of international marketing and obtaining profit by certain states but a means of solving the global problems of humanity and achievement of the global economic progress and social well-being.

The positive consequences of formation of Industry 4.0 include reduction of the global unemployment level and provision of sustainable development and well-balanced growth of the global economic system. The most optimal scenario of development of Industry 4.0 is its formation not just in developed but also in developing countries and formation as a new vector of development of the global economy, as well as acquisition of the infrastructure building role for provision of systemic influence on the global socio-economic system.

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Peculiarities and Problems of Formation of Industry 4.0 in Modern Russia

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Abstract The purpose of this chapter is to determine specific peculiarities and key problems of formation of Industry 4.0 in modern Russia. The authors use the methodological recommendations in the sphere of monitoring of the process of Industry 4.0 formation and evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy, which were offered in the previous chapters, and the method of SWOT analysis. As a result of the research, the authors substantiate that the process of formation of Industry 4.0 in modern Russia has its specifics. In particular, despite the fact that Russia was late—as compared to developed countries—to proclaim the course at formation of Industry 4.0, the national program in this sphere is more detailed, and the most realistic forecast has been compiled—which allows conducting highly-effective management and monitoring of the process of Industry 4.0 formation in Russia and achieving high results, as compared to developed countries. However, the problems on the path of formation of Industry 4.0 in modern Russia are emphasis on digital economy instead of Industry 4.0, incompleteness of the process of formation of the socio-economic platform (digital society and digital economy), and remoteness of private business from financing and management of R&D and entrepreneurial projects in the sphere of Industry 4.0.

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Keywords Industry 4.0 · Developed countries · Modern russia · Modernization
Digital society · Digital economy

1 Introduction

In the 21st century, Russia has started a full-scale modernization of its socio-economic system. The necessity for this modernization and its strategic priority for the Russian economy are explained by internal reasons—striving for achievement of the high level of national production and high rate of growth of national economy in the interests of import substitution, as well as increase of the population's living standards in Russia.

Secondly, modernization is connected to external (marketing) reasons—interest in achieving and supporting high global competitiveness of domestic entrepreneurship and the national economic systems on the whole, reducing dependence of GDP on fluctuations of global markets, and establishing the positions of the country at the international arena as one of the leading developed countries of the world.

Successful implementation of both strategic priorities of development of modern Russia's socio-economic system is stimulated by formation of Industry 4.0. High-tech nature of Industry 4.0 allows achieving innovational development of the economic systems and developing knowledge economy, thus increasing effectiveness, sustainability, and global competitiveness of this system.

Due to this, determining specific peculiarities for adapting the strategy of modernization of the Russian socio-economic system and determining the key problems of formation of Industry 4.0 in modern Russia for compilation of realistic and precise forecasts of modernization and development of perspective means of solving these problems in the interests of quick formation of Industry 4.0 and achievement of global leadership in this sphere are very important.

2 Materials and Method

In order to determine the peculiarities and problems of formation of Industry 4.0 in modern Russia, the authors of use the methodological recommendations in the sphere of monitoring the process of formation of Industry 4.0 (Chap. 8) and evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy (Chap. 9), and the method of SWOT analysis.

The theoretical platform of the research includes the materials of publications of modern scholars that are devoted to studying practical experience and perspectives of formation of Industry 4.0 in modern Russia: Dorofeev et al. (2017), Maksimchuk and Pershina (2017), Mikhailovna and Semyonovich (2016), Plakitkin and Plakitkina (2017), Reitsma et al. (2017), Romanova (2017), Shamanin et al. (2015), and Veselovsky et al. (2017).

3 Results

As a result of systemic and comparative analysis of the process of Industry 4.0 formation in modern Russia, as compared to other developed countries, the following peculiarities were determined. Firstly, Russia was late, as compared to other developed countries, to proclaim the course at formation of Industry 4.0. The first mentions of the concept of Industry 4.0 in international scientific literature date back to 2012. Since 2014, the leading developed countries started adopting strategies of formation of Industry 4.0. In Russia, official interest to this concept was expressed only in 2017.

Secondly, the first results in formation of Industry 4.0 in Russia are to be achieved by 2024. Certain leading developed countries expect substantial shifts in formation of Industry 4.0 by 2022, other—by 2025, Russia has an intermediary position among developed countries—it defined the timeframe of the national strategy of Industry 4.0 formation as 2018–2024.

Thirdly, implementation of the concept of Industry 4.0 is conducted within the national program of formation of digital economy. Despite the close connection between digital economy and Industry 4.0, these concepts are rather different. In view of the fact that formation of digital economy and digital society is a platform for formation of Industry 4.0, it is logical to define implementation of the program as a preceding stage that prepares the socio-economic system to the following formation of Industry 4.0. This is shown by absence of the term “Industry 4.0” in the program.

Fourthly, despite the fact that the national program is oriented at formation of digital economy in Russia, it is based on technologies relating to Industry 4.0, which shows that Industry 4.0 is viewed in Russia as a tool of formation of digital economy. The basic technologies of Industry 4.0 that lie in the basis of implementation of this program are big data; neurotechnologies and artificial intelligence; systems of distributed register; quantum technologies; new production technologies; industrial Internet; components of robototronics and sensors; wireless technologies; technologies of virtual and alternate realities (Government of the RF 2017).

Fifthly, the strategy of formation of Industry 4.0 is studied and described in detail, which allows for monitoring and control over its execution. The main normative and legal document that defines this strategy is the national program “Digital economy of the Russian Federation”, adopted by the Decree of the Government of the RF dated July 28, 2017 No. 1632-r. (Government of the RF 2017).

The advantage of this program, as compared to the strategies of other countries, is its program-oriented direction. While in other countries governments stop at evaluation of readiness of socio-economic system and setting the goals of formation of Industry 4.0, Russia has defined step-by-step measures and indicators of implementing the program of formation of digital economy, which reflects decisiveness of the Russian government as to its practical implementation.

This program describes the process of management of formation of digital economy in Russia and presents a “road map”, which determines the volumes and sources of financing, tasks and terms of their implementation for the following main directions:

- formation of the normative and legal basis for formation of digital economy;
- modernization of the educational system and preparation of personnel for digital economy;
- development of leading production technologies that are necessary for creation of digital entrepreneurship;
- development of information infrastructure for formation of digital economy;
- provision of information security for reducing the risk component and effective crisis management of digital economy.

The target indicators of formation of digital economy in Russia in 2024 are as follows:

- presence of high-tech and competitive—at the global level—companies in the sphere of Industry 4.0 (at least 10 companies);
- completion of the process of modernization of the main spheres of national economy on the basis of digital technologies and presence of digital healthcare, digital education, and "clever" cities (at least 10 platforms);
- presence of digital small and medium entrepreneurship (at least 500 companies);
- completion of the process of modernization of the system of higher education, as a result of which universities prepare specialists in the sphere of digital technologies who possess theoretical and practical competences (at least 120,000 specialists annually);
- successful implementation of R&D projects and creation of leading technologies in the sphere of Industry 4.0 (at least 30 projects and technologies).

The program states that it will be financed from the federal budget in the volume of RUB 100 billion annually. That is, the aggregate financing of this program for seven years will constitute RUB 700 billion. At that, the expected growth of GDP or other advantage for the economic systems from implementation of this program are not taken into account, which does not allow evaluating its forecast effectiveness.

Based on the above, monitoring of the process of Industry 4.0 formation in Russia in 2017 was performed (Table 1), and evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in Russia in 2018–2024 was conducted (Table 2).

The data of Table 1 show that the level of digitization of the modern Russian society is rather wide—Internet technologies are widely accessible, covering 72% of the Russian population. Despite the fact that target value of this indicator for transition to the next stage of formation of Industry 4.0 is 90%, it is possible to consider that as to this indicator modern Russia corresponds to the level of developed countries and is ready for formation of Industry 4.0.

Institutional provision of the process of formation of Industry 4.0 in modern Russia has not yet been formed. The concept of Industry 4.0 is indirectly mentioned only in one government document—the program of formation of digital economy—at that, without the tern "Industry 4.0". Therefore, less than 1% of the legislative basis in Russia is modernized in view of the concept of Industry 4.0, which is a serious restraining factor on the path of practical implementation of this program and transition to the next stage of formation of Industry 4.0 in Russia.

Table 1 The results of monitoring of the process of Industry 4.0 formation in Russia in 2017

Stage	Key indicators of development of Industry 4.0 at each stage	Target values	Values of indicators in Russia
Preparation of socio economic systems	Level of society's digitization (accessibility of Internet technologies)	>90%	72%
	Mentions of Industry 4.0 in normative and legal documents of the state	>50%	less than 1%
	Aggregate volume of financing of digitization of the socio-economic systems	>5% of GDP	5.3%

Source compiled by the authors based on: Government of the RF (2017), RBC (2017), International Telecommunication Union (2017)

Table 2 Evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in Russia in 2017–2024

Type	Indicators	Values of indicators for the years		
		2017	2024	Growth (Δ)
Indicators of result	$\Delta N_{ci,\ pcs}$	0	30	30.00
	$N_{ci,\ pcs}$	0	10	10.00
	$S_{ii,\ \%}$	0	33.33	33.33
	$D_{ind.4.0/GDP,\ \%}$	3.9	10	2.56
	$S_{ind./conv.,\ \%}$	3	8	2.67
	Direct average of growth	–	–	78.56
Indicators of expenditures	KI, pcs/RUB trillion	0	3.37	3.37
	$S_{int./mat.,\ \%}$	10	30	3.00
	$S_{art./hum..,\ \%}$	0	1	1.00
	Direct average of growth	–	–	7.37
Result	$CE_{ind.4.0/ke}$	–	–	578.99

Source calculated by the authors based on: Government of the Russian Federation (2017), RBC (2017)

Industry 4.0 is not currently financed in Russia—neither in the aspect of entrepreneurship not in the aspect of scientific research in this sphere. At that, statistics of financing of digitization of socio-economic system is given and it is stated that the volume of investments of private companies in digitization in Russia constitutes 2.2% of GDP, government expenditures for digitization of socio-economic systems equal 0.5% of GDP, and expenditures of households in the digital sphere are at the level of 2.6% of GDP (RBC 2017). Therefore, aggregate volume of this financing constitutes 5.3% of GDP. This is a rather large value, which shows Russia's readiness for transition to the next stage of formation of Industry 4.0.

Table 2 shows that at present (2017) there are no technologies in the sphere of Industry 4.0 in Russia that are ready for practical application; however, by 2014 there should be at least 30 such technologies, of which 10 should be implemented into practice (33.33%). At that, the share of digital economy in GDP of Russia is 3.9%. By 2024, it should be increased to 10% (RUB 8.9 trillion). Share of production of individual goods in Russia is lower than in other developed countries and constitutes 3%. By 2024, it should be raised to 8%.

According to the forecasts, knowledge intensity of the Russian Industry 4.0 in 2024 should constitute 3.37 pcs/RUB trillion. This value is obtained as a result of calculating the ratio of 30 leading technologies in Industry 4.0 to RUB 8.9 trillion. At that, large success in creation and implementation of technologies of artificial intelligence in Russia is not expected by 2024, and share of these technologies in the structure of intellectual resources will not exceed 1%.

Thus, effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in Russia in 2024 is estimated at 578.99, i.e., advantages from its formation will exceed expenditures by 500 times. As compared to the leading developed countries (the USA, the UK, Germany, Japan), where expected effectiveness is 1000-fold, this value might seem low.

However, in view of the fact that in all modern countries such calculations are performed on the basis of forecast data, it is logical to suppose that Russia has a more realistic forecast. In any case, the received value of effectiveness is very high and shows expedience of formation of Industry 4.0 and its active stimulation of formation of knowledge economy in Russia. The received conclusions are in the basis of the performed SWOT analysis of formation of Industry 4.0 in modern Russia (Table 3).

As is seen from Table 3, there are substantial preconditions for formation of Industry 4.0 in modern Russia—acknowledgment of the necessity for digitization of the socio-economic system at the state level and allocation of financing from the federal budget. This should be an impulse for scientific research and formation of the technological platform of Industry 4.0, as well as a signal for the Russian companies for digitization of business.

The problems of formation of Industry 4.0 in modern Russia are caused by lack of formation of the socio-economic platform (digital society and economy) and institutional platform (modernization of normative and legal provision in view of Industry 4.0) and underdevelopment of public-private partnership. Due to lack of successful domestic experience and high risks, commercial attractiveness of projects in the sphere of Industry 4.0 is low. Without partnership with private business, the state has to bear expenditures and conduct management of investment and innovational projects in Industry 4.0, which is a large load onto the federal budget and reduces effectiveness of these projects primarily in the aspect of non-flexibility of management.

Opportunities and perspectives of formation of Industry 4.0 in modern Russia are based on further digitization of the socio-economic systems, modernization of normative and legal provision, and development of th institute of public-private

Table 3 SWOT analysis of formation of Industry 4.0 in modern Russia

S	Strengths of formation of Industry 4.0 in modern Russia	– Acknowledging the necessity for formation of Industry 4.0 at the state level; – State financing Industry of 4.0
W	Weaknesses of formation of Industry 4.0 in modern Russia	– Lack of formation of the socio-economic platform (digital society and economy); – Underdevelopment of the institute of public-private partnership
O	Opportunities and perspectives of formation of Industry 4.0 in modern Russia	– Further digitization of the socio-economic system; – Development of the institute of public-private partnership
T	Threats and risks to formation of Industry 4.0 in modern Russia	– Non-execution of the program of digitization of the socio-economic system; – Threat to information security of digital economy
Factors of geo-political and socio-demographic character	Threats	– Threat of sanction measures for the Russian Industry 4.0; – Threat of increase of social contradictions in the Russian society
	Risks	– Risk of slowdown of the process of formation of Industry 4.0 due to opposition of external trade partners; – Risk of social opposition to the changes related to formation of Industry 4.0
	Opportunities	– Support for external trade partners; – Social approval of the process of Industry 4.0 formation

Source compiled by the authors

partnership, which is stimulated by the adopted program of digitization of the Russia's economy. Threats and risks of formation of Industry 4.0 in modern Russia include non-execution of this program and threat to information security of digital economy.

For the purpose of fuller reflection of peculiarities of the process of Industry 4.0 formation in modern Russia, the traditional matrix of SWOT analysis is expanded and supplemented by threats, risks, and opportunities of the geo-political and socio-demographic character. Formation of Industry 4.0 is potentially connected to such threats to the modern Russian economy as additional sanctions and increase of social contradictions in society.

Risks of formation of Industry 4.0 are related to slowdown of this process due to opposition of trade partners (primarily, in the integration association EAEU) and social opposition to changes. At the same time, additional opportunities in the sphere of formation of Industry 4.0 are caused by support for external trade partners and social approval of this process.

4 Conclusions

It was determined that the process of formation of Industry 4.0 in modern Russia has its specifics. Despite the fact that Russia was late—as compared to other developed countries—to proclaim the course at formation of Industry 4.0, the state program in this sphere is more detailed and the most realistic forecast has been prepared, which allows for highly-effective management and monitoring of the process of formation of Industry 4.0 in Russia and for achievement of the highest results among developed countries.

However, the problems on the path of formation of Industry 4.0 in modern Russia include emphasis on digital economy instead of Industry 4.0, incompleteness of the process of formation of the socio-economic platform (digital society and digital economy), and remoteness of private business from financing and management of R&D and entrepreneurial projects in the sphere of Industry 4.0. Perspective solutions of these problems should be found in further studies in this sphere.

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Comparative Analysis of Formation of Industry 4.0 in Developed and Developing Countries

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Abstract The purpose of the article is to perform comparative analysis of formation of Industry 4.0 in developed and developing countries. As peculiarities of formation of Industry 4.0 in developed countries have been studied in this book in the process of studying successful experience of formation of Industry 4.0 in the countries of the world, the authors focus on determining the specifics of formation of Industry 4.0 in developing countries. In order to ensure compatibility of data for developed and developing countries, the similar methods are used—which are based on the authors' methodological recommendations for monitoring the process of formation of Industry 4.0 in developing countries in 2017 and evaluating effectiveness of Industry 4.0 from the point of view of stimulation of development of knowledge economy in developing countries. During comparison of results of research of the essence and peculiarities of formation of Industry 4.0 in developed and developing countries, the method of comparative analysis is used. For determining the barriers on the path of formation of Industry 4.0 in developing countries, the authors use the method of systemic and problem analysis. For complex study of specifics of formation of

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Industry 4.0 in developing countries, the objects are the countries that are peculiar for various levels of socio-economic development and belonging to various geographical regions of the world: the South African Republic, China, India, and Brazil. As a result of the research, it is substantiated that the process of formation of Industry 4.0 in developing countries has its peculiarities and is different than in developed countries. As compared to developed countries, in which the process of formation of Industry 4.0 was started earlier and aimed at marketing and social results, developing countries face institutional (absence of state policy of formation of Industry 4.0) and financial barriers and seek economic goals. At the same time, the initiative approach to formation of Industry 4.0 in developing countries, within which the initiators of this process are economic subjects (companies), envisages larger flexibility and effectiveness as compared to the directive approach (state initiative), which is applied in developed countries.

Keywords Industry 4.0 · Knowledge economy · Developed countries
Developing countries

1 Introduction

In order to obtain the largest positive effect in the scale of the global economic systems from formation of Industry 4.0, it is necessary to involve developing countries into this process, which was initially started and led by developed countries. Most of the concepts of socio-economic development in the process of practical application acquire their own specifics in developed and developing countries.

For example, the concept of ecological responsibility in developed countries, where it appeared initially, envisages full refusal from industrial production, which does damage to the environment, and annual publication of ecological corporate reports of large industrial companies in open access.

Implementing the concept of ecological responsibility in this version is impossible in the global scale, as it would lead to deficit of industrial products. That's why in developing countries, on the territory of which ecologically hazardous industrial productions were moved, this concept acquired different treatment, related to periodic reconsideration of ecological standards and improvement of disposal facilities of industrial companies.

Similarly, implementation of the concept of modernization of economic systems in developed countries leads to transition to a completely new technological mode in the interests of leading future vectors of development of the global economic system, while in developing countries it is related to update of equipment and technologies to the global level in the interests of overcoming technological underrun.

Based on this, a hypothesis is offered that the process of formation of Industry 4.0 in developing countries has its peculiarities and differs from that which is taking place in developed countries. The offered hypothesis predetermined the goal of this chapter, which is comparative analysis of formation of Industry 4.0 in developed and developing countries.

2 Materials and Method

Peculiarities of formation of Industry 4.0 in developed countries have been studied in this book in the process of studying successful experience of a formation of Industry 4.0 in countries of the world (Chap. 10). So for the purpose of comparative analysis, we shall focus on determining the specifics of formation of Industry 4.0 in developing countries.

For provision of compatibility of the data for developed and developing countries, the same methods are used—which are based on the authors' methodological recommendations for monitoring of the process of formation of Industry 4.0 in developing countries in 2017 (Chap. 8) and evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in developing countries (Chap. 9).

During comparison of the results of studying the essence and peculiarities of the process of formation of Industry 4.0 in developed and developing countries, the method of comparative analysis is used. For determining the barriers on the path of formation of Industry 4.0 in developing countries, the authors use the method of systemic and problem analysis.

For complex study of specifics of formation of Industry 4.0 in developing countries, the objects are the countries that peculiar for various levels of socio-economic development and belonging to various geographical regions of the world: the SAR, China, India, and Brazil.

The authors use materials of the works of modern authors that are devoted to studying the peculiarities and problems on the path of formation of Industry 4.0 in developing countries: Sackey et al. (2017), Li (2017), Chong et al. (2017), Tortorella and Fettermann (2017), Zhang et al. (2017), Santos et al. (2017), Smits (2017), Suri et al. (2017), Ignat (2017), Bortolini et al. (2017), Bogoviz et al. (2017).

3 Results

According to the report by PricewaterhouseCoopers in 2016, according to the sociological survey of more than 2000 globally-oriented industrial companies from the SAR, 33% of South-African companies conduct their activities on the basis of digital technologies, but it is expected that by 2020 their share will reach 70%. The report states that strategies of transition to Industry 4.0 were established at a lot of industrial companies of the SAR and envisage expanded automatization, cloud computing, 3D printing, intellectual algorithms, and Internet services for transformation of business processes.

South African companies are going to use technological capabilities of Industry 4.0 in close future for collecting individual orders with the help of digital technologies, develop individualized products with the help of digital technologies, conduct automatized transfer of data on the products into connected systems of planning and production, and perform integrated servicing of customers (PricewaterhouseCoopers 2017).

This report does not provide precise numbers that reflect the volume of investments that private companies of the SAR are ready to use for creation and practical application of technologies of Industry 4.0. We also have not found any mention of Industry 4.0 in official government documents, which shows underdevelopment of normative and legal provision of Industry 4.0 in the SAR, as well as absence of state support for this direction and its limitation by specific private and corporate initiatives.

