Journal of Open Innovation:
Technology, Market, and Complexity

Article

Human Resources Readiness for Industry 4.0

Jaroslav Vrchota *, Monika Maříková, Petr Řehoř, Ladislav Rolínek and Radek Toušek

Faculty of Economics, University of South Bohemia in České Budějovice, 370 05 České Budějovice, Czech Republic; marikova@ef.jcu.cz (M.M.); rehor@ef.jcu.cz (P.Ř.); rolinek@ef.jcu.cz (L.R.); tousek@ef.jcu.cz (R.T.)
* Correspondence: vrchota@ef.jcu.cz

Received: 8 November 2019; Accepted: 23 December 2019; Published: 27 December 2019

Abstract: Industry 4.0 is related to major changes, particularly in production. As such changes might have major implications for the labour market; the paper focuses on the assumptions of the human capital and its preparedness for Industry 4.0 in the Czech Republic. The findings are based on EUROSTAT, MEYS, OECD, ISCED, CZSO, and WEF. Based on such data, twelve indicators were selected and described in the results. Subsequently, the correlation analysis was carried out, using the data of the Czech Republic in order to estimate which indicators are related and thus to obtain a more detailed view of areas that need to be improved. The level of computer skills in the Czech Republic are increasing. Internet connection is around 80%. The share of technical workers in the Czech Republic is in the range of 30–40%. In terms of expenditure on education, the Czech Republic belongs to the countries of the eastern region. The number of graduates of technical professions managed to catch up with the development of the European Union (EU). In terms of employment in High-tech and Medium-high-tech areas, the Czech Republic is one of the leaders in the EU. Czech students have great potential in basic computer skills.

Keywords: Industry 4.0; readiness; preparedness; human resources; competences; Czech Republic; EU; computer skills; lifelong learning; employees in ICT; education level

---

1. Introduction

Each period is related to something new, that people have been working on for a long time and that might be called a revolution. It brings major changes especially in production, where robots are introduced, digitized and automated. These changes can have major implications for the labour market, so this paper focuses precisely on the assumptions of the human capital and its preparedness for Industry 4.0. At present, whole national economies and, above all, industries are undergoing major changes caused by the introduction of information technology, cyber-physical systems, and artificial intelligence systems in production, services and all sectors of the economy. Such changes and their impact are so significant that they are defined as Industry 4.0.

The aim of this paper is to describe the human resources prerequisites for the implementation of Industry 4.0 in the Czech Republic and to find out the links between the factors so that the Czech Republic can improve the areas in which it lags behind. On the basis of data analysis of European Union (EU) states, the authors try to identify areas where it is possible to increase the level of human capital quality so that it is better prepared for the introduction of Industry 4.0.

The percentage of industry (excluding electricity, mining and quarrying) in the Czech Republic is 24%, making it one of the countries that is the most dependent on industry. Dependence on industry has changed significantly in 10 years in some countries, with an increase in Poland (2%) and Germany (1%) only; Great Britain and France, on the other hand, reported the most significant decline.

As part of a study on the need for the introduction of Industry 4.0 in the European Union, a study was undertaken showing the preparedness of different EU states based on an index including production process intensity, degree of automation, worker readiness, innovation intensity, industry openness, innovation network and internet use in the enterprises. The Czech Republic, together with Hungary and Slovakia, are the states with a traditionally high level of industry within the national economy. In contrast, Germany, Ireland, and Austria for example, are the states with a high traditional rate of economy, but also readiness in relation to Industry 4.0. There is quite a large group of states with great potential for industry, such as France, Finland, Belgium and Denmark. At last, there are indecisive and hesitating states with not very high share of industry in GDP and low readiness index at the same time. Those are mostly the countries of southern Europe, together with Estonia, for example.

2. Theoretical Background

Industry 4.0 understands Maskuriy et al. [1] as a brand new philosophy that brings social change and affects areas ranging from safety, education, science, labour market and welfare systems. This view extends Zambon et al. [2] with the impact of devices and functions being addressed as services that constantly communicate with each other, achieving the high level of coordination and competitiveness mentioned by Mehrpouya et al. [3] in terms of optimizing work. Developed countries dealing with support and systemic changes to use the most of the opportunities of such major changes, avoiding the risks involved [4]. The Czech Republic also needs to respond to these trends and remain Europe's competitive economy. It is important to realize that the changes that the industrial revolution is bringing to a major impact on employment and labour productivity, thus affecting the entire development of society, may be particularly at risk for less qualified individuals, but on the contrary they may bring new job qualification requirements. Retraining and further education will be a necessity for those who will still want to be successful in society [5].

Industry plays a key role in the European Union economy, representing 15% of value added (compared to 12% in the US). It serves as a major driver of research, innovation, productivity, job creation and exports. Due to its impact on services, industry is regarded as the main social and economic strength of Europe.

European industry has lost much production and many jobs since the last decade and is facing tougher competition of the emerging countries. The EU is quite diverse in this sense, while the German and Eastern European industry is gaining market share and its productivity is growing rapidly; the other EU countries are more likely to deindustrialize [6]. The Czech Republic, together with Hungary and Slovakia, are the countries with a traditionally increased industry participation in the national economy [7]. Industry in the Czech Republic is the driver of the Czech economy—its importance for maintaining competitiveness in Europe and globally through Industry 4.0 is vital [8].

As reported by the above, the position of the Czech Republic is rather good due to the traditionally very high share of industry in GDP, used to increase readiness for Industry 4.0 and thus achieve sufficient competitive advantage within the region [7]. It is not easy to define Industry 4.0., as different authors define the term differently, so it is worth mentioning the most important characteristics of Industry 4.0—Smart Robots and Machines, Big Data, Factory 4.0., New Quality Connections, Energy and Decentralization [6,9,10]. From the economic perspective, i4.0 aims at cost and risk reductions, performance improvements and flexibility [11,12] increased productivity [13,14], virtualization of the process and supply-chain, mass customization [15], individualization of demand or batch size one [16], creating resilient industries [17,18].

As Industry 4.0 introduces systems of greater complexity due to the automation and interconnection of all its elements, organizational and process understanding will be included into core qualifications of industrial workers [19], meaning the ability to recognize elements of the whole production system, identification of system boundaries [20], understanding of functions and relations within the system and thus the ability to predict systems behaviour [21]. Industry 4.0 therefore also requires new skills of the engineers to work across disciplines in order to enable these massive digital changes [22]. Small-medium enterprises (SMEs) will have difficulties transforming successfully to digital production.

There might be several reasons; lack of investment, mismatch of required employee profile and the reluctance to change.

The Table 1 below shows additional qualifications and skills for future challenges in the Industry 4.0 manufacturing environment. The skills are divided into personal and technical, classified into "must have skills", "should have skills" and "can have skills". Such skills, arising as a result of the digitization trend, show clear similarities to past trends, such as electrification and automation, and the significant socio-economic impacts are also indicated [23–26].

Table 1. Classification of necessary skills and abilities for Industry 4.0.

	Must Have	Should Have	Can Have
Technical	IT skills Ability to process and analyze data Knowledge of statistics Organizational and procedural awareness Ability to use the latest devices	Knowledge management Interdisciplinary general knowledge of technologies Awareness of data protection and IT security Specialized knowledge of production and processes	Programming Specialized knowledge of technology Knowledge of ergonometry Legislative awareness
Personal	Self and Time management Adaptability to change Teamwork Social skills Communication skills	Belief in new technologies Lifelong learning	

Education and further professional development are also important key factors for achieving Industry 4.0 goals, significantly changing employees' work skills. As a result, partnerships between business and higher education institutions might become even more important in the future. It will be important to open up access to scientific and engineering studies and place more emphasis on transferable skills and skills assessment [27]. There are several initiatives to deal with this lack of new knowledge and skills between the academic and industrial world. As an example, Academy Cube [17] and eSkills for Jobs 2016, an initiative of the European Commission [28]. According to the report by Reference [29], current employees do not have the required skills for industry 4.0. It is necessary to realize that many jobs will be lost, but on the other hand new ones will be created in other areas [30]. These new opportunities however most probably will demand workers that are highly skilled, innovative and dynamic [31], with a preference for the employees with high IT competence that have a good understanding of practical, engineering and programming skills [29,30].

Regarding the human role in industry 4.0 in general, the requirements for professional, social, and personal competences will increase. Such competences are classified by Dombrowski [32] into:

- Professional (problem solving, decisiveness, wide range of expertise, interdisciplinary approach);
- Personal (responsibility, systematic thinking);
- Social (communication skills, adaptability).

