UNDERSTANDING INDUSTRY 4.0

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UNDERSTANDING INDUSTRY 4.0: AI, THE INTERNET OF THINGS, AND THE FUTURE OF WORK

BY

BRUNO S. SERGI

Harvard University, USA and University of Messina, Italy

ELENA G. POPKOVA

Plekhanov Russian University of Economics, Moscow, Russia

ALEKSEI V. BOGOVIZ

National Research University "Higher School of Economics", Russia

AND

TATIANA N. LITVINOVA

Volgograd State Agrarian University, Russia

United Kingdom – North America – Japan – India – Malaysia – China

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About the Authors

Bruno S. Sergi is an Instructor of the Economics of Emerging Markets and the Political Economy of Russia and China at Harvard University and an Associate of Harvard's Davis Center for Russian and Eurasian Studies and the Harvard Ukrainian Research Institute. He also teaches International Economics at the University of Messina. He is the Series Editor of *Cambridge Elements in the Economics of Emerging Markets*, the Co-series Editor of the Emerald Publishing book series *Lab for Entrepreneurship and Development*, and the Associate Editor of *The American Economist*. He is the Scientific Director of the Lab for Entrepreneurship and Development and of the International Center for Emerging Markets Research at RUDN University in Moscow.

Elena G. Popkova is a Doctor of Economics, a Professor, and a leading Researcher at Plekhanov Russian University of Economics, Moscow, Russia. Her spheres of scientific interest include economic growth, sustainable development, globalization, humanization of economic growth, developing countries, institutionalization of social development, development planning, and strategic planning. She is a Guest Editor for *International Journal of Educational Management* (special issue, 2016, 2018), *International Journal of Trade and Global Markets* (special issue, 2017), *Journal of Entrepreneurship in Emerging Economies* (special issue, 2017), and *Contributions to Economics* (Springer book series). She has more than 300 publications in Russian and foreign peer-reviewed journals and books.

Aleksei V. Bogoviz is a Professor in the Department of Local Administration at the School of Public Administration and a Faculty of Social Sciences in the Higher School of Economics in Moscow, Russia. His spheres of scientific interest include economic growth, sustainable development, globalization, developing countries, institutionalization of social development, planning of development and strategic planning, agriculture, agro-industrial complex, digital economy, and state management. He has more than 200 publications in Russian and foreign peer-reviewed journals and books.

Tatiana N. Litvinova is an Associate Professor of the Department "Economics" in Volgograd State Agrarian University. Her scientific interests include economic growth, sustainable development, development planning, strategic planning, and Russian market of agricultural machinery. She has multiple publications in Russian and foreign peer-reviewed journals on these topics.

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Foreword

The global transition to the Fourth Industrial Revolution (Industry 4.0) is already underway. R&D on leading digital technologies is now conducted around the world. The essential novelty of these disparate technologies, aimed at revolutionizing cyber-physical systems, allows them to be classified together as "Industry 4.0." These technologies include the Internet of Things, the blockchain, 3D printing, technologies of virtual and alternate reality, technologies to manage Big Data processing, the use of artificial intelligence, and others.

The increasing accessibility of these leading technologies is stimulating the intensive development of hi-tech spheres of the economy. There is high demand for such breakthrough innovations from both private business and governments, which seek the common goal of an increase in the effectiveness and provision of high global competitiveness in the economy in the long-term. The inflow of public and private financing, as well as the rapid implementation of the results of R&D, ensures practical implementation. In a relatively short period of time (by 2025–2030) it will be possible to replace older technologies in all business processes and to form companies of a new type, which will be part of Industry 4.0.

Each of the three earlier industrial revolutions radically increased the effectiveness of economic activities, reducing marginal costs and raising labor efficiency, but at the same time led to negative social consequences – the growth of unemployment rates and the necessity for retraining and changes in the professions. The consumer and professional spheres of human society are closely interconnected. The advantages of mass accessibility and the emergence of new types of goods in the economy in the short- and even mid-term was outweighed by the drawbacks of complex social adaptations necessitated by changes in the labor market.