In China, strategic foundations of formation of Industry 4.0 are determined by the national program "Made in China 2025". The program states that industry is has been a basis of prosperity of modern China and the key landmark of its development—since emergence of industrial civilization in mid-18th century. Despite the absence of mention of Industry 4.0, this document states that modern China has to use historical possibilities for restoration of industrial production and formation of progressive socio-economic system.

This program gives "Four comprehensive parts" of the strategic plan of modernization of Chinese industry: formation of prospering digital society, implementation of necessary political reforms, provision of primacy of law, and supporting the party discipline. Their successful implementation will allow turning China into the global leader of industrial production (State Council of China 2015)

These items of the program reflect its rather political than economic direction. It does not contain statistical and/or forecasting data and does not describe specific measures for practical implementation in the economic aspect. Therefore, it denotes national goals of modernization of Chinese industry and it is possible to suppose that implementation of this concept, including the measures for transition to Industry 4.0, will be conducted at the corporate level.

There us mentioning of strategic direction and readiness to formation of Industry 4.0 at the national level in India. At the same time, Indian entrepreneurs show interest to this concept. For example, the Indian businessman Akash Gupta, who is a representative of the industrial company *Grey Orange Pte. Ltd.* believes that India should stimulate the inflow of investments and form a modern infrastructure, which is necessary for formation of Industry 4.0, for corresponding to the global standards of quality of industrial products (Gupta 2017). Therefore, the concept of Industry 4.0 is far from practical implementation in India, though it poses certain interest for business and the national economy.

In Brazil, there are no official normative and legal documents related to the issues of formation of Industry 4.0, and interest to this concept is shown only by private companies and research organizations. The report of one of such organizations—"CNI"—provides results of statistical and sociological surveys, according to which 48% of Brazil companies use at least one digital technology in their activities, and more than 50% of Brazilian companies are interested in usage of advantages of Industry 4.0 for modernization and support for global competitiveness of their business (CNI 2017).

Table 1 Results of monitoring of the process of formation of Industry 4.0 in developing countries in 2017

Stage	Key indicators of development of Industry 4.0 at each stage	Target values	Values of indicators in countries of the world			
			SAR (%)	China (%)	India (%)	Brazil (%)
Preparation of socio-economic system	Level of society's digitization (accessibility of Internet technologies)	>90%	42	65	22	60
	Mention of Industry 4.0 in normative and legal documents of the state	>50%	0	0	0	0
	Total volume of financing of scientific research	>5% of GDP	0.93	1.70	0.1	1.16

Source Compiled by the authors based on: International Telecommunication Union (2017), UNESCO Institute for Statistics (2017)

At that, readiness of Brazilian entrepreneurs to invest into scientific research and implementation of technologies of Industry 4.0, as well as adopted strategies of transition of Brazilian industrial companies to Industry 4.0 are not mentioned. Based on the performed overview of the process of formation of Industry 4.0 in developing countries, we performed monitoring of this process, the results of which are presented in Table 1.

As is seen from Table 1, according to the values of indicators that characterize progress in formation of Industry 4.0, developing countries are at the preliminary stage of formation of Industry 4.0, which shows that in this countries the process has not yet started and will probably be started in near future. Thus, the level of society's digitization in developing countries is lower than in developed countries; the SAR—42%, China—65%, India—22%, and Brazil—60%.

Industry 4.0 is not mentioned in normative and legal documents of developing countries, and scientific research in the sphere of Industry 4.0 are not financed by the state. According to the report by the UNESCO Institute for Statistics for 2017, total volume of financing of scientific research in the SAR constitutes 0.93% of GDP, in China—1.70% of GDP, in India—0.1% of GDP, and in Brazil—1.16% of GDP. Therefore, the volume of investments in creation of technologies in the sphere of Industry 4.0 constitutes (or will constitute in future) a certain share of the above values of this indicator, and in all developing countries these values are lower than the target 5% of GDP.

The results of the performed evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in developing countries in 2017-2020/2025/2030 are shown in Table 2.

It should be noted that while in developed countries evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy is performed on the basis of government forecasts, preceded by large-scale

Table 2 Evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy in developing countries in 2017-2020/2025/2030

Type	Indicators	Values of indicators in modern countries of the world for the years							
		SAR		China		India		Brazil	
		2017	2020	2017	2025	2017	2030	2017	2030
Indicators of result	ΔN_{ci}	0	5	0	10	0	5	0	5
	N_{ci}	0	1	0	3	0	1	0	1
	$S_{ii, \%}$	0	20	0	30	0	20	0	20
	$D_{ind.4.0/GDP, \%}$	0	2	0	4	0	1	0	3
	$S_{dcs/s, \%}$	0	10	0	15	0	12	0	14
	$S_{ind./conv., \%}$	1	3	1	7	1	2	1	4
	Result	–	5.00	–	10.00	–	5.00	–	5.00
Indicators of expenditures	KI, pcs/thousand people	0	5	0	10	0	5	0	5
	$S_{int./mat., \%}$	2.5	5	3,0	10	1.0	3.0	2,0	4.0
	$S_{art./hum.., \%}$	0	0	0	0	0	0	0	0
	Expenditures	–	10.00	–	1.00	–	6.67	–	5.00
Result	$CE_{ind.4.0/ke}$	–	0.50	–	10.00	–	0.75	–	1.00

Source Calculated by the authors based on: PricewaterhouseCoopers (2017), State Council of China (2015), Gupta (2017), CNI (2017), International Telecommunication Union (2017), UNESCO Institute for Statistics (2017)

analysis on the basis of previse statistical information, in developing countries we have to conduct evaluation based on scattered statistics and results of sociological surveys of entrepreneurs, which could be a reason for large distortion of initial data and precision of received results and conclusions.

That's why calculations in Table 2 are performed not for receiving specific numerical values of indicators of effectiveness of Industry 4.0 from the point of view of stimulation of development of knowledge economy but for determining general tendencies and peculiarities of Industry 4.0 formation in developing countries. The received results show that due to absence of official acknowledgement and financing, the rate of Industry 4.0 formation is significantly lower than in developed countries. This is manifested in the smaller number of technologies that are planned to be created and implemented in the sphere of Industry 4.0.

The determined peculiarities of the process of Industry 4.0 formation in developed and developing countries allowed conducting comparative analysis, the results of which are given in Table 3.

As is seen from Table 3, during formation of Industry 4.0 in developed countries, external goals (global marketing) are dominating, while developing countries seek internal goals (growth and development of economy). Additional (accompanying)

Table 3 Comparative analysis of formation of Industry 4.0 in developed and developing countries

Criteria of comparison	Developed countries	Developing countries
Dominating main goals of Industry 4.0 formation	External goals (global marketing)	Internal goals (growth and development of economy)
Additional (accompanying) goals of Industry 4.0 formation	Opening human potential	Modernization of entrepreneurship
Dominating sphere of interests during Industry 4.0 formation	Social: expansion of individual production	Economic: starting massive production
Level of implementation of the concept of Industry 4.0	National and state strategies of development	Corporate, strategies of development of separate companies
Influence of Industry 4.0 on knowledge economy	Development of knowledge economy	Formation of knowledge economy
Readiness of socio-economic platform for Industry 4.0 formation	Formed digital society and digital economy	Digital society and digital economy in the process of formation
Financial barriers on the path of Industry 4.0 formation	Absent or low	High
Expected results	Near ten years	Near fifteen years

Source Compiled by the authors

goals of Industry 4.0 formation in developed countries are related to opening of human potential, and in developing countries they are brought down to modernization of entrepreneurship.

During formation of Industry 4.0 in developed countries, the social sphere of interests, which is oriented at expansion of individual production, dominates, and in developing countries—the economic sphere, oriented at start of mass production. The level of implementation of the concept of Industry 4.0 in developed countries is national and envisages adoption of state strategies of development, in developing countries it is corporate and envisages adoption of strategies development of separate companies. The influence of Industry 4.0 on knowledge economy in developed countries is related to its development, and in developing countries—to its formation.

Developed countries are peculiar for readiness of the socio-economic platform to formation of Industry 4.0—i.e., formed digital society and digital economy, while in developing countries this platform is in the process of formation. Financial barriers on the path of formation of Industry 4.0 in developed countries are absent or low, and in developing countries they are rather high due to deficit of financial resources. In developed countries, the first results in the sphere of formation of Industry 4.0 are expected during the next 10 years, and in developing countries, due to belated adoption of this concept—during the next 15 years.

We also determined the threshold value of the growth rates of indicators for developed and developing countries, which are given in Table 4.

Table 4 Threshold values of growth rates of indicators for developed and developing countries by 2025

Type	Indicators	Threshold values of the growth rates of indicators			
		Developed countries		Developing countries	
		Minimum	Maximum	Minimum	Maximum
Indicators of result	ΔN_{ci}	200	800	5	10
	N_{ci}	80	700	1	3
	$S_{ii,\ \%}$	40	90	20	30
	$D_{ind.4.0/GDP,\ \%}$	10	40	1	4
	$S_{dcs/s,\ \%}$	50	60	10	15
	$S_{ind./conv.,\ \%}$	10	90	2	7
	Result	2	100	5	10
Indicators of expenditures	KI, pcs/thousand people	800	2000	5	10
	$S_{int./mat.,\ \%}$	50	70	3	10
	$S_{art./hum..,\ \%}$	3	10	0	0
	Expenditures	24	70	1	10
Result	$CE_{ind.4.0/ke}$	84	4000	1	10

Source Compiled by the authors

The threshold values that are given in Table 4 should be landmarks for tracking progress during formation of Industry 4.0 in the studied countries. As is seen, these values for developed countries are higher than for developing countries, which is predetermined by their higher opportunities in formation of knowledge economy.

4 Conclusions

Thus, as compared to developed countries, in which the process of Industry 4.0 formation was started earlier and aimed at marketing and social results, developing countries face the institutional (absence of state strategy of formation of Industry 4.0) and financial barriers and seek economic goals. At the same time, the initiative approach to formation of Industry 4.0 in developing countries, within which the initiators of this process are economic subjects (companies), envisages larger flexibility and effectiveness as compared to the directive approach (state initiative), which is applied in developed countries.

It should be concluded that the determined peculiarities of Industry 4.0 formation in developed and developing countries are preliminary, as this process is at the initial state in developed countries, and at the stage of preparation to further establishment of Industry 4.0 in developing countries. This does not allow determining the whole specter of specific features that will be peculiar for the process of Industry 4.0 formation in developed and developing countries, when this process will undergo active practical implementation.

However, based on the current generally acknowledged peculiarities of developed and developing countries, it is possible to make a conclusion on the potential future specifics of the process of Industry 4.0 formation in these categories of countries. Industrial orientation of developing countries, related to their international production and specialization on industry, predetermines formation of Industry 4.0 as an infrastructure building sphere that stimulates modernization of economic systems on the whole.

At that, emphasis on development of the service sphere in developed countries could be a reason for preservation of less significant role in economy with Industry 4.0—only as one of the spheres of spheres of industry. At that, as development countries are already peculiar for high knowledge intensity, it is only logical that Industry 4.0 will be used in these countries as a tool for further development of knowledge economy, while in developing countries Industry 4.0 will be viewed as a self-goal.

This allows forecasting the course of development of the process of formation of Industry 4.0 in developed and developing countries and developing the managerial mechanisms that are adapted to peculiarities of its course in the determined categories of countries. However, it should be taken into account that all suppositions have probabilistic character, which is a limitation of this research, and require further verification with accumulation of practical experience of formation of Industry 4.0 in developed and developing countries, which determines perspectives of further scientific research.

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Part V
Perspectives of Development of Industry 4.0 in Modern Knowledge Economy

Priorities of Development of Industry 4.0 in Modern Economic Systems with Different Progress in Formation of Knowledge Economy

Yulia V. Ragulina

Abstract The purpose of the article is to develop the priorities of development of Industry 4.0 in modern economic systems, characterized by different progress in the sphere of formation of knowledge economy. The methodology of the research includes the method of prioritizing and dialectical and logical methods, which are used for determining the logic of the process of Industry 4.0 development and priorities of managing this process depending on the progress in the sphere of formation of knowledge economy. For graphic interpretation of the conclusions and compiled recommendations, the authors use the method of formalization of data. The author classifies the goals of development of Industry 4.0 according to the criterion of advantages for knowledge economy and offer a logical scheme of development of Industry 4.0 in modern economic systems depending on the progress in the sphere of formation of knowledge economy. As a result, it is concluded that management of development of Industry 4.0 should be conducted in view of the achieved progress in the sphere of formation of knowledge economy. The offered priorities and the developed logical scheme of managing the development of Industry 4.0 in modern economic systems depending on the progress in the sphere of formation of knowledge economy takes into account this peculiarity and allows using it in the best way for the economic system. They allow for successful adaptation of this process to any economic systems due to flexibility of management.

Keywords Industry 4.0 · Knowledge economy · Priorities of development
Interdependence · Modern economic systems

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1 Introduction

Differences between modern economic systems are very strong. Some of them correspond to the actual tendencies and develop the service sphere and high-tech sphere, while other specialize in industry and/or agriculture. At the same time, some economic systems are better provided with certain types of resources, some are more inclined to innovations due to flexibility of society and business, while other strive to preservation of traditions and show high opposition to changes, etc.

These differences are manifested not only in contrast between developed and developing countries—they are present and are rather strong even among the countries of the same category. That's why division of countries into categories is relative—it has to simplify the task of global economic analysis of the global economic system, but does not allow developing universal models of management for the whole categories that are highly-effective for all countries that belong to them.

Due to this, for provision of successful application of created models in various economic systems they do not have to offer specific measures but be of framework character and explain the logic of management of target socio-economic phenomena and processes—i.e., set priorities of this management. This explains topicality of definition and scientific substantiation of priorities of development of Industry 4.0 in modern economic systems.

In view of close connection between Industry 4.0 and knowledge economy, we offer a hypothesis that management of development of Industry 4.0 should be conducted in view of achieved progress in the sphere of formation of knowledge economy. The purpose of this chapter is to develop the priorities of development of Industry 4.0 in modern economic systems, characterized by different progress in the sphere of knowledge economy formation.

2 Materials and Method

The methodology of the research includes the method of prioritizing and the dialectical and logical methods, which are used for determining the logic of the process of Industry 4.0 development and priorities of management of this process depending on the progress in the sphere of formation of knowledge economy. For graphic interpretation of the conclusions and compiled recommendations, the method of formalization of data is used.

The author uses the existing materials of scientific studies and publications, in which interconnection between Industry 4.0 and knowledge economy is studied. These works include (Brandl et al. 2015; Danaher et al. 2018; Degelsegger-Márquez et al. 2017; Dragičevic et al. 2017; Fouquet 2017; Graf and Gardin 2018; Kopecká and Soukup 2017; Möllenstädt 2017; Tsakalerou 2018; Ullrich et al. 2016; Veselovsky et al. 2017).

3 Results

As a result of complex study of Industry 4.0 and knowledge economy, the following priorities of development of Industry 4.0 in modern economic systems with different progress in formation of knowledge economy are determined.

Firstly, it is necessary to take into account progress in the sphere of formation of knowledge economy during development of the strategy of development of Industry 4.0. Depending on the level of readiness of socio-economic platform to formation of Industry 4.0 (this readiness is determined by progress in formation of knowledge economy), determined by the level of establishment of digital society and digital economy, this process could be oriented either at formation (in case of readiness of the platform) or at further development (in case of unreadiness of the platform) of knowledge economy.

Secondly, orientation at achievement and maximization of positive externalities (advantages) in the sphere of knowledge economy in the process of development of Industry 4.0 is expedient. Models of development of Industry 4.0 are classified according to various criteria through the prism of advantages for knowledge economy in the following way (Table 1).

As is seen from Table 1, according to the criterion of relation to economic system, we distinguish external goals of development of Industry 4.0 (global marketing), which advantage for knowledge economy is growth of global competitiveness of knowledge economy, and internal goals of development of Industry 4.0 (growth and

Table 1 Classification of goals of development of Industry 4.0 according to the criterion of advantages for knowledge economy

Criterion of classification	Types of goals of development of Industry 4.0	Advantages for knowledge economy
Relation to economic system	External goals (global marketing)	Growth of global competitiveness of knowledge economy
	Internal goals (growth and development of economy)	Growth of efficiency and acceleration of growth rate of knowledge economy
Target economic subjects	Opening of human potential	Increase of knowledge intensity of economy
	Modernization of entrepreneurship	Acceleration of diffusion of knowledge and innovations in economy
Target sphere of interests	Social goal: expansion of individual production	Increase of population's living standards
	Economic goal: starting mass production	Increase of population's living standards

Source Compiled by the authors

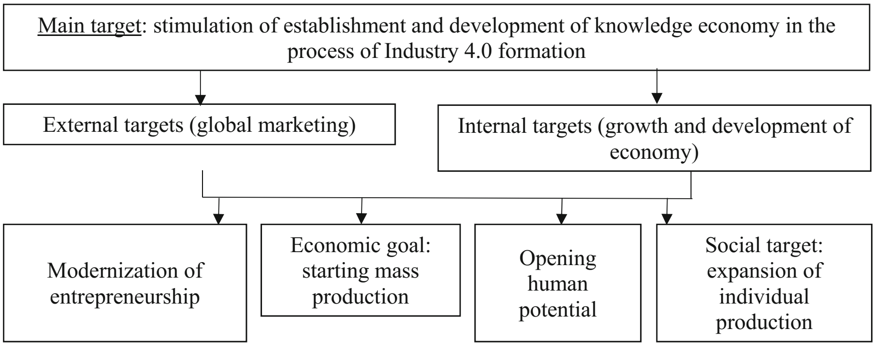

Fig. 1 Tree of targets for development of Industry 4.0 according to the criterion of advantages for knowledge economy *Source* Compiled by the authors

development of economy), which positive influence on knowledge economy is related to growth of efficiency and acceleration of growth rate of knowledge economy.

According to target economic subjects of development of Industry 4.0, we distinguish the goal of opening of human potential (target subjects are employees), which leads to knowledge intensity of economy, and modernization of entrepreneurship (target subjects are business structures), which stimulates acceleration of diffusion of knowledge and innovations in economy.

According to the criterion of the target sphere of interests, we distinguish the social target, which envisages expansion of individual production and stimulates the increase of population's living standards (improvement of quality of consumed goods and services), and the economic goal, which envisages start of mass production and increase of population's living standards (increase of accessible goods and services).

It should be noted that depending on the peculiarities economic practice of modern socio-economic systems, this classification could be expanded. Also, these targets are not mutually interchangeable—they could be combined depending on the peculiarities development economic systems. Based on the data from Table 1, we built a tree of targets of development of Industry 4.0 according to the criterion of advantages for knowledge economy (Fig. 1).

Figure 1 shows that the main target is stimulating the establishment and development of knowledge economy in the process of Industry 4.0 formation. Its achievement envisages orientation at external and internal goals, which are equal. Their achievement requires reaching the following goals (in the order of priority): modernization of entrepreneurship, economic goal, opening of human potential, and social goal.

Thirdly, it is necessary to compare the possibilities of economic systems, determined by the progress in formation of knowledge economy, and targets of development of Industry 4.0 during goal-setting of this process. According to the previously offered methodological recommendations for conduct of evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy (Chap. 9), we distinguish the following main tasks of development of Industry 4.0:

– creation of innovational technologies in the sphere of Industry 4.0 (in case of developed sphere of science and education);
– implementation of innovational technologies in the sphere of Industry 4.0 (in case of availability of accessible technologies);
– increase of the share of Industry 4.0 (as a high-tech sphere of national economy) in structure of GDP (in case of its high investment attractiveness, stability, and intensity of development);
– development of production of unique products and separate items for individual orders (in case of availability of necessary technologies and payment capacity);
– increase of knowledge intensity of economy (in case of availability of highly-qualified and innovations-active specialists and commercial attractiveness of knowledge-intensive innovational and investment projects);
– expansion of usage and emphasis on intellectual production resources (in case of the developed system of protection of rights for the objects of intellectual property);
– development of technologies of artificial intelligence and expansion of their practical application (in case of availability of necessary financial resources and accessibility of these technologies).

During selection of tasks of development of Industry 4.0 from the offered list, it is necessary to consider possibilities and strategic goals of development of knowledge economy, for maximization of aggregate advantages from their practical implementation for economic system.

Fourthly, planning of terms of implementation of the tasks of Industry 4.0 should be conducted according to their complexity from the point of view of progress in formation of knowledge economy. If knowledge economy is in the process of its establishment and the platform for formation of Industry 4.0 is not fully formed, it is recommended to plan larger direction of implementation of this process's tasks, as the possibilities of the economic systems in this case are very limited.

Fifthly, target values should be assigned to the indicators of development of Industry 4.0 in view of all forecast scenarios and possibilities of the economic systems, determined by progress in formation of knowledge economy. These indicators cold be the indicators that were offered for evaluation of effectiveness of Industry 4.0 from the point of view of stimulation of development of knowledge economy, or additional indicators that are adapted to peculiarities of the economic system.