In order to succeed in the Fourth Industrial Revolution, manufacturing sector enterprises need to prepare their employees for the following competencies—using new methods and technologies that will be key elements of industrial work 4.0, improving new forms of organizational structures related to processes and personnel issues, enabling new human role in production processes [33]. The holistic method for managing human resources for Industry 4.0 lists four required employee competencies that are technical, methodological, social and personal competencies [34]. The topic of human resources readiness for Industry 4.0 is not discussed in the literature, therefore it was also chosen for the needs of this article, which compares it at the national level of individual European countries.

3. Materials and Methods

The aim of this paper is to describe the human resources prerequisites for the implementation of Industry 4.0 in the Czech Republic and to find out the links between the factors so that the Czech Republic can improve the areas in which it lags behind. The following sources of data are used—Statistical Office of the European Union [35], Ministry of Education, Youth and Sports of the Czech Republic [36], Organization for Economic Cooperation and Development [37], International Standard Classification of Education [38], Czech Statistical Office [39], World Economic Forum [40]. Such data sources are used as they are primarily the aggregate data of different European regions, therefore it would be very difficult to carry out independent research. The data from these sources were combined into 12 main indicators, as described in the results. An issue related to such databases and authorities is the very lengthy publication of data; therefore, although data were collected at the end of 2018, some indicators failed to obtain data later than 2015.

Subsequently, a correlation analysis was carried out for data from the Czech Republic in order to estimate which indicators were related and obtain a more detailed view of the main areas that need to be improved in the Czech Republic to improve the introduction of Industry 4.0 into the enterprises.

Statistical Methods

Pearson and Spearman correlation coefficients were used to assess the relationship between the factors affecting the preparedness of the Czech Republic for Industry 4.0 in the area of human resources and to compare the dependence of different indicators predicting better adaptability of human capital to the advent of new technologies and systems, assuming data normality.

The data analysis always suggests the null hypothesis H0, which claims that the factors do not correspond to each other and an alternative hypothesis that the former has an influence on the latter.

Hypothesis 0 (H0): $\rho\ (X, Y) = 0$.

Hypothesis 1 (H1): $\rho\ (X, Y) \neq 0$.

The data were compared with the European Union average and the best and worst countries in the indicator were highlighted. In order to use the Pearson correlation coefficient, it was first necessary to verify the normality of both variables [41,42]. To verify the (one-dimensional) normality (1) the histograms of the Shapiro-Wilko test (p = value) were used followed by the Q–Q plots. Subsequently, the data were analyzed using Pearson correlation coefficient (2) [43].

$$R = \frac{r}{\sqrt{1-r^2}}\sqrt{n-2}\ [41] \tag{1}$$

$$r = \frac{\sum(x_i-\overline{x})(y_i-\overline{y})}{\sqrt{\sum(x_i-\overline{x})^2\sum(y_i-\overline{y})^2}} = \frac{S_{xy}}{S_xS_y}\ [43]. \tag{2}$$

Subsequently, for the sake of clarity, the results are summarized in graphs; their interdependencies were statistically compared using Statistica 12.

4. Results

Human resources, their readiness, the ability to learn new things, all are key factors in the success of introducing Industry 4.0 into businesses. The document, Human Resources Quality, describes and evaluates several indicators in the following areas—qualifications and skills of the population, participation in education, expenditure on education, human resources for the development of technology and knowledge intensive industries. All indicators contain a time series of values, a detailed description of the methodology and an evaluation of the Czech Republic and its position within the European Union. The prerequisites for successful implementation in the Czech Republic are the following [44]:

- Structure of the population by education level
- Level of computer skills
- Availability and use of the Internet
- Population flexibility and adaptability
- Share of technical workers and experts in employment
- Lifelong learning
- Mobility of students in tertiary education
- Education expenditure
- Number of technical and natural science graduates
- Number of employees in ICT
- Employment in high-tech, medium-high-tech and knowledge intensive sectors
- Use of computers by students

All the above indicators are compared with sample states of the European Union, so that it is clear what is the main competitiveness in the area of human resources of the Czech Republic. The data of the Czech Republic are compared with the European average (EU 28), and with the neighbour states.

4.1. Structure of the Population by Education Level

The ISCED (International Standard Classification of Education) indicator shows the level of education of the population aged 24 to 64 years [36–38]. The data are classified using the ISCED methodology (0–8), with level 0–2 as the population without education, with primary education and lower secondary education (most often the primary education in the Czech Republic); ISCED level 3–4 as the education at the upper-secondary and post-secondary level (such as a school-leaving certificate, apprenticeship certificate and vocational schools); and ISCED 5–8 as tertiary education, tertiary vocational schools, bachelor and master forms of study and higher education.

From 2000 to 2015, there was a significant increase in tertiary education at the expense of primary and secondary education. Such a trend also showed in other EU countries. The biggest increase began in 2010. This trend introduced a growing shortage of unskilled and low-skilled labour. The share of educational level in the EU population varies considerably. The situation in 2015 is shown in Figure 1.

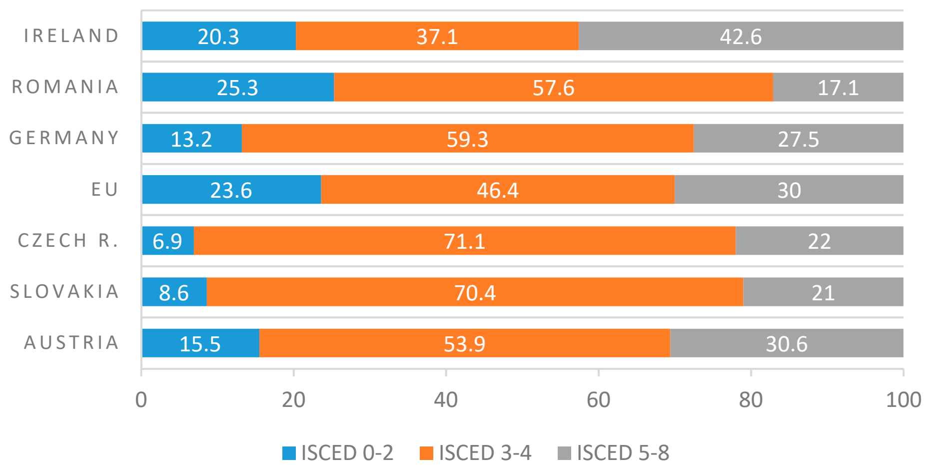

Figure 1. Share of educational attainment of population aged 25–64 in selected countries in 2015.

Compared to the European average, there are approximately 25% more employees with a secondary school-leaving certificate in the Czech Republic. Compared to other European Union states, there is also a lower share of low-skilled employees in the Czech Republic, amounting to 6.9%, compared to the European average of 23.6%, similar to the Slovak Republic. The Czech Republic also reports a lower level of higher education, 8% below the EU average. Comparing the states with the highest share of employees at ISCED 5–8 level, Ireland reports 42.6%, and on the other hand, Romania is 17.1%. Austria and Germany also report a level higher than the Czech Republic.

To increase competitiveness in the upcoming phase of Industry 4.0, favoring knowledge-based employees, there is a priority of increasing ISCED levels 5–8. Although the Czech Republic has achieved primacy in terms of secondary education and is still below the European average for tertiary education. It is one of the priorities not to increase the capacity of higher education institutions, but rather to focus on their improvement and the structure of study programs [35–38].

4.2. Level of Computer Skills

Information technology in Industry 4.0 will play a crucial role in the employability of people in the labour market. Computer skills are nowadays indispensable in terms of both personal and professional life. The level of such skills depends primarily on the age of the person, the economic level of the state, often associated to the household equipment (income, education) and Internet access. Household equipment is often enough to substitute sufficient ICT in public areas (libraries, municipalities, schools). These skills are measured in the population aged 16–74 and represent a series of computer-related actions. Overall, the level is divided into three categories.

The level of computer skills in the Czech Republic increases, with the greatest progress made between 2009 and 2011, when the proportion of users with zero knowledge decreased by almost 12%. However, it should be noted that there are still about 30% of the population who do not have any computer skills as you can see in Table 2.

Table 2. Share of computer skills in 2015 in population in selected countries.

	Level of Computer Skills			
	None	**Low**	**Medium**	**High**
Austria	22	15	29	34
Slovakia	23	20	32	25
Czech Republic	32	18	23	27
EU	30	15	26	29
Germany	21	18	31	30
Bulgaria	48	16	21	15
Finland	14	13	27	46

In terms of computer literacy, the Czech Republic is still 2% below the European average and lags behind the other countries headed by Finland (46%) as seen in Table 2. The lowest-level countries include Bulgaria, with almost half of the population without computer skills. In terms of these statistics, the difference between the Czech Republic and, for example, Austria and Germany is not so striking. However, in terms of competences and competitiveness in the labour market, the workers with a high level of computer skills will be preferred in the future [35–38].