As the market for educational services cannot adapt instantaneously, creating new specialties and educational programs to retrain representatives of professions that disappear, and the labor market cannot offer a quick replacement for these lost professions, previous industrial revolutions led to long periods of social adaptation. The reduction of effective demand caused by professional categories losing their source of earned income hindered society from taking advantage of the mass production and accessibility of innovational goods – so the growth of living standards was only seen in the long-term (in 5–10 years).

The Fourth Industrial Revolution will not be an exception. On the contrary, unlike the earlier industrial revolutions, which envisaged the automatization of certain spheres of the economy or business processes, the new industrial

revolution will lead to almost complete automatization, which will influence almost all spheres and all business processes. This is a fact that leads us to expect deep transformational processes in the professional sphere of human society and the elevated risk of the emergence of a social crisis.

However, as of now, at the beginning of the Fourth Industrial Revolution, it is possible to prevent such a social crisis by implementing preventative measures to mitigate the effects of the rapid modernization of the professional sphere of human society. This book sets out to determine the most probable changes in the key spheres of the economy, to determine the most prestigious spheres and professions that will be effected, and to offer recommendations on the choices that public and private sector leaders should make to successfully master the disruptions ahead. We hope that this book will become a guide for all interested parties – job applicants, undergraduates, employees, employers, universities, and governments – and will allow for a reduction in the uncertainty of the coming changes and better strategies for adapting to these changes.

Bruno S. Sergi, Elena G. Popkova, Aleksei V. Bogoviz, &
Tatiana N. Litvinova

Part I

Overview of Future Professions in Industry

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Chapter 1

Outlines of the Context for Industry 4.0

1. Introduction

The modern global economy has entered the Fourth Industrial Revolution. Though it is at an early stage and breakthrough (revolutionary) digital technologies are still being developed and tested, the widespread interest in new technologies and the opportunities that they bring means that the leading economies are now fully embracing the transition to Industry 4.0. Germany was the first country to establish a national industrial strategy for Industry 4.0 in 2012, followed by the UK, which has adopted Industry 4.0 as the leading sphere of growth for industry and envisages "Eight great technologies".

The United States proclaimed Industry 4.0 to be the critical tool for implementing its national strategy of innovational development. France has based its industrial reform program on the technologies of Industry 4.0 (Ministère de l'Economie et des Finances, 2015). Japan has determined Industry 4.0 as a top-priority in implementing its plan of scientific and technological modernization. The recently implemented initiatives of China for the development of industry through the application of technologies of Industry 4.0 and the creation of a digital economy based on the technologies of Industry 4.0 shows that the involvement of new and emerging markets in the Fourth Industrial Revolution and its truly global scale.

These national economic strategies and programs generally have a 2022–2025 time horizon. Therefore, the next five to seven years are likely to see the first transformation processes in global industry, and, in the next 10–15 years, radical transformations created by the technologies of Industry 4.0. These developments will make redundant current technologies (belonging to technological mode 3.0). The disruptions caused by the formation of Industry 4.0 in the next 10–15 years will completely change the structure of the global economy.

2. About the Transformation Processes

Number of employees rate in the industry according to OECD (2019) and share of industry in GDP according to World Bank (2019a, 2019b) are shown in Table 1.1 (as of 2018).

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The data from Table 1.1 show the absence of visible interconnection between the number of employees and the level of development of industry in the leading countries as to manufacture of industrial products, their share in GDP (Top 10) as of 2018.

The data from Table 1.1 show the absence of a visible connection between the number of employees and the level of development of industry in the leading manufacturing countries and their share of global GDP (Top 10). The data also show a high unemployment rate in this industrial sector.

Table 1.1: Number of Employees in the Industry and Share of Industry in GDP (as of 2018).

