Education System and Labor Market in the Context of Digital Transformation

Askar Akaev, Alexander Petryakov, Reiff-Stephan Jorg, and Laszlo Ungvari

Abstract Modern economic systems are characterized by great flexibility and ever-changing demands in relation to labor skill level. The need for constant knowledge renewal and continuity of the education process are becoming key factors in ensuring sustainability in the labor market. The chapter analyzes current trends in professional training found in different OECD countries and Russia and evaluates the adjustment level of higher education systems to new technological challenges. It is shown that despite dynamic changes in the education sector, it remains largely geared toward training professionals to staff the "Third Industrial Revolution." A structural shift from training medium-skilled professionals to training high-skilled professionals, including those in STEM (Science, Technologies, Engineering, and Mathematics) fields, will become a pivotal moment in education development. The countries that will succeed in coping with this structural challenge within a short period of time will gain considerable competitive advantages in international markets for high-tech goods and services.

Keywords Education system · Labor market · Labor skill level

A. Akaev
Institute for Mathematical Research of Complex Systems, Lomonosov Moscow State University, Moscow, Russia

A. Petryakov (✉)
Saint Petersburg State University of Economics, Saint-Petersburg, Russia

R.-S. Jorg
Technical University of Applied Sciences Wildau, Wildau, Germany
e-mail: jrs@th-wildau.de

L. Ungvari
Development in Relations of Industrial and Education Management GmbH, Wildau, Germany
e-mail: ungvari@driem-international.com

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1 Introduction

In the twentieth century, market systems, especially those in highly developed countries, progressively implemented mechanization and automation of manual labor, by developing predominantly labor-saving technologies. This resulted in a declining share of low-skill occupations in manufacturing, which was offset by a growing share of better-paid jobs for college-educated middle-class workers. This process, however, halted in the 1970s. In the wake of the economic crises of the 1970s and 1980s, demand for labor started polarizing. Data on the American economy from 1970 to 2010 indicates that the employment share of high-skilled workers increased from 23.4% to 39.4%, whereas the share in medium- and low-skill occupations declined from 40.5% to 31.6% and from 36% to 29%, respectively (Katz & Margo, 2014). The same trends were typical of 17 OECD member countries. Recent research has revealed that in the period from 1995 to 2015, the share of high-skill jobs increased from 29% to 37%, the share of medium-skill jobs declined from 49% to 40% and the share of low-skill jobs grew only marginally from 21% to 23% (OECD, 2017).

With the onset of the NBIC technological revolution, when the technologies of the Fourth Industrial Revolution and the Industrial Ethernet have become a practical reality and allowed fully automated make-to-order production and delivery, the trend toward actively pushing people out from the sphere of production and even services have materialized as well. Digital technologies are intensely labor-saving, which makes their use in the labor market "toxic." Digital computer technologies automated routine tasks from the very start. Robots have replaced workers on assembly lines. Large-scale digitalization, computerization, and robotization will accelerate the process of technological replacement of labor with capital within the next few decades. While thus far automation has been pushing people out from the mundane sphere of manual work and services, as of now, it will be pushing them out from the field of intellectual work by replacing routine mental workers, i.e., medium-skilled professionals who are mostly middle-class employees.

This means that the Fourth Industrial Revolution along with the complete automation of production and accelerated productivity and GDP growth may have some negative social consequences, primarily in the form of a drastic reduction in middle-skill occupations for the middle class and a further increase in income inequality in society. This is especially notable due to the empirical fact that the growth of economic inequality accelerated in almost every country after the first decade of the 2000s.

Since an increased demand for skilled labor is a major feature of the digital economy, one is to expect a new stage in labor market evolution caused by the transition to a high-tech and research-intensive digital economy, which implies that high-skilled labor will be concentrated in the branches relying on expertise in STEM (Science, Technologies, Engineering, and Mathematics). It follows that enhanced STEM literacy will ensure that any professional remains in high demand in the market for high-skilled labor.

STEM education is a new model integrating natural science and engineering. It relies on the convergent approach: mathematics, physics, chemistry, and biology are taught not discretely but in close relation to each other to tackle existing engineering and technology challenges. Such an approach directs a professional to regard the challenges at hand in a holistic way rather than in the context of a particular field of science or technology. Another cornerstone of STEM education is project-based research and training. This format combines a graduation project with an internship at a technology company where students can work on a complex technology project as part of a team and thereby develop “flexible” skills. As a result, graduates gain valuable on-the-job experience in their professional field.

Presently, STEM professionals are the most sought-after employees in the global labor market. The US Bureau of Labor Statistics forecasts that demand for STEM specialists will exceed that for professionals in other fields by 76% over the next decade. The US market alone will require approximately 10 million employees, and the personnel shortage will remain great even despite further accelerated training. Meanwhile, the average annual salary in STEM occupations stands at $ 86,980, which is more than double the $ 39,810 for other professions or trades in the country. Russia currently needs over 200,000 employees with STEM degrees, and by 2025 the shortage will grow to 300,000 employees.

2 Qualifications, Education, and Wage Level

The relationship between the remuneration for work and the level of educational attainment and qualifications (skills) has been one of the key issues in all economic formations. Historical data indicates that from the fourteenth to the nineteenth century, i.e., up to the end of the Industrial Revolution, the skill premium for craftsmen, especially carpenters, in Great Britain was 1.5 higher than that for laborers in construction (Roser & Nagdy, 2020). Separate studies on the same subject in relation to the development of the capitalist economy in the twentieth century have also revealed that the wage gap never closed even though it had its variations and temporary increases due to the peculiarities of national economies. For instance, data on the US economy shows that educational and occupational wage differentials were exceptionally high at the beginning of the twentieth century and then decreased in several stages over the next eight decades. However, starting in the early 1980s, the labor market premium to skill rose sharply, and by 2005 the college wage premium was back at its 1915 level (Goldin & Katz, 2007). In view of its particular importance, this issue of the American economy is closely examined in a number of scientific papers which acknowledge that there is a growing polarization in wages in the present-day US economy and part of it is due to differences in educational attainment: remuneration for work is proportional to the level of education (Acemoglu & Restrepo, 2017; Autor, 2014; Blau & Kahn, 2005).