It is important to note that it is necessary to consider the current values during determination of target values for all indicators. A large scatter of the current and target values of the indicators is not allowable, as it makes the set goal and tasks unattainable and/or will distort the results of monitoring of the course of their execution. That is, during formation of target values for indicators, it is necessary to consider not tactic or strategic needs but the current possibilities of the economic system.

Sixthly, during selection of the tools of implementing the tasks of development of Industry 4.0 it is necessary to consider the possibilities and interests of stimulation of

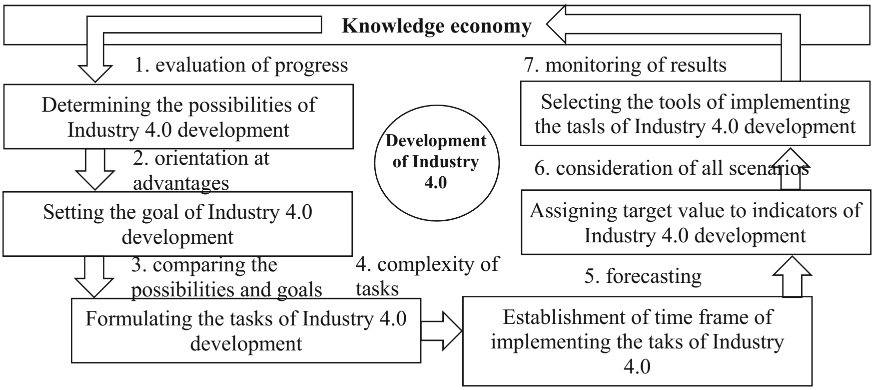

Fig. 2 Logical scheme of managing the development of Industry 4.0 in modern economic systems depending on the progress in the sphere of formation of knowledge economy. *Source* Compiled by the authors

progress in formation of knowledge economy. It is necessary to take into account that not only results but also expenditures for development of Industry 4.0 could stimulate progress in formation of knowledge economy. That's why it is recommended to consider all existing alternatives during selection of optimal tools.

Seventhly, monitoring of the results of Industry 4.0 development should be conducted in view of stimulation of this process for progress in the sphere of formation of knowledge economy. Depending on the results of monitoring, the following measures are recommended:

– in case of substantial progress in formation of knowledge economy and expansion of possibilities for development of Industry 4.0, it is recommended to reconsider the goals of management of this process (adding more goal and/or increasing the values of the indicators of result);
– in case of large underrun from the set time of implementation of the set tasks, it is recommended to reconsider the selected tools for achieving them, and in case of strong underrun for all tasks—to change the tasks and/or extension of terms of their implementation.

According to the offered priorities, the logic of the process of managing the development of Industry 4.0 in modern economic systems, characterized by different progress in the sphere of knowledge economy formation is offered (Fig. 2).

Figure 2 shows that knowledge economy is an initial point and final target landmark of development of Industry 4.0. This makes the process cyclic—management of the process of development of Industry 4.0 at all distinguished stages is conducted in connection to knowledge economy and is constantly modified depending on the achieved changes and accumulated experience.

Sequence of the stages of managing the process of development of Industry 4.0 in modern economic systems depending on the progress in the sphere of formation of knowledge economy envisages initial determination of possibilities of development of Industry 4.0, further goal-setting and formulation of tasks of Industry 4.0 development, planning the timeframe of their implementation, assigning target values to the indicators of development of Industry 4.0, and selection of tools of implementation of tasks and monitoring of results.

4 Conclusions

It should be noted that knowledge economy exists not in the parallel way with Industry 4.0, and development of this process directly influences each other, with close interconnection. Formation of knowledge economy is a precondition for formation of Industry 4.0, progress in formation of knowledge economy is an accelerator of development of Industry 4.0, and successes in the sphere of Industry 4.0 stimulate the development of knowledge economy.

The offered priorities and the developed logical scheme of managing the development of Industry 4.0 in modern economic systems depending on the progress in the sphere of formation of knowledge economy takes into account this peculiarity and allows using it in the best possible way for the economic system. They allow for successful adaptation of this process to any economic systems due to flexibility of management.

However, a certain limitation of the obtained results is complexity of their practical application. The developed logical scheme of managing the development of Industry 4.0 in modern economic systems depending on the progress in the sphere of formation of knowledge economy requires active participation of state regulator and is applied on the basis of expert evaluation, which predetermines a certain share of subjectivism in practical implementation of this model and its susceptibility to risk.

Thus, in case of incorrect evaluation of possibilities of the economic systems in developed Industry 4.0, it is possible to make non-optimal decisions that are related to incorrect goal setting, formation of unattainable tasks, application of incorrect methods, and imprecise determination of time that is required for implementing the strategy of development of Industry 4.0. Overcoming this subjectivism in the offered model and development of new, more precise models of management of Industry 4.0 development in modern economic systems, characterized by different progress in the sphere of formation of knowledge economy, is a perspective direction for further scientific studies.

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The Mechanism of Managing the Process of Formation and Development of Industry 4.0 in Modern Economic Systems

Sergey A. Abramov, Alexey V. Tolmachev, Vyacheslav V. Golikov, Irina A. Peters and Ulyana A. Pozdnyakova

Abstract The purpose of the work is to develop the mechanism of managing the process of establishment and development of Industry 4.0 in modern economic systems. The methodology of the research includes the methods of systemic, problem, structural & functional, and logical analysis, induction, deduction, and method of graphic presentation of conclusions and offered recommendations (method of formalization of data). The authors study the stages of the process of formation and development of Industry 4.0 and offer methodological recommendations for state management at each of them—determining target directions and perspective tools of management. As a result, the authors develop and offer the mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems that allows reducing uncertainty of this process and ensuring target actions of the state in the required directions at each stage of this process. This process is cyclic, and each its stage leads to accumulation of larger experience and optimization of work and development of Industry 4.0. The offered mechanism shows that formation and development of Industry 4.0 does not require application of new and/or complex managerial tools from the state, as standard tools of state regulation of economy suffice. At that, the most important condition of achievement of high effectiveness during management of the process of formation and development of Industry 4.0 in modern economic systems is the complex character of application of these tools.

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Keywords Mechanism of management of the process of formation and development of industry 4.0 · Modern economic systems

1 Introduction

Transition to Industry 4.0 is called the Fourth Industrial Revolution—which reflects the systemic and comprehensive character of economy's transformations under the influence of this process, as well as their cardinal and unprecedented nature. As is known, even the innovations that are applied in the scale of separate economic systems (at the micro-level) could provoke macro-level or even global economic crisis, which was proved by the depression of the global economy of the early 21st century.

Initiatives in the sphere of formation of Industry 4.0 are taken in the national scale. The initial successes of developed countries could be a signal for adoption of the national strategies of Industry 4.0 formation in developing countries, and then the industrial revolution will become global. Due to this, two main scientific and practical problems appear.

The first one is connected to high risk component of transition of modern socio-economic systems to Industry 4.0 as a new vector of their innovational development. Within this problem, Industry 4.0 is viewed as a potential accelerator of new economic crisis. Also, it can provide or not provide various advantages for socio-economic systems.

The second problem could be defined as potential lost profit from initial unsuccessful experience of formation of Industry 4.0 in developed or developing countries, due to which other countries become disappointed or lose trust to the concept of Industry 4.0 and refuse from its practical implementation. Of course, if this concept has more dangers for socio-economic systems or is utopian (its practical implementation is impossible), refusal from it is expedient and necessary.

However, if unsuccessful experience of practical implementation of this concept is predetermined by insufficient elaboration of its methodological tools, refusal from formation of Industry 4.0 will lead to global lost profit, related to unrealized possibilities of innovational development of socio-economic systems and acceleration of growth rate and increase of sustainability the global economy.

Both these problems require scientific elaboration and detailed research. However, finding the solution to the first problem is impossible due to insufficiency of scientific data and absence of experience in Industry 4.0 formation. The second problem should be studied and solved at the current rate of preparation of socio-economic system to formation of Industry 4.0—which is viewed in this chapter. The purpose of this chapter is to develop the mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems.

2 Materials and Method

The methodology of the research includes the methods of systemic, problem, structural & functional, and logical analysis, induction, deduction, and method of graphic presentation of conclusions and offered recommendations (method of formalization of data).

The theoretical basis of the research consists of fundamental and applied research and publications on the issues of managing the process of formation and development of Industry 4.0 in modern economic systems: Pfliegl and Keller (2015), Tönjes (2017), Shamim et al. (2017), Wartzack et al. (2017), Tupa et al. (2017), Emmer et al. (2017), Eigner et al. (2016), Gerberich (2017), Junker and Domann (2017), Gentner (2016), Sanders and Wulfsberg (2015), Eigner et al. (2015), and Wang (2015).

3 Results

As a result of study and comparative analysis of various variants of formation of Industry 4.0, we selected the following optimal variant of organization of this process. At the first stage, the companies (that do not initially belong to the sphere of Industry 4.0) conduct marketing research for determining mass demand for products of Industry 4.0 and collect individual orders for products of this sphere. This ensures such advantage from formation of Industry 4.0 as balance of demand and offer.

Having evaluated potential demand and the level of its payment capacity, with segmentation of the markets of products of Industry 4.0 and selection of its target segments, industrial companies send queries for innovations (technologies) and intellectual resources (highly-qualified specialists) in the sphere of Industry 4.0 to the system of science and education.

Successful passing of this stage of the process of formation of Industry 4.0 required strengthening of connection between the system of science and education and the system of entrepreneurship. For that, the state can use various tools of creation of favorable conditions and stimulation of integration of these spheres, including stimulation of cluster processes in economy, protection of rights for objects of intellectual property, strengthening and development of contractual law, etc.

At the second stage, the system of science and education—based on the signals that are received from entrepreneurship and, probably, own marketing research, conducts scientific research and development, as a result of which it creates and patents innovations in the sphere of Industry 4.0 and creates educational programs and prepares highly-qualified specialists (intellectual resources), who are ready to work in this sphere. Created resources and innovations are transferred into the system of entrepreneurship.

At this stage, the state has to support the growth of efficiency of the system of science and education, aimed at conduct of largest possible number of scientific studies and developments and receipt of successful results that are expressed in creation of innovations (technologies) in the sphere of Industry 4.0. For that, it is possible to use such tools of stimulation of scientific activity of organizations of this system as provision of grants and other forms of state financing of scientific research and development in the sphere of Industry 4.0.

Also, it is necessary to stimulate preparation of the largest possible number of highly-qualified specialists (high-quality intellectual resources) in the sphere of Industry 4.0. For that, it is recommended to use such tools of state management as standardization (formation of quality standards) of education in the sphere of Industry 4.0 and placement of state order for preparation of specialists in the sphere of Industry 4.0.

At the third stage, industrial companies place their own or attract external investments into innovational projects in the sphere of Industry 4.0. Within these projects, according to the received innovational technologies, they transform intellectual resources into products in the sphere of Industry 4.0. At that, two following processes in various proportions take place:

- transition of old (existing) industrial companies into the sphere of Industry 4.0 within modernization of their production technologies and equipment;
- creation of new industrial companies directly in the sphere of Industry 4.0 on the basis of new production technologies and equipment.

The role of state management of the process of Industry 4.0 formation at this stage consists in provision of high investment attractiveness of innovational projects of entrepreneurship in the sphere of Industry 4.0.

For that, standard measures of creation of favorable investment climate and state stimulation of inflow of investments into economy could be used: provision of government guarantees for return of investments for reducing the risk component of innovational projects, provision of tax preferences for investors (tax subsidies, tax holidays, etc.), and providing investors with access to preferential terms of crediting of business by provision of profitable conditions of crediting for purchase of new technologies and equipment and training of personnel.

At the fourth stage, finished products are sold in the sphere of Industry 4.0 in two main directions. 1st direction—B2C—envisages selling products of Industry 4.0 to final consumers (individuals). Depending on previously accepted orders, this could be individual (execution of individual orders) or mass (without preliminary orders) sale.

2nd direction—B2B—envisages selling products of Industry 4.0 to companies that use these products in their business-processes or for their further processing (as intermediary products) or as production equipment. This direction is related to transformation of the whole system of entrepreneurship for the infrastructure building role of Industry 4.0.

At this stage, the task of state management of the process of Industry 4.0 formation is stimulation of demand for Industry 4.0. Within the 2nd direction, the above standard measures for creating favorable investment climate and state stimulation of inflow of investments could be used. Within the 1st direction, it is recommended to use such measures as social advertising, aimed at attraction of interest or increase of

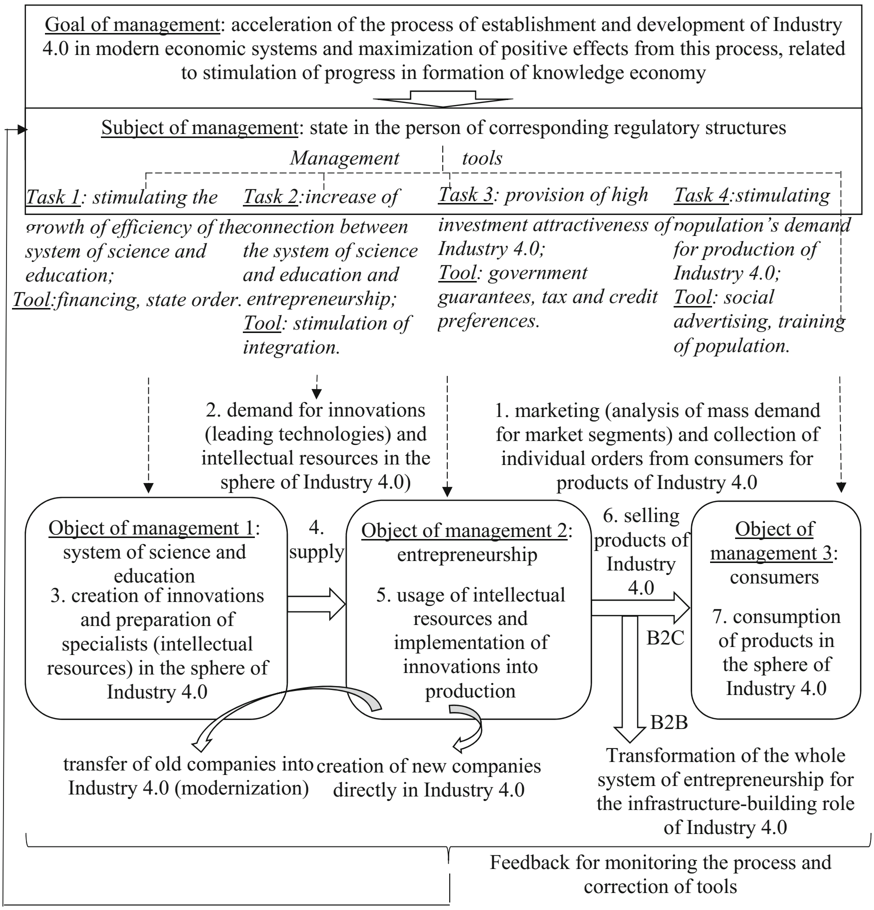

Fig. 1 The mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems. *Source* Compiled by the authors

trust (increase of loyalty) of society to products of Industry 4.0, and training of population (accessible consultations) on the issue of advantages and foundations of usage of Industry 4.0 products.

Based on the above, it is offered to use the following mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems (Fig. 1).

As is seen from Fig. 1, the purpose of management within the offered mechanism is acceleration of the process of formation and development of Industry 4.0 in modern economic systems and maximization of positive effects from this process, related to stimulating the progress in formation of knowledge economy. The subject of management is state in the person of corresponding regulatory structures. The objects of management are the system of science and education, entrepreneurship, and consumers. As is seen from Fig. 1, state management is conducted at each stage of the process of formation of Industry 4.0 and offers to use the corresponding tools. Also, the model envisages feedback between objects and subjects of management for monitoring the process and correction of tools—which is not shown in the model.

4 Conclusions

It should be concluded that the developed and presented authors' mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems allows reducing the uncertainty of this process and ensuring target actions of the state in required directions at each stage of this process. This process is cyclic, and each its stage leads to accumulation of more experience and optimization of work and development of Industry 4.0.

The presented mechanism vividly shows that for the purpose of formation and development of Industry 4.0, the state does not have to use new and/or complex managerial tools—standard tools of state regulation of economy suffice. At that, the most important condition of achievement of high effectiveness during management of the process of formation and development of Industry 4.0 in modern economic systems is the complex character of application of these tools.

Only target influence on all objects of management, presented within the developed mechanism with the help of the offered tools, will allow starting and ensuring continuous work of this mechanism. The failures and errors of state management at one of the stage of the process of formation and development of Industry 4.0 in modern economic systems will inevitable influence other stages and lead to termination of work of this mechanism.

It should be emphasized that the offered mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems is oriented at work in normal conditions—in the stable period. In the conditions of crisis, which could be manifested not only in reduction of growth rate of economy but also in reduction of consumer and business activity, deficit of assets in state budgets, etc., accessibility of the offered tools of state management of the process of formation and development of Industry 4.0 in modern economic systems decreases. That's why during further research it is expedient to pay attention to development of methodological recommendations for state management of the process of formation and development of Industry 4.0 in modern economic systems in the period of crisis.

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Modernization of the Standards of Education and Personnel Training Due to Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation

Konstantin V. Vodenko, Maria A. Komissarova and Mikhail M. Kulikov

Abstract The authors analyze the specifics of functioning and development of the institute of continuous professional education as a space for formation of professional competences and labor functions of future employees of various sectors of economy in the conditions of development of knowledge economy and Industry 4.0. It is concluded that it is necessary to use in socio-economic discourse the notion "continuous professional education", which emphasizes functional specifics of received knowledge, provide continuous updated of professional knowledge and skills, and focus on continuity of the training process in the professional sphere. It is noted that the problem of convergence for federal state educational standards of the version 3+ and professional standards could be solved in case of selection of the necessary totality of forms of professional activities, determination of the corresponding competences, and presenting the level description of competences through labor actions.

Keywords Institute of education · Professional competences · Labor functions Educational standards · Professional standards · Knowledge economy · Industry 4.0

In the modern conditions, Russian economy sets new requirements to specialists who work in various professional spheres, and, therefore, to the very system of professional training of these specialists. Education becomes the main capital of human and the leading resources of economy. It is possible to speak of formation of a new type of education—post-industrial—which is oriented at development of socio-professional capabilities of personality, whole its main factor is socio-professional development

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of the subject in socially useful activities. This type of education envisages a range of models of professional training, which are systematized on Table 1.

Formation of a new type of education creates for human and society on the whole new realia, when it is possible to adapt to new conditions only with professional progress, which should be ensured by the educational system. Due to this, such notions and professional education and continuing education become topical. According to the law "Regarding education in the Russian Federation", professional education is a type of education that is aimed at students' acquiring in the process of mastering of main professional educational programs the knowledge, skills, and capabilities and formation of competences of a certain level or volume that allow conducting professional activities in a certain sphere and (or) perform work in specific profession or specialty.

Continuing education is a process that is "built into human life, not limited by special educational activities in classrooms" (Mitina 2004); a means of socialization, integration of individuals into professional society and society on the whole, and a means of successful adaptation to the changing social reality. Continuing education focuses on the process of improvement of competence, change of "life scenarios", behavioral stereotypes and stimulates further growth of professional and general cultural competences and development of human, not just obtaining additional education (additional training, second higher education) (Rozin 2000). The modern system of continuing professional education in Russia is presented in the scheme (Fig. 1).