4.3. Availability and Use of the Internet

The Internet in today's, and probably the future, world will increasingly affect both economic and social growth. At the same time, it is one of the most important prerequisites for the introduction of Industry 4.0. This indicator is often associated with previous levels of computer skills, and it plays a very important role in national statistics. Nowadays, ICT competences, including the use of the Internet belongs, are ranked among the levels of traditional literacy represented by reading, writing, mathematics and basic knowledge of primary sciences as seen by the previous generations.

This indicator expresses the proportion of the population in sample states, aged 16–74, who on average used the Internet at least once a week during the last three months before the statistical survey, wherever they were.

The Czech Republic recorded the biggest shift in terms of Internet use between 2005 and 2007, where the number of people using the Internet doubled. At present, the Czech Republic, like other EU countries, reaches around 80%, with Luxembourg (93%), Denmark (92%) and Scandinavian countries as the most connected, see Figure 2.

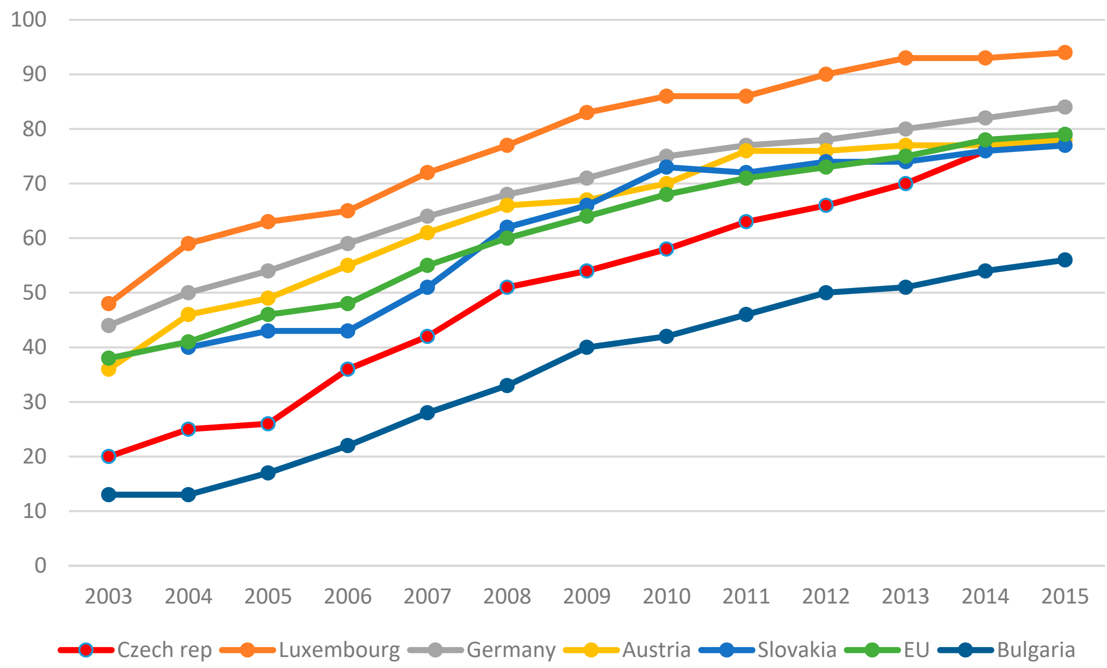

Figure 2. Internet availability in selected countries in 2003–2015 in relative terms per capita.

On the other hand, countries such as Bulgaria (54%), Romania (55%) and Greece (59%) are in the worst position. In the future, only a very slight increase is expected. In terms of the introduction of Industry 4.0 prepared states will differ from the unprepared mainly by the Internet coverage and its speed and stability of the connection, for which it is necessary to get ready [35–38].

4.4. Population Flexibility and Adaptability

People's flexibility in the labour market plays an important role in employment, job change and the search for the right job. In general, flexibility is based on many factors including motivation, attitude, experience, education, family, value ranking, affordability of housing and others [27]. From the economic point of view, it is a very positive phenomenon, promoting economic growth; for this reason, it is considered a suitable prerequisite for the introduction of Industry 4.0. Most EU states strive to find a balance, on the one hand, trying to protect employees from redundancy on the one hand and, on the other hand, trying to allow companies to respond flexibly to market and demand changes.

The evaluation is based on a questionnaire survey supported by the OECD on a representative sample of approximately 4,000 people from each EU Member State. Subsequent data are adjusted based on the strictness of national legislation on employment protection [37] to the 10-degree scale, with 10 as the highest possible flexibility.

Most countries reported values similar to the European Union average (6) over 14 years, with the Czech Republic reporting an upward trend over the past three years. In terms of flexibility, Ireland is traditionally the best, as opposed to, for example, France, differing from the rest of Western Europe in recent years. In general, this trend is criticized by a number of experts who claim to be influenced by the economic situation of the country and thus by the current labour market supply [35–38].

4.5. Share of Technical Workers and Experts in Employment

Regarding Industry 4.0 preparedness, the employees with higher qualification requirements are more important in the overall employment. They are expected to benefit more from new technologies and innovations. Also their ability to establish their profession for the needs of Industry 4.0 is significantly greater.

The classification of employees in these areas is based on the Canberra Manual [28], which defines the bearers of technological progress (experts) and executors of technical progress (technicians). The generally positive trend of increasing the share of technical workers and experts is seen as a gradual transition to the knowledge economy.

It includes the employees in ISCO-08 positions. Previously, the KZAM-R category of employment in the Czech Republic was used, similar to this classification, but due to greater uniformity in EU countries, CZ-ISCO is used since 2011 which is identical as ISCO-08. It includes the employees from the second (scientific and professional mental employees) and the third class (technical, medical, pedagogical employees and employees in related fields).

Most countries, together with the Czech Republic, range between 30–40% of total employment in these fields. The Czech Republic recorded a decline between 2010 and 2011 due to the change from KZAM-R to CZ-ISCO and thus to a change in the methodology of staffing. Traditionally, the worst situation is in Romania, Bulgaria and Greece, where the proportion is 20%. On the other hand, Luxembourg, Sweden, and Denmark, for example, are above average, where in all these cases the share of technical professions and experts in total employment is more than 40%.

From the point of view of development, there is a slight increase in all EU countries, the countries with the highest percentage increase per year include Portugal (+9%), Great Britain (+8.8%). On the other hand, Slovakia recorded a gradual decline. It dropped by 5% during the last five years [35–38].

4.6. Lifelong Learning

Employee requirements are constantly changing and evolving. As an example, the computer skills were an advantage for a job for many years; however nowadays such skills are a necessity. For this reason, the employees' efforts for their continuous education are important. The participation of the adult population in education represents to some extent the preparedness of 25+ employees for the new Industry 4.0 era, increases their competitiveness in the labour market and, last but not least, it develops the company. The information gathered in schools, now more than ever, is outdated and needs to be updated.

Lifelong learning is linked to the introduction of diversified pathways that will enable education of different age and social groups. Schools, and also businesses, municipalities, libraries, interest and professional organizations play an important role. The importance of this index is also evidenced by its inclusion in the Lisbon Strategy, where the EU goal is for each member country to have a higher share of the population (25–64 years) than 12.5%. The information presented represents the proportion of the population (25–64 years) involved in formal (intent to obtain a certificate) and non-formal education (intent to educate) in last four months. This data does not include information learning, which is the acquisition of competences during everyday work. The Czech Republic almost reached the EU average during eight years, which is still behind the set target of 12.5% by 1.7%. Traditionally, the Nordic countries, with Denmark (32%), are in the best position, see Table 3.

Table 3. Percentage of population (25–64 years) participating in education (%) in 2002–2015.

	Czech Republic	Germany	Slovakia	Austria	EU	Denmark	Bulgaria
2002	5.6	5.8	8.5	7.5	7.1	18	1.2
2003	5.1	6	3.7	8.6	8.4	24.2	1.3
2004	5.8	7.4	4.3	11.6	9.1	25.6	1.3
2005	5.6	7.7	4.6	12.9	9.6	27.4	1.3
2006	5.6	7.5	4.1	13.1	9.5	29.2	1.3
2007	5.7	7.8	3.9	12.8	9.3	29	1.3
2008	7.8	7.9	3.3	13.2	9.3	29.9	1.4
2009	6.8	7.8	2.8	13.8	9.3	31.2	1.4
2010	7.5	7.7	2.8	13.8	9.1	32.5	1.2
2011	11.4	7.8	3.9	13.4	8.9	32.3	1.3
2012	10.8	7.9	3.1	14.1	9	31.6	1.5
2013	9.7	7.8	2.9	14	10.5	31.4	1.7
2014	9.3	7.9	3	14.2	10.7	31.7	1.8
2015	9.4	7.8	3	14.4	10.8	32	2

Regarding Czech neighbors and major competitors, Austria (14.4%) is much better. In general, participation in lifelong learning is much more popular among people with tertiary education, where their willingness to learn and at the same time the increasing demands for occupational positions are expected. The worst states are Bulgaria, Romania, Croatia, and Slovakia [35–38].