The same issue is relevant for a lot of European countries. There are countries in Europe with both high skill inequality and high wage inequality (Italy and

Germany), and others with both low skill inequality and low wage inequality (Scandinavian countries), there are also countries with high skill inequality but low wage inequality (France), although, generally, workers with higher skills have wages that are 60% higher than those of low-skilled workers (Broecke, 2016). Extensive research undertaken by the Organization of Economic Cooperation and Development (OECD) (OECD, 2011; OECD, 2015; Paccagnella, 2015) shows that there is evidence at the inter-country level that, as a rule, countries which are better at meeting the demand for skills also have lower wage inequality. Yet, from 33% to 57% of wage inequality in OECD countries is attributed to differentials in skill levels. University graduates earn on average 1.57 times more than high school graduates (OECD, 2019).

Research conducted under the auspices of the International Labour Organization (ILO) and involving developed as well as developing economies uncovers some inter-country differences: in European countries, wage distribution is skill-related, that is, the bottom seven deciles are made up of employees with secondary education whereas the upper three deciles include a higher share of workers with university degrees. In the Russian Federation, a similar distribution is quite surprising: deciles three to ten appear to be dominated by university graduates (ILO, 2017).

Despite a variety of established views on the interrelation of levels of educational attainment, qualification, and wages, there prevails an opinion that long-term trends attest to a close relationship among them. Occasional mismatches mostly occur because technological changes transform the level and distribution of demand for workforce that is partly overcome by labor reallocation. The latter implies that employees have to comply with new requirements for educational attainment and qualification.

3 Interrelations between Technological Change and Level of Qualification

Economic development, especially in the last two centuries, has been driven, in large part, by advancements in science and education. Their tight interconnection provided the material-producing sectors and later the service sector with new technologies and materials, which enabled rapid transformations in economic and social spheres. Yet, as world experience indicates, the interrelations between technical progress and employment have always been intricate and nuanced. At the company level, innovative technologies have most commonly resulted in job cuts. At the level of individual sectors and the national economy as a whole, this adverse effect has been alleviated through institutional factors (such as state intervention or spatial shifts) or market mechanisms (internal labor migration, establishing new companies, etc.). Economic literature boasts of many works describing mechanisms for the interaction of innovative technologies and employment, of which some recent ones are worthy of notable mention (Arntz et al., 2016; Autor & Salomons, 2018; Bessen, 2018; Graetz & Michaels, 2018; Pellegrino et al., 2015).

One of the first pioneer studies published in 2003 pointed out that production and clerical medium-skill jobs are characterized by highly intensive activities that can be accomplished by following explicit rules (so-called "routine tasks") and relatively easily replaced with computer programs (Autor et al., 2003). Rapid advancement that began in the field of information and communication technologies in the early 1980s accelerated the automation of such routine tasks, enabling the start of people replacement in many medium-skill occupations, such as accounting, record-keeping, and batch production. This resulted in a significant reduction in the relative economy-wide demand for common medium-skill occupations. However, there is still a substantial layer of nonstandard manual cognitive tasks in the economy that are not yet easily accomplished by machines or software (e.g., driving a car or cleaning an office).

These trends induced in the labor market by technological factors took place against the backdrop of a significantly increased educational attainment level of those employed in the economy. For instance, the share of the employed in the US economy with a secondary education in 1985 amounted to 73.9% against 24.5% in 1940 and subsequently increased to 89.8% in 2018 (US Department of Education, 2020). Concurrently, European and American economies witnessed a growing wage gap between high- and medium-skilled workers (i.e., those with secondary education and those with tertiary education): in 2008, earnings of the average college graduate in the USA exceeded those of the average high school graduate by 97% while in the early 1980s this gap amounted to only 15–20% (Acemoglu & Autor, 2011). Due to a fall in occupations specializing in routine tasks medium-skilled professionals were washed out from the labor market and reallocated into two zones, that is, into the zone of high-skill and high-wage labor and into the zone of low-skill and low-wage labor. This new social phenomenon has come to be called the "employment polarization" (Autor & Dorn, 2013).

In the 1980s, about one in three Americans was employed in a routine occupation; currently, the figure stands at one in four. Also, since 1991, employment in routine occupations has been failing to recover from recessions even though it did turn around during the recessions of the 1970s and 1980s (Siu & Jaimovich, 2012). The polarization process accelerated after the 2000s. This was facilitated by emerging computer technologies with AI elements which already started replacing people in the spheres that require performing advanced cognitive activities, such as rendering financial or legal aid services, education, and healthcare. A number of breakthrough technologies enabled a new technological leap. There was a rapid advancement of NBIC technologies (Roko, 2011). The new technologies of the Fourth Industrial Revolution along with Industry 4.0 became a practical reality (Kagermann et al., 2013; Schwab, 2016; Schwab & Davis, 2018). Meanwhile, the Industrial Internet, a digital platform that ensures effective Internet-based interactions among objects of industrial production, is becoming the underlying infrastructure for Industry 4.0 (Greengard, 2015). The rise of intelligent robots means they will be widely used in most social and economic spheres of life (Ford, 2015). Also, there has appeared a multifunctional digital information technology designed to reliably record various assets and operations with them, that is, Blockchain technology (Swan, 2015).