Country	**Employment in Industry (in Thousands)**	**Share of Industry in GDP**
Australia	2,459	23.03
Austria	1,062	25.27
Belgium	964	19.75
Canada	3,519	27.53
Chile	1,882	29.96
Czech Republic	1,987	33.46
Denmark	525	19.86
Finland	547	23.97
France	5,435	17.36
Germany	11,418	27.60
Greece	575	14.79
Hungary	1,394	26.44
Ireland	412	19.66
Israel	654	18.67
Italy	5,986	21.36
Japan	15,823	29.30
Korea	6,602	35.87
Latvia	21	19.52
Lithuania	343	26.42
Luxembourg	23	11.58
Mexico	13,377	30.04
Netherlands	1,282	17.53
New Zealand	532	20.44
Norway	512	29.90

Table 1.1: (*Continued*)

Country	Employment in Industry (in Thousands)	Share of Industry in GDP
Poland	5,180	28.93
Portugal	1,177	19.41
Slovak Republic	940	30.97
Slovenia	317	28.77
Spain	3,776	21.61
Sweden	908	22.14
Switzerland	928	25.17
Turkey	7,483	29.16
United Kingdom	5,796	18.57
United States	28,849	18.88
Colombia	4,306	26.64
Russian Federation	19,480	30.05

Source: Compiled by the authors based on OECD (2019) and World Bank (2019a, 2019b).

The importance of studying the transformation processes that are expected to take place in the context of the formation of Industry 4.0 is emphasized by the fact that this topic is already well studied. A content analysis of existing work and a systematization of accumulated scientific knowledge allowed us to perform classification of conceptual approaches to determining potential scenarios for the development of industry in the context of the formation of Industry 4.0 according to the criterion of dominating technologies. The comparative analysis and a description of these distinct approaches are given in Table 1.2.

As seen in Table 1.2, the first conceptual approach to determining scenarios for the development of industry in the context of the formation of Industry 4.0 envisages AU. During the organization of production, this means a full AU of the production process. At present, there are examples of fully automatized industrial production, for example, the car-maker Opel (Rüsselsheim, Germany). AU envisages preliminary programming by a human of separate production operations and their general sequence, as well as the further execution of these operations in a set sequence by an automatized production system.

The role of the human is reduced to technical maintenance (including diagnostics and repairs) of such an automated production system. The current worker who performs manual, mechanized, or partially automatized production will not be required within this future scenario.

With the organization of distribution, the future scenario envisages full AU (including logistics, supply, and sales). The role of the human will be reduced to technical maintenance (including diagnostics and repairs) in such an automated distribution system. The current professions of logistician and sales assistant,

Table 1.2: Scenarios for the Development of Industry in the Context of the Formation of Industry 4.0.

Characteristics and Outlines of the Industry		**Conceptual Approach and its Scenario for the Industry**		
		Automatization (AU)	**Artificial intelligence (AI)**	**Robotization (RB)**
Production	Dominating technology	Automatized production	3D-printing	Manipulators and robototronics
	Role of human	Technical maintenance (including repairs) of automatized production	Design, implementation, and technical maintenance of 3D printing	Using manipulators, creating and teaching robots, technical maintenance
	Demand for current professions	*Analog*: technician *Demand*: absent	*Analog*: technician *Demand*: absent	*Analog*: technician *Demand*: absent
Distribution	Dominating technology	Automatized distribution	IoT	Drones
	Role of human	Technical maintenance (including repairs) of automatized distribution	Technical maintenance (including repairs) of the IoT	Management and technical maintenances of drones
	Demand for current professions	*Analog*: logistician *Demand*: absent	*Analog*: technician *Demand*: low	*Analog*: driver *Demand*: low
Management	Dominating technology	Big Data and cloud technologies	AI	Quantum calculations, the blockchain
	Role of human	Monitoring, control	Monitoring, control	Monitoring, control
	Demand for current professions	*Analog*: manager *Demand*: low	*Analog*: manager *Demand*: low	*Analog*: manager *Demand*: low

Source: Compiled by the authors.

conducting manual or computerized roles in the logistical planning and sale of industrial products, will be in low demand in this future scenario.

The management of industrial production within this scenario, envisages the usage of Big Data technologies (technologies for the automatized processing of large arrays of data) and cloud technologies (technologies for storing information in the virtual environment, which reduces the risk of its loss during failures of hardware and software). The role of the human is reduced to monitoring and control over the work of these technologies. The real professions of the manager and HR manager will be in low demand in this future scenario. Further analysis of this scenario is presented in the works: Bogoviz (2019), Kuo, Ting, Chen, Yang, and Chen (2017), Moeuf, Pellerin, Lamouri, Tamayo-Giraldo, and Barbaray (2017), Popkova (2019), Popkova, Ragulina, and Bogoviz (2019), Bauer, Pokorni, and Findeisen (2019), Dostatni, Diakun, Grajewski, Wichniarek, and Karwasz (2019), Galvão et al. (2019), and Wrobel-Lachowska, Polak-Sopinska, and Wisniewski (2019).