4.7. Mobility of Students in Tertiary Education

Mobility of students is generally seen as positive; it represents the transfer and development of knowledge and experience for students, increases their flexibility, and deepens their language and cultural knowledge. However, this effect is only positive if these students return to their home country again. Unfortunately, in many cases, this is not the case for countries predominantly in the Eastern European region and there is an outflow of intelligence with all the negative economic and social consequences. In all these examples, however, it is important to mention the motives that are always positive from the perspective of EU development, such as technical progress, overcoming cultural differences, and a desire for international experience.

The aggregate figure is obtained on the basis of three different indicators. These are outgoing mobility rate, incoming mobility rate and number of foreign students. A positive development in the Czech Republic between 2002 and 2015 needs to be mentioned; there was a permanently upward trend. Overall, the trend of development in almost all EU Member States is positive, with very little shifts in the UK, for example, where, although students have a very good financial background, they do not use mobility. The limiting factor, as mentioned, is for many countries the lower economic level in families, as they are often burdened with the mobility of their children. A very positive trend is observed, for example, in Slovakia, where the percentage of students using mobility is around 15%, which is almost 12% more than in the Czech Republic. The leaders in student mobility include Luxembourg (70%) [35–38].

4.8. Education Expenditure

Education plays a primary role in terms of competitiveness in the labour market and also in terms of population preparedness for Industry 4.0. It can also be argued that there is a direct correlation between expenditure on education and population education. The indicator of total expenditure per student is expressed on the basis of data obtained representing expenditure on educational institutions (public, private, foreign funds), and the sum of current and investment expenditure. All volume is subsequently converted into purchasing power standard (PPS) through purchasing power parity in order to eliminate differences in purchasing power of national currencies. All forms of study are included in the number of students.

Expenditure on education in the Czech Republic is increasing steadily; it is also necessary to take into account the rate of inflation, slightly distorting because of the chosen consumer basket (energy). Traditionally, the largest expenditures are related to tertiary education at universities. Currently, there are proportional differences between the levels of education by 1900 PPS. In terms of the EU Member States, the Czech Republic is still below the European average. The countries with the lowest share of expenditure on education include Bulgaria and Romania where the total expenditure is only about 9700 PPS. There is a striking difference between these states and the Nordic countries of Europe, where the expenditure reaches up to 33,000 PPS (Denmark, Sweden). Similarly, to Slovakia, Estonia and Poland, the Czech Republic belongs to countries with expenditures below 20,000 PPS such as the countries in the eastern region. There is a need to put more emphasis on education spending, as its development and timeliness can play a crucial role in the graduates' readiness for the new requirements of the labour market associated with Industry 4.0, where the Czech Republic should measure and be competitive with Austria and Germany, to which it currently loses about 13,400 PPS and 10,800 PPS.

4.9. Number of Technical and Natural Science Graduates

Graduates of technical universities represent the greatest potential in terms of new innovations, increasing competitiveness and ensuring the country's economic growth; in this respect, they play an irreplaceable role in terms of introducing Industry 4.0 into production, services and everyday life. The indicator itself also needs to take into account the outflow of such educated workforce abroad, this effect is currently being mitigated by the Czech Republic as much as possible and, thanks to improving working conditions, to reduce the migration of tertiary educated workforce.

The methodology according to Reference [38] is used. Generally, the indicator expresses the share of graduates of the universities per thousand inhabitants aged 20–29, this age is taken as the range for completing tertiary education.

The Czech Republic succeeded in catching up with the trend of European Union development around 2008, reaching approximately 15 graduates per 1000 inhabitants of an appropriate age group. The number of these graduates has almost tripled in the last 12 years, but it should be added that their share of the total number of university graduates has been gradually decreasing, while students prefer humanities, although their employment in the labour market continues to decline. In terms of this trend, the Czech Republic reaches the same level as Austria and Germany, but it should be noted that for the Czech Republic these fields are historically a priority. Cyprus and the Netherlands and Malta report the lowest levels, while Lithuania, France and Ireland are surprisingly the leaders, with the best results in terms of preparedness for the upcoming Industry 4.0.

From a practical point of view, it is important not to emphasize only a high number of the graduates, but also their high quality. For this reason, it is always necessary to take into account the availability of education, the number of students admitted, the success of studies, the interest in studying and the quality of teachers.

4.10. Number of Employees in ICT

Information technology is playing an increasingly important role in employment, and it will not be possible to switch to Industry 4.0 without a sufficiently broad and high-quality employment base. In terms of methodology, the ICT sector is defined in the area of manufacturing industry and services according to the International Standard Industry Classification [45].

Within the Czech Republic there is a noticeable decrease in ICT workers between 2010 and 2011, not caused by the outflow of labour, but by a change in methodology where the International Standard Classification of Occupation in section ISCO-88 was used until 2010.

In 2011, the ISCO-08 standard started to be used, in line with the OECD Guidance on Measuring the Digital Economy: A New Perspective [37].

Regarding the European Union, the share of these employees has risen slightly above 3% to 3.4% since 2011. On the other hand, Slovakia, which is 1% below the European average in terms of ICT employees, reported a steady decline. Ireland is the worst member of the EU, which, like the Czech Republic, experienced a significant decline between 2010 and 2011 due to a change in methodology that takes into account more new IT technologies. On the other hand, Finland is best prepared for new technologies and thus also for new technologies in ICT, where there is a perceptible growth in the share of ICT employees (6.3%) in the total.

4.11. Employment in High-Tech, Medium-High-Tech and Knowledge Intensive Sectors

In terms of the future development of the state's economy, human activities in the high- and medium-technology-intensive sectors in manufacturing and in services in knowledge-intensive sectors play an increasingly important role. These activities are usually monitored as a share of value added, exports and total employment in different countries.

In terms of the total sum of High-tech and Medium-high-tech, the Czech Republic ranks among the leaders in the European Union (approximately 6%). Similar to the Czech Republic, Germany and Slovakia, as an example, are in the same position see Figure 3. On the other hand, countries such as Greece, Cyprus, Latvia and Lithuania are the worst. None of the above mentioned countries has a share of 2% of total employment. In terms of trend development, it is necessary to mention the gradual growth in these sectors in the Czech Republic, which is mainly the development of Medium-High-tech industry.

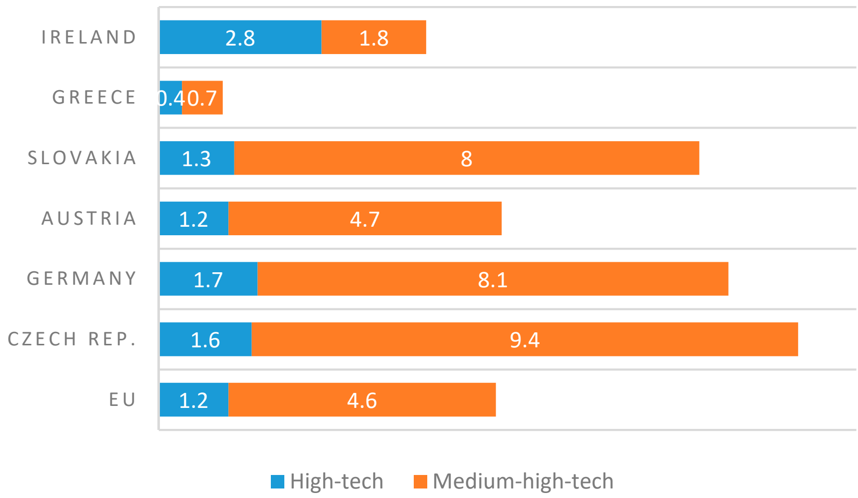

Figure 3. Employment in High-tech and Medium-high-tech sectors in 2015 in selected European Union (EU) countries.

The Czech Republic, with an employment share of 1.6% in High-tech and 9.4% in Medium-High-tech, is among the European leaders, see Figure 3. Ireland has the highest share of High-tech compared to Medium-high-tech in the European Union, with High-tech reaching approximately twice that of most EU countries. In addition to Ireland, Malta, Denmark and Hungary also have a high share of high-tech employment. In terms of Industry 4.0, the Czech Republic is very well focused on key areas of industry. Therefore, it is necessary to take advantage of this traditional advantage, to support it by developing knowledge in ICT and a sufficient number of suitable technically proficient graduates.