All these technologies in the aggregate constitute a new, digital infrastructure capable of transforming the whole economic landscape. This new stage in technological development will involve a loss of many traditional professions. Most low-skill jobs in the service sector will remain available to people for the sole reason that it will be economically unviable to substitute them with expensive intelligent machines. It is, therefore, to be expected that a considerable share of medium-skilled employees may be eligible for low-wage positions in the service industries. To avoid such a scenario and to maintain demand for middle-class medium-skilled workers, significant adjustments should be made to practices in professional education and training so as to ensure that new requirements for employees match up with their level of professional educational attainment.

4 Modern Professional Education and the Labor Market

In developed countries, the modern system of education and professional training was established after the Second World War. It primarily catered to the needs of the middle class that at that time provided the basis for the economic and political stability in developed capitalist societies, and mostly trained professionals with medium and upper-medium skills. In very general terms, this system included the following levels of education and qualifications. The lowest educational qualifications are provided by primary education (4 years of study), which offers minimal body of knowledge and basic training in reading, writing, and arithmetic. The next level of education is lower secondary education (typically, 9 years of study). These two levels of education prepare workers for unskilled or low-skill jobs. Upper secondary education provides general secondary or vocational training (typically, 10–12 years of study). Combined with two-year college programs and four-year bachelor's programs, these three levels of education account for training professionals with medium and upper-medium skills. It can thus be seen that 12–16 years of training is enough to attain a qualification level and enter the middle class by income level.

The next upper levels of education, master's and doctoral, aim at training highly qualified professionals, and their training takes from 18 to 20 years. The Soviet system of education was quite similar to the described above: it took 10–12 years to train medium-skilled professionals and 16–20 years to prepare high-skilled ones. Below, there is a dynamics of the share of the US population over 25 years old with a bachelor's degree or higher, over the period 1940–2018. As seen from Fig. 1, the proportion of high-skilled workers was growing at a slower rate than that of medium-skilled workers. By 2018, the share of the latter amounted to 89.8% and that of the former to 34.5%. So, it can be concluded that the American system of education was primarily geared toward the education and professional training of medium-skilled workers. And it is precisely this social group that formed the basis of the American

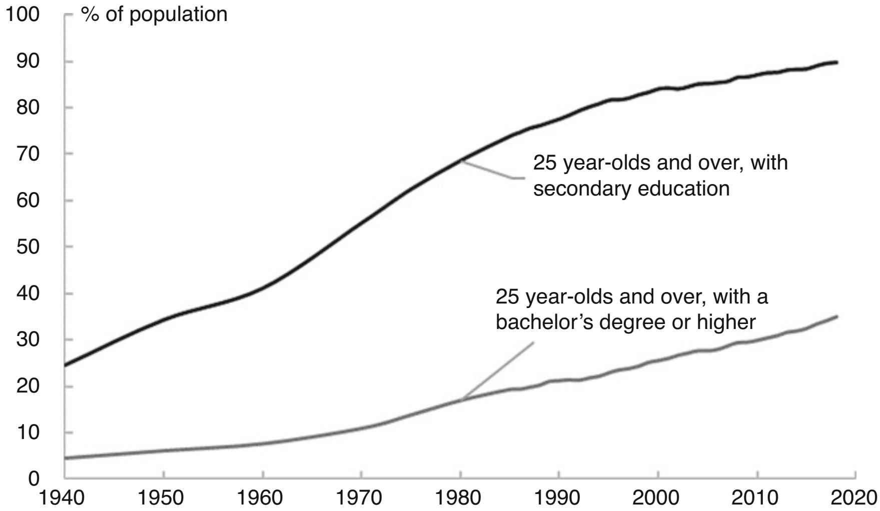

Fig. 1 Dynamics of educational attainment in the USA. Source: US Census Bureau (1940–2015)) Current Population Survey

Table 1 Educational attainment of 25–64 year olds (% of total population)

	Secondary education			Tertiary education		
Countries	2010	2015	2016	2010	2015	2016
USA	89.0	88.4	90.1	41.7	44.6	45.7
Germany	85.8	86.8	86.5	26.6	27.6	28.3
Russia	92.8	93.7	94.0	50.4	52.4	53.1
OECD average	75.0	77.6	78.8	30.6	34.7	35.8

middle class. But, as was shown earlier, the explosive growth of the information and communication technology sector, which started in the 1980s, initiated the trend toward replacing people in medium-skill occupations with means of automation, robotization, and software products.

Table 1 represents data on the educational attainment of 25–64 year olds across different countries, including Russia (OECD, 2019). The table singles out two levels of education: secondary (10–12 years of study) and tertiary, encompassing bachelor's (two- and four-year programs), master's, and doctoral.

As seen from the table, the employment rate of tertiary-educated adults in Russia is very high—almost twice that in Germany. This raises a legitimate question as to the closeness of relations between education systems and the rapidly changing demands of the modern labor market in terms of skills and professional training of new employees.

According to the International Standard Classification of Education (UNESCO, 2012), the OECD and UNESCO identify nine levels of education (UNESCO, 2017).

