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Structural changes in the manufacturing sector as an effect of implementing the concept of Industry 4.0

Abstract: The purpose of the study is to identify changes taking place in the employment structure within NACE 'Section C – Manufacturing' which accompany the implementation of the Industry 4.0 concept. The spatial scope of the analysis covers seven EU member states, i.e. Czechia, Germany, Poland, Slovenia, Slovakia, Romania and Hungary. The time range includes the years 2011–2018. All the new technologies that make up Industry 4.0 accelerate industrial transformation processes, additionally transforming the labour market, business management methods and the structure of the goods and services market. The main foundations of the Industry 4.0 concept include automation and robotics, which are increasingly implemented in new areas of life. The fastest-growing market is that for industrial robots which are used in enterprises more and more often and directly affect labour demand. Most industrial robots are used in the manufacturing of motor vehicles, trailers and semi-trailers, excluding motorcycles (Division 29) with Germany and Czechia being leaders in their use. The analysis shows that an increase in robotisation reduces the demand for work for the young, and this only increased in countries that present a low robotisation rate and outdated manufacturing activity.

Keywords: employment; industrial robots; Industry 4.0; manufacturing; structural changes

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Introduction

The dynamic changes currently taking place in industry in the world economy are related to the 4th industrial revolution: the development of digital technology and electronics. This involves the integration of digital and physical systems in all sectors of the economy. The latest developments in information and communication technologies (ICT) are revolutionising manufacturing and service activity. The 4th industrial revolution marks the next stage of revolutionary changes in the organisation of production processes. Industry 4.0 is a commonly used term, but the term Economy 4.0 is also found as the changes go far beyond industry.

The concept of Industry 4.0 has been gaining importance since 2011 when it appeared for the first time at the Hanover trade fair. It is the central pillar of the German strategy for industry development (*"High-Tech Strategy 2020 for Germany"*) which aims to make the German economy a global leader in technological innovation (Lee, 2013; Mosconi, 2015).

The term has also been adopted as the name for the general direction of changes in industrial policy by the European Commission, promoting the idea of strengthening the competitiveness of the European industry. The main goal is to influence structural changes in the thinking and operating of industrial sectors of European Union economies so that they can continue to drive sustainable growth and employment. Nowadays, industrial policy, implemented by individual countries, *de facto* aims at reorienting national economies towards Industry 4.0. This situation stems from the concern to maintain or restore jobs and also to increase the competitiveness and added value of domestic production (Berger, 2016). Industry 4.0, based on digital technologies, shows great potential for the development of production technologies and the possibility of creating customer value. The vision for the industry of the future indicates that enterprises will function as intelligent factories connected digitally in real-time. The effect of these changes will bring a significant improvement in industrial processes of production, engineering, the use of materials, and in the supply chain (Nosalska, 2019).

The implementation of the Industry 4.0 concept in individual economies is handled in different ways. It is accompanied by changes not only in industry in terms of production methods, but also demand for labour. The study aims to identify changes taking place in the employment structure in 'Section C – Manufacturing industry' accompanying the implementation of the Industry 4.0 concept. The spatial scope of the analysis covers seven European Union countries, i.e. Czechia, Germany, Poland, Slovenia, Slovakia, Romania and Hungary. The countries were selected for review based on the importance of industry in creating added value and employment. The time range covers the years 2011–2018, i.e. the period from 2011 when changes in the industry were first identified as Industry 4.0, to 2018, which was determined by the availability of statistical data. The descriptive and statistical analysis methods were included in the study, and the data was obtained from the Eurostat database.

Industry 4.0 – theoretical framework

In the 21st-century product, life cycles are shorter and shorter. Consumers demand more complex and more unique products in more significant quantities. Resources are not used sustainably, and this is a challenge that manufacturing activity must meet. A response to this challenge is Industry 4.0, namely as a concept that integrates all parts of the production process using intelligent systems connected in a network (Grabowska, 2018).

It is widely accepted that the 4th industrial revolution is driven mainly by the considerable increase in the amount of available data and its analysis (big data), the use of mobile connectivity to transmit data from devices (Internet of Things) and the automation of production processes (robotisation). Data analytics enables companies to deepen cooperation with suppliers, to respond better to customer needs, and to allow for cost and product optimisation (*Przemysł 4.0*, 2019). Undoubtedly, all the new technologies which are in Industry 4.0 accelerate the transformation processes of industry, additionally changing the labour market, methods of doing business and the structure of the market for goods and services. What is essential in the economy is that all these solutions interpenetrate and logically interact with almost every area of the economy.