4.12. Use of Computers by Students

Future economic developments will increasingly be linked to the use of computers and the ability of individuals to handle and use them. Therefore, these competencies need to be developed by potential employees during their studies. The following chart shows the percentage of students (secondary schools) using a computer at least one hour per week to play games (not so important in terms of IT competence) and at least one hour per week to search and retrieve information.

The percentages of students (secondary schools) using a computer at least one hour per week to play games (not as important in terms of IT competence) and at least one hour per week to search and retrieve information are compared.

The Czech Republic has great potential for students in terms of basic computer competencies that will need to be further developed and specialized in the future. It ranks second in Europe, in terms of the percentage of students using computers to search for information on the Internet, unfortunately, for example, towards the leading Finland, students spend more time playing games. For example, students from Serbia play the most games (68%). In terms of comparison across the region, the Czech Republic is better than Austria and Germany.

4.13. Statistical Analysis of Relations

Based on the data, detailed analyzes of the relations of different factors will be carried out. A certain interconnection of the data is expected. For the sake of clarity, the complete procedure for correlation determination is given here as an example, further results will be interpreted in the Appendix A for better clarity and reduction of the total number of pages.

Internet accessibility and lifelong learning—example calculation. To illustrate a complete data analysis, the factors of internet accessibility and lifelong learning were chosen as an example see Figure 4; the other combinations of the factors are briefly summarized in the next chapter.

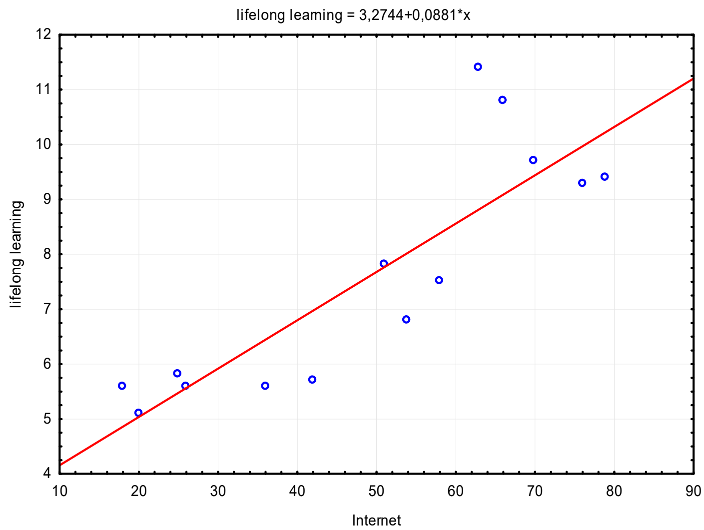

Figure 4. Scatter plot of the relation between Internet accessibility and lifelong learning.

Lifelong learning is a prerequisite for the development of knowledge and better preparedness of employees for new technologies and processes. At the same time, there is a null hypothesis H0 that claims that internet availability does not correlate with the share of lifelong learning in the population and an alternative hypothesis that claims that internet availability affects the share of lifelong learning.

The scatter plot shows that there is a positive linear dependence between the availability of the Internet and lifelong learning, which, according to rather high determination coefficient ($R^2 = 0.7366$), is considered strong. By using the availability of the Internet almost 74% of the variability in the share of lifelong learning is explained.

Subsequently, the normality of both data groups was tested. Data were tested both visually, using the histograms in Figure 5 and then using the Shapiro-Wilko test. As revealed by the graphical expression of Internet use, data normality is proved, as the normality of data on the surface ($p = 0.3295$) is not rejected. For lifelong learning, the normality of the data is not visually so evident, which is also illustrated by the level of significance (p = 0.0623), however a normal distribution is proved as it reaches the specified level of significance of 0.05.

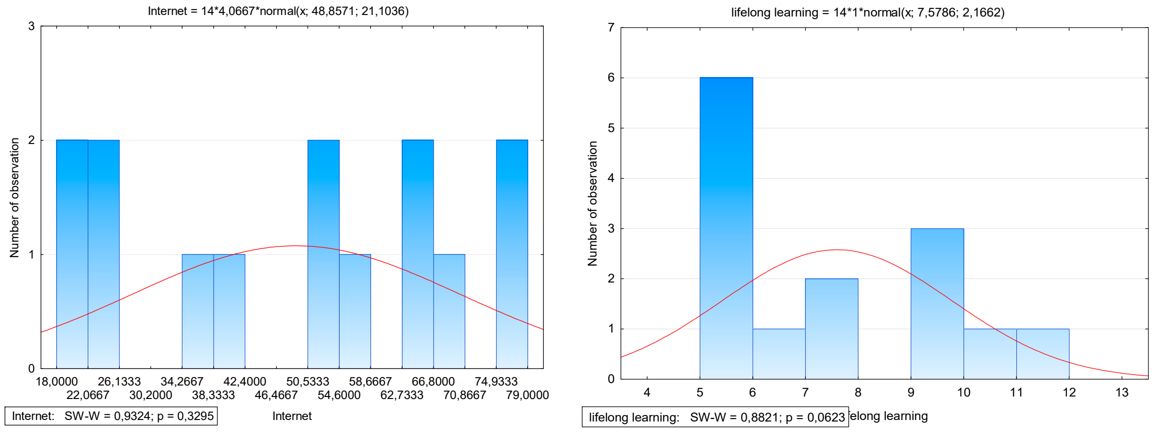

Figure 5. (**a**) Data distribution among Internet users; (**b**) data distribution in terms of lifelong learning.

The results of the correlation of both variables are shown in Table 4. On the basis of p-value = 0.0000, null hypothesis of independence is rejected in favor of a bilateral alternative using the Pearson coefficient at the significance level of 0.05. The existence of a linear dependence is proved, supported by a positive Pearson correlation coefficient of 0.8582. At the same time, in terms of the Spearman correlation, as p-value is very close to zero and the coefficient R = 0.8587, we can tend to reject the null hypothesis in favor of H1.

Table 4. Correlation tests.

	Pearson			Spearman		
Variable	**Internet**	**Lifelong Learning**	***p*-Value**	**Internet**	**Lifelong Learning**	***p*-Value**
Internet	1.000	0.858	0.000	1.000	0.858	0.000
Lifelong learning	0.858	1.000		0.858	1.000	

As revealed by the results, both correlation tests succeeded in rejecting null hypothesis in favour of the alternative, demonstrating the correlation between Internet use and the percentage of the population (25–64 years) participating in education (in %). This correlation is linear and increasing, so it is assumed that the introduction of the Internet will have a positive impact on the development of lifelong learning, which plays a key role in the adaptation of employees within Industry 4.0.

4.14. Other Results

The table in Appendix A summarizes the correlations of the Pearson correlation coefficient, including p-values, at the same significance level of 0.05. Statistically significant correlations are labelled red, with the p-value of less than 0.05. In addition to the above mentioned relation between Internet accessibility and access to lifelong learning, there are also other links.

As seen in the tables below, significant relations between the factors are shown, a very significant correlation includes a relation (0.956) between the share of tertiary educated and Internet availability. It is positive and it is apparent that both factors influence each other. A similarly strong link (0.9474) is found between the accessibility of the Internet and student mobility, possibly due to greater awareness and sharing of experience and services offered more interest in the visits of students who subsequently draw experience abroad. Another strong link (0.9580) is the share of tertiary educated people and the level of high computer knowledge, where it is evident that along with education, computer knowledge is deepened.

In general, the availability of the Internet is positively related to most other factors, such as the share of employees in high-tech fields (0.9105), the number of graduates in technical fields (0.9233). On the other hand, the link with the share of employees in ICT was not proved. This may be due to the fact that if a person intends to pursue ICT, they usually use the Internet and it is a priority for them, so that the increase in Internet availability no longer has a major impact on this group.

On the other hand, it is difficult to explain why the relation between Internet accessibility and population flexibility was not proved, as Internet accessibility could be expected to facilitate greater mobility and population flexibility.

The population flexibility factor is not correlated with any other factor. Interestingly, there is no relation with student mobility, although it could be assumed that a student who was on a long-term study stay during their studies would be more flexible in finding work. Also specialized professions, such as High Tech and ICT could be expected to move more often for work and thus be more flexible.

On the other hand, high computer knowledge correlates strongly with the availability of the Internet, which is an increase in the level of IT knowledge among the population, and at the same time there is a correlation with the share of tertiary educated people. At the same time, it was not possible to prove a correlation with the share of technically skilled workers, when it can be assumed that these employees already had sufficient PC knowledge before and thus their group did not increase. At the same time, higher computer knowledge enables a better and higher quality of lifelong learning and there is a correlation.