Table 1 Models of socio-professional activities

Model	Specifics	Main component	Target orientations
Model of professional adaptation	Execution of activities according to the set rules and norms	Domination of the tendency of adaptation to professional activities and self-determination in them	Professional qualification (knowledge, capabilities, skills)
Model of independent organization	Training of specialists who are capable of independent organization of their activities, making decisions and bearing responsibility for them	The main component is the process of self-organization of person	Professional competence (general culture and professional)
Model of professional self-development	Self-realization of person in profession, combination of autonomous and group work	The central component is readiness for innovations	Professional culture (qualities and capabilities that lead to efficiency of cognitive, social, and professional activities, high level of professional mobility)

Source Developed by the authors

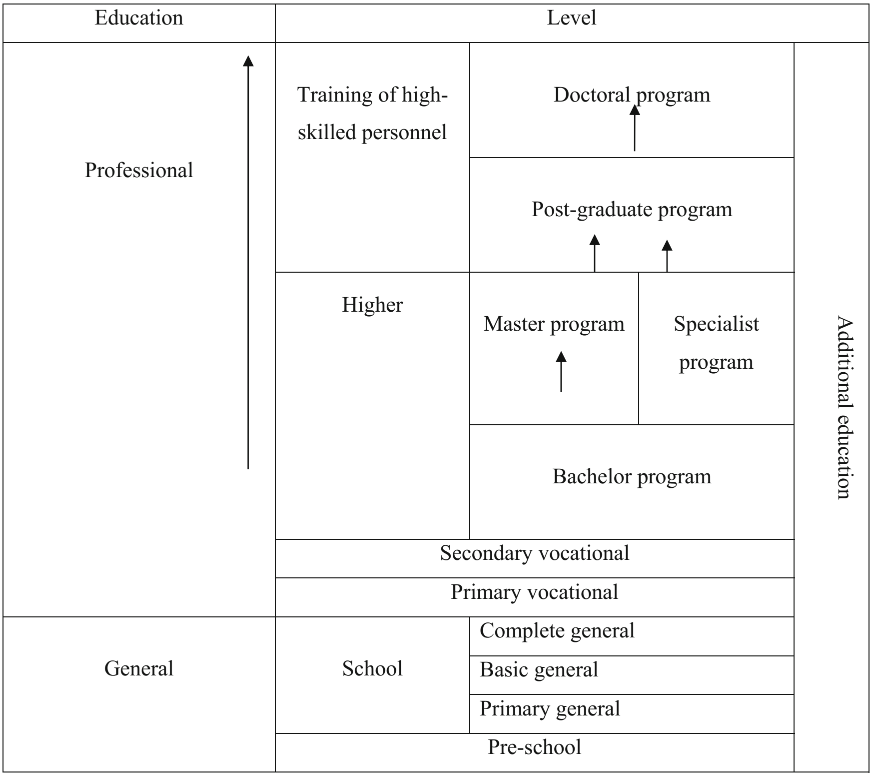

Fig. 1 Levels of continuing education. *Source* Developed by the authors

It is expedient to use in the socio-economic discourse the notion "continuing professional education", which emphasizes functional specifics of received knowledge, envisages provision of continuing update of professional knowledge and skills, and focuses on continuity of process of learning in the professional sphere. The logic of continuing professional education includes the second, third, etc. higher educations and the courses of additional training. There is also a possibility for multiple change of professional and educational trajectories and supplementing competences and qualifications for improving the main professional activities, which reflects specifics of market relations to which modern human has to adapt (Shcherbakova 2015; Vodenko et al. 2017; Rodionova et al. 2017). The systemic attributes of continuing professional education are systematized in the following scheme (Fig. 2).

Continuing professional education is based on the concept of professional establishment of personality and is conducted by means of formation of motives and necessary competences for studying during the whole life. Its essence and purpose is to ensure comprehensive professional formation, creation of conditions for constant update, development, and self-realization of each human over the whole professional

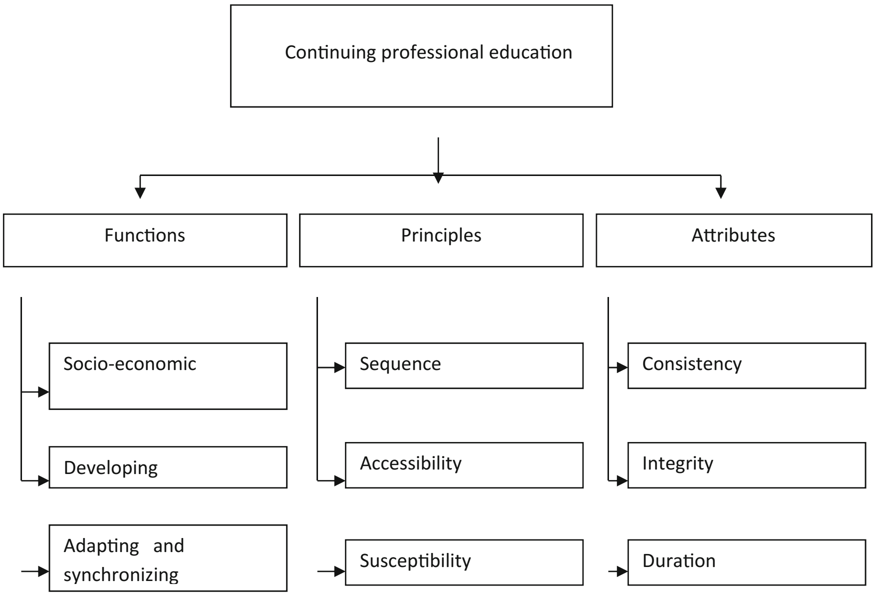

Fig. 2 The system of continuing professional education. *Source* developed by the authors

life. Hence the goal of continuing professional education as to personality—satisfaction of personality's need for development, self-development, self-expression, and realization in professional life. As for society, the purpose of continuing professional education is creation of personnel resources and their modernization (Shcherbakova 2015).

Studying specifics of development of the system of continuing professional education requires the corresponding methodology. Education could be studied in the context of the institutional and systemic approaches (Table 2).

Generalization of the described approaches to studying education allows for a conclusion on their mutual complementarity and understanding education as an organized system, in which the process of person's formation is realized for the purpose of reproduction, update, and improvement of social relations and society on the whole, and, secondly, as a social institute, which is seen as a totality of historically established sustainable and reproducing types of social interactions that have to satisfy society's needs for transfer of knowledge from some generations to others, and is presented as a system that includes totality of persons and establishments, social functions and role, management and social control.

At present, within substantiation of transition from knowledge-oriented to activities-oriented mode of education, the competence-based approach is considered as a certain tool for increasing the social dialog between higher school and the world of labor, a means of expansion of their cooperation and solving the problem of lack of coordination between the sphere of education and labor market. Accord-

Table 2 The institutional and systemic approach to studying education

Issues for comparison	Institutional approach	Systemic approach
The notion of education	Education is interaction between social groups and societies, which is organized for achievement of the goals and execution of tasks of formation of personality and its professional socialization	Education as a system is peculiar for totality of the following interacting components: educational programs, educational standards, educational establishments, and bodies of management of education
Sphere of application	Effective during studying the system of education for the purpose of determining the connections between its elements. Institutional consideration of education envisages determining its connections with production, science, culture, and other social institutes and systems	Systemic approach is more often implemented in the course of analytical, research, managerial, and reforming activities in the sphere of education
Objects of research	Education is viewed as an elements of the system of public relations, which interacts with other elements. The institutional approach envisages analysis of activities interaction between social groups in the sphere of education.	Systemic approach characterizes education as autonomous structural and integrated sphere. Systemic approach is peculiar for "supra-personal" description of the system, which includes the subjects of education (teachers and students)
The main aspects of research	Education is studied as a certain sustainable and dynamic public organization in the sphere of education, upbringing, and professional training	Systemic approach studied the structure of education in connection to the performed functions

Source Compiled by the authors

ing to A. V. Lubsky and G. I. Gerasimov, a professionally competent graduate can think independently, possess cognitive independence and capability to obtain new knowledge, and possess them as a tool of cognitive and practical activities in the conditions of innovational society—in order to be professionally competitive and successful (Gerasimov and Lubsky 2014, p. 121). The opinion that in innovational society a higher school graduate has to possess professional culture of innovational and project content and be capable of diversifying his professional activities is well-reasoned.

The basis for formation of the educational environment within which professional competences of future workers are formed is the Bologna Declaration (1999) and

Table 3 Federal State Education Standards 3+ for the group of specialties 380,000 "economics and management"

Specialties	Academic bachelor program				Applied bachelor program			
	Block 1 Disciplines (modules)		Block 2 Prac-tices	Block 3 State final exami-nation	Block 1 Disciplines (modules)		Block 2 Prac-tices	Block 3 State final exami-nation
	Basic part	Variable part	Variable part	Basic part	Basic part	Variable part	Variable part	Basic part
38.03.02 Management	N/A				81–87	90	54–63	6–9
38.03.03 h management	N/A				105–108	102–108	15–27	6–9
38.03.04 State and municipal management	102	120	6–12	6–9	96–99	120–123	9–18	6–9
38.03.06 Trade business	102–114	105–114	12–18	6–9	93–108	105–114	18–27	6–9
38.03.07 Commodity science	N/A				84–102	105–108	24–42	6–9
38.03.10 Housing services and communal infrastructure	99–105	105	24–30	6–9	99–105	87–93	33–48	6–9

other documents on education, which were adopted in recent years, that establish the level system of education (bachelor–master—Ph.D.). The existing multi-level structure of higher professional education, which exists in the RF, reflects the provisions of the Bologna agreements. Hence, the existing levels of higher education (bachelor, specialist, and master) could be deemed the basis of generally recognized structure of qualifications (Koroleva et al. 2010). In particular, bachelor program requires the increase of practical direction and the corresponding demand. This is proved by the federal state educational standards (version 3+). Thus, we analyzed the standards within the enlarged groups of specialties "Economics and management". The results of analysis confirm the above thesis (Table 3). It should be noted that structure of secondary vocational and post-graduate professional education underwent the changes that are oriented at changes of the structure of labor market and structural changes in the sphere of science, technologies, and social sphere.

The task of creation of educational standards of the third generation was caused by the necessity for Russia's joining the Bologna process. The main role in determining the quality of education was transferred from the state to a more specific customer of education. The text of the standard establishes the provision that mandatory tech-

Table 4 Problems and perspectives of implementation and development of federal state education standards of the third generation

Unsolved problem	Perspective state
Lack of certain Professional standards	Bringing the Federal state education standards in correspondence with the Professional standards
Double nature and excess of the Federal state education standards	Development of "framework" Federal state education standards for the enlarged group of specialties
Impossibility to measure the competences and lack of clarity	Application of single approach to formulation of competences
Application of quantitative characteristics in requirements to conditions of implementation of the Federal state educational standards	Description of requirements to quality of conditions of implementation of the Federal state education standards
Lack of succession of the Federal state education standards according to the level of education	Formation of successive list of the Federal state education standards according to the levels of education
Lack of common requirements to the Funds of assessment means that measure the quality of mastering of competences	Development of the single approach to the Federal state education standards on the basis of international standards

nologies with educational program is the requirement of formation of sustainable and effective social dialog between higher school and labor sphere. During development of the standards of the third generation, employers and public institutes are involved in formation of goals and determining the list of disciplines of higher professional education. At present, employers needs not just qualification, which is determined by a certain set of knowledge, but competence, which combines qualification, capability to work in a group, initiative, creativity, and skill to transfer knowledge from one sphere into another. At that, requirements to the profession are formulated in the form of packages of competences, as labor market evaluates not knowledge as such but a capability to perform the existing functions and master new ones (Shcherbakova 2015). However, development of the third generation standards did not solve the problems that are shown in the scheme (Table 4).

The federal state education standards of the third generation are based on the competence-based approach as a totality of general principles of determining the goals of education, selection of content of education, organization of educational process, and evaluation of educational results. Competence is the basic quality of individual, which is related to effective and (or) prominent execution of work, the level of which is determined by specific criteria (S. Spencer, L. Spencer) (Spencer and Spencer 2005, p. 320). It is possible to distinguish general cultural and professional competences. General cultural competence is related to such specific qualities that allow an individual to act effectively in certain business situations. A special role belongs to professional competences, which envisage individual's capability to perform the required actions on the basis of existing practical experience and take

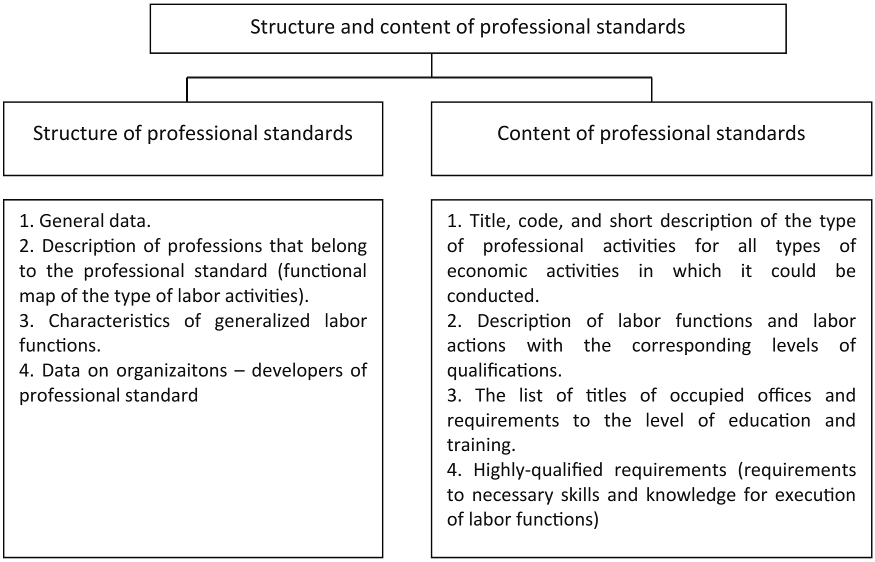

Fig. 3 Structure and content of professional standards

into account availability of skills and knowledge that are required for solving the tasks of professional character.

Professional competences are treated as standards of work behavior of a specialist. The content of professional competences is totality of interconnected factors (knowledge, skills, means of professional communication, resource potential of specialist's personality, which are related to a certain circle of objects and processes and are necessary for efficient activities). Professional competences should reflect autonomous character and flexibility of specialist in part of solving the professional problems; developed cooperation with colleagues and professional inter-personal environment, effective usage of capabilities that allows for efficient conduct of professional activities according to requirements of work place in the modern labor environment.

At present, the process of formation of future specialists in the sphere of continuing professional education is regulated also by professional standards. The technology of development of professional standards envisages conduct of wide monitoring of requirements of employers to qualification of personal for the specter of professions that are significant for the Russian economy. The structure and content of professional standards are shown in Fig. 3.

At present, there is an attempt to converge the requirements of educational and professional standards. However, there are certain difficulties. According to analysis, the process of convergence of requirements passed several stages, which did not end with planned result.

The first step to convergence of federal state education standards and professional standards was performed at the end of the first decade of the 21st century, federal state education standards of the third generation had to be developed with participation of representatives of labor market and pass the procedures of discussion in the environment of employers. According to clear reasons, participation of employers in most cases had formal character, so expected convergence of positions was not achieved.

The second step was performed during development of professional standards, where in the initial version the developers were recommended to include professional competences. As a rule, developed did not use the formulations of competences, and in the following model of professional standards, adopted by the Ministry of Labor, all requirements were expressed in the language of labor functions, detailed in the form of labor actions and related to necessary knowledge and skills.

The third step to achievement of convergence between federal state education standards and professional standards was developed in the actualized version of federal state education standards of the version 3+, where professional competences for applied bachelor program were recommended to compile on the basis of professional standards or qualification requirements.

Experience of convergence of the standards was vividly expressed in the Methodological recommendations for development of the main professional educational programs in view of the corresponding professional standards, adopted by the Ministry of Education and Science of the Russian Federation dated January 22, 2015, No. DL-1/05vn. However, the path of achievement of convergence was not specified in recommendations. They were to describe educational programs or programs of disciplines for solving certain professional tasks of execution of labor functions. Such descriptions in educational programs are not always given, and if they are included into an educational program, they have the form of a list from professional standard that does not influence the real educational process.

Thus, the problem of convergence for federal state education standards of the version 3+ and professional standards could be solved if the necessary totality of the forms of professional activities is selected, the corresponding competences are determined, and the level description of competences through labor functions is provided.

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Transformation Changes in the System of Professional Competences of a Modern Specialists in the Conditions of Knowledge Economy’s Formation and the Innovational Approach to Training

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Abstract The purpose of the article is to study the transformation changes in the system of professional competences of modern specialist in the conditions of knowledge economy’s formation and formation of Industry 4.0 and to develop the innovational approach to its study and preparation. Methodology of this approach is based on application of competence-based approach to education and learning, the method of compiling a map of competences of a modern specialist, and the method of graphic interpretation of authors’ conclusions and recommendations (the method of data formalization). As a result of studying the structure and logic of organization of the educational services market and labor market by the example of modern Russia, it is concluded that a narrow specialization of employees is in demand. Business processes of modern Russian companies are strictly differentiated; ordinary employees, innovators, and technical specialists are separated. In the conditions of knowledge economy’s formation and formation of Industry 4.0, wide specialization of employ-

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ees will be in demand. As production functions will be automatized, the number of companies' employees will be reduced, and each employees will have to conform to requirements from all three categories. Transition to new requirements to a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0 will be related to transformation changes in the system of his professional competences. We compiled a map of professional competences of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0 and distinguished three main professional competences, which a production specialist should possess in the conditions of knowledge economy and Industry 4.0: competence of generation of innovations, computer programming, and digital thinking. According to the above transformation changes in the system of professional competences of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0, it is necessary to pass from narrow specialization of specialists' training to creation of wide specialization of employees. For that, an innovational approach (Fig. 1) to teaching and training of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0 is presented.

Keywords System of professional competences · Modern specialist · Knowledge economy · Industry 4.0 · Innovational approach to teaching and training of specialists

1 Introduction

In the conditions of knowledge economy's formation and formation of Industry 4.0, the main innovational phenomena and processes are concentrated in the technological and economic sphere and they influence other spheres of modern human's activities. In the social sphere, ideology is changed and new life settings are developed—which are aimed at reconsideration of the role and meaning of human in knowledge economy and Industry 4.0 and search for possibilities of perspective directions of using potential new technologies.

As a consumer, modern human faces the necessity for mastering new technologies for successful and highly-effective usage, as well as receipt of the whole set of necessary services, most of which become digital. As a worker, human undergoes even more serious transformation changes—higher requirements in the sphere possession of new technologies are set, which determines his competitiveness in the labor market and the possibility of employment, as with development of knowledge economy and formation of Industry 4.0 the number of jobs that do not require usage of new technologies will be reducing.

This changes the image of a modern specialist, who has to start preparations for the changing technical and economic landscape by mastering the potentially popular professional competences—which is the hypothesis of this research. Due to this, modernization changes in the system of education, which allows adapting it to training of specialists who are competent in the conditions of knowledge economy and Industry 4.0 becomes topical.

The purpose of the chapter is to verify the offered hypothesis, study transformation changes in the system of professional competences of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0, and to develop the innovational approach to training.

2 Materials and Method

The foundations of formation and characteristics of the system of professional competences of a modern specialist and the traditional approach to his training are presented in the works (Astakhova 2017; Chistyakova et al. 2017; Chung et al. 2016; Gronau et al. 2017; Lima et al. 2017; Veraldo et al. 2018). However, future outlines of this system in the conditions of knowledge economy's formation and formation of Industry 4.0 are poorly studies and requires further scientific elaboration.

The methodology of the research includes the competence-based approach to education and learning, the method of compiling a map of competences of a modern specialist, and the method of graphic interpretation of authors' conclusions and recommendations (method of data formalization).

3 Results

As a result of studying the structure and logic of organization of educational services market and labor market by the example of modern Russia, we came to the conclusion that narrow specialization of employees is in high demand now. Business processes of modern Russian companies are strictly differentiated, and ordinary employees, innovators, and technical specialists are separated. Let us view each of these categories in detail.

Ordinary employees specialize in execution of production functions that are related to manufacture of goods and/or provision of services (processing of documents or work with company's customers). They do not have to conform to the requirements in the sphere of promotion of new ideas and creation of new knowledge and technologies—moreover, feedback between employees and management is not developed at most companies, due to which, even in case of offers for improvement of company's work and a desire to bring them to company's management's attention, the employees does not usually have such an opportunity.

In the aspect of possession of new technologies, ordinary employees at a lot of offices and companies should possess the competence of usage of these technologies. This competence includes a skill to work with standard (e.g., Microsoft Word) and specialized (e.g., 1C Accounting) computer programs and use office equipment (printer, scanner, copy machine, fax, etc.). The company's management accepts a responsibility to provide this equipment and software in the form that is fit for work.

Innovators specialize in execution of non-production functions that are related to development of recommendations and practical solutions for optimizing the company's work and modernization of its activities. They could form groups of innovators, or the role of innovators could be performed by managers of various levels. In the aspect of possession of new technologies, they have to conform to the same requirements as ordinary employees.

Technical specialists specialize in execution of non-production functions that are related to repairs of office equipment and setting up the software. The innovational component of their activities is brought down to zero, and the main requirement that is set to them is provision of continuous work of technical and software devices that are used in production and innovational activities of the company.

In the conditions of knowledge economy's formation and formation of Industry 4.0, wide specialization of employees will be in high demand. As production functions will be automatized, the number of companies' employees will be reduced, and each of them will have to conform to requirements from all three categories. An employee will have to do the following:

– perform routine processes that constitute production activities of human or that are related to observation and control over work of automatized technical means and communication systems;
– ensure technical operating condition of devices, including their installation, setting, repairs, and programming;
– manifest innovational activity, knowing all peculiarities of company's work and offering practical solutions for its improvement.

Transition to new requirements to a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0 will be connected to transformation changes in the system of its professional competences. Based on the performed analysis, we compiled a map of these competences (Table 1).

