How can the Fourth Industrial Revolution change the global power relations?

Julianna Csugány[1]

Abstract

Nowadays, we live in the era of the Fourth Industrial Revolution or Industry 4.0, in which the digitization, automatization and robotization process reorganizes the production systems. The Fourth Industrial Revolution develops the inventions of the previous era, so it can also be called the Second Information Revolution, enabling the wider use of information and communication technologies. Artificial intelligence, machine learning, cloud computing, Big Data, internet of things (IoT), the blockchain, cyber-physical systems, robots, and sharing economy are related to this revolution which transforms our life. We have to face new challenges, but at the same time, new possibilities arise in the economy. This empirical research aims to present the macroeconomic effects of the Fourth Industrial Revolution, comparing the countries' performance in the field of new technologies based on relevant statistical data's. Technological progress is the driving force of economic growth, so countries who can the fastest in adaption to the new techno-economic paradigm, become the leader in the new era. The research question to be analyzed is which country can be the winner of this era, as well as how can the Fourth Industrial Revolution change the global power relations. The United States dominated in the previous industrial revolution, but nowadays some developing countries, for example, China, are leaders in some industries, so competition is intensified between countries. The quantitative research aims to compare technological leading countries' performance in several fields affected by the Fourth Industrial Revolution.

Keywords: the Fourth Industrial Revolution; Industry 4.0; digitization; technological leading countries

JEL Codes: O11, O31, O57

[1]Department of Economics, Eszterházy Károly University, Eger, Hungary. csugany.julianna@uni-eszterhazy.hu

1. Introduction

Nowadays, we live in the era of the Fourth Industrial Revolution, when digitization induces fundamental changes in economic processes to which we have to adapt. There are changes in all areas of our life, new technologies replace the old ones, which generate efficiency and productivity growth, that we can call Schumpeterian creative destruction in the economy. It reflects that innovation has many positive effects on the economy but there are negative consequences as well. Economic actors who are dominant in new technologies win, but the owners of old technologies lose. In the macroeconomic aspect, countries who are leaders in innovation, as well as creating and adapting new technologies realize higher growth rates while technological followers are lagging behind. Because of this, the dynamic technological progress has changed the global power relations. The First Industrial Revolution was begun at the end of the 18th century when first inventions appeared in the British textile industry. At this time, Great Britain was the technological leader country. At the end of the 19th century, the invention of internal-combustion engines and mass production had launched revolutionary changes. In the Second Industrial Revolution, Germany and United States played an important role in innovation. The appearance and spread of information and communication technologies generated the Third Industrial Revolution in which United States dominated and became the world's technological leader country. The research question is *which country can be the winner of the era of the Fourth Industrial Revolution, as well as how global power relations can change in this era*.

During industrial revolutions, new industries are emerging, while the nature of traditional industries is changing. Nowadays, the digitization changes the economic processes, for example, the artificial intelligence and the robotics transform the mechanisms of industry and services, while the internet of things (IoT) connects the devices, and Big Data can create several opportunities to improve the economic performance. The information and communication technologies are used almost every sector of the economy, the main drivers of this process are the Internet which facilitates the communication between people and machines in different places. Summarizing the potential impacts of industry 4.0, Kovács (2017) emphasized that this industrial revolution transforms our working and living conditions. Furthermore, the efficiency is improving, the new technologies can enhance the realization of sustainable and green economy and finally they generate overall productivity growth.

This research aims to compare the current and potential technological leader countries' performance in relevant fields of the Fourth Industrial Revolution. *United Kingdom, Germany, United States, Japan, China and Rep. of Korea* are included in this analysis. UK, Germany and US were dominated in the previous industrial revolution, Japan, but even more China and Rep. of Korea will be technological leader in the future. Japan has a special situation because this country was not dominated in the previous industrial revolution, but it has been a technological leader in several fields, mainly in electronics. The main macroeconomic indicators related to technological progress and the special fields of the Fourth Industrial Revolution will be analyzed using comparative statistical methods.

2. The main features of industrial revolutions: how the Fourth Industrial Revolution can be characterized?

Based on empirical evidence, before the first industrial revolution there is no significant difference in income between countries (Williamson, 2009, p. 183). According to Mokyr (2004), the complementarity of radical innovations, i.e. macroinventions, and incremental innovations, i.e. microinventions, accounted for the enormous economic impact of Industrial Revolution, which launched not only technological progress, but also an increase in the income of the world's countries. The first inventions appeared in the British textile industry, steambased mechanization in industry and agriculture also led to productivity gains, and finally, a qualitative change took place in all sectors of the economy. From the second half of the 19th century, revolutionary changes occurred again, this time from the United States and Germany. There have been world-wide technological innovations in the steel industry, in chemistry and in electricity, macroinventions appeared in new and more industries. A new era has begun with the invention of internal-combustion engines which has led to the recovery of transport and trade (Mokyr 2005). In the late 1960s in the United States, the appearance of information and communication technologies (ICTs) induced a new wave of technological progress mainly in the service sector, resulting in fundamental structural change in the economy. Nowadays, we live in the era of the Fourth Industrial Revolution or Industry 4.0, in which the digitization reorganizes the production systems. Big Data, internet of things (IoT), artificial intelligence, cyber-physical systems and robots are typically related to this revolution. We have to face new challenges, but at the same time new possibilities arise in the economy to improve the efficiency and generate productivity and economic growth.

There are several approaches that seek to classify the technologies, i.e. main drivers of industry 4.0. Schwab (2016) identified the megatrends clustered by three groups (physical, digital, biological) which are the main drivers of the 4th Industrial Revolution. Based on this classification, there are four main physical manifestations of the technological megatrends, i.e. autonomous vehicles, 3D printing, advanced robotics and new materials. The digital manifestation is the internet of things, which described as a relationship between things and people to enhance an efficient operation