The second conceptual approach to determining scenarios for the development of industry in the context of the formation of Industry 4.0 envisages the creation and distribution of AI. During the organization of production, this means the usage of 3D printing (three-dimensional printing). This technology allows for the rapid manufacturing of industrial products as single items with the help of 3D printers. This ensures the timely execution of individual orders, as there is no necessity for the automatized production process.

The role of the human in such a scenario is reduced to design, implementation, and technical maintenance (including diagnostics and repairs) of the 3D printing process. People must still set the parameters for a 3D printer with precision and keep it functioning (timely maintenance, an update in software, etc.). But workers who conduct manual, mechanized, or partially automatized production in this industry, will not be in great demand in the future.

The organization of distribution within this scenario will see the internet of things (IoT) become dominant, within which the communication of technical devices (industrial equipment, sensors) will be conducted without human participation. The role of the human will revolve around technical maintenance (including diagnostics and repairs) of the IoT. Technicians who conduct technical maintenance (including diagnostics and repairs) of applied technologies belonging to technological mode 3.0 will be in low demand in the future.

During the management of industrial production within this scenario, AI will be used. The role of the human worker will be limited to the monitoring and control of the work of AI. The existing profession of manager and HR manager will be in low demand in the future within this scenario. This trend is studied in Bogoviz, Gulyaeva, Semenova, and Lobova (2019), Bogoviz, Lobova, Ragulina, Chernitsova, and Shkodinsky (2019), Bogoviz, Osipov, Chistyakova, and Borisov (2019), Longo, Nicoletti, and Padovano (2017), Pereira and Romero, (2017), Popkova and Sergi (2018), Hitpass and Astudillo (2019), Imran and Kantola (2019), and Krystek, Alszer, and Bysko (2019).

The third conceptual approach to determining the scenarios for the development of industry in the context of the formation of Industry 4.0 envisages

robotization (RB). During the organization of production, this means the usage of manipulators (industrial robots that are remotely controlled) and robototronics. At present, there are advances in developing the application of robots in industrial production. For example, batteries for Apple laptops (at production departments in China) have been manufactured by robots since 2014.

The role of humans in such a scenario is reduced to managing the usage of manipulators, creating and teaching robots, and technical maintenance (including diagnostics and repairs). The profession of the worker who currently conducts manual, mechanized, or partially automatized production tasks in the industry will have no demand in the future within this scenario.

During the organization of distribution within this scenario, it is likely that the use of drones (remotely controlled by human or fully automatic) will increase greatly. Humans will have a role in controlling such drones and will remain responsible for their technical maintenance (including diagnostics and repairs). However, the profession of a driver will have a very meager demand.

The management of industrial production within this scenario will depend upon quantum technologies and blockchain (highly effective technologies for the deciphering and processing of digital data), and the role of people will simply be to monitor and control the work of these technologies. The current profession of manager and HR manager will be in low demand in the future within this scenario. These developments are described in the works: Crnjac, Veža, and Banduka (2017), Brynjolfsson and McAfee (2014), Shvab (2017), Kurosz and Milecki (2019), Peraković, Periša, and Sente (2019), and Świątek (2019).

Thus, by studying the existing conceptual approaches to determining the scenarios for the future development of industry in the context of the formation of Industry 4.0 we see contradictions and profound impacts and changes on the current system of industrial professions, which are studied in the publications of Loshkareva, Luksha, Ninenko, Smagin, and Sudakov (2015).

3. Toward a Unified Scenario?

The systemic analysis of scenarios for the development of industry in the context of the formation of Industry 4.0, within various conceptual approaches, shows that they are interconnected. We took this a step further and unified these scenarios (Fig. 1.1).