As is seen from Fig. 1, three main professional competences are distinguished—a production specialist should possess them in the conditions of knowledge economy and Industry 4.0. The first of them is the competence of generation of innovations. It has to create new knowledge, modernize existing technologies, and develop innovational technologies. It includes knowledge of existing information (traditions) in the sphere of professional specialization, a skill to generate new knowledge and information on the basis of existing knowledge and information, and the skill of highly-intellectual activities that leads to promotion of new ideas and their manifestation in innovations.

The second competence is the competence of computer programming. It is aimed at managing the interaction between inanimate objects, performed on the basis of the Internet of Things. It includes knowledge of foundations and technologies of computer programming, a skill to compile algorithms and digital codes, and a skill of creation and correct of computer programs.

Table 1 Map of professional competences of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0

Competence	Direction of competences' application	Characteristic of competences
Competence of generation of innovations	Creation of new knowledge, modernization of existing technologies and development of innovational technologies	– Knowledge of existing information (traditions) in the sphere of own professional specialization – A skill—based on existing knowledge and information—to generate new knowledge and information – A skill of highly-intellectual activities, which leads to promotion of new ideas and their expression in innovations
Competence of computer programming	Management of interaction between inanimate objects, performed on the basis of the Internet of Things	– Knowledge of basics and technologies of computer programming – Knowledge of creating algorithms and digital codes – Skill of creation and correction of computer programs
Competence of digital thinking	Preparation of digital information for automatization of everyday and business-processes	– Knowledge of the essence and logic of the process of computer processing of information – Skill of transfer of qualitative information into qualitative form – Skill of digitization of data (recording information on digital carriers in the form fit for computer processing)

Source Compiled by the authors

The third competence is the competence of digital thinking. It is aimed at preparation of digital information for automatization of everyday and business processes. It includes knowledge of the essence and logic of the process of computer processing of information, transfer of qualitative information into quantitative form, and a skill of digitization of data (recording information on digital carriers in the form that is fit for computer processing).

According to the above transformation changes in the system of professional competences of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0, it is necessary to pass from narrow training of

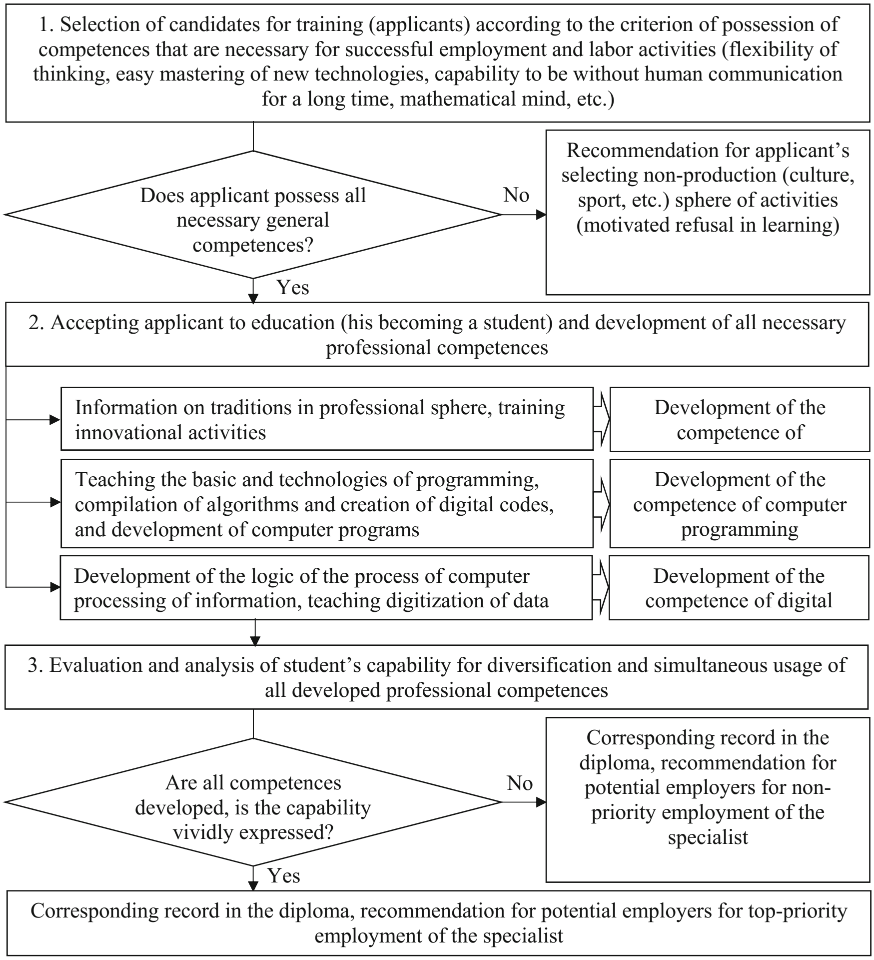

Fig. 1 Innovational approach to teaching and training of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0. *Source* Compiled by the authors

specialists to preparation of employees with wide specialization. For that, we developed the innovational approach to training of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0 (Fig. 1).

As is seen from Fig. 1, the offered innovational approach envisaged three-step training of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0. At the first stage of this process, candidates for training (applicants) are selected according to the criterion of possession of general competences that are necessary for successful employment and labor activities, including flexibility of thinking, mastering of new technologies, ability to remain without human communication for a long time, mathematical mind, etc.

If applicant does not possess all necessary general competences, he has to selected non-production (culture, sport, etc.) sphere of activities and he is refused to be taught. In the opposite case, he is accepted for studies and is taught all necessary professional competences (second step) according to the compiled map of competences (Table 1). At the third step, thorough evaluation and analysis of student's capability to diversity and use all developed professional competences is performed.

If not all competences are developed and/or capability for their diversification or simultaneous usage is not expressed vividly, a corresponding record is made in the diploma, and recommendation for non-priority employment for this specialist is issued. In the opposite case, a corresponding record is made in the diploma, and recommendation for top-priority employment for this specialist is issued.

4 Conclusions

Thus, it is possible to conclude that the working hypothesis is correct—with knowledge economy's formation and formation of Industry 4.0, the requirements to a modern specialist grow. In future, after completion of these processes, he will have to possess three functions: servicing (monitoring and control) of production processes, technical support, and innovational activity. This envisages serious transformation changes in the system of professional competences of a modern specialist.

In the conditions of knowledge economy and Industry 4.0, he will have to possess such professional competences as generation of innovations, computer programming, and digital thinking. The innovational approach to training of a modern specialist in the conditions of knowledge economy's formation and formation of Industry 4.0 is presented. This approach allows selecting the best candidates for training and the best students as a result of training and issuing recommendations for potential employers for their employment.

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The Algorithm of Managing the Process of Formation and Development of Industry 4.0 in the Modern Economic Systems in the Conditions of Knowledge Economy's Formation

Elena S. Akopova and Natalia V. Przhedetskaya

Abstract The purpose of the article is to develop a perspective algorithm that allows adapting the corresponding management not only to socio-economic peculiarities of a country but also to its possibilities and interests in formation of knowledge economy for provision of high flexibility of this process. During development of the algorithm of managing the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation, the authors use the methods of analysis, synthesis, induction, deduction, and formalization, as well as special methods of economic science—modeling of socio-economic systems and special-purpose method. As a result, the authors offer the algorithm of managing the process of formation and development of Industry 4.0 in the modern economic systems in the conditions of knowledge economy's formation, which advantage, apart from flexibility, it its complex character: the offered algorithm takes into account not only the purposes of formation and development of Industry 4.0 but also the possibilities of the socio-economic systems in their achievement, determined by progress in formation of knowledge economy, and allows balancing these purposes with the purposes of knowledge economy's formation, thus optimizing the management of the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation. Advantages of this algorithm include the universal character: it could be applied in any socio-economic systems, as it envisages consideration of national peculiarities and successful adaption to them; it could also be used at any phase of the economic cycle, including the phase of stability and the phase of crisis. An advantage of the algorithm is its interactive character: it is based not on tough frameworks but on the choice from existing alternatives and

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constant correction of the strategy of managing the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation depending on the current situation. This algorithm is cyclic: it envisages accumulation of experience, which ensures constant improvement of managing the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation.

Keywords State management · Formation and development of industry 4.0 Modern economic systems · Knowledge economy

1 Introduction

Successful management of the process of formation and development of Industry 4.0 in modern economic systems is based on flexibility and adaptability of this management due to the following two reasons. The first reason is related to the fact that the concept of Industry 4.0—due to its novelty—will be based on theoretical models, conventional forecasts, and separate poorly studied examples with uncertain long-term consequences. Insufficiency of practical experience in formation and development of Industry 4.0 does not allow to use verified solutions and requires manifestation of creativity and constant change of the initial plans.

The second reason is the deep character of transformations of socio-economic systems in the process of formation of Industry 4.0. Even in case of large accumulated experience of successful formation and development of Industry 4.0 and highly-effective management of this process in similar economic systems, each new system can have its own unique and unpredictable risks that are related to this process.

This is caused by the fact that peculiarities of business environment and consumer culture and specifics of international economic connections could lead to large differences in the processes of formation of Industry 4.0 in economic systems, even if they do not possess a lot of similar features and belong to the same category of the countries according to criteria of socio-economic development. That's why socio-economic systems can use only their own experience in formation of Industry 4.0 during compilation of high-precision forecasts and development of managerial strategies.

For solving this problem and providing the necessary flexibility of management of the process of formation and development of Industry 4.0 in modern economic systems, the authors seek the goal of development of a perspective algorithm that allows adapting the corresponding management not only to socio-economic peculiarities of the country but also to its possibilities and interests in formation of knowledge economy.

2 Materials and Method

During development of the algorithm of managing the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation, the author use the methods of analysis, synthesis, induction, deduction, and formalization, as well as special methods of economic science – modeling of socio-economic systems and special-purpose method.

The theoretical basis of the research includes the works of modern authors that are devoted to studying the essence, peculiarities, and problems of the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation: Arrizubieta et al. (2017), Blöchl et al. (2017), Bogner et al. (2015), Glück (2015), Hachmann et al. (2016), Hoffmann (2016), Hübner et al. (2017), Lydon (2017), Moreno et al. (2017), Reis and Gins (2017), Riedel et al. (2015), Sánchez et al. (2016), Santos et al. (2017), Schröder et al. (2015), Tamás and Illés (2016), Trstenjak and Cosic (2017), and Wehle and Dietel (2015).

The performed literature overview and content analysis of the existing scientific research and publications on the topic of managing the process of formation and development of Industry 4.0 in modern economic systems showed that most of them focus on determination of the principles of this management and description of the essence of the process of managing separate technologies and systems within Industry 4.0.

At that, insufficient attention is paid to development of systemic methodological recommendations, which are ready for practical application in any socio-economic systems, as well as solving the issues of balancing the interests of formation and development of Industry 4.0 and knowledge economy's formation. This chapter has to fill the gaps in the system of modern economic scientific knowledge in the sphere of Industry 4.0.

3 Results

We offer the following algorithm of managing the process of formation and development of Industry 4.0 in the modern economic systems in the conditions of knowledge economy's formation (Fig. 1).

Let us view this algorithm in detail. As is seen from Fig. 1, it includes seven consecutive stages at which logical selection from the existing alternatives is performed. At the first stage, global marketing in the sphere of Industry 4.0 is conducted—which is aimed at determination of actual tendencies, analysis of accumulated experience in formation of Industry 4.0, and determination of possibilities and problems of formation and development of Industry 4.0 in modern economic systems. As a result of this stage, strategic national goals of formation and development of Industry 4.0 are determined.

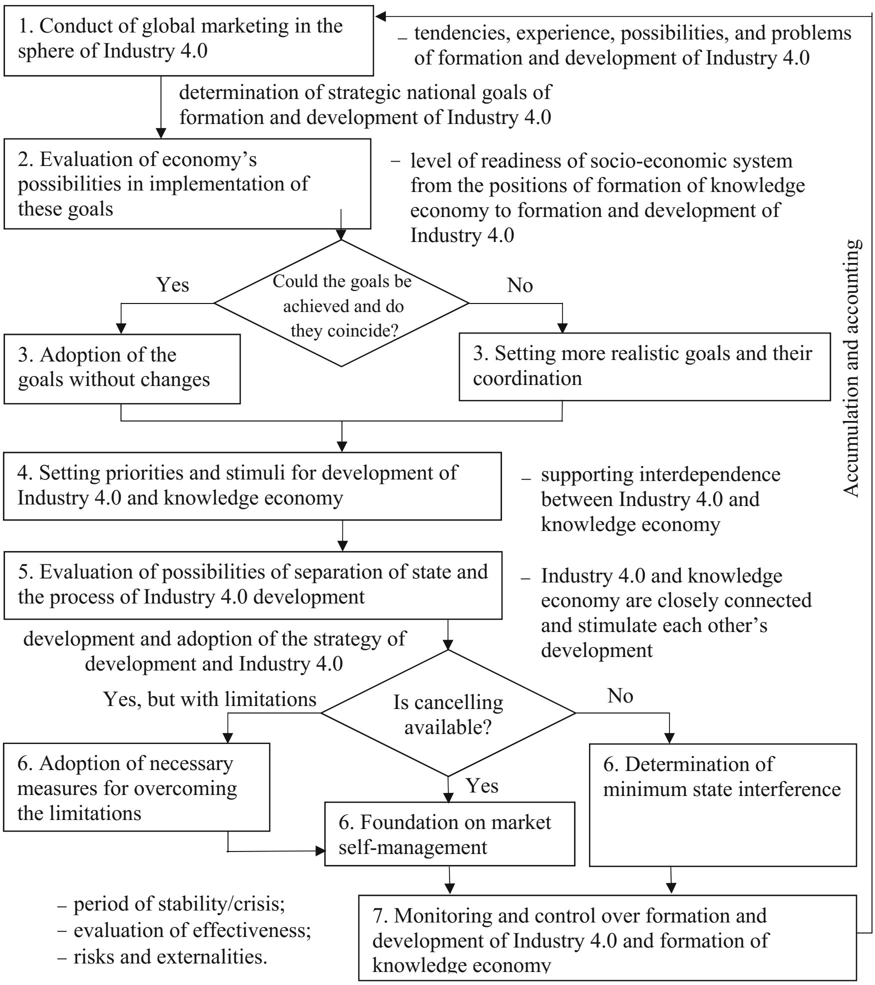

Fig. 1 The algorithm of managing the process of formation and development of Industry 4.0 in the modern economic systems in the conditions of knowledge economy's formation. *Source* Compiled by the authors

At the second stage, evaluation of possibilities of economy in implementation of these goals is evaluated—i.e., the level of readiness of socio-economic systems from the positions of formation of knowledge economy to formation and development of Industry 4.0 is assessed. At the third stage, if the goals of formation and development of Industry 4.0 and knowledge economy's formation coincide, and large progress is achieved in formation of knowledge economy for formation of Industry 4.0, the goals that were determined at the first stage are accepted without changes.

If the goals of formation and development of Industry 4.0 and knowledge economy's formation do not coincide or the goals of formation of Industry 4.0 require larger progress in formation of knowledge economy, more realistic and more coordinates goals are set for the short-term and mid-term—which will lead to achievement of the strategic (long-term) goals of formation and development of Industry 4.0, which were set at the first stage.

At the fourth stage, formation of priorities and stimuli for development of Industry 4.0 and knowledge economy are formed. At that, it is necessary to support interdependence between Industry 4.0 and knowledge economy. For that, the developed and presented mechanism of managing the process of formation and development of Industry 4.0 in modern economic systems could be used (Chap. 15).

At the fifth stage, possibilities of separating the state from the process of Industry 4.0 development are assessed. As Industry 4.0 and knowledge economy are closely connected and stimulate each other's development, the role of the state should be brought down to supporting favorable conditions for their simultaneous development. If it's possible, the strategy of formation and development of Industry 4.0 with foundation on market self-management and progress in formation of knowledge economy is developed and adopted.

If this is possible but with limitations – as in the case of insufficiently favorable (tax and investment) climate, lack of necessary technologies and equipment, etc., it is recommended to adopt the corresponding measures for creation of favorable conditions (improvement of business climate, installation of the required technologies and equipment, etc.), which allow for transition to market self-management.

If the market mechanism is not well-coordinated, it is expedient to determine the minimum necessary state interferences into market processes and refuse from its excess in future with orientation at reduction (if possible) and complete termination. The reasons of such course of events according to this scenarios are as follows:

– social factors: traditional public mode that leads to strong social opposition to formation and development of Industry 4.0 and knowledge economy;
– economic factors: underdevelopment or violations in the work of institutional provision of Industry 4.0 and knowledge economy;
– technological factors: negative results of scientific research and development, systemic failures in the work of technical devices in the sphere of Industry 4.0;
– international factors: unfavorable geo-economic situation, violation of international economic connections and related failures in supply of necessary technologies, spare parts, and equipment for formation and development of Industry 4.0.

The seventh stage envisages monitoring and control over formation and development of Industry 4.0 and knowledge economy's formation. It is conducted in three main directions. The first direction is related to determining the level of favorable character of the macro-economic situation for implementing these processes. Thus, in the conditions of socio-economic crises, it is necessary to pay more attention to processes of formation and development of Industry 4.0 and knowledge economy's formation than in the period of stability, as in the period of crisis the macro-economic situation is unstable, and these processes can become uncontrolled, which will lead to distortions in implementation of adopted strategies of their formation and development.

The second direction is evaluation of effectiveness of Industry 4.0 from the point of view of stimulating the development of knowledge economy. For that, the authors' methodological recommendations could be used (Chap. 9). If the target values of separate indicators or coefficient of effectiveness are not achieved, it is necessary to correct the initial strategy of formation and development of Industry 4.0 in the conditions of knowledge economy's formation, in case of exceeding and/or overtaking the planned rate of implementation of this strategy, it is recommended to reconsider strategic goals and terms of their implementation.

The third direction is envisages evaluation of potential and realized risks, and, what is more important, negative externalities ("side effects") for socio-economic system from formation and development of Industry 4.0. In case of exceeding the allowable level of risk and emergence of critical negative externalities, it is necessary to increase state interference with market processes and, if necessary, termination (until elimination) of the process of formation and development of Industry 4.0.

As a result of the performed monitoring and control, experience is accumulated and analyzed, and return to the first stage is performed. That is, the developed algorithm of managing the process of formation and development of Industry 4.0 in the modern economic systems in the conditions of knowledge economy's formation is cyclic and allows for continuing work of this process in the interests of socio-economic system.

4 Conclusions

Thus, the authors offer a perspective methodological tools for achieving flexibility and adaptability of managing the process of formation and development of Industry 4.0 in modern economic systems. The developed algorithm has the following additional advantages:

- complex character: the offered algorithm takes into account not only purposes of formation and development of Industry 4.0 but also the possibilities of the socio-economic system in their achievement, which are determined by progress in formation of knowledge economy, and allows balancing these goals with the goals of knowledge economy's formation, thus optimizing the management of the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation;
- universality: this algorithm could be used in any socio-economic systems, as it envisages consideration of national peculiarities and successful adaptation to them, and it could be used at any phase of the economic cycle, including the phase of stability and the phase of crisis;
- interactive character: the developed algorithm is based not on tough framework but on selection from existing alternatives and constant correction of the strategy of managing the process of formation and development of Industry 4.0 in modern

economic systems in the conditions of knowledge economy's formation depending on the current situation;
– cyclicity: the authors' algorithm envisages accumulation of experience, which ensures constant improvement of management of the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation.

A drawback of the offered algorithm for managing the process of formation and development of Industry 4.0 in modern economic systems in the conditions of knowledge economy's formation is its framework character, which complicates its practical application by economic systems. Higher detalization of this algorithm is impossible at this stage due to insufficient experience in formation of Industry 4.0. That's why it is expedient to take into account the accumulated experience and new data for elaboration of the offered algorithm during further research.

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Part VI
Optimization of the Process of Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation

Systemic Contradictions of Modern Economic Systems That Hinder Formation and Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation and Methods of Overcoming Them

Julia V. Gnezdova, Elena N. Rudakova and Olga P. Zvyagintseva

Abstract The purpose of the article is to determine the contradictions and perspective means of overcoming them. The authors use the method of systematization and classification, the method of systemic and problem analysis, induction, deduction, and the method of data formalization. It is found that different categories of countries are peculiar for various systemic contradictions that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation. In developed countries, these contradictions are related to lack of desire of private business to stimulate implementation of national strategies of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and emerge due to high level of risk of these strategies with uncertain private commercial effect and social consequences. In developing countries, systemic contradictions are usually caused by unreadiness of separate elements of economic systems (social sphere, investment and financial sphere, normative and legal sphere, etc.) for formation and development of Industry 4.0 in the conditions of knowledge economy's formation. At that, despite high interest of economic subjects, practical implementation of initiatives in the sphere of Industry 4.0 at this stage of socio-economic development of economic systems is impossible. The authors determined that systemic contra-

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dictions in these categories of countries are opposite to each other. Based on this, it is concluded that the most effective means of provision of quick formation and development of Industry 4.0 in the conditions of knowledge economy's formation is not overcoming of these contradictions separately, the methods for which are given in this chapter, but strengthening of the integration processes in the global economy. Unification of efforts and close systemic interaction between the developed and developing countries will allow eliminating these contradictions due to elimination of their initial reasons with minimum expenditures of resources and time, as well as smallest transformations in economic systems.