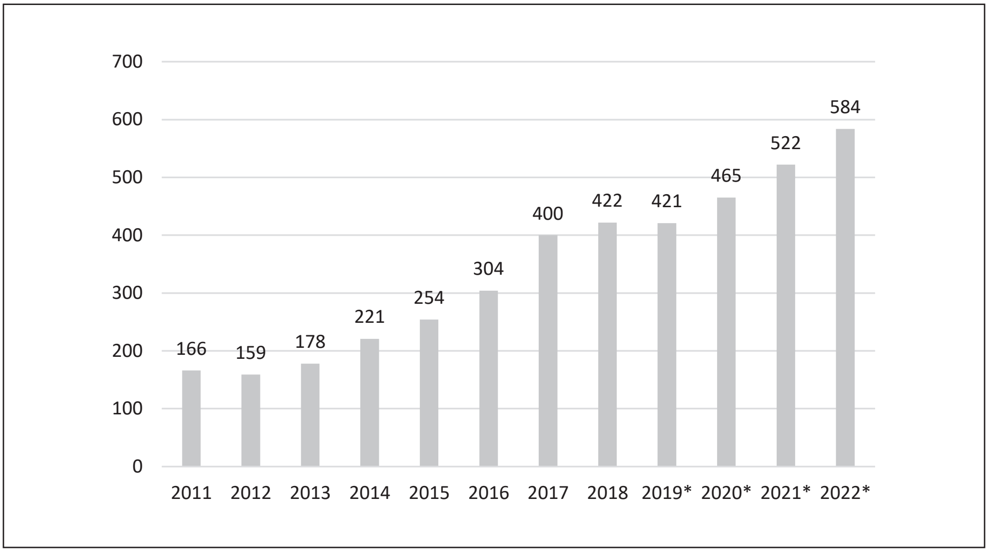
Robotisation – sale and use of industrial robots

One of the main foundations of the Industry 4.0 concept is automation and robotisation, and these are entering new areas of life. The market for industrial robots is growing the fastest; they are increasingly used in enterprises and have a direct impact on the demand for labour. Robots and industrial manipulators have the most significant impact on the number and structure of jobs in industry. According to the definition of the Central Statistical Office of Poland (GUS), these are devices that constitute a set of measures that independently manipulate materials, details and tools. They are used to perform movement functions in basic production processes in an automatic way. The devices have a hard coding system or open-source software to change the positions and sequences of work operations following one or more axes of movement and (or) moving along a given trajectory.

The sale and use of robots in global industrial production are continually growing, and European Union countries, especially Germany, have a significant share in it. Data from the International Federation of Robotics (IFR) show that the sale of robots worldwide in 2018 amounted to 422 000 units and was 6% higher compared to 2017 (Figure 1).

In 2011–2018 the sale of robots globally increased more than 1.5 times, and forecasts show that it will continue to grow. The International Federation of Robotics

Figure 1. The sale of industrial robots in the world in 2011–2022 (in 000s)