As can be seen in Fig. 1.1, the biggest impact in the sphere of Industry 4.0, in the presented model of 2025–2030, is the use of AI, which controls the production and distribution processes of Big Data technologies, cloud technologies, quantum calculations, and blockchain. Industrial production excludes the direct participation of human workers and is organized by the new technologies of 3D print, automatized production, manipulators, robototronics, and the IoT.

The distribution of industrial products excludes the direct participation of and interaction with people. Rather we envisage that the proper placement of electronic orders, electronic and automatized marketing, automatized distribution, and the supply of industrial products through the application of drones to consumers of all types: business-to-business (B2B: entrepreneurial structures selling

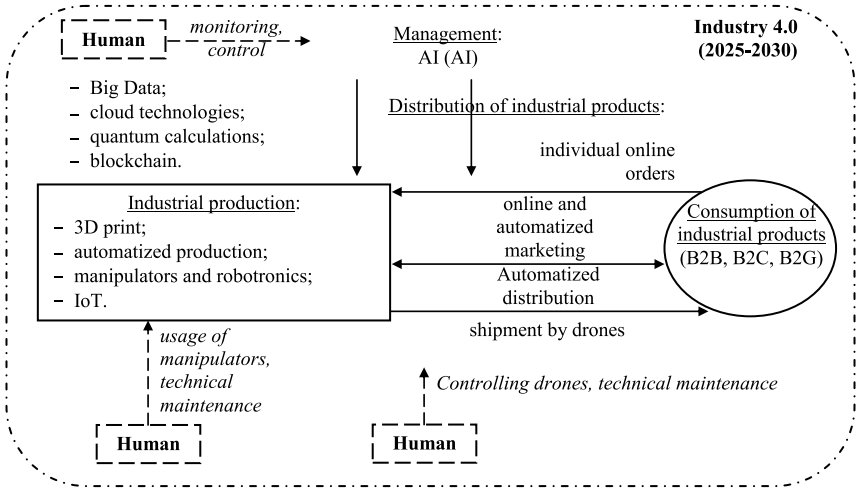

Fig. 1.1: A Unified View for the Future Outline of Industry in the Context of the Formation of Industry 4.0. *Source*: Compiled by the Authors.

products to other entrepreneurial structures), business-to-consumers (B2C: entrepreneurial structures selling products to consumers), and business-to-government (B2G: entrepreneurial structures selling products to the state). Humans retain the roles of monitoring, control, and remote management and technical maintenance of the technologies of Industry 4.0. Thus, by 2025–2030 industry will have a completely different structure. Based on the use of the technologies of Industry 4.0, future industry will exclude the direct participation of people not only in the production process but also in distribution and managerial functions.

In Industry 4.0, humans will still have a role in the remote management of technologies that need their participation (manipulators, drones), monitoring and control of AI, and technical maintenance of new technologies. But many of the current roles and professions in the manufacturing industries will not be applicable or in demand in the future. Therefore, we must determine the future structure of industry in the context of the formation of Industry 4.0 and the transformation processes that are taking place now and are expected to rapidly accelerate in the future.

Our classification of conceptual approaches in determining the scenarios for the development of industry in the context of the formation of Industry 4.0 has been made according to the criterion of dominating technologies. The contradiction of scenarios for the development of industry within these distinct conceptual approaches has been determined – AU, AI, and RB – related to the fact that each of them focuses on specific technologies of Industry 4.0, neglecting other technologies. The universal regularity of all scenarios has been determined: an acknowledgment of profound changes to the current system of industrial professions. Systemic analysis of scenarios for development of industry in the context of the formation of Industry 4.0 have been described within various conceptual

approaches, illustrating that not only do they not contradict each other but are tightly interconnected. We unified these scenarios and presented future outlines of industry in the context of the formation of Industry 4.0. The industrial system will have different outlines by 2025–2030, and industry will exclude the direct participation of humans not only in the production stage but also in the distribution and managerial processes. Humans will have the role of remotely managing technologies that need direct participation (manipulators, drones, etc.), monitoring and control over AI, and technical maintenance of the technologies of Industry 4.0. The existing analogs in industry will not be applicable or available professions in the future.