Positive information is related to the correlation between the number of tertiary educated and the number of technical graduates, where the Czech Republic is expected to regain its dominant position in terms of technical knowledge in the region. An interesting negative correlation came from the share of ICT employees, where it can be assumed that they do not need tertiary education as in the past. Correlations with the employees in high-tech fields also suggest such reflection.

The share of technical staff does not correlate with any factor other than the share of ICT staff. From this fact it can be assumed that in the Czech Republic, the technical and ICT fields focus much more often on secondary education and less on tertiary education.

Interestingly, lifelong learning has a negative correlation with the share of ICT employees, where, on the contrary, it was assumed that the ICT employees are constantly educating and keeping up to date with new technologies and innovations, since IT is generally seen as a rapidly changing environment. At the same time, the relation with expenditure on tertiary education was not proved, so it is assumed that lifelong learning is not primarily carried out by institutions, but by employers and by the own initiative of employees. There is a strong correlation with the availability of the Internet and computer knowledge.

Student mobility has a correlation with most factors, the strongest is the availability of the Internet, as described above, and the share of tertiary educated with the number of graduates in technical fields.

Expenditure on tertiary education has the strongest correlation with the number of employees in high tech fields, as it is assumed that education of such specialists will be more expensive for new technologies. Another correlation was found with the mobility of students, where subsidies from European and other programs abroad are often considered as costs for universities, so data may be distorted here. At the same time, expenditure on tertiary education does not correlate with the number of graduates of technical fields or the total proportion of technical staff, as shown in the figure below.

There is a strong correlation between the number of technical graduates and the availability of the Internet; as is evident in general, the Internet is increasing interest in technical disciplines and the technical professions are making greater use of the Internet, which requires high computer skills. There was also a correlation with the share of tertiary educated and lifelong learning. On the other hand, it was not possible to prove it among graduates of technical fields or the share of ICT employees.

5. Discussion and Conclusions

The aim of the paper was to describe the human resources prerequisites for the implementation of Industry 4.0 in the Czech Republic and to find out the links between the factors so that the Czech Republic can improve the areas in which it lags behind. On the basis of data analysis of European Union states, the authors identify areas where it is possible to increase the level of human capital quality so that it is better prepared for the introduction of industry 4.0.

The importance of Industry 4.0 is discussed by a number of studies, such as GfK Enigma research [46], where 82% of SMEs in Germany feel ready for digitization (on a sample of 247 enterprises). Similarly, there are 68% of the companies mentioned by Schulz [47] interviewed in 28 manufacturing enterprises whether they are using technology associated with Industry 4.0. In another research, Kelkar [48] points out that 79% of manufacturing enterprises (any size) perceive Industry 4.0 as very important for its development (research was conducted in 227 enterprises), as in Computer Science Corp [49], where 63% of US manufacturing enterprises (900 in the sample) identified Industry 4.0 as necessary for the further development. In line with these conclusions, a study on 235 German enterprises from Price Waterhouse Coopers [50] claims that the enterprises plan to increase digitization between 24–86% in next five years. The DIHK (Deutscher Industrie- und Handelskammertag) study [35], which states that 94% of enterprises perceive digitization as important for their development, is the highest. This research was carried out irrespective of the size or area of business of 1849 German enterprises [36]. Ślusarczyk [51] carried out his research on secondary data in US, Germany, Japan and Poland, summing up that 80% of the enterprises perceive Industry 4.0 as very significant.

In terms of access to human resources, Industry 4.0—a revolution in work organization [38] study in 278 enterprises, predominantly in the engineering industry, is noticeable. The study found that 54% of the enterprises expect an increase in the number of employees after the introduction of Industry 4.0 and 26% of the enterprises expect the current number of employees to stagnate.

Gudanowska et al. [52] revealed that workers for Industry 4.0 should have a better professional knowledge as well as technical skills. Employees should have highly developed communications skills, be dedicated to precise task completion and be able to work autonomously as well as in a team. They should also be open to exchange and sharing of knowledge and experience.

Below are the conclusions about the various factors influencing the successful implementation of Industry 4.0 in the Czech Republic [53], as well as identifying areas where it is necessary to increase the level of human capital. The problems with human resources was commented on in a survey by one of the managers: "The biggest drawback is now employees, when the Czech Republic has historically the lowest unemployment rate (2.6%) and we have to take everyone who has hands." In the long term, the Czech Republic achieves primacy in terms of secondary education [54], on the other hand remaining below the European average for tertiary education. As reported by Čechák [55], the lack of skilled workers, both university and secondary school students with technical specialization, continues to grow in the Czech Republic. Now it is one of the priorities not to increase the capacity of higher education institutions, but rather to focus on improving the quality and the structure of the study programs. The Government of the Czech Republic responded to this situation by changing the accreditation policy of higher education study programs with an emphasis on the quality of teaching and science as Platonova et al. [56] mentions in the Russian case. Regarding lifelong learning, the Czech Republic has almost reached the EU average. In general, participation in lifelong learning is much more popular among people with tertiary education [57], as their willingness to learn and at the same time the increasing demands for their jobs are expected [58]. The importance of employer support in this area mentions Gudanowska et al. [52] employees should be constantly retrained. Mobility of students is another factor that increases the maturity of human capital [59]. There was a positive development in the Czech Republic between 2002 and 2015, with an increasing trend. Overall, the trend of development in almost all EU Member States is positive. The limiting factor, as mentioned, is the lower economic level in families, as they are often burdened with children's mobility. Of course, investing in education is very important [60,61]. In terms of expenditure on education, the Czech Republic ranks with expenditures below 20,000 PPS, to the countries of the eastern region. There is a need to put more emphasis on education expenditure, as its development and urgency might be crucial in the graduates' readiness for the new labour market requirements associated with Industry 4.0 [62,63]. The Czech Republic should be comparable and competitive with Austria and Germany, for which it currently loses around 13,400 PPS and 10,800 PPS. The last identified area related to education is the number of technical graduates. The Czech Republic succeeded in catching up with the trend of European Union development around 2008, reaching approximately 15 graduates per 1000 inhabitants of an appropriate age group. The number of these graduates has almost tripled in the last 12 years, but it should be noted that their share of the total number of university graduates has been gradually decreasing, while students prefer humanities [64], although their employment in the labour market continues to decline as Trifu [65] mentions in Romanian economy or Nemcek et al. [66] in Slovakia. This problem is often solved by sponsoring students of Engineering programs [67].

Another area that influences the successful implementation of Industry 4.0 concerns the Internet, its accessibility [68] and the level of computer skills [54]. Currently, the Czech Republic, similar to other EU countries, is around 80% in terms of Internet access. The level of computer skills in the Czech Republic is increasing, with the greatest progress between 2009 and 2011, when the proportion of users with zero knowledge decreased by almost 12%. However, it should be noted that there are still about 30% of the population without computer skills. In terms of computer illiteracy, the Czech Republic is still below the European average. On the other hand, the Czech Republic has great potential for students in terms of basic computer competencies that will need to be further developed and specialized in the future. It ranks the second in Europe in terms of the percentage of students using computers to search for information on the Internet, unfortunately, for example, compared to the leading Finland, the Czech students spend more time playing games.

In terms of the total sum of High-tech and Medium-high-tech, the Czech Republic ranks among the leaders in the European Union. In terms of the share of technical workers, it ranges 30–40% of total employment in these fields. The Czech Republic recorded a decline between 2010 and 2011 due to the change from using KZAM-R classification to CZ-ISCO, and thus to a change in the methodology of staffing.

The limits of this research include the fact that national data of individual countries are always delayed by approximately 2 years, so it is always an analysis of data that is no longer up-to-date. Research does not include the economic situation of individual countries and market developments, which may also have an impact on the indicators analyzed. The data used in this research are secondary as it is not in the authors' ability to obtain primary data to such an extent.

Future research objectives include monitoring these indicators over a longer period of time and designing methodologies to enhance the competencies of future employees in the Industry 4.0 period.