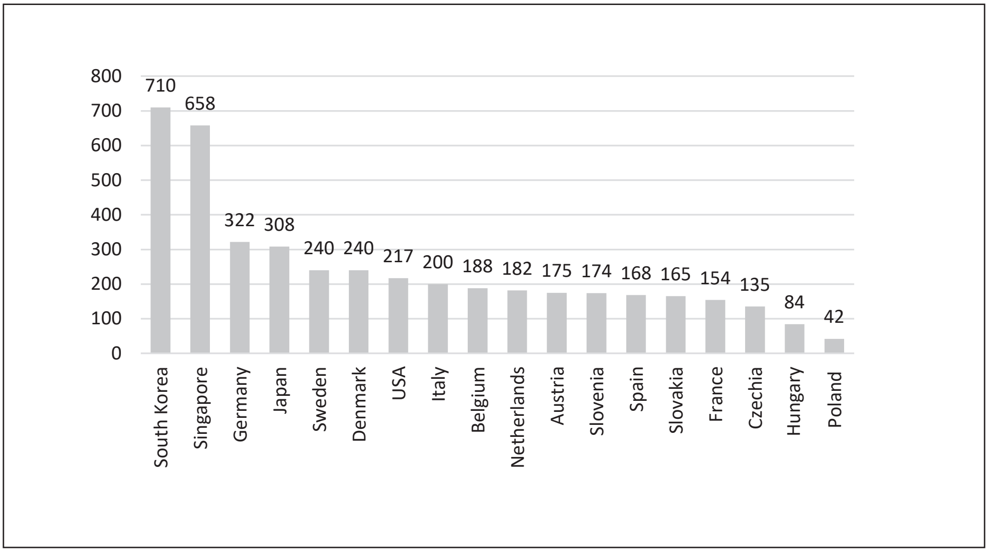


* International Federation of Robotics forecast

Source: author's study based on IFR data (2019) estimates that in 2020–2022 the average annual increase in the global robot sale will be 12%. It is the Chinese economy that plays a unique role in the industrial robot market. Robotics development is one of the critical areas in the Chinese government's plan "Made in China 2025", and it is covered by a state incentive system supporting both domestic (local) and international producers to use industrial robots. Among European Union countries, the highest position in terms of the use of robots is in Germany, the fifth-largest market for industrial robots in the world. In 2018 the number of robots sold in Germany increased by 26% compared to 2017. In Poland 2651 industrial robots were installed in 2018, which means an increase of 40% compared to the previous year. However, comparisons of absolute numbers do not take into account the size of economies. Therefore, relative measures are a better indicator to assess their use in individual countries. One of these measures is the so-called robotisation index (robot density), i.e. the number of robots per 10 000 employed in the manufacturing industry (Łapiński, Peterlik, Wyżnikiewicz, 2015). In 2018 on average there were 99 robots per 10 000 employees in the world, but in Europe, it was 114. The highest rate was in South Korea, i.e. 710 robots per 10 000 employees (Figure 2).

Robotisation growth rate varies significantly in the European Union. Germany is the leader with an indicator of 322 per 10 000 employees, followed by Sweden and Denmark (240) and Italy (200). In Poland, the robotisation growth rate in 2018 came to 42. In the manufacturing industry, most industrial robots are used in 'Division 29 – the Manufacture of motor vehicles, trailers and semi-trailers, excluding motorcycles'. Industrial robots are used in the automotive industry, in sectors producing new utility products (including electronics, household appliances), and also in the laboratory, medical and chemical industries which are based on extreme precision. This group also comprises companies involved in metal processing and the production of machines and devices. More and more robots are used in food processing and the production of plastic products.

Figure 2. The number of industrial robots per 10 000 employees in 2018



Source: IFR (2019)

INDUSTRY IN THE EUROPEAN UNION IN 2011–2018

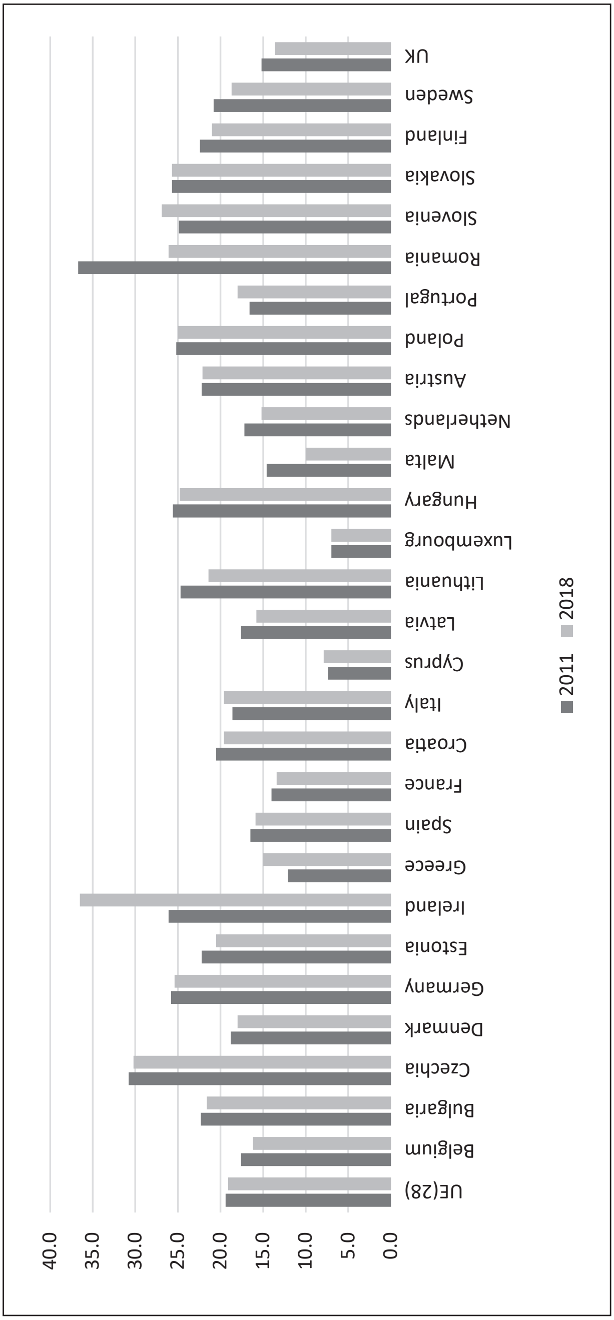
Following the Code List for the Classification of Business Activities in Poland PKD 2007, industry includes four sections: B – Mining and quarrying; C – Manufacturing industry; D – Production and supply of electricity, gas, steam, hot water and air for air conditioning systems, and E – Water supply; sewerage, waste management and remediation activity. In 2018 in the 28 EU countries industry accounted for the most substantial part accounting for 19,1% of gross value added[1], and section C – Manufacturing accounted for 16% of gross value added. Among European Union countries, the share of industry in generating gross value added is very diversified. In 2018 this share ranged from 7,0% in Luxembourg to 36,5% in Ireland (Figure 3).