Keywords Systemic contradictions · Modern economic systems · Formation and development of Industry 4.0 · Knowledge economy

1 Introduction

Perspectives of development of Industry 4.0 in modern knowledge economy are predetermined by timeliness of the necessary institutional measures, adequacy of the state policy of management of this process, and the level of coordination of efforts and initiatives of all interested parties. The accumulated experience in the sphere of formation and development of Industry 4.0 in the conditions of knowledge economy's formation shows contradictions of this process.

On the one hand, the concept of Industry 4.0 was scientifically acknowledge during several years after its appearance and began to be applied at the level of private entrepreneurial initiatives and at the level of national strategies of development. On the other hand, despite a lot of initiatives, there are no results of formation and development of Industry 4.0 in the conditions of knowledge economy's formation, and all existing information in this sphere is based on forecast data.

As compared to the concept of knowledge economy, it is possible to see that it acquired practical application and is being implemented in various countries. Statistical accounting of the global and macro-economic progress in the sphere of formation of knowledge economy is conducted at the level of international organizations. This contradiction shows the problems on the path of practical implementation of the concept of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and emphasizes high topicality of scientific research of this problem and search for means for solving it.

The working hypothesis of the research consists in the fact that modern economic systems are peculiar for systemic contradictions that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation. The purpose of the chapter is to verify the offered hypothesis, determine these contradictions, and determine the perspective means of overcoming them.

2 Materials and Method

The performed content analysis of scientific literature on the issues of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in modern economic systems showed that they are studied indirectly in a lot of works of modern authors. Thus, readiness of economic systems to formation of Internet economy is studied in the article (Sukhodolov et al. 2018), and peculiarities of managing the leading technologies (by the example of nano-technologies)—in the article (Frolov et al. 2015).

These works study the possibilities and barriers on the path of modernization of modern economic systems (by the example of Russia), of which transition to Industry 4.0 is a part. However, the revolutionary character of formation and development of Industry 4.0 sets higher requirements to modern economic systems than the process of formation of Internet economy and formation of nano-industry, which complicates application of these works to studying readiness of modern economic systems to formation and development of Industry 4.0 in the conditions of knowledge economy's formation.

We also determined that the works of modern authors that are devoted to studying the foundations of transition of economic systems to Industry 4.0, among which are publications (Meißner et al. 2017; Klement et al. 2017; Guizzi et al. 2017; Sanders et al. 2017; Rylnikova et al. 2017; Maksimchuk and Pershina 2017; Veselovsky et al. 2017), emphasize high complexity of this process, predetermined by its revolutionary direction. The work (Jakobs et al. 2018) states that the modern global economy is not ready for the Fourth Industrial Revolution. At that, the works do not provide specific practical peculiarities and problems of socio-economic systems that are related to formation and development of Industry 4.0 in the conditions of knowledge economy's formation, which reduces their practical value.

As a result of acquaintance with applied research in the sphere of studying the essence of the process of formation of Industry 4.0, which include (Legat and Vogel-Heuser 2017; Chiu et al. 2017; Kopacz et al. 2017; Cotet et al. 2017; Giannetti 2017; Rodič 2017; Kai et al. 2017; Chromjakova et al. 2017; Bortolini et al. 2017; Li et al. 2017), we came to the conclusion that their authors concentrate on the problems of separate technologies in the sphere of Industry 4.0 and experience of separate companies in transition to Industry 4.0. Therefore, these works are peculiar for narrow direction, which does not allow using them during macro-economic analysis of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in modern economic systems.

Thus, systemic contradictions of modern economic systems that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation and methods of overcoming them are poorly studied and requires further scientific research—which is performed in this chapter. The authors use the methods of systematization and classification, the method of systemic and problem analysis, induction, deduction, and method of data formalization.

3 Results

As a result of complex study of accumulated experience and peculiarities of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in various modern economic systems, we determined and systematized their systemic contradictions that hinder this process. These contradictions are classified according to two categories of countries: developed and developing countries, with provision of their causes and means of overcoming them (Table 1).

As is seen from Table 1, during studying the category of developed countries, we determined two main systemic contradictions that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation. The first one is related to initiative at the macro-level with relative passivity at the micro-level. That is, despite the adopted official national strategies of transition to the new technological

Table 1 Systemic contradictions of modern economic systems that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation and methods of overcoming them

Category of countries	Systemic contradictions	Reasons for appearance	Means of their overcoming
Developed countries	Initiative at the macro-level with relative passivity at the micro-level	Low investment attractiveness of Industry 4.0 for private investors and companies	Further strengthening of normative and legal provision
	Deficit of investments in Industry 4.0 with accessibility of financial resources		Expansion of stimuli for private investors
Developing countries	Differences in the level of social and economic development	Slow growth rate of social progress	Stimulation of formation of digital society
	Large number of private entrepreneurial initiatives during opposition to the industrial revolution at the macro-level	Lack of state's interest in the industrial revolution	Development of civil society, strengthening of business connections, and promotion of private interests at the state level
	Large number of innovational ideas, but lack of the possibility for their practical implementation	Lack of protection of intellectual property, deficit of investments	Incrase of protection of intellectual property, improvement of investment climate

Source Compiled by the authors

mode (Industry 4.0) in developed countries, entrepreneurial structures show weak interest to the future Industrial Revolution and do not want to participate in it.

The second contradiction consists in deficit of investments in Industry 4.0 with accessibility of financial resources. Developed countries are peculiar for excess of capital (financial resources)—however, only government investments are directed into Industry 4.0 from these countries. In the conditions of post-crisis development of modern economic systems, a lot of counties face the problem of deficit of state budget—but even in case of absence of this problem, the top-priority item of government expenditures is social measures. In both cases, Industry 4.0 is financed by the state according to the leftover principle, which leads to deficit of investments in this sphere.

The reason for emergence of these contradictions is low investment attractiveness of Industry 4.0 for private investors and companies. In the post-crisis conditions, private investors prefer to minimize the risk of investing. That's why innovational projects in the sphere of Industry 4.0, which are peculiar for high risk level and long-term period of return of investments, possess low investment attractiveness—despite the expected high profitability rate in the future.

A perspective means of overcoming the first contradiction is further strengthening of normative and legal provision in the sphere of Industry 4.0. Strong institutional base will allow raising interest of private companies and attracting them to implementation of national strategies of Industry 4.0 formation. A means of overcoming the second contradiction is expansion of stimuli for private investors in the sphere of Industry 4.0. These stimuli should reduce the risk level and could include provision of state guarantees of return of investments, provision of tax credits or tax holidays for the R&D, implementation of innovations in production, etc.

In developing countries, systemic contradictions that hinder the formation and development of Industry 4.0 in the conditions of knowledge economy's formation include differences in the level of social and economic development, caused by slower rate of social progress and formation of digital society, as compared to economic progress and formation of digital economy. These contradictions include the large number of private entrepreneurial initiatives with opposition to the Industrial Revolution at the macro-level. That is, entrepreneurial structures show readiness and interest in transition to Industry 4.0, while the state does not show any interest to the new Industrial Revolution.

Another systemic contradiction in developing countries is a lot of innovational ideas, but lack of the possibility for their practical implementation. Most of developing countries have large intellectual potential—developed human resources that possess high qualification and creative (innovational) capabilities. However, due to lack of protection of intellectual property and deficit of investments, intellectual potential in developing countries is not fully implemented which slows down formation and development of Industry 4.0.

These systemic contradictions, which hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation in developing countries could be overcome with stimulation of formation of digital society by implementing the corresponding state social policy, development of civil society, strengthening of business connections, promotion of private interests at the state level, increase of protection of intellectual property, and improvement of investment climate—especially, in the sphere of Industry 4.0.

4 Conclusions

Thus, it was determined that different categories of countries are peculiar for various systemic contradictions that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation. In developed countries, these contradictions are related to lack of desire of private business to stimulate implementation of national strategies of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and lead to high level of risk of these strategies with uncertain private commercial effect and social consequences.

In developing countries, systemic contradictions are predetermined by unreadiness of separate elements of economic systems (social sphere, investment and financial sphere, normative and legal sphere, etc.) to formation and development of Industry 4.0 in the conditions of knowledge economy's formation. At that, despite high interest of economic subjects, practical implementation of initiatives in the sphere of Industry 4.0 at this stage of socio-economic development of economic systems is impossible.

We determined that systemic contradictions in these categories of countries are directly opposite. For example, government initiatives dominate in developed countries, and entrepreneurial initiatives dominate in developing countries; developed countries have necessary investments, but commercial attractiveness of projects in the sphere of Industry 4.0 is low, while developing countries have a lot of commercially attractive projects in the sphere of Industry 4.0, but there's also deficit of investments, etc.

That's why we think that the most effective means of providing quick formation and development of Industry 4.0 in the conditions of knowledge economy's formation is not overcoming of the determined contradictions separately, the methods for which are given in this chapter, but strengthening of integration processes in the global economy. Unification of efforts and close systemic interaction between developed and developing countries will allow eliminating these contradictions due to elimination of their basic reasons with minimum expenditures of resources and time and the smallest transformations in economic systems.

We're sure that there's a need for refusal from competition for common profit and global good. Economic subjects and economic systems should shift from orientation at own interests that are related to formation and keeping of competitive advantages at the global arena, to common interests in the scale of the global economy. This will allow preventing the future tendency for increase of differentiation of countries in the global economy and harmonizing relations between participants of the global economic system.

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The Institutional Model of Formation and Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation

Alexander A. Galushkin, Andrey G. Nazarov, Elena N. Sabyna and Tatiana V. Skryl

Abstract The purpose of the article is to develop the institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and to determine the relevance of the institutional provision of this process in the modern economic systems. The research is performed within the new institutional economic theory (neo-institutionalism) and is based on the following methods: empirical methods, which are aimed at determining and descripting the institutes that are necessary for successful formation and development of Industry 4.0 in the conditions of knowledge economy's formation; the method of analytical modeling that is applied for developing the institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation. The authors also use the method of formalization for graphical interpretation of this model and the method of comparative analysis, which is used by the authors for determining the relevance of institutional provision of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in modern economic systems through comparing the received model to the institutional practice of developed and developing countries of the world. As a result, the authors develop and present the institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation, which reflects the need of modern economic systems for the corresponding institutes. The performed comparative analysis showed that institutional provision of the process of forma-

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tion and development of Industry 4.0 in the conditions of knowledge economy's formation in modern economic systems is not formed and is peculiar for three main problems: incompletion of the process of formation of necessary institutes, presence of "institutional traps", and weakness of connections of various institutes.

Keywords Institutionalization · Industry 4.0 · Knowledge economy · Developed countries · Developing countries

1 Introduction

The existing systemic contradictions of modern economic systems that hinder formation and development of Industry 4.0 in the conditions of knowledge economy's formation and methods of overcoming them are of the institutional nature. Firstly, systemic character of these contradictions shows larger depth of their distribution in the structure of socio-economic systems. This makes detailed study of these contradictions with the help of the method of surface analysis impossible and requires studying the institutional foundations of implementation of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation.

Secondly, these contradictions are manifested in the work of socio-economic institutes—state, entrepreneurship, civil society, etc. Moreover, the revolutionary character of transition of modern economic systems to Industry 4.0 is a basis for the idea that traditional institutes could not be applied in this process, and it is necessary to created and develop highly-effective work and sustainable interaction between new—relevant institutes. That's why without institutional analysis, studying the causal connections of emergence and overcoming of these contradictions cannot ensure precise results.

This explains the topicality of studying the institutional aspect of formation and development of Industry 4.0 in the conditions of knowledge economy's formation. The authors offer a hypothesis that the institutes that are necessary for successful formation and development of Industry 4.0 in the conditions of knowledge economy's formation are not yet formed in modern economic systems. The purpose of the chapter is to develop the institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and to determine the relevance of institutional provision of this process in modern economic systems.

2 Materials and Method

Insufficient elaboration of the institutional aspect of formation and development of Industry 4.0 in the conditions of knowledge economy's formation is proved by the small number of studies in this scientific sphere and lack of references to connection to the institutional theory.

Most studies are devoted to various issues of modernization of difference universities in the process of formation of Industry 4.0 and formation of knowledge economy. These include Mosey et al. (2012), Hilty et al. (2009), Chen et al. (2017), Kadir (2017). That is, from the positions of the institutional theory, they view only the institute of science and education, while other institutes that participate in the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation remain without scholars' attention.

In other works, experts' attention is focused on studying the institutional mechanisms of formation and development of knowledge economy without connection to Industry 4.0. These are publications Sukhodolov et al. (2018), Pokrovskaia (2017). Managerial issues of state regulation of the process of knowledge economy's formation are studied in the works Amavilah et al. (2017), Macias Vazquez and Alonso Gonzalez (2016), Chou and Gornitzka (2014), Bogoviz et al. (2017).

In its turn, certain authors analyze the essence and peculiarities of managing the process of formation and development of Industry 4.0 on the basis of the institutional theory. These include the works Savtschenko et al. (2017), Pfliegl and Keller (2015). At that, peculiarities of functioning and development of socio-economic systems in the conditions of knowledge economy's formation are not taken into account.

Based on the performed literature overview on the selected topic, it is possible to conclude that the existing research and publications do not envisage the institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation, and unification of results of research of various authors does not allow creating such model. This is a basis for further scientific studies, which are aimed at research of the institutional aspect of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and compilation of the corresponding institutional model.

The authors perform the research within the new institutional economic theory (neo-institutionalism) and use the following methods of this theory: empirical methods, which are aimed at determining and describing the institutes that are necessary for successful formation and development of Industry 4.0 in the conditions of knowledge economy's formation; the method of analytical modeling that is applied for developing the institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation.

The authors also use the method of formalization for graphic interpretation of this model and the method of comparative analysis for determining the relevance of institutional provision of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in modern economic systems through comparison of the received model with the institutional practice of developed and developing countries of the world.

3 Results

Complex study of the process of institutionalization of Industry 4.0 in the conditions of knowledge economy's formation in countries of the world allows determining the main common features and the key institutes that are involved in this process and defining their roles. As this process envisages revolutionary transformations in the economic system on the whole, it is necessary to regulate it for crisis management and maximization of positive effect.

This requires the institute of strategic management of the process of formation and development of Industry 4.0. This institute is created on the basis of the state and acquires the form of state establishment (or several establishments), which is assigned with responsibilities and authorities for setting the goals and landmarks of development of Industry 4.0 and conduct of monitoring and control over the process of formation and development of Industry 4.0. This could be an existing establishment, which acquires a new role, or a new establishment, which has to perform this role in the economic system.

In developed countries, development and adoption of the strategy (setting goals and landmarks) of formation and development of Industry 4.0 are performed at the level of the highest legislative body, and the functions of conduct of monitoring and control over the process of formation and development of Industry 4.0 are set on the corresponding ministries and departments, which are responsible for preparation and supporting in the actual state of infrastructural provision of Industry 4.0. In developing countries, this institute is not yet formed.

Successful functioning of Industry 4.0 requires highly-effective resource provision, which requires creation of the three following institutes. The 1st is the institute of venture investments into Industry 4.0. Within this institute, the terms for attraction and distribution of investments between innovational projects in the sphere of Industry 4.0 are set—i.e., financing of this sphere is ensured.

2nd: the institute of R&D in the sphere of Industry 4.0. This institute could be created on the basis of entrepreneurial structures and on the basis of R&D institutes. It provides technological support for the Fourth Industrial Revolution. 3rd: the institute of preparation of personnel for Industry 4.0. It is created within the sphere of science and education and provides personnel support for Industry 4.0.

At present, these institutes are not developed in developed or developing countries. Despite the national projects and forecasts, there are no educational programs for training of specialists in the sphere of Industry 4.0; scientific R&D in this sphere are conducted in the limited scale, and private investments into this sphere are scarce. That's why insufficient resource provision is a restraining factor on the path of formation and development of Industry 4.0 in modern economic systems.

The main—production—function in the process of formation and development of Industry 4.0 is performed by the institute of entrepreneurship in the sphere of Industry 4.0. Within this institute, products in the sphere of Industry 4.0 are manufactured. On the basis of the existing infrastructure and accessible resources, this institute created goods, performs works, and provides services in the sphere of Industry 4.0.

This could be private or state entrepreneurship and entrepreneurship in the form of public-private partnership. At present, this institute is not yet formed in the countries of the world, and products in the sphere of Industry 4.0 are not manufactured.

A top-priority meaning of Industry 4.0 for the national economy is a basis for state stimulation of business activity in this sphere. In order to ensure target application of the measures of this stimulation, it is necessary to ensure systemic control over the activities of entrepreneurial structures, which allows determining the authenticity of their work in the sphere of Industry 4.0.

In addition to this, unprecedented novelty of products in the sphere of Industry 4.0 is a reasons of its potential danger for consumers. That's why there's a necessity for control over quality of these products. Both these functions are to be performed by the institute of certification of quality of products in the sphere of Industry 4.0. Absence of entrepreneurship in the sphere of Industry 4.0 eliminates the necessity for control of quality of the products of this sphere and is a reason for underdevelopment of this institute in modern countries of the world.

Successful selling of the products of Industry 4.0 and obtaining of useful effect from its practical usage requires the institute of consumption of the Industry 4.0 products. This institute could be created in B2C- and/or B2B spheres of economy. Within this institute, the products of Industry 4.0 are purchased and used. At present, this institute is at the stage of formation. In developed countries, digital society is already created, and this institute is almost ready, while in developing countries digital society is in the process of formation, which does not allow for creation of this institute.

Based on the performed institutional analysis, we developed the following institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation (Fig. 1).

The model that is presented in Fig. 1 shows the systemic character and integrity of institutional provision and close interaction between all institutes that are involved in the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation. It is possible to see that the mechanism of work of Industry 4.0 envisages stage-by-stage application of these institutes. The institute of strategic management starts the process of formation and development of Industry 4.0.

Then, the institutes of resource provision start working: the institute of venture investment into Industry 4.0, the institute of R&D in the sphere of Industry 4.0, and the institute of training of personnel for Industry 4.0. Then, the institute of entrepreneurship in the sphere of Industry 4.0 starts working, which is followed by the institute of certification of quality of products in the sphere of Industry 4.0, which is followed by the institute of consumption of Industry 4.0 products.

Consecutive work of various institutes reflects dynamics of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation. Successfulness of this process is largely determined by presence and effectiveness of functioning of all distinguished institutes. At that, it should be acknowledged that some of them appear with necessity under the influence of the mechanism of formation and development of Industry 4.0 in the conditions of knowledge econ-

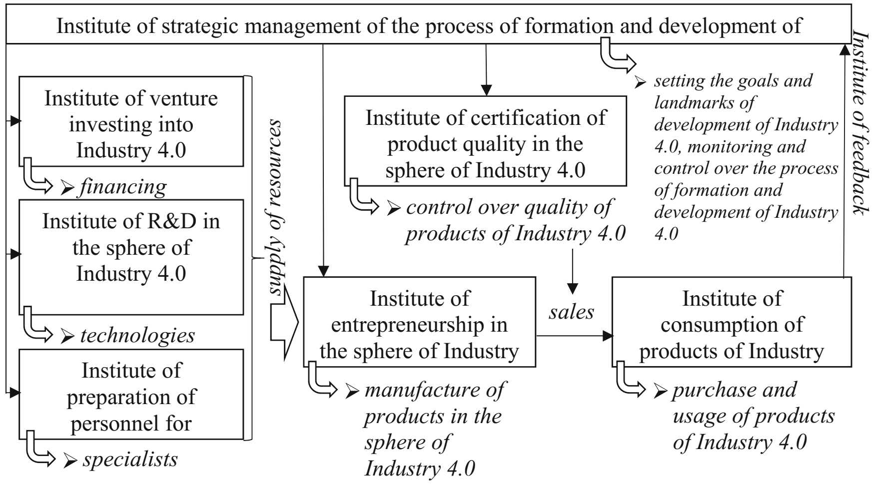

Fig. 1 The institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation. *Source* Compiled by the authors

omy's formation, and other—the institute of strategic management and institutes of resource provision—should be created beforehand, for starting this process.

The model also offers the mechanism of feedback between final consumer and strategic center, which ensures constant possession of complete, precise, and actual information on formation and development of Industry 4.0 in the conditions of knowledge economy's formation and ensures timely correction of the strategy and tactics of management of this process.