Author Contributions: Conceptualization, J.V.; methodology, J.V.; validation, M.M., L.R.; formal analysis, P.Ř.; investigation, J.V.; resources, M.M.; data curation, M.M.; writing—original draft preparation, J.V.; writing—review and editing, M.M., R.T.; visualization, J.V.; supervision, P.Ř.; project administration, J.V.; funding acquisition, L.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by "EF-150-GAJU 047/2019/S" and "EF-IGS2017- Vrchota-IGS24B1"

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Pearson correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11
1	1.0000	−0.2641	−0.2514	−0.1091	−0.3840	−0.3528	−0.2745	0.2359	−0.5241	−0.0486	−0.1044
2	−0.2641	1.0000	0.9374	0.9562	−0.2042	0.8582	0.9474	0.6838	0.9233	−0.4773	0.9105
3	−0.2514	0.9374	1.0000	0.9580	−0.3312	0.8694	0.8526	0.5081	0.8456	−0.6487	0.8209
4	−0.1091	0.9562	0.9580	1.0000	−0.3622	0.7942	0.8942	0.6742	0.7936	−0.6182	0.8852
5	−0.3840	−0.2042	−0.3312	−0.3622	1.0000	−0.4828	0.0201	−0.2229	0.0400	0.8486	−0.4491
6	−0.3528	0.8582	0.8694	0.7942	−0.4828	1.0000	0.6464	0.2732	0.8077	−0.7672	0.7943
7	−0.2745	0.9474	0.8526	0.8942	0.0201	0.6464	1.0000	0.6991	0.8928	−0.2350	0.8343
8	0.2359	0.6838	0.5081	0.6742	−0.2229	0.2732	0.6991	1.0000	0.4709	−0.1370	0.7734
9	−0.5241	0.9233	0.8456	0.7936	0.0400	0.8077	0.8928	0.4709	1.0000	−0.2955	0.7855
10	−0.0486	−0.4773	−0.6487	−0.6182	0.8486	−0.7672	−0.2350	−0.1370	−0.2955	1.0000	−0.5396
11	−0.1044	0.9105	0.8209	0.8852	−0.4491	0.7943	0.8343	0.7734	0.7855	−0.5396	1.000

p-value < α (0.05) is marked in red; Variables: 1—Population flexibility and adaptability; 2—Availability and use of the Internet; 3—Level of computer skills; 4—Structure of the population by education level; 5—Share of technical workers and experts in employment; 6—Lifelong learning; 7—Mobility of students in tertiary education; 8—Education expenditure; 9—Number of technical and natural science graduates; 10—Number of employees in ICT; 11—Employment in high-tech, medium-high-tech sectors.

References

1. Maskuriy, R.; Selamat, A.; Maresova, P.; Krejcar, O.; Olalekan, D.O. Industry 4.0 for the Construction Industry: Review of Management Perspective. *Economies* **2019**, *7*, 68. [CrossRef]
2. Zambon, I.; Cecchini, M.; Egidi, G.; Saporito, M.G.; Colantoni, A. Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs. *Processes* **2019**, *7*, 36. [CrossRef]
3. Mehrpouya, M.; Dehghanghadikolaei, A.; Fotovvati, B.; Vosooghnia, A.; Emamian, S.S.; Gisario, A. The Potential of Additive Manufacturing in the Smart Factory Industrial 4.0: A Review. *Appl. Sci.* **2019**, *9*, 3865. [CrossRef]
4. Prinsloo, J.; Sinha, S.; Von Solms, B. A Review of Industry 4.0 Manufacturing Process Security Risks. *Appl. Sci.* **2019**, *9*, 5105. [CrossRef]
5. Ministerstvo průmyslu a obchodu (MPO) Iniciativa Průmysl 4.0. Available online: http://www.nuv.cz/eqf/iniciativy-prumysl-4-0-prace-4-0-a-vzdelavani-4-0 (accessed on 11 October 2019).
6. Gilchrist, A. *Industry 4.0: The Industrial Internet of Things*; Springer Science + Business Media: New York, NY, USA, 2016; ISBN 978-1-4842-2046-7.
7. Berger, R. *Industry 4.0: The New Industrial Revolution How Europe will Succeed*; DK groupe: Berlin, Germany, 2014.
8. Mládek, J.; Průmysl. 4.0—Revoluce Probíhá. Available online: https://www.businessinfo.cz/app/content/files/dokumenty/Prumysl-4.pdf (accessed on 10 October 2015).
9. Ivanov, D.; Dolgui, A.; Sokolov, B.; Werner, F.; Ivanova, M. A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0. *Int. J. Prod. Res.* **2016**, *54*, 386–402. [CrossRef]
10. Bartodziej, C.J. *The Concept Industry 4.0: An Empirical Analysis of Technologies and Applications in Production Logistics*; Springer Gabler: Wiesbaden, Germany, 2017; ISBN 978-3-658-16502-4.
11. Leonard, J. Building Tomorrow's Smarter Factories. *Prof. Eng.* **2015**, *28*, 16.
12. Sommer, L. Industrial revolution—Industry 4.0: Are German manufacturing SMEs the first victims of this revolution? *JIEM* **2015**, *8*, 1512–1532. [CrossRef]
13. Chung, C. Smart factories need smarter supply chains. *Plant Eng.* **2015**, *69*, 19.
14. Schuh, G.; Potente, T.; Wesch-Potente, C.; Weber, A.R.; Prote, J.P. Collaboration Mechanisms to Increase Productivity in the Context of Industrie 4.0. *Procedia Cirp* **2014**, *19*, 51–56. [CrossRef]
15. Brettel, M.; Friederichsen, N.; Keller, M.; Rosenberg, M. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. *Int. J. Mech. Aerosp. Ind. Mechatron. Manuf. Eng.* **2014**, *8*, 37–44.
16. Lasi, H.; Fettke, P.; Kemper, H.-G.; Feld, T.; Hoffmann, M. Industry 4.0. *Bus. Inf. Syst. Eng.* **2014**, *6*, 239–242. [CrossRef]
17. Kagermann, H.; Helbig, J.; Hellinger, A.; Wahlster, W. Recommendations for Implementing the Strategic Initiative Industie 4.0: Securing the Future of German Manufacturing Industry. 2017. Available online: http://forschungsunion.de/pdf/industrie_4_0_final_report.pdf (accessed on 11 October 2019).
18. Lee, J.; Bagheri, B.; Kao, H. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. *Manuf. Lett.* **2015**, *3*, 18–23. [CrossRef]
19. Botthof, A.; Hartmann, E.A. *Zukunft der Arbeit in Industrie 4.0*; Springer: Berlin/Heidelberg, Germany, 2015; ISBN 978-3-662-45914-0.
20. Nolting, L.; Priesmann, J.; Kockel, C.; Rödler, G.; Brauweiler, T.; Hauer, I.; Robinius, M.; Praktiknjo, A. Generating Transparency in the Worldwide Use of the Terminology Industry 4.0. *Appl. Sci.* **2019**, *9*, 4659. [CrossRef]
21. Gehrke, L.; Rule, D.; Kühn, A. *Industry 4.0.: A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective*; VDI: Düsseldorf, Germany, 2015.
22. Jin, S.H.; Choi, S.O. The Effect of Innovation Capability on Business Performance: A Focus on IT and Business Service Companies. *Sustainability* **2019**, *11*, 5246. [CrossRef]
23. Ford, M. *Rise of the Robots: Technology and the Threat of a Jobless Future*; Basic Books: New York, NY, USA, 2016; ISBN 978-0-465-09753-1.
24. Syverson, C. Will History Repeat Itself? Comments on 'Is the Information Technology Revolution Over? *Int. Product. Monit.* **2013**, *1*, 37.