Table 2 Levels of educational attainment according to international education standards

Level of qualification	International Standard Classification of Education (UNESCO, 2012) Level	Verbal description
Low	0	Incomplete primary
	1	Primary
	2	Lower secondary
Medium	3	Upper secondary
	4	Post-secondary non-tertiary
	5	Short-cycle tertiary
	6	Bachelor's or equivalent
High	7	Master's or equivalent
	8	Doctoral or equivalent

Table 3 Distribution of the population over 25 years of age, by level of educational attainment corresponding to different qualification levels (%)

	Levels of qualification				
	Low			High	
Country	Total	Including unskilled adults (levels 0–1)	Medium	Total	Including doctoral or equivalent
Australia	18.1	4.4	73.5	8.4	1.2
Canada	8.4	2.2	81.4	10.3	–
France	20.6	6.8	67.1	12.3	0.9
Germany	13.3	3.7	73.6	13.1	1.4
Italy	38.3	5.7	46.9	14.9	0.5
Japan	–	–	100.0	–	–
South Korea	11.8	4.2	83.0	4.7	–
UK	20.7	0.2	66.1	13.2	1.4
USA	9.2	3.3	77.7	13.1	2.0
China	75.5	28.2	24.0	0.4	–
Russia	4.8	0.5	65.6	29.6	0.3

Table 2 contains descriptions for every level and their equivalents in the Russian system of education standards.

We used this classification to systematize data on levels of educational attainment in different countries as in 2017–2018 (Table 3). Table 3 indicates that the distribution of labor supply by the level of educational attainment is approximately the same in such countries as the USA (the share of low qualifications ≅9.2%; the share of medium qualifications ≅77.7%; the share of high qualifications ≅13.1%), Germany (13.3%; 73.6%; 13.1%), the UK (20.7%; 66.1%; 13.2%), and France (20.6%; 67.1%; 12.3%). In some countries, due to a quite abnormally high proportion of workers with medium levels of qualification (81.4% in Canada, 83.5% in South Korea, and a whopping 100% in Japan), the patterns of distribution are different.

Table 4 Dynamics of the share of the employed population with medium and high levels of qualification, 1990–2018 (%)

Country	Medium		High	
	1990	2018	1990	2018
Canada	49.6	81.4	–	7.1
France	48.3	67.1	–	12.3
South Korea	48.4	83.0	–	4.7
Sweden	55.4	65.8	–	19.7
USA	77.6	89.8	10.1	13.1

Yet, if one looks closely at the share of the employed with a medium level of educational attainment over the last 25 years (see Table 4), it becomes evident that this process was not evenly distributed.

It is particularly notable that the share of the employed with a high level of qualification in the USA has increased insignificantly over the last 30 years. As for the share of the employed with a medium level of qualification, it has notably almost doubled in Canada and South Korea. Sweden, a country traditionally known for its high social standards, demonstrates consistency in the field of training medium-skilled professionals. A high share of workers with a medium level of qualification may indirectly indicate that the system of education in these countries is largely geared toward training professionals for the traditional rather than digital economy. A marked feature of Tables 3 and 4 is that they show the distribution of labor by the levels of qualification established in the labor market.

In the digital age, market demand for highly qualified workers will be growing for a whole variety of reasons. Firstly, digital technologies are expected to generate a considerable number of new jobs in such spheres as big data analytics, AI training and management, development of intelligent computing technologies and software, training, maintenance, and management of intelligent robots. Secondly, diffusion of new technologies always produces an indirect effect by creating new occupations in related industries. Jobs in these emerging industries will require deep and versatile math and engineering expertise and work skills that can only be attained by completing graduate and postgraduate studies. For instance, high-tech sector currently employs 2.9 million people in the USA (1.9% of all the employed) and 2.4% of all the labor force in Germany. McKinsey Global Institute predicts that an increase in spending on technology will generate, within the global economy, a demand for 20–46 million additional, mostly highly skilled, workers by 2030, and half of them will be needed in such countries as China, Germany, India, the Netherlands, and the USA. It is also expected that by then work activities taking up around 30% of the time spent in all occupations will be automated (Manyika et al., 2017). The US Department of Labor projects that by 2024 new jobs will be created in the following STEM fields: ICT (+76%), Mathematics (+7%), Science (+6%), Engineering (+11%) (US BLS, 2014).

Secondly, the world today is going through another stage in labor market evolution caused by the transition to a high-tech and research-intensive economy. At present, research- and knowledge-intensive industries are generally divided into two subcategories: leading-edge technologies with a threshold of 9% of internal

R&D expenditure on sales; and high-level technologies with a threshold of 3% (Gehrke et al., 2012). It should be pointed out that nearly all the technologies forming a new, digital economy are advanced. This is mostly due to the fact that these technologies are associated with knowledge generation based on human capital investments (Gehrke et al., 2012). So, expectations are raised as to some exponential growth in spending on science and education. It should also be taken into account that the R&D sector employs "rare production factors," that is, highly trained professionals, researchers, and scientists. It follows that the growing knowledge intensity of the digital economy also increases demand for highly qualified professionals from the STEM sector.

At the EU level, STEM core fields of study include life science; physical science; computing; mathematics and statistics; engineering and engineering trades; manufacturing and processing. As for professional occupations, core STEM occupations are science and engineering professionals; ICT professionals; science, engineering, and ICT associate professionals (technicians). STEM professionals encompass a wide range of knowledge-intensive occupations, including scientists (i.e., physicists, mathematicians, and biologists), engineers, and architects. There were 6.6 million employed in these occupations in the EU28 in 2013. They comprised 17% of all professionals and 3% of the total employment. STEM technicians encompass technical occupations connected with research and technology, including technicians in physics, life science, engineering, supervisors, and process control technicians in industry, ship, aircraft, and ICT technicians. In 2013, there were 9.7 million employed in this group in the EU28. They comprised 27% of all technicians and 5% of the total employment (DTI, 2015).

Consider the dynamics of the share on STEM graduates in selected OECD countries over the period 2010–2017 (OECD, 2018). See Tables 5a and 5b.