4 Conclusions

It should be concluded that developed and presented institutional model of formation and development of Industry 4.0 in the conditions of knowledge economy's formation reflects the need of modern economic systems for the corresponding institutes. The performed comparative analysis showed that institutional provision of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in modern economic systems is not yet formed and is peculiar for three main problems.

The first problem is incompletion of the process of formation of the necessary institutes. In developing countries, only one out of seven institutes that are necessary for formation and development of Industry 4.0 is in the process of formation—the institute of entrepreneurship in the sphere of Industry 4.0. In developed countries, most institutes are formed, but some of them are not formalized and need to be legislatively adopted.

The second problem is presence of "institutional traps". The most vivid example of this phenomenon is the institute of venture investing in developed countries. Having appeared in the interests of optimization of capital flows (financial resources), this institute serves private commercial interests and, despite high need of Industry 4.0 for investments and society's interest in its development, the required investments are not directed into this sphere due to high risks of investors.

The third problem is instability of connections of various institutes. For example, the institute of entrepreneurship in the sphere of Industry 4.0 and the institute of consumption of Industry 4.0 products are not connected. Digital society does not interact with high-tech entrepreneurial structures, which complicates selling of their products due to complexity of their usage by consumers. Products of Industry 4.0 is revolutionary, which requires close interaction between these institutes, which allows informing consumers on advantages of these products and teaching them peculiarities of their usage.

Thus, successful institutionalization of Industry 4.0 in the conditions of knowledge economy's formation requires formalization of non-formalized institutes, overcoming of "institutional gaps", and strengthening of connections between various institutes that are involved in this process. Determining of perspective regulatory mechanisms, which allow implementing these measures in practice, is a perspective direction for further scientific studies.

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Scenarios of Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation and Their Consequences for Modern Economic Systems

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Abstract The purpose of the chapter is to determine the main possible scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and to determine their consequences for modern economic systems. The methodology of the research, which is conducted in this chapter, is based on using the method of macro-economic scenario analysis. This analysis is of the qualitative character, as it is performed not by the example of specific socio-economic systems but abstract (generalized) modern economic systems. This method is supplemented by analysis of causal connections and the method of formalization of scientific data.

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The performed analysis allowed determining the main scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and showed that their consequences could be different. Lack of statistical data and experience of formation and development of Industry 4.0 is a basis for setting the same probability for all distinguished scenarios. The most pessimistic scenario is the one envisaging implementation of hidden threats to the concept of Industry 4.0 in the process of its practical implementation, as its consequences are imbalance and crisis of economic systems and of the global economy on the whole. There's also scenario that envisages impossibility of practical implementation of the concept of Industry 4.0. It belongs to pessimistic scenarios, as it is related to implementation of innovational macro-economic project—formation of Industry 4.0. Optimistic scenarios include turning Industry 4.0 into the tool of formation of knowledge economy, which could be accompanied by appearance of large problems and their absence, which determine the time period of implementation of these scenarios. Positive consequences of these scenarios for modern economic systems are related to stimulation of quick formation of knowledge economy. The most optimistic scenario is the one that envisages implementation of the Fourth Industrial Revolution, related to transition to Industry 4.0, on the basis of knowledge economy. Consequences of this scenario include the change of technological mode, innovational development of economic systems, and studying anti-crisis effect.

Keywords Scenarios of development · Industry 4.0 · Formation of knowledge economy · Consequences · Modern economic systems

1 Introduction

During development of the strategies of formation and development of Industry 4.0 in the conditions of knowledge economy's formation, economic systems should take into account all possible variants of development of events. This is necessary for successful comparison of risks and profits from implementation of this process. Formation of Industry 4.0 is an innovational projects that is implemented in the macro-economic scale—at the level of economic systems.

That's why during implementation of this project it is expedient to conduct classical analysis, which envisages determining advantages and drawbacks and forming the risk threshold for each economic systems. In case of exceeding the risk threshold, it is expedient to refuse from practical implementation of the concept of Industry 4.0, as it could lead to destabilization of the economic systems that is in the phase of crisis or post-crisis restoration.

Preliminary analysis of causal connections for formation and development of Industry 4.0 is required for compilation of a reserve plan—i.e., plan of actions in case of various circumstances. This will allow preventing the emergence or minimizing the scale of crisis of socio-economic systems in case of emergence of negative consequences. Clear detailed plan for each of consequences will allow for quick reaction.

A basis for forecasting is also striving for maximization of the target and the corresponding positive effects. Preliminary analysis allows determining the optimal means of achieving the target effect and determining the possible additional advantages from formation and development of Industry 4.0 in the conditions of knowledge economy's formation, thus maximizing the effectiveness of this process, by reducing expenditures of resources and time with simultaneous increase of gained advantages.

These reasons show actuality of forecasting the scenarios of practical implementation of the concept of Industry 4.0 and analysis of their consequences. The purpose of this chapter is to determine the main possible scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and to determine their consequences for modern economic systems.

2 Materials and Method

Overview of the existing scientific literature on the studied issue allowed concluding that the level of its elaboration is high. The methods of diagnostics of functioning of various technologies of Industry 4.0 are studied in a lot of works of modern authors, which include (Li et al. 2017; Wilke and Magenheim 2017; Zug et al. 2015).

Traditional and innovational technologies of scenarios analysis of formation and development of Industry 4.0 in modern economic systems are described in detail in the works (Dragičevic et al. 2017; Sánchez et al. 2016; Da Silva and Kaminski 2016; Herter and Ovtcharova 2016; Erol et al. 2016; Kiesel and Wolpers 2015; Chakraborty 2016; Bogoviz et al. 2017).

Scenarios of formation and development of knowledge economy in countries of the world are described in publications (Iastremska and Martynenko 2015; Leslie and Rantisi 2012), and Internet economy—(Popkova et al. 2018; Sukhodolov et al. 2018a, b, c, d).

However, despite the high level of elaboration, the issue of this chapter cannot be solved on the basis of existing research and publications, as some of them reflect mostly micro-economic aspect, while this problem belongs to the macro-economic level of socio-economic systems. Other works develop the methodological basis of the research of this problem, without ensuring its approbation and offering no practical results.

Other studied take into account separate manifestations (components) of this problem—knowledge economy or high-tech spheres of economy,—hindering the generalization of the received results and conclusions for the process of development of Industry 4.0 in the conditions of knowledge economy's formation. These reasons show the necessity for further scientific study of scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and their consequences for modern economic systems.

The methodology of the research is based on using the method of macro-economic scenario analysis. This analysis is of mostly qualitative character, as it is performed not by the example of specific socio-economic systems, but with abstract (generalized) modern economic systems. This method is supplemented by the method of analysis of causal connections and the method of data formalization.

3 Results

As a result of scenario analysis, the following scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and their consequences for modern economic systems were determined (Table 1).

As is seen from Table 1, we distinguished five main scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation. The first scenario envisages turning Industry 4.0 into a tool for formation of knowledge economy without significant problems. It allows implementing the concept of Industry 4.0 in the mid-term period (5–10 years).

The second scenario envisages turning Industry 4.0 into a tool of formation of knowledge economy with substantial problems. These problems could have various nature and include social barriers (underdevelopment of digital society), technological barriers (unreadiness of technologies of Industry 4.0 to practical usage), political barriers (underdevelopment or weakness of normative and legal provision of formation and development of Industry 4.0) and other barriers. Due to this, the term of practical implementation of the concept of Industry 4.0 grows and reached long-term period (10–20 years and more).

Within first two scenarios, Industry 4.0 has a secondary role in economic systems, being one of high-tech spheres of industry. It limits the influence of Industry 4.0 on economic systems and reduces the scale of their innovational development, which is expressed at the meso-level—i.e., at the level of separate spheres of economy—-spheres of Industry 4.0 and related spheres. Anti-crisis effect is also minimal. At the same time, positive externalities dominate in the form of stimulation of formation of knowledge economy.

The third scenario is implementation of the Fourth Industrial Revolution on the basis of knowledge economy. In this case, Industry 4.0 is a new technological mode that transforms modern socio-economic systems. This scenario envisages large-scale transformations of economic systems, which are possible only in the long-term.

Due to comprehensive influence of Industry 4.0 on socio-economic systems, maximum scale of their innovational development and large anti-crisis effect are achieved within this scenario. This scenario envisages domination of positive externalities—additional advantages that appear in the process of formation and development of Industry 4.0—the scale of which could be different and depends on the peculiarities of socio-economic systems that implement the concept of Industry 4.0.

The fourth scenario reflects impossibility of practical implementation of the concept of Industry 4.0. As any innovational project, the concept of formation of Industry

Table 1 Scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and their consequences for modern economic systems

Characteristics of scenarios	Scenarios of Industry 4.0 in the conditions of knowledge economy's formation				
	Turning of Industry 4.0 into a tool for formation of knowledge economy		Implementation of the fourth industrial revolution on the basis of knowledge economy	Impossibility of practical implementation of the concept of Industry 4.0	Hidden threats to the concept of Industry 4.0
	Absence of significant problems	Presence of significant problems			
Approximate probability of scenario's implementation	0.20	0.30	0.20	0.15	0.15
Resulting role of Industry 4.0 in economic systems	One of high-tech spheres of industry		New technological mode	Ineffective project	Source of crisis
Period of implementation of scenario	Mid-term	Long-term	Long-term	Uncertain period	
Scale of innovational development of economic systems	Innovational development is manifested at the meso-level—at the level of separate spheres of economy		The whole economy undergoes innovational development	Innovational development does not take place	Could be various
Anti-crisis effect from Industry 4.0	Anti-crisis effect is minimal		Large anti-crisis effect	Anti-crisis effect is zero	Could be various
Determining externalities ("side effects")	Positive externalities dominate in the form of stimulation for formation of knowledge economy		Positive externalities dominate	Could be different	Negative externalities dominate

Source Compiled by the authors

4.0 could be unrealistic or require creation of such socio-economic conditions in economic systems that are unattainable as of now. In this case, time and resources that are spent for this project will not be returned and will not bring the expected target results—which makes this project ineffective.

The period of implementation of this scenario is not determined. It depends on the time when economic systemsы realize that the concept of Industry 4.0 does not lead to achievement of the set goal and refuse from its practical implementation. Within this scenario, formation of Industry 4.0 is not achieved, there is no innovational development of economic systems, and there is no anti-crisis effect. Externalities ("side effects") could be various and could include unexpected advantages and various threats.

The fifth scenario is emergence of hidden threats to the concept of Industry 4.0. This scenario is the worst, as it turns Industry 4.0 into a source of crisis of modern socio-economic systems. That is, practical implementation of the concept of Industry 4.0 is failed, during which negative consequences ("side effects") of formation and development of Industry 4.0 are seen.

This scenario could be implemented in any time period, as negative consequences could be manifested after a long period of time. It should be noted that this scenario does not exclude achievement of target and corresponding advantages from formation and development of Industry 4.0. That is, innovational development of economic systems and gaining the anti-crisis effect are possible. However, negative externalities are so large that they exceed positive effects and lead to the necessity for refusal from practical implementation of the concept of Industry 4.0.

Table 1 shows probability of implementation of each distinguished scenario. According to the forecast, the most probable (0.30) is the scenario that envisages turning Industry 4.0 into the tool for formation of knowledge economy with substantial problems. Next (0.2) come the scenario that envisages turning Industry 4.0 into the tool of formation of knowledge economy with no substantial problems and the scenario that envisages implementation of the Fourth Industrial Revolution. The least probably (0.15) are the scenarios that envisage impossibility of implementation of the concept of Industry 4.0 or presence of hidden threats.

4 Conclusions

The performed analysis allowed determining the main scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and showed that their consequences could be various. Absence of statistical data and experience of formation and development of Industry 4.0 is a basis for setting equal probability for all distinguished scenarios. The most pessimistic scenario is the one that envisages implementation of hidden threats to the concept of Industry 4.0 in the process of its practical implementation, as its consequences are imbalance and crisis of economic systems, and, probably, global economy on the whole.

There's also scenario that envisages impossibility of practical implementation of the concept of Industry 4.0. It belongs to pessimistic scenarios, as it is related to implementation of ineffective innovational macro-economic project—formation of Industry 4.0. Optimistic scenarios include turning Industry 4.0 into the tool of formation of knowledge economy, which could be accompanied by emergence of substantial problems or their absence, which determine the time period of implementation of these scenarios.

Positive consequences of these scenarios for modern economic systems are related to stimulation of quick formation of knowledge economy. The most pessimistic—i.e., optimal—scenario is the one that envisages implementation of the Fourth Industrial

Revolution, which is related to transition to Industry 4.0 on the basis of knowledge economy. Consequences of this scenario are change of the technological mode, innovational development of economic systems, and gaining anti-crisis effect.

It should be noted that these scenarios are generalized—which is a limitation of the results of the performed research. Compiling more precise forecasts on the basis of at least initial experience and preliminary statistical information of specific socio-economic systems will allow considering the scenarios in detail—which constitutes the perspectives for further scientific studies in this sphere.

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Methodology of Criterial Evaluation of Consequences of the Industrial Revolution of the 21st Century

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Abstract The purpose of this chapter is to develop the methodology of criterial evaluation of consequences of the Industrial Revolution of the 21st century. At that, the authors use the traditional methodology of evaluating the effectiveness of socio-economic phenomena and processes, modifying it with application of general scientific methods of research: induction, deduction, analysis, synthesis, and formalization, As a result, the authors offer criteria for determining evaluation of consequences of the Industrial Revolution of the 21st century and methodological recommendations for their practical application. Due to systematization and classification of these criteria, the authors' formula has been developed for evaluating the effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0. The advantages of the offered methodology of criterial evaluation of consequences of the Industrial Revolution of the 21st century is consideration of not only main and target indicators of formation and development of Industry 4.0 in modern economic systems but also additional indicators. The offered recommendations for bringing the indicators to general measuring units with the help of special coefficients allow conducting complete and complex evaluation of consequences of the Fourth Industrial Revolution. The advantage of the offered methodology is high

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level of its detalization. The explained logic of treatment of the results of criterial evaluation of consequences of the Industrial Revolution of the 21st century with the help of this methodology envisages not only traditional accounting of the value of resulting indicator—coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0 but also considering other estimate criteria. Their model combinations allow determining the implemented scenarios of formation and development of Industry 4.0 in the conditions of knowledge economy's formation.

Keywords Criterial evaluation · Consequences of the industrial revolution of the 21st century · Industry 4.0

1 Introduction

The spontaneous character of industrial revolutions leads to potential danger for economic systems, as it makes these revolutions unpredictable, increasing the risk component in economy. Probably, due to this reason, the leading developed countries have taken measures for preventing spontaneous formation and development of Industry 4.0, overtaking private entrepreneurial initiatives in this sphere and adopting national strategies of its formation. Leading the new industrial revolution and aiming it in the necessary direction, the governments will be able to maximize positive socio-economic effects from this revolution and bringing down its possible drawbacks to minimum.

However, despite multiple advantages of these strategies, which allow making the Fourth Industrial Revolution manageable and, therefore, more predictable and less dangerous, their serious drawback is low level of detalization of methodological provision of managing the process of formation and development of Industry 4.0. In other words, strategies of management of the Fourth Industrial Revolution point out the necessity for monitoring and control over this process and set the ones responsible for them (the corresponding ministries and departments), but the methodology of its conduct is not described.

Complexity and diverse character of the Industrial Revolution do not allow using standard methods of evaluation of traditional socio-economic phenomena and processes to evaluation of its consequences, and uniqueness of the Fourth Industrial Revolution does not allow applying the methods of evaluation of consequences of previous industrial revolutions. This actualizes the scientific problem of development of methodological provision of evaluating the consequences of the Industrial Revolution of the 21st century. The purpose of the chapter is to develop the methodology of criterial evaluation of consequences of the Industrial Revolution of the 21st century.

2 Materials and Method

Methodological aspects of the Fourth Industrial Revolution, related to formation and development of Industry 4.0 in modern economic systems, are studied in multiple works of various authors. Traditional methodologies of studying causal connections and monitoring and control of the process of implementing the innovational projects, which include various measures for activation of economic growth at the corporate, regional, and national levels, as well as formation of Internet economy, are viewed in publications (Sukhodolov et al. 2018; Popkova et al. 2018; Bogoviz et al. 2017, 2018; Veselovsky et al. 2017).

Methodological recommendations for evaluating the consequences of creation and implementation into industrial production of separate technologies within the Industry 4.0 are given in the works (Demel et al. 2017; Perini et al. 2017; Tao et al. 2016). Technologies of evaluation of consequences of formation and development of Industry 4.0 for entrepreneurial structures and economic systems are described in the works (Zug et al. 2015; De Aguirre 2017; Bauernhansl et al. 2014; Bosso 2012; Demeter 2010; Li et al. 2017; Saniee et al. 2017; Murofushi and Tavares 2017; Mueller-Hummel and Langhorst 2016; Bisang et al. 2015; Šenberger and Hořická 2013).

The performed literature overview showed insufficient elaboration of the topic by modern science. Comprehensive methodological provision of criterial evaluation of consequences of the Industrial Revolution of the 21st century is not yet formed, which does not allow for monitoring and control of the process of formation and development of Industry 4.0 and makes its highly-effective management impossible—which requires further research aimed at formation of this methodological provision.

The authors solve this problem using the traditional methods of evaluation of effectiveness of socio-economic phenomena and processes, modifying it with application of general scientific methods—induction, deduction, analysis, synthesis, and formalization.

3 Results

As a result of studying and systematizing the methodological recommendations of modern authors and in view of peculiarities of possible scenarios of development of Industry 4.0 in the conditions of knowledge economy's formation and their consequences for modern economic systems, we offer the following criteria for evaluating the consequences of the Industrial Revolution of the 21st century (Table 1).

As is seen from Table 1, the offered estimate criteria are systematized and classified according to the principle of significance in the process of the Industrial Revolution of the 21st century and the character of their influence on socio-economic systems. Table 1 shows that measuring units of target positive and main negative consequences of formation and development of Industry 4.0 coincide—monetary units.

Table 1 Criteria for evaluating the consequences of the Industrial Revolution of the 21st century

Types of consequences		Symbols	Criteria	Measuring units
Positive consequences	Target	$GAV_{ind4.0}$	Gross added value created in Industry 4.0	$ billion
		$GAV_{sph.ec.}$	Gross added value created in spheres of economy that are based on products of Industry 4.0	
	Non-target	ΔIPLS (+)	Growth of the value of index of population's living standards	Points
		ΔIKE	Growth of the value of index of knowledge economy	Points
		$Dind4.0_{GDP}$	Share of Industry 4.0 in structure of GDP	%
		SHT_{GDP}	Share of high-tech spheres in the structure of GDP	%
		SIP_{exp}	Share of innovational products in the structure of export	%
		IS_{innov}	Volume of import substitution in innovational sphere of economy	$ billion
		ΔISS (+)	Growth of the value of index of sustainability of society	Points
		qGDP (−)	Reduction of standard deviation of GDP of countries of the world	$ billion
		DGDP (−)	Reduction of dispersion of GDP of countries of the world	%
		qRSD (−)	Reduction of standard deviation of GDP per capita of the countries of the world	$

(continued)

Table 1 (continued)

Types of consequences		Symbols	Criteria	Measuring units
		DDGDP (−)	Reduction of dispersion of GDP per capita of the countries of the world	%
Negative consequences and expenditures	Main	$SI_{ind4.0}$	Volume of state investments into Industry 4.0	$ billion
		$PI_{ind4.0}$	Volume of private investments into Industry 4.0	
		$II_{ind4.0}$	Volume of investments into infrastructure of Industry 4.0	
	Additional	GI_{innov}	Growth of import of innovational products	
		ΔIPLS (−)	Growth the value of the index of population's living standards	Points
		ΔISS (−)	Reduction of the value of index of sustainability of society	Points
		qGDP (+)	Increase of standard deviation of GDP of countries of the world	$ billion
		DGDP (+)	Increase of dispersion of GDP of countries of the world	%
		qRSD (+)	Increase of standard deviation of GDP per capita of countries of the world	$
		DDGDP (+)	Increase of dispersion of GDP per capita of countries of the world	%

Source Compiled by the authors

This ensures compatibility of data and allows using the classical methodology of evaluation of effectiveness as to the Industrial Revolution of the 21st century. This methodology has been modified in view of distinguished criteria and peculiarities of Industry 4.0, as a result of which the following formula has been received:

$$\begin{aligned} \mathrm{Ceff}_{\mathrm{ind.rev.}} = & \left(\mathrm{GAV}_{\mathrm{ind4.0}} + \mathrm{GAV}_{\mathrm{sph.ec}} + \mathrm{S}_{\mathrm{innov}} + \mathrm{qGDP}(-) + \mathrm{qRSD}(-)\right) * \mathrm{PIC}/ \\ & (\mathrm{SI}_{\mathrm{ind4.0}} + \mathrm{PI}_{\mathrm{ind4.0}} + \mathrm{II}_{\mathrm{ind4.0}} + \mathrm{qGDP}(+) + \mathrm{QRSD}(+)) * \mathrm{PRC} \end{aligned} \tag{1}$$

where

$\mathrm{Ceff}_{\mathrm{ind.rev.}}$ coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0;
PIC product of increasing coefficients;
PRC product of decreasing coefficients.