25. Brynjolfsson, E.; McAfee, A. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*; W. W. Norton & Company: New York, NY, USA, 2014; ISBN 978-0-393-23935-5.
26. Karre, H.; Hammer, M.; Kleindienst, M.; Ramsauer, C. Transition towards an Industry 4.0 State of the LeanLab at Graz University of Technology. *Procedia Manuf.* **2017**, *9*, 206–213. [CrossRef]
27. Motyl, B.; Baronio, G.; Uberti, S.; Speranza, D.; Filippi, S. How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey. *Procedia Manuf.* **2017**, *11*, 1501–1509. [CrossRef]
28. eSkills for Job 2016. Available online: http://eskills4jobs.ec.europa.eu/ (accessed on 10 October 2017).
29. Industrial Global Union. The Challenge of Industry 4.0 and The Demand for New Answers. Available online: http://www.industriall-union.org/sites/default/files/uploads/documents/2017/SWITZERLAND/Industry4point0Conf/draft_integrated_industry_4.0_paper_5_17.10.2017.pdf (accessed on 21 October 2019).
30. Bonekamp, L.; Sure, M. Consequences of Industry 4.0 on Human Labour and Work Organisation. *J. Bus. Media Psychol.* **2015**, *6*, 33–40.
31. Shamim, S.; Cang, S.; Yu, H.; Li, Y. Management approaches for Industry 4.0: A human resource management perspective. In Proceedings of the IEEE Congress on Evolutionary Computation (CEC), Vancouver, BC, Canada, 24–29 July 2016; pp. 5309–5316.
32. Dombrowski, U.; Wagner, T. Arbeitsbedingungen im Wandel der Industrie 4.0: Mitarbeiterpartizipation als Erfolgsfaktor zur Akzeptanzbildung und Kompetenzentwicklung. *ZWF Zeitschrift für wirtschaftlichen Fabrikbetrieb* **2014**, *109*, 351–355. [CrossRef]
33. Prinz, C.; Morlock, F.; Freith, S.; Kreggenfeld, N.; Kreimeier, D.; Kuhlenkötter, B. Learning Factory Modules for Smart Factories in Industrie 4.0. *Procedia Cirp* **2016**, *54*, 113–118. [CrossRef]
34. Hecklau, F.; Galeitzke, M.; Flachs, S.; Kohl, H. Holistic Approach for Human Resource Management in Industry 4.0. *Procedia Cirp* **2016**, *54*, 1–6. [CrossRef]
35. Eurostat—Your Key to European Statistic. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 15 October 2018).
36. Ministerstvo školství, mládeže a tělovýchovy (MŠMT). Available online: http://www.msmt.cz/vzdelavani/skolstvi-v-cr/statistika-skolstvi (accessed on 15 October 2018).
37. OECD Measuring the Digital Economy: A New Per-Spective. Available online: http://www.oecd-ilibrary.org/science-and-technology/measuring-the-digital-economy_9789264221796-en (accessed on 13 November 2014).
38. ISCED. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php/International_Standard_Classification_of_Education_(ISCED (accessed on 15 October 2019).
39. Český statistický úřad (ČSÚ). Available online: https://www.czso.cz/documents/10180/23169600/ht_odvetvi.pdf/cb4dc782-a3e0-43a4-8d96-99b8d1f14cca (accessed on 15 October 2018).
40. World Economic Forum Reports. Available online: https://www.weforum.org/reports (accessed on 15 October 2018).
41. Freund, R.J.; Wilson, W.J.; Mohr, D.L. *Statistical Methods*, 3rd ed.; Elsevier: Amsterdam, The Netherlands, 2010; ISBN 978-0-12-374970-3.
42. Meloun, M.; Militký, J.; Hill, M. *Statistická analýza vícerozměrných dat v příkladech*; Academia: Praha, Czech Republic, 2012; ISBN 978-80-200-2071-0.
43. Spellman, F.R.; Whiting, N.E. *Handbook of Mathematics and Statistics for the Environment*; CRC Press, Taylor & Francis Group: Boca Raton, FL, USA, 2014; ISBN 978-1-4665-8637-6.
44. Czesaná, V.; Matoušková, Z.; Havlíčková, V.; Sobková, M.; Šímová, Z.; Krčková, A. *Konkurenční schopnost České republiky—Kvalita lidských zdrojů*; Grada: Praha, Czech Republic, 2015.
45. International Trade Centre Industry Claficiation. Available online: https://www.investmentmap.org/industry_classification.aspx (accessed on 15 October 2018).
46. GfK Enigma Umfrage in mittelständischen Unternehmen zum Thema Digitalisierung—Bedeutung für den Mittelstand im Auftrag der DZ Bank. Available online: https://www.dzbank.de/content/dam/dzbank_de/de/library/presselibrary/pdf_dokumente/DZ_Bank_Digitalisierung_Grafiken.pdf (accessed on 17 September 2014).
47. Schulz, A. Industrie 4.0 steht noch ganz am Anfang. Available online: https://www.flyacts.com/industrie-4-0-steht-noch-ganz-am-anfang/ (accessed on 15 December 2014).
48. Kelkar, O.; Heger, R.; Dao, D.K. Studie Industrie 4.0—Eine Standortbestimmung der Automobil- und Fertigungsindustrie. Available online: https://www.mhp.com/fileadmin/mhp.de/assets/studien/MHP-Studie_Industrie4.0_V1.0.pdf (accessed on 11 October 2019).

49. Computer Sciences Corp Industrie 4.0 Die Studie mit Ländervergleich (DACH) 2015. Available online: http://assets1.csc.com/de/downloads/Ergebnisse_CSC-Studie_4.0.pdf (accessed on 25 October-2019).
50. PriceWaterhouseCoopers Industry 4.0: Building the Digital Enterprise. Available online: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf (accessed on 20 October 2019).
51. Ślusarczyk, B. INDUSTRY 4.0—ARE WE READY? *PJMS* **2018**, *17*, 232–248. [CrossRef]
52. Gudanowska, A.E.; Alonso, J.P.; Törmänen, A. What competencies are needed in the production industry? The case of the Podlaskie Region. *Eng. Manag. Prod. Serv.* **2018**, *10*, 65–74. [CrossRef]
53. Vrchota, J.; Volek, T.; Novotná, M. Factors introducing Industry 4.0 to SMEs. *Soc. Sci.* **2019**, *8*, 130. [CrossRef]
54. Urbánková, E.; Hospodková, P.; Severová, L. The Assessment of the Quality of Human Resources in the Midwife Profession in the Healthcare Sector of the Czech Republic. *Economies* **2018**, *6*, 38. [CrossRef]
55. Čechák, V. *Současné trendy v oblasti vzdělávání. Lidský Kapitál A Invest. Vzdělávání: Teor. A Praxe V Návaznosti Na Průmysl 4.0*; Libre: Liberec, Czech Republic, 2018.
56. Platonova, E.; Mysarskiy, M.; Fedotova, O.; Igumnov, O.; Bogomolova, J. Reorganization of the Russian Universities as the Direction of the Implementation of the New Structure of Higher Education. In *Edulearn16: 8th International Conference on Education and New Learning Technologies*; Chova, L.G., Martinez, A.L., Torres, I.C., Eds.; Iated-Int Assoc Technology Education & Development: Valenica, Spain, 2016; pp. 4555–4564. ISBN 978-84-608-8860-4.
57. Henke, J. Third Mission as an Opportunity for Professionalization in Science Management. *Publications* **2019**, *7*, 62. [CrossRef]
58. Steffl, M.; Jandova, T.; Dadova, K.; Holmerova, I.; Vitulli, P.; Pierdomenico, S.D.; Pietrangelo, T. Demographic and Lifestyle Factors and Memory in European Older People. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4727. [CrossRef]
59. Leung, M.W.H. Unraveling the Skilled Mobility for Sustainable Development Mantra: An Analysis of China-EU Academic Mobility. *Sustainability* **2013**, *5*, 2644–2663. [CrossRef]
60. Messer-Davidow, E. Investing in College Education: Debtors, Bettors, Lenders, Brokers. *Humanities* **2017**, *6*, 20. [CrossRef]
61. Volek, T.; Novotná, M. Gross value added and total factor productivity in Czech sectors. *Contemp. Econ.* **2015**, *9*, 17–28. [CrossRef]
62. Istrate, M.; Horea-Serban, R.; Muntele, I. Young Romanians' Transition from School to Work in a Path Dependence Context. *Sustainability* **2019**, *11*, 1254. [CrossRef]
63. Vrchota, J.; Pech, M. Readiness of Enterprises in Czech Republic to Implement Industry 4.0: Index of Industry 4.0. *Appl. Sci.* **2019**, *9*, 5405. [CrossRef]
64. Li, M.; Lu, Y.; Yang, F. Shaping the Religiosity of Chinese University Students: Science Education and Political Indoctrination. *Religions* **2018**, *9*, 309. [CrossRef]
65. Trifu, A.E. Impact of the number of graduates on the Romanian economy. In Proceedings of the 4th World Conference on Educational Technology Researches (Wcetr-2014), Barcelona, Spain, 28–29 November 2014; Ozdamli, F., Ed.; Elsevier Science Bv: Amsterdam, The Netherlands, 2015; Volume 182, pp. 522–528.
66. Nemcek, B.; Kremenova, I.; Fabus, J. An analysis of unemployment due to number of university graduates in the Slovak republic. In Proceedings of the International Conference on New Horizons in Education, Inte 2014, Paris, France, 25–27 June 2014; Iaman, A., Eskicumali, A., Eds.; Elsevier Science Bv: Amsterdam, The Netherlands, 2015; Volume 174, pp. 2395–2400.
67. Alves, M.C.; Alexander, M.M.; Camara-Poot, V.M.; Ortega, M.E. *Increasing the Number of Sponsored Mexican Graduate Students in Engineering*; Amer Soc Engineering Education: Washington, DC, USA, 2015.
68. Chung, S.; Lee, J.; Lee, H.K. Personal Factors, Internet Characteristics, and Environmental Factors Contributing to Adolescent Internet Addiction: A Public Health Perspective. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4635. [CrossRef]