First off, it is important to point out that leading countries (Germany, South Korea, and the UK) apparently prioritize STEM studies, approximately one-third of bachelor's graduates earn their degrees in STEM subjects. Germany and Sweden have approximately the same proportions among master's graduates. The share of doctoral graduates in STEM disciplines approaches 50% across all the selected countries and amounts to a whopping 62.4% in France. These trends in training highly qualified professionals are congruent with labor market demands. In EU countries, the STEM employment rate has been growing steadily since 2000. In 2013, the number of STEM employees was 13% higher than in 2000. It is also projected that employment in STEM occupations will increase by 12.1% by 2025. In 2013, around 3 million of the 15 million STEM professionals employed in EU28 countries worked in high-tech industries. A higher labor market demand for STEM occupations translates into higher wages in the field: the average wage premium for STEM professionals amounts to 19% (DTI, 2015).

Traditional European STEM disciplines are very close to those encompassed within the US field of Science and Engineering. Data provided by the National Science Board, which keeps track of vocational training in S&E, and the National Center of Education Statistics allowed for tracing the dynamics of US graduates with high qualifications over the period 2000–2015 (NCES, 2018; NSB, 2018).

Table 5a Dynamics of the share of STEM graduates in selected OECD countries (%)

Field of study	Germany	France		Sweden	
	2017	2010	2017	2010	2017
Bachelor's degree					
Natural sciences, mathematics, and statistics	6.0	11.4	10.1	2.1	3.7
ICT	5.0	4.2	3.0	2.0	4.1
Engineering	23.9	9.0	8.3	9.6	11.3
Total	34.9	24.6	21.4	13.7	19.1
Master's degree					
Natural sciences, mathematics, and statistics	11.6	8.3	7.8	5.6	4.6
ICT	4.4	4.0	3.5	2.2	2.0
Engineering	19.4	17.5	15.6	24.1	24.1
Total	35.4	29.8	26.9	31.9	30.7
Doctoral degree					
Natural sciences, mathematics, and statistics	29.1	42.1	42.8	–	20.3
ICT	3.4	5.2	5.4	–	5.2
Engineering	13.2	12.4	14.2	–	24.9
Total	45.7	59.7	62.4	–	50.4

Table 5b Dynamics of the share of STEM graduates in selected OECD countries (%)

Field of study	South Korea		Canada		UK	
	2010	2017	2010	2017	2010	2017
Bachelor's degree						
Natural sciences, mathematics, and statistics	7.6	5.9	10.4	9.8	–	17.0
ICT	2.4	4.8	1.9	2.3	–	4.1
Engineering	23.6	21.0	8.8	8.9	–	8.2
Total	33.6	31.7	21.1	21.0	–	29.3
Master's degree						
Natural sciences, mathematics, and statistics	5.5	5.2	10.5	6.5	–	8.3
ICT	0.7	3.0	2.1	3.4	–	2.8
Engineering	16.9	15.2	9.4	12.7	–	9.7
Total	23.1	23.4	22.0	22.6	–	20.8
Doctoral degree						
Natural sciences, mathematics, and statistics	11.3	13.3	31.3	26.2	25.0	29.1
ICT	1.1	3.3	4.0	3.5	4.5	3.9
Engineering	22.7	24.4	20.0	21.4	14.8	14.7
Total	35.1	41.0	55.3	51.1	44.3	47.7

Let us consider two US trends. First, there has been a considerable growth in the number of S&E graduates: in the course of 15 years, it increased 1.7 times and exceeded 1 million people in 2015. Second, S&E graduates constitute nearly 30% of the total number of all graduates and 34% of the bachelor's graduates. It is also important to point out that the US system of education keeps a strong focus on training professionals with medium qualifications, namely, graduates with two-year

Table 6 Comparative dynamics of US graduates with medium and high qualifications, including the S&E, (thousand people)

Qualification level	2000	2015		
	S&E	S&E	Total	Share, %
Associate's in S&E (2 years)	38.0	91.0	1014.3	23.0
Associate's in S&E technologies (2 years)	83.7	144.0		
Bachelor's	398.3	649.2	1894.9	34.0
Master's	96.0	180.9	758.9	23.0
Doctorate	28.0	39.2	178.5	21.0
Total	644.0	1104.3	3846.6	28.0

associate's degrees. Data in Tables 5a, 5b and 6 indicate that Western education systems training STEM professionals with medium and high qualifications adjust to the changing needs of the labor market and can, to a significant degree, meet economic demand for professionals much needed in the emerging digital economy.

5 Modern System of Education in Russia

The dissolution of the USSR forced the Russian system of education to go through a difficult period of transformation and adjustment to new economic conditions. There can be no doubt that the country's educational potential inherited from the socialist system was largely lost. The task of establishing a new system of professional training is fraught with many challenges, most notably related to ensuring the quality of graduate training and the compliance of their qualifications with labor market needs. Table 7 cites data from the Rosstat on the number of graduates 2006–2018 with different qualification levels, whereas Table 8 shows the distribution of graduates by the level of qualification: medium, high, and very high (Russia in Figures, 2012, 2018, 2019).

First of all, most conspicuous is the fact that the number of graduates with secondary complete general education has halved and the number of blue- and white-collar workers has shrunk to a quarter over the last 15 years. All this combined has reduced the share of medium-skilled graduates from 70% to 58%. Overall, this trend can be seen as positive since the share of highly skilled professionals has concurrently risen from 28% to 41%. However, these qualitative changes were accompanied by a decline in the absolute number of highly qualified professionals, especially compared to 2011, by more than a third. It is also prominent that the share of graduates with very high qualifications, that is, postgraduates and doctorates, has fallen dramatically—by half. Data from the Russian Ministry of Education made it possible to analyze the dynamics of percentage distribution among highly qualified professionals who attained bachelor's, specialist's, or master's degrees in 2013–2018 (MSHE, 2019). The results of this analysis are shown in Table 9.