As is seen from Formula (1), the resulting indicator that reflects the results of evaluation of consequences of the Industrial Revolution of the 21st century is coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0. This coefficient is calculated by the traditional method of evaluation of effectiveness—finding the ratio of product of benefits (positive consequences) and product of increasing coefficients to product of the sum of expenditures (negative consequences) and product of decreasing coefficients.

The values of increasing and decreasing coefficients are determined on the basis of developed scales, which allow using for calculation of coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0 the values of the criteria that are not measured in monetary units. These scales are given in Table 2.

As is seen from Table 2, adjustable decreasing coefficients can take values from 0.8 to 1.0, and increasing coefficients—from 1.0 to 1.2. Logic of treatment of the results of criterial evaluation of consequences of the Industrial Revolution of the 21st century is explained in Table 3.

The data of Table 3 show that during consideration of the results of criterial evaluation of consequences of the Industrial Revolution of the 21st century it is necessary to pay attention to the distinguished main combinations of the values of criteria, which show implementation of certain scenarios of formation and development of Industry 4.0 in the conditions of knowledge economy's formation. Let us view these combinations and the corresponding scenarios in detail.

With large growth of the index of knowledge economy (more than 0.5 points), combined with low share of Industry 4.0 in the structure of GDP (less than 5%), it is possible to state that the scenario that envisages turning Industry 4.0 into the tool of knowledge economy has been implemented. This means that the Industrial Revolution has not taken place, but formation and development of Industry 4.0 ensured progress in formation of knowledge economy.

With large value of the coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0 (more than 5) and domination of positive externalities over negative ones, this scenario of development of events should be

Table 2 Interval scales for assigning the values to increasing and decreasing coefficients of effectiveness of the Industrial Revolution of the 21st century

Type of externalities	Criteria	Intervals of the values of criteria and the values that are assigned to the corresponding coefficients				
		0.8	0.9	1.0	1.1	1.2
Positive externalities—increasing coefficients	ΔIPLS (+)	–	–	(0–0,1)	[0.1–0.5)	0.5 and more
	ΔIKE	–	–	(0–0,1)	[0.1–0.5)	0.5 and more
	$Dind4.0_{GDP}$	–	–	(0–5)	[5–10)	10 and more
	SHT_{GDP}	–	–	(0–40)	[40–70)	70 and more
	SIP_{exp}	–	–	(0–20)	[20–50)	50 and more
	ΔISS (+)	–	–	[0.05–0.1)	[0.1–0.5)	0,5 and more
	DGDP (−)	–	–	(0–5)	[5–20)	20 and more
	DDGDP (−)	–	–	(0–5)	[5–20)	20 and more
Negative externalities—decreasing coefficients	ΔIPLS (−)	0.5 and more	[0.1–0.5)	(0–0,1)	–	–
	ΔISS (−)	0.5 and more	[0.1–0.5)	(0–0,1)	–	–
	DGDP (+)	20 and more	[5–20)	(0–5)	–	–
	DDGDP (+)	20 and more	[5–20)	(0–5)	–	–

Source Compiled by the authors

treated as implementation of the Fourth Industrial Revolution in the sphere of Industry 4.0 on the basis of knowledge economy. That is, the Industrial Revolution has taken place and ensured advantages for economic systems and the global economy.

With the critically low value of coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0 (less than 1), the scenario that envisages impossibility of practical implementation of the concept of Industry 4.0 is implemented. This means that the Industrial Revolution has not taken place, but perhaps ensured other positive effects.

Table 3 Logic of treatment of the results of criterial evaluation of consequences of the Industrial Revolution of the 21st century

Combination of the values of criteria	Scenarios of formation and development of Industry 4.0 in the conditions of knowledge economy's formation	Treatment of consequences of the Industrial Revolution
– $\Delta IKE \geq 0.5$; – $Dind4.0_{GDP} < 5$	Turning Industry 4.0 into the tool for formation of knowledge economy	The Industrial Revolution has not taken place, but formation and development of Industry 4.0 ensured progress in formation of knowledge economy
– $Ceff_{ind.rev.} > 5$; – Positive externalities > negative externalities	Implementation of the Fourth Industrial Revolution in the sphere of Industry 4.0 on the basis of knowledge economy	The Industrial Revolution has taken place and ensures advantages for economic systems and the global economy
– $Ceff_{ind.rev.} < 1$	Impossibility for practical implementation of the concept of Industry 4.0	The Industrial Revolution has not taken place, but probably ensured other positive effects
– $\Delta ISS\ (-) \geq 0,5$; – Negative externalities > positive externalities	Hidden threats to the concept of Industry 4.0	The Industrial Revolution has taken place, but poses a threat and needs to be stopped

Source Compiled by the authors

With large reduction of the value of the index of sustainability of society (more than 0.5 points) and domination of negative externalities over positive ones, the scenario that is related to emergence of hidden threats to the concept of Industry 4.0 takes place, which means that the Industrial Revolution has taken place, but is a threat and needs to be terminated.

4 Conclusions

Concluding the results of the performed research, it should be noted that the chapter offers not only criteria for evaluation of consequences of the Industrial Revolution of the 21st century, but also methodological recommendations for their practical usage. Due to systematization and classification of these criteria, the authors' formula for evaluating the effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0 is developed.

An advantages of the presented methodology of criterial evaluation of consequences of the Industrial Revolution of the 21st century is consideration of not only the main and target indicators of formation and development of Industry 4.0 in modern economic systems but also additional indicators. The offered recommendations for bringing the indicators to common measuring units with the help of special coefficients allow conducting the most complete and complex evaluation of consequences of the Fourth Industrial Revolution.

The advantages of the offered methodology is the high level of its detalization. The explained logic of treatment of the results of criterial evaluation of consequences of the Industrial Revolution of the 21st century envisages the traditional consideration of the resulting indicator—coefficient of effectiveness of the Industrial Revolution of the 21st century in the sphere of Industry 4.0 and all other estimate criteria. Their distinguished model combinations allow determining the implemented scenarios of formation and development of Industry 4.0 in the conditions of knowledge economy's formation.

However, a drawback and limitation of the offered methodology for evaluating the consequences of the Industrial Revolution of the 21st century is impossibility of its approbation as of now. Due to this, with accumulation of practical experience of formation and development of Industry 4.0 in modern economic systems, there could appear a need for elaboration of the offered methodology, as well as specification or expansion of the list of estimate criteria—which is a perspective direction for further scientific research.

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The Approach to Managing the Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation for Implementation of the Optimal Scenario

Tatiana B. Fonina, Inna V. Mishchenko, Valentina V. Latysheva and Iraida N. Romanova

Abstract Unattractiveness of the traditional scenario of implementing the Industrial Revolution of the 21st century, which envisages domination of developed countries and deepening of disproportions of the global economy, leads to necessity for developing the methodological approach to global management of development of Industry 4.0 in the conditions of knowledge economy's formation for implementation of optimal scenario, which envisages implementation of the global Fourth Industrial Revolution in the sphere of Industry 4.0 on the basis of knowledge economy simultaneously in all interested countries of the world. Development of such approach is the purpose of this chapter. The methodological basis of the research includes the method of systemic, problem, and structural and functional analysis, as well as special-purpose and formalization methods. The authors develop and present the new approach to managing the development of Industry 4.0 in the conditions of knowledge economy's formation for implementation of the optimal scenario, which is not just an alternative but a direct opposition to the traditional approach that is

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used during management of all previous industrial revolutions. The new approach is more preferable, as it ensures multiple advantages, which include prevention of crisis of socio-economic systems, which is traditionally viewed as an inseparable components of industrial revolutions. In addition to this, formation of Industry 4.0 will ensure innovational development of modern socio-economic systems, which will allow accelerating the process of their overcoming the long recession. Another advantages of the new approach is stimulating reduction of the level of differentiation of countries in the global economy. The offered approach is based on the mechanism of integration, which allows ensuring systemic interaction of all interested participants of global economic relations in the process of formation and development of Industry 4.0 and obtaining the synergetic effect.

Keywords Managing the development · Industry 4.0 · Knowledge economy
Implementation of the optimal scenario

1 Introduction

Experience of previous industrial revolutions shows that in case of absence of global management, revolutionary technological transformations start and pass very intensively in certain economic systems, which gain the largest advantages from the revolution, but then they influence all other participants of international economic relations.

However, total coverage of industrial revolutions does not mean equality of rights, possibilities, advantages, and drawbacks that are faced by their participants. Economic systems that showed delay in taking the path of revolutionary transformations of industry become outsiders of this process, in which they lose their global competitiveness, and experience the drawbacks of industrial revolutions.

These drawbacks include social contradictions (public dissatisfaction with the country's underrun in the international race of technologies) and ecological costs—the countries that are outsiders in industrial revolutions are suppliers of natural resources for leading developed countries and the territories to which harmful industrial production are moved and which receive waste from this production.

These reasons show unattractiveness of this scenario of implementing the Industrial Revolution of the 21st century and the necessity for developing the methodological approach to the global management of development of Industry 4.0 in the conditions of knowledge economy's formation for implementing the optimal scenario, which envisages implementation of the global Fourth Industrial Revolution in the sphere of Industry 4.0 on the basis of knowledge economy simultaneously in all interested countries of the world. This approach is to be developed in this chapter.

2 Materials and Method

The issues of optimization of managing the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation and implementation of the Fourth Industrial Revolution are the objects of a lot of scientific discussions and works. Some authors focus on substantiating the necessity and developing technical solutions for optimization of certain business processes of entrepreneurial structures due to their transition to Industry 4.0. These are Vallhagen et al. (2017), Wehle and Dietel (2015), and Wiedemann and Wolff (2013).

Other scholars emphasize existence of wide possibilities and offer methodological recommendations in the sphere of optimization of the industrial system of economy and gaining advantages from international trade due to quick formation of Industry 4.0 and mastering of competitive advantages in this sphere. They include (Meudt et al. 2017; Maksimchuk and Pershina 2017; Santana et al. 2017). Other scholars point out advantages for other—adjacent to Industry 5.0—spheres of national economy as a result of the Fourth Industrial Revolution: Kim et al. (2016) and Mozaffari et al. (2015).

Other experts emphasize the necessity for overcoming the technological underrun of developing countries and using the possibilities of the future Industrial Revolution for reduction of disproportions in socio-economic development of various participants of modern international economic relations. They include (Ragulina et al. 2015; Popkova et al. 2018a, b, c; Bogoviz et al. 2017).

Thus, modern scientific literature is dominated by traditional isolationist and competitive approach to managing the Fourth Industrial Revolution, which envisages formation and development of Industry 4.0 in developed countries at the initial stage. This approach is peculiar for the most developed fundamental and methodological basis.

At the same time, a lot of scholars note the necessity for search for new, alternative approach, which allows for equal distribution of advantages from the new industrial revolution between all participants of the global economic system. This approach does not have a strong methodological basis and requires further development—which is studied in this chapter. The methodology of the chapter includes the methods of systemic, problem, and structural and functional analysis, as well as special-purpose and formalization methods.

3 Results

For implementation of the optimal scenario of the Fourth Industrial Revolution, the isolationist and competitive approach should be replaced by the new, integrating approach to management of development of Industry 4.0 in the conditions of knowledge economy's formation. The new approach envisages unification of efforts of all participants of international economic relations that are interested in formation and development of Industry.

The role of developed countries, which initiated transformation processes in their socio-economic systems, related to formation of Industry 4.0, consists not in traditional strengthening of their leading positions in the markets and ousting their rivals but in support for developing countries and their acquaintance with the Fourth Industrial Revolution.

Within this approach, the global purpose of management of development of Industry 4.0 in the conditions of knowledge economy's formation consists in optimization of the process of formation and development of Industry 4.0 in the conditions of knowledge economy's formation in the global scale. That is, here we speak of maximization of not macro-economic results of separate countries but socio-economic results in the scale of the global economy on the whole. Achievement of this goal requires adoption of the following principles (key landmarks) by participants of this process:

- the principle of priority of Industry 4.0 over knowledge economy: for implementation of the optimal scenario, which envisages start of the Fourth Industrial Revolution, knowledge economy could be a platform for formation and development of Industry 4.0, but not vice versa—turning Industry 4.0 into the tool of formation of knowledge economy is a deviation from the optimal scenario and should be prevented;
- principle of interaction and cooperation of countries regardless of classification categories (level and rate of their socio-economic development): developed and developing countries should unify efforts not only within their categories but also with representatives of other categories of countries for achieving the highest results in formation of Industry 4.0 and its formation not only as a new sphere of industry but the source of the Fourth Industrial Revolution;
- principle of priority of common interests (society) over individual and refusal from competitive struggle: formation and development of Industry 4.0 should be viewed not as a means of receipt of competitive advantages by certain countries but as the direction of development of the global economy on the whole; at that, the interests of provision of long-term social well-being should dominate over private short-term commercial (economic) interests.

These principles should be observed by all participants of the global economic relations. In order to achieve the set goal, it is recommended to implement the following macro-economic measures of managing the development of Industry 4.0 in the conditions of knowledge economy's formation:

- announcement of the national course at international production specialization in the sphere of Industry 4.0: Industry 4.0 should be announced as the main sphere of economy—for ensuring its priority and providing the possibility for starting the Fourth Industrial Revolution on the basis of Industry 4.0;
- stimulation of business activity in Industry 4.0: it is necessary to created favorable conditions (business climate, which includes infrastructural, tax, credit, regulatory,

and other spheres) for formation and development of entrepreneurship in the sphere of Industry 4.0;
- stimulation of modernization of entrepreneurial structures from various spheres of national economy in view of new possibilities that appear in the conditions of formation and development of Industry 4.0: products of Industry 4.0 should be used for optimization of business processes in other spheres of economy, which will allow assigning Industry 4.0 with the infrastructure-building role in the system of entrepreneurship;
- stimulation of international cooperation in the sphere of Industry 4.0: it is necessary to refuse from the ideas of protectionism and adopt the strategy of freetrading, to stimulate integration initiatives in entrepreneurship, and achieve high effectiveness of the mechanism of public-private partnership.

The mechanism of action of the integration approach envisages provision and joint usage of intellectual resources by developed and developing countries. This will allow forming transnational teams of scholars for conducting leading scientific R&D in the sphere of Industry 4.0. At that, it is important to ensure protection of rights for the objects of intellectual property at the global level.

Due to unification of investment resources of developed countries and natural resources of developing countries, technologies and equipment will be created in the sphere of Industry 4.0. They will become the basis for formation of joint (public-private) and international companies and transnational clusters in the sphere of Industry 4.0. This will allow distributing risks among all participants of innovational projects in the sphere of Industry 4.0 and ensuring access of all participants to advantages from formation and development of Industry 4.0.

Based on the above, the following approach to managing the development of Industry 4.0 in the conditions of knowledge economy's formation for implementation of the optimal scenario is offered (Fig. 1).

As is seen from Fig. 1, due to integration, the offered new approach to managing the development of Industry 4.0 in the conditions of knowledge economy's formation for implementation of the optimal scenario allows maximizing synergetic effect from the Fourth Industrial Revolution, which has the forms of innovational development of the global economy, achievement of the global anti-crisis effect, achievement of sustainable development of the global economic system, maximization of social and ecological benefits from formation of Industry 4.0, reduction of disproportions, and leveling the structure of the global economic system.

4 Conclusion

Thus, the developed and presented new approach to managing the development of Industry 4.0 in the conditions of knowledge economy's formation for implementing the optimal scenario is not just an alternative but direct opposition to the traditional approach that was used during management of all previous industrial revolutions.

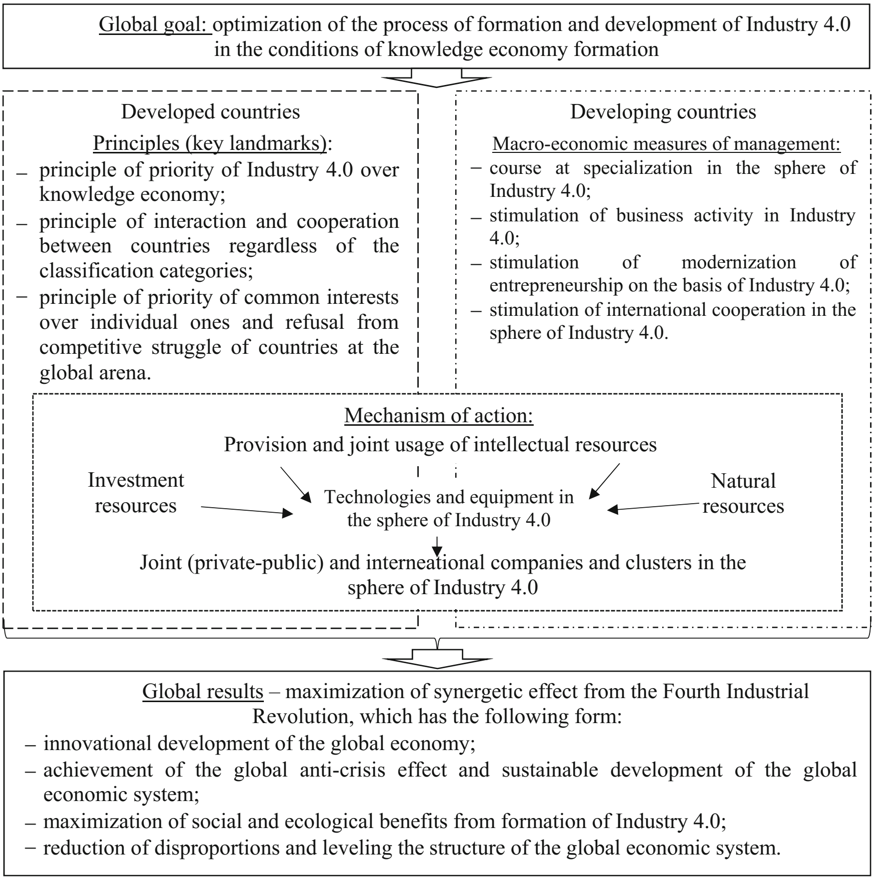

Fig. 1 The approach to managing the development of Industry 4.0 in the conditions of knowledge economy's formation for implementation of the optimal scenario. *Source* Compiled by the authors

The new approach is preferable, as it ensures multiple advantages, which include prevention of the crisis of socio-economic systems, which is traditionally viewed as an inseparable component of industrial revolutions.

In addition to this, formation of Industry 4.0 will ensure innovational development of modern socio-economic systems, which will allow accelerating the process of their overcoming the long recession. Another advantage of the offered new approach is stimulating the reduction of the level of differentiation of countries in the global economy. The offered approach is based on the mechanism of integration, which allows ensuring systemic interaction between all interested participants of the global economic relations in the process of formation and development of Industry 4.0 and achievement of synergetic effect.

However, success of implementation of this approach is determined by readiness of countries of the world to make mutual concessions and give up own interests for the purpose of achieving the common benefit in the scale of the global economic system on the whole and maximization of individual benefit in the future. This will probably require additional measures of global economic regulation, conducted at the level of international organizations. Development of the system of such measures is a perspective direction for further scientific studies.

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Conclusions

Thus, the performed research confirmed the offered hypothesis—Industry 4.0 possesses sufficient potential and wide perspectives in starting the new Industrial Revolution in the 21st century. This revolution is unique by its nature—it envisages not only deep changes in technical organization of economic systems but also systemic social transformations that are related to reconsideration of human's role in the modern world. That's why this revolution is very important in the social aspect and requires close attention from the academic society.

The performed work contributes into development of fundamental provisions of the concepts of Industry 4.0 and development of methodological provision of this concept. The offered conclusions and recommendations could be used by state regulators for optimizing managing the process of formation and development of Industry 4.0 and by economic subjects (entrepreneurial structures) that conduct transition to Industry 4.0.

Based on the official statistical information and practical examples, we showed that Industry 4.0 is closely connected to knowledge economy. First successes of countries of the world in formation of knowledge economy open possibilities for formation of Industry 4.0, which will stimulate acceleration of progress in development of knowledge economy. Therefore, the modern global economy passes to a new level of socio-economic development and revolutionary changes, which will influence all spheres of national economy and are inevitable.

It should also be noted that despite the complex character of the research, not all aspects related to the new industrial revolution have been studied, as this sphere has insufficient experience and factual scientific data—which does not allow determining most potential problems or finding their solutions. Industry 4.0 deserves thorough attention and systemic scientific study. In view of revolutionary direction of the process of formation and development of Industry 4.0 and its strong influence on the social component of economic systems, we deem it necessary to focus on determination and management of social risks of Industry 4.0 during further scientific studies.

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