In fifteen European Union countries, the share of industry in generating gross value added was higher than the average for the EU-28. The most industrialised country in the EU turned out to be Ireland, where the share of industry in generating the gross added value for the entire economy reached 36,5%. Among European Union countries, industry is also significant for the economies of Czechia, Slovenia, Romania, Slovakia, Germany and Poland where the share of industry in creating added value exceeds 25% of the gross value added. In the years 2011–2018, the highest increase in industry, measured as a share in gross value added, was in Ireland (by 10.4 percentage points), and the most significant decrease in Romania (by 10.6 pp). For a detailed analysis of structural change in employment as a result of the implementation of the Industry 4.0 concept, countries were selected where the share of 'Section C – Manufacturing industry' in the creation of added value exceeded 19%, i.e. Czechia, Slovenia, Germany, Hungary, Romania, Slovakia and Poland (Figure 4). Ireland was excluded from the analysis due to problems with the interpretation of data for this country where traditional measures such as GDP or the gross value added are not reliable. An open economy, resources of qualified specialists, and a competitive CIT (Corporate Income Tax) contributed to attracting to Ireland many of the world's largest companies, mainly technological, e.g. Apple, AerCap. However, it often involved relocating only the headquarters of these companies, not the production plants. A situation like this has meant that the actual impact of industry on the economy is significantly limited. If industrial companies do not operate in Ireland, they do not create places of work there. In Ireland,'Section C – Manufacturing' generates 34,6% of gross value added but the share of employed is only 10,1% of the total working population.

In the conditions of building a knowledge-based economy and shaping the information society, the participation of the most technologically advanced branches of industry in the employment structure is particularly important. These generate multiplier effects in socio-economic development and are characterised by much more favourable economic effects in comparison with traditional industry (Rachwał, 2010). The study focuses on industrial processing, as it is the section that implements the Industry 4.0 concept most quickly, mainly through the use of industrial robots. Additionally, manufacturing includes activities that are sensitive to economic fluctuations and in which there are intense changes in the structure of production and employment (Bartosik, 2013). In most EU countries, the share of 'Section C – Manufacturing' in gross