Table 7 Dynamics of graduate output from Russian educational and research institutions (thousand people)

Type of graduates	2006	2011	2016	2017	2018
Students with a Certificate of Basic General Education	1944.1	1354.1	1198.3	1234.3	1283.0
Students with a Certificate of Secondary Complete General Education	1466.0	1466.0	647.8	635.2	621.2
Graduates of training programs for skilled workers, office workers	703	581	368	199	194
Graduates of training programs for mid-level specialists	684	572	446	469	507
Graduates with bachelor's, specialist's and master's degrees	1151	1468	1161.1	969.5	933.2
Postgraduates (people)	33,561	33,763	25,992	18,069	17,729
Postgraduates with a publicly defended dissertation (people)	10,650	9611	3730	2320	2198
Doctoral graduates (people)	1383	1321	1346	253	330
Doctoral graduates with a publicly defended dissertation (people)	450	382	151	65	82

Table 8 Distribution of graduates from Russian educational and research institutions by the level of qualification

Level of qualification	2006	2011	2018
Medium	70.0	63.0	58.0
High	28.0	35.0	41.0
Postgraduates and doctorates	2.0	2.0	1.0
Total	100	100	100

Table 9 Percentage of graduates from Russian institutions of higher education by level of qualification (%)

Level of qualification	2013	2014	2015	2016	2017	2018
Bachelor's degree	9.3	17.5	45.3	65.7	75.6	70.8
Specialist's degree	86.3	76.4	48.7	27.2	10.2	11.0
Master's degree	4.4	6.1	6.0	7.1	14.2	18.2
Total	100	100	100	100	100	100

As seen from Table 9, there has been a sharp increase in the relative share of bachelor's degrees, which are awarded today to every seventh graduate from a higher education program. The share of master's degrees has grown more than fourfold while the share of specialist's degrees has reduced more than sevenfold over the same time period.

The percentage of graduates by occupation and field of study is also of certain interest. As noted before, core STEM occupations are set to play a key role in many sectors of the emerging digital economy. The dynamics of graduate output by STEM occupation in regard to bachelor's, specialist's, and master's degrees is presented in

Table 10 Dynamics of graduate output from Russian institutions of higher education (including STEM fields) by level of qualification

Level of qualification	2013			2015			2018		
		including STEM			including STEM			including STEM	
	All	ppl	%	All	ppl	%	All	ppl	%
Bachelor's degree	120,172	16,426	13.0	589,754	124,822	21.0	660,950	144,125	21.0
Specialist's degree	1,114,277	94,168	8.0	633,316	63,535	10.0	101,766	25,068	24.0
Master's degree	56,521	19,802	35.0	77,401	26,391	34.0	170,437	57,841	33.0
Total	1,290,970	130,396	10.0	1,226,156	142,708	11.0	933,153	227,034	24.0

Table 11 Postgraduate and doctorate output by STEM field of study in Russia

Fields of study	Postgraduates			Doctorates		
	2011	2016	2017	2011	2016	2017
All	33,082	25,992	10,612	1321	1346	253
Physics and Mathematics	1910	1677	907	87	111	14
Chemistry	806	658	428	50	49	4
Engineering	7547	7286	3079	345	366	50
Earth Science	1111	1050	336	46	47	5
Agriculture	1074	954	381	37	40	13
Biology	1750	1437	763	45	42	9
STEM fields, total	14,198	13,062	5894	610	655	95
STEM graduate share	42.0%	50.0%	55.0%	46.0%	48.0%	37.0%

Table 12 Comparative table of output of STEM graduates with bachelor's, master's, and doctoral degrees in Russia and the USA

Levels of qualification	Russia, 2018			USA, 2015		
	All	including STEM		All	including S&E	
		ppl	%		ppl	%
Bachelor's program	660,950	144,125	21.0	1,849,900	649,200	34.0
Master's and Specialist's programs	272,203	82,909	30.0	758,900	180,900	23.0
Doctoral program	15,795	6197	39.0	178,500	39,200	21.0
Total	948,948	233,231	24.0	3,846,600	1,104,300	28.0

Table 10. Table 11 contains similar data but in regard to postgraduates and doctorates (Russia in Figures, 2012, 2018, 2019).

As seen from Tables 10 and 11, there has been a significant increase in the share of STEM bachelor's and specialist's degrees over the last 6 years. The proportion of STEM master's degrees remains stable at 33% and that of postgraduate and doctoral degrees has barely changed over the last ten years and is generally around 50%. Conversely, there has been a decline in the total number of STEM high-skilled graduates: there are now three times fewer postgraduate degrees and almost five times fewer doctoral degrees awarded in the STEM field. This is an extremely alarming symptom indicative of an emerging development trend discordant to current global trends. For comparison purposes, Table 12 shows the total output of graduates, including those in STEM fields, in Russia and the USA in 2018 and 2015, respectively.

As seen from Table 12, the education systems of both countries devote great attention to the training of professionals for STEM-based industries and occupations. Interestingly, the USA has the highest relative proportion of STEM professionals among bachelor's graduates (34%) and the lowest among doctoral graduates (21%). In Russia, on the contrary, 30–40% of graduates with master's, postgraduate and doctoral degrees specialize in STEM. However, the overall output of STEM graduates in the USA is quite impressive and exceeds 1.1 million people a year, which is

Table 13 Distribution of the employed by level of educational attainment

Level of educational attainment	2008	2011	2015	2016	2017	2018
Employed in the economy, total	100	100	100	100	100	100
With higher education	27.9	29.5	33.0	33.5	34.2	34.2
With secondary vocational education, including: – On training programs for mid-level specialists – On training programs for skilled workers (office workers)	47.5 28.2 19.3	46.4 26.9 19.5	45.0 25.8 19.2	45.1 25.9 19.2	44.8 25.6 19.2	45.0 25.5 19.5
With secondary complete general education	20.1	19.7	18.4	18.1	17.4	17.2
With basic general education	4.1	3.9	3.4	3.2	3.4	3.4
With no schooling	0.4	0.5	0.2	0.1	0.2	0.2

five times more than that in Russia. This is a strong incentive to start thinking about the direction in which the Russian system of education should make a breakthrough.