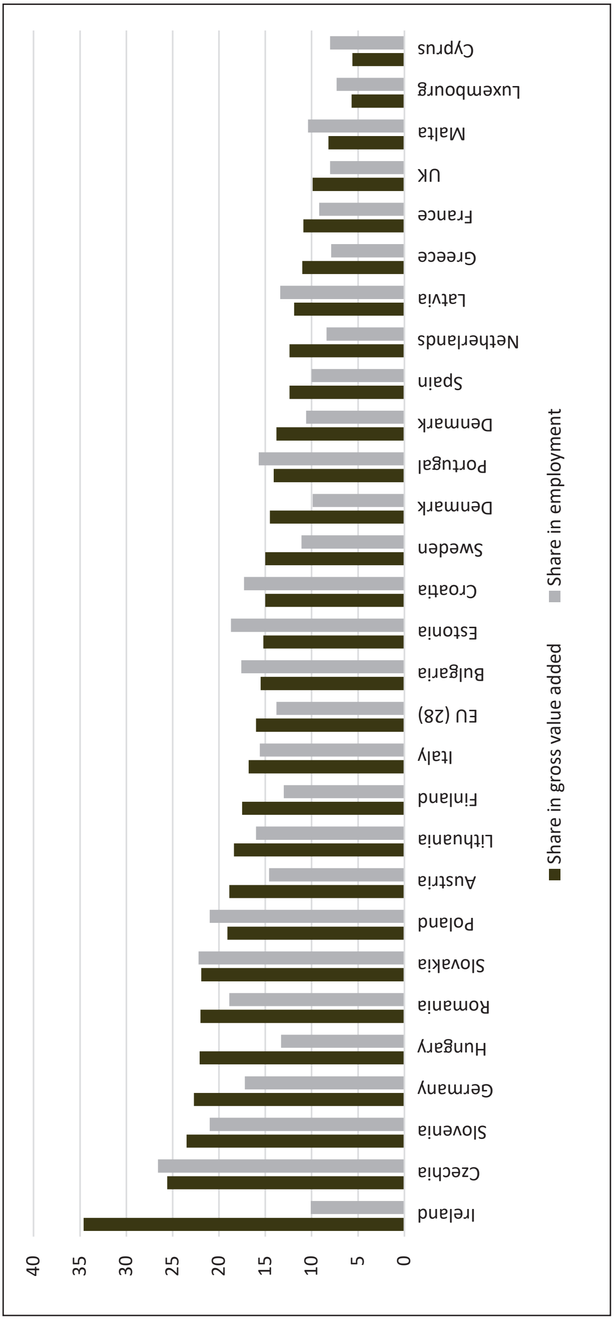
[1] Gross value added – is the sum of gross value added of all institutional sectors or branches of economic activity. It is calculated as the difference between global production and intermediate consumption.

Figure 3. The share of industry in generating gross value added in European Union countries in 2011 and 2018 (%)



Source: Eurostat data

Figure 4. Share of 'Section C – Manufacturing' in gross value added and in employment in European Union countries in 2018 (%)



Source: Eurostat data

value added was higher than the share in employment. Generally speaking, it proves the dominance of modern industrial production. However, an inverse relationship occurs in eleven EU countries, indicating a greater importance of labour- and capital-intensive industries. Among the countries selected for analysis, three had a higher share in employment than in gross value added, i.e. Czechia, Poland, and Slovakia, which may indicate a slightly outdated structure of production in these countries.

Changes in the employment structure in manufacturing in selected European Union countries

Economies undergo permanent changes in the structure of production and employment. There are different reasons for these changes, but most often they include technical progress or changes in consumer demand. In the long run, this is a beneficial process that improves resource reallocation and increases labour productivity, and finally, it translates into prosperity. In the short term, however, it may lead to job loss and the need to retrain employees or change their place of residence.

In 2011–2018 employment in manufacturing in all surveyed countries increased by an average of 13,0% (Figure 5). The highest increase in the number of employed aged 15–64 occurred in Hungary (25,3%), and the lowest in Germany (3,2%). The rise in employment was accompanied by structural transformations in the percentage share of individual branches of manufacturing[2] in employment. Five divisions faced enormous changes: Division 10 – Manufacture of food products; Division 25 – Manufacture of fabricated metal products, except machinery and equipment; Division 27 – Manufacture of electrical equipment; Division 28 – Manufacture of machinery and equipment not covered elsewhere in the classification, and Division 29 – Manufacture of motor vehicles, trailers, and semi-trailers, excluding motorcycles. Following IFR data, these are the sections that most often use industrial robots.