Tables 9–11 contain data on the dynamics and percentage distribution of graduates from Russian educational and research institutions. These figures reflect the structure of the supply of highly qualified professionals in the labor market. But it is also necessary to consider the percentage distribution of the employed by level of educational attainment. This data is shown in Table 13.

Comparison of data from Tables 9–11 reveals a discrepancy in qualification levels between the percentage distribution of graduate output and the current structure of the labor market. The education system produces more high-skilled graduates than the labor market can employ. This may explain why 9% of 2010–2015 graduates with master's degrees and about 15% of those with bachelor's degrees are unemployed (MoL, 2016). One of the contributing factors to this situation can be a discrepancy in qualification levels between the percentage distribution of graduate output (i.e., supply) and the economic demand of the labor market.

6 Levels of Qualification, Industry, and Regions

As can be seen, the issue of discrepancy between the level of qualification attained by the bulk of graduates with a higher education degree and market expectations is complex. It involves closely intertwined technological factors, the ever-changing behaviors of firms and companies, labor migration, and regional factors. Indeed, as it was already mentioned above, periodic mismatches between supply and economic demand for skilled workforce can be reduced through labor reallocation, which raises an important practical question: Can regions with no high-tech industries benefit from such technologies? If yes, then in what way?

One of the latest studies of data covering 15 EU countries (Austria, Belgium, Denmark, Spain, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Sweden, and the UK) and also including Australia, Japan, South Korea, and the USA over the period 1970–2017 yielded a number of interesting and applicable results (Autor & Salomons, 2017). The value of the study also lies in its analysis of development dynamics for 32 industries.

Most notably, the study draws two conclusions about the effect of productivity on employment:

- Productivity growth resulting from technological progress has produced positive effects at the national economy level on aggregate employment growth over the last 35 years in all countries studied.
- These positive employment effects have been distributed across all groups of workers unevenly.

An uneven distribution of these effects can be due to a change in the relative demand for skills within industries, which upsets the established balance among differently skilled workers, and to sectoral reallocations stemming from unbalanced productivity growth across industries that spur changes in aggregate labor demand by skill group. To substantiate this statement, the authors refer to some calculations, whose results indicate that a 10% productivity gain in high-tech services, and in health and education, raises economy-wide employment by 0.7–0.9%. The external effects of productivity growth in low-tech services are roughly twice as great as in any other sector, and estimated at 1.7%. This effect may stem from the fact that low-tech services are the largest sector in all five major economies studied, encompassing 30–40% of employment (Autor & Salomons, 2017, pp. 29–30, 41–42). Consequently, it is at the intersection of industries and regions where the greatest effects for regional development may be achieved.

7 Conclusion

1. The conducted analysis has revealed that the supply of professionals generated by the modern education system by level of their qualification mostly meets the demand of a Third Industrial Revolution economy (1950–2010), although rapidly advancing technologies of the Fourth Industrial Revolution persistently shift demand for labor toward high-skilled professionals.
2. The digital economy, high-tech and research-intensive, is bound to need increased expenditure on education and R&D. Most of all, it will require experts and researchers from such STEM fields as R&D, high-tech, engineering, and mathematics for digital technologies and AI.
3. Leading industrially advanced countries have significantly bolstered training for medium- and high-skilled STEM professionals (i.e., in bachelor's, master's, and doctoral programs) in accordance with the demands of the emerging digital economy by taking advantage of state support and private funds.
4. In the future, broadening training for STEM professionals may be economically constrained, among other things, by online global recruitment platforms and affiliates of high-tech companies bringing in retired employees to execute contracts. Such global online platforms as Upwork and Kaggle can potentially attract

over 4 million top-level professionals to solve tasks associated with STEM occupations.

5. A complex approach conjugating both established qualification levels of the employed in the industries and the technological development level of the region itself appears to be the most promising avenue to take when planning regional development. Given the external effects of productivity growth in high-tech services, there are always opportunities for development in low-tech services which account for 30–40% of the total employment even in the most developed countries.

References

Acemoglu, D., & Autor, D. H. (2011). Skills, tasks and technologies: Implications for employment and earnings. *Handbook of Labor Economics, 4B*, 1043–1171.

Acemoglu, D., & Restrepo, P. (2017). Robots and jobs: Evidence from US Labor Markets (NBER Working Paper No. 23285). https://doi.org/10.3386/w23285

Arntz, M., Gregory, T., & Zierahn, U. (2016). The risk of automation for jobs in OECD countries: A comparative analysis (OECD Social, Employment and Migration Working Papers 189).

Autor, D., & Salomons, A. (2017). Robocalypse now—Does productivity growth threaten employment? Paper prepared for the ECB Forum on Central Banking.

Autor, D. H. (2014). Skills, education, and the rise of earnings inequality among the other 99 percent. *Science, 344*(6186), 843–851.

Autor, D. H., & Dorn, D. (2013). The growth of low-skill service jobs and the polarization of the US labor market. *The American Economic Review, 103*(5), 1553–1597.

Autor, D. H., Levy, F., & Murnane, R. (2003). The skill content of recent technological change: An empirical exploration. *Quarterly Journal of Economics, 118*(4), 1279–1333.

Autor, D. H., & Salomons, A. (2018). Is automation labor share-displacing? Productivity growth, employment, and the labor share (NBER Working Paper No. 24871).

Bessen, J. E. (2018). Automation and jobs: When technology boosts employment (Boston Univ. School of Law, Law and Economics Research Paper No. 17-09).

Blau, F. D., & Kahn, L. M. (2005). Do cognitive test scores explain higher U.S. wage inequality? *The Review of Economics and Statistics, 87*(1), 184–193.

Broecke, S. (2016). Do skills matter for wage inequality? IZA World of Labor, vol. 232. https://doi.org/10.15185/izawol.232

Danish Technological Institute (DTI). (2015). Does the EU need more STEM graduates? https://op.europa.eu/en/publication-detail/-/publication/60500ed6-cbd5-11e5-a4b5-01aa75ed71a1

Ford, M. (2015). *The rise of the robots: Technology and the threat of a jobless future*. Basic Books.

Gehrke, B., Frietsch, R., & Rammer, C. (2012). *Re-definition of research-intensive industries and goods*. Commission of Experts for Research and Innovation.

Goldin, C., & Katz, L. F. (2007). The race between education and technology: The evolution of U.S. educational wage differentials, 1890 to 2005 (NBER Working Paper 12984).

Graetz, G., & Michaels, G. (2018). Robots at work. *Review of Economics and Statistics, 100*(5), 753–768.

Greengard, S. (2015). *The internet of things*. MIT Press.

ILO. (2017). Wage inequality in the workplace. (Global Wage Report 2016/17).

Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0—Securing the Future of German Manufacturing Industry (Final Report of the Industrie 4.0 Working Group).* Acatech: National Academy of Science and Engineering.

Katz, L. F., & Margo, R. A. (2014). Technical change and the relative demand for skilled labor: The United States in historical perspective. In L. Boustan, C. Frydman, & R. A. Margo (Eds.), *Human capital in history*. University of Chicago Press and NBER. https://doi.org/10.7208/chicago/9780226163925.003.0002

Manyika, J., et al. (2017). *A future that works: Automation, employment, and productivity*. McKinsey Global Institute.

Ministry of Labor of the Russian Federation (MoL) (2016). Analysis of the position of graduates with higher and secondary education in the labor market in Russia. http://spravochnik.rosmintrud.ru/storage/app/media/Analiz%20polojeniya%20vepucknikov_VNII%20tpuda.pdf

Ministry of Science and Higher Education of the Russian Federation (MSHE). (2019). https://minobrnauki.gov.ru/

National Center for Education Statistics (NCES). (2018). Digest for education statistics. https://nces.ed.gov/programs/digest/

National Science Board (NSB). (2018). 'Science & Engineering Indicators. https://www.nsf.gov/statistics/2018/nsb20181/report

OECD. (2011). *Divided we stand: Why inequality keeps rising*. OECD Publishing.

OECD. (2015). Skills and wage inequality. OECD Employment Outlook 2015. Paris: OECD Publishing.

OECD. (2017). *OECD Employment Outlook 2017*. OECD Publishing. https://doi.org/10.1787/empl_outlook-2017-en

OECD. (2018). Distribution of graduates and entrants by Field. https://stats.oecd.org/Index.aspx?datasetcode=EAG_GRAD_ENTR_FIELD

OECD. (2019). *Education at a glance 2019: OECD indicators*. OECD Publishing. https://doi.org/10.1787/f8d7880d-en

Paccagnella, M. (2015). Skills and wage inequality: Evidence from PIAAC (OECD Education Working Papers, No. 114). https://doi.org/10.1787/5js4xfgl4ks0-en

Pellegrino, G., Piva, M., & Vivarelli, M. (2015). How do new entrepreneurs Innovate? *Economia e Politica Industriale, 42*(3), 323–341.

Roko, M. C. (2011). The long view of nanotechnology development: The national nanotechnology initiative at 10 years. *Journal of Nanoparticle Research, 13*, 427–445.

Roser, M., & Nagdy, M. (2020). *Returns to education*. Our World in Data. https://ourworldindata.org/returns-to-education

Russia in Figures. (2012). Brief Statistical Book. M: ROSSTAT. https://gks.ru/bgd/regl/b12_11/Main.htm

Russia in Figures. (2018). Brief statistical collection. M: ROSSTAT. https://gks.ru/bgd/regl/b18_11/Main.htm

Russia in Figures. (2019). Brief statistical book. M: ROSSTAT. https://gks.ru/bgd/regl/b19_11/Main.htm

Schwab, K. (2016). *The fourth industrial revolution*. Crown Business.

Schwab, K., & Davis, N. (2018). *Shaping the future of the fourth industrial revolution: A guide to building a better world*. Portfolio Penguin.

Siu, H., & Jaimovich, N. (2012). Jobless recoveries and the disappearance of routine occupations (NBER Working Paper No. 18334).

Swan, M. (2015). *Blockchain: Blueprint for a new economy*. O'Reilly Media.

U.S. Department of Education. (2020). National Center for Education Statistics. https://nces.ed.gov/fastfacts/display.asp?id=27

UNESCO. (2017). Institute for statistics. Educational attainment—Share of population by educational attainment. http://data.uis.unesco.org/index.aspx?queryid=168

UNESCO. (2012). *Institute for statistics. International Standard Classification of Education ISCED 2011*. http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf

US BLS. (2014). Employment Projection 2014. www.bls.gov/emp/ep_table_102.htm

US Census Bureau. (1940–2015). Current Population Survey.