Table 1. Employment in selected branches of industrial processing in 2011 and 2018 (in % of total employment in section C)

Countries	Manufacture of food products		Manufacture of motor vehicles		Manufacture of electrical equipment		Manufacture of machinery and equipment		Manufacture of fabricated metal products	
	2011	2018	2011	2018	2011	2018	2011	2018	2011	2018
Czechia	7.8	7.1	14.0	16.0	5.3	5.6	7.6	8.5	11.1	10.8
Germany	10.5	10.2	15.1	15.1	4.8	3.7	14.0	17.0	9.8	8.9
Poland	16.3	13.8	7.4	9.3	4.1	3.9	4.3	5.2	8.7	8.9
Romania	11.4	12.6	8.4	15.8	4.6	4.8	4.3	3.8	5.6	5.5
Slovakia	7.8	7.0	15.4	19.8	5.8	6.7	8.1	10.9	9.6	9.1
Slovenia	6.6	7.1	9.4	12.7	9.8	10.9	5.3	5.5	14.2	12.7
Hungary	12.9	12.8	11.0	16.2	6.4	6.3	5.4	6.8	7.4	8.7

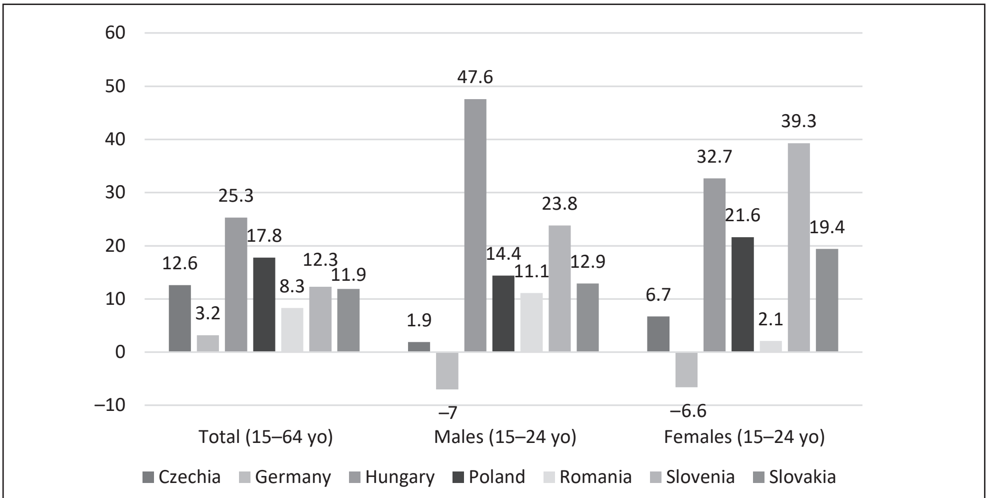
Source: Eurostat data

[2] The Polish Classification of Businesses Code PKD 2007 recognises that section C - Manufacturing consists of 23 divisions.

The most extensive changes in the employment structure concerned two divisions, i.e. Division 29 – Manufacture of motor vehicles and Division 28 – Manufacture of machinery and equipment. In Romania, the share of employees in 'Manufacture of motor vehicles' increased by 7.4 pp, while in Germany the share in 'Manufacture of machines and devices' increased by three pp (Table 1). In the analysed period, 'Manufacture of food products' (Division 10) and 'Manufacture of finished metal products' (Division 25) lost their importance. In Poland, the share employed in 'Manufacture of food products' decreased by 2.5 pp, and in Slovenia, the share employed in 'Manufacture of finished metal products' decreased by 1.5 percentage points.

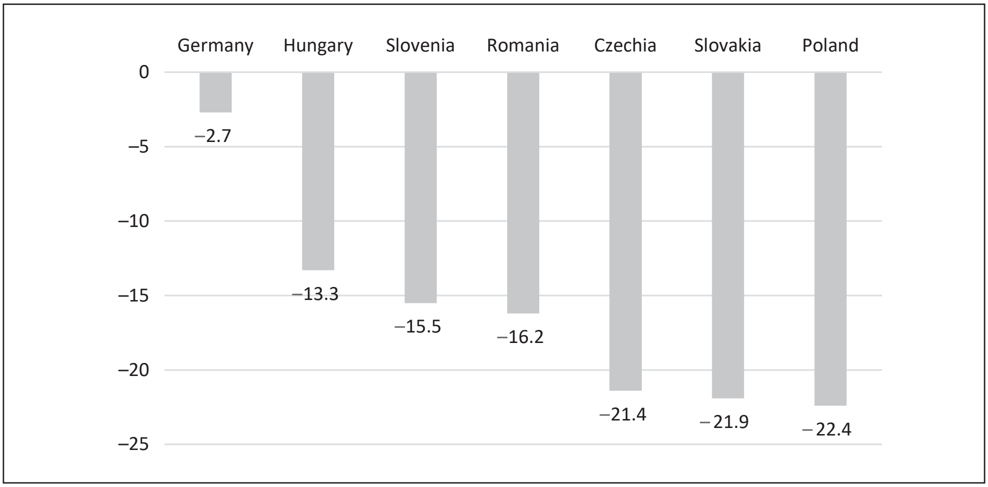
Particularly significant changes occurred in the youngest group of employees. In 2011–2018 the number employed aged 15–24 in 'Section C – Manufacturing industry' increased by 1,9%, in the European Union (28) while the number of young men increased by 2,7%. Still, among women, there was a slight decrease of 0,1%. In Hungary, the increase was the highest and amounted to 47,6% for men, and 32,7% for women (Figure 5). In Hungary, the rise in the number of employed young men occurred mainly in 'Division 25 – Manufacture of fabricated metal products, excluding machinery and equipment' (an increase from 3200 in 2011 to 8300 in 2018), and women in 'Division 29 – Manufacture of motor vehicles, trailers, and semi-trailers, excluding motorcycles' (an increase from 3100 to 5700). A decrease in the number of young workers occurred in Germany, concerning both men and women, amounting to –7% and –6,6%, respectively. The most significant decline in jobs for young men in Germany occurred in 'Division 25 – Manufacture of fabricated metal products, excluding machinery and equipment' (from 103 500 to 82 900), 'Division 24 – Manufacture of metals' (26 200 up to 16 300) and 'Division 29 – Manufacture of motor vehicles, trailers, and semi-trailers, excluding motorcycles' (from 92 200 to 82 900). Because the German economy has the

Figure 5. Changes in the number of people working in manufacturing in selected European Union countries in 2011–2018 (%)



Source: author's calculations based on Eurostat data

Figure 6. Changes in the population aged 15–24 in selected European Union countries in 2011–2018 (%)



Source: author's calculations based on the Eurostat data

highest rate of robotisation, it can be assumed that this influences changes in the age structure of employees. Computers and robots replace people primarily in the performance of tasks that can be described by algorithms, i.e. structured and repetitive tasks; in other words, routine tasks (Brynjolfsson, McAfee, 2014). This means that industrial robots mainly replace the work of young, poorly educated workers, especially men. In Poland, in the analysed period, the number of young working men increased by 14,4% and young women by 21,6%.

It is worth emphasising that the decline in the number of young workers in the manufacturing industry in Germany was not affected by the decrease in total population aged 15–24. Figure 6 shows the changes in the population aged 15–24 in selected countries in 2011–2018. It can be seen that in all analysed countries the population aged 15–24 decreased, but the smallest decrease, of –2,7%, was in Germany. The most substantial reduction of those aged 15–24 in the analysed period occurred in Poland (–22,4%), Slovakia (–21,9%) and Czechia (–21,4%), i.e. in countries where an increase in the number of young people working in the manufacturing industry was recorded.

Conclusions

The Industry 4.0 concept radically changes manufacturing, its division structure, and the requirements for the competences and skills of employees. New technologies that contribute to Industry 4.0 accelerate the transformation processes, additionally changing the labour market, in particular the demand for labour, methods of conducting a business activity, and the structure of the market for goods and services. The research shows that Germany is the most technologically advanced country in the European Union, while at the same time, using industrial robots to the greatest extent.

The implementation of the Industry 4.0 concept is accompanied by significant structural changes in employment, mainly in manufacturing. The use of industrial robots does not limit the total number of people working in manufacturing. Still, it reduces the number of places of work for young people aged 15–24, especially men. These are people who, due to their age, do not have the high qualifications and competencies necessary to operate industrial robots or to collaborate with robots (cobots). The technologies used within Industry 4.0 replace people primarily in the performance of simple, repetitive, routine tasks that can be described using algorithms. In the next few years, we can expect the occurrence of factors favouring the robotisation of enterprises. Falling unemployment and the ageing of the population are already causing difficulties in finding employees in many European Union countries. Therefore, investing in employees who understand the need to implement changes, as well as providing them with the opportunity to expand their knowledge in this field continuously are fundamental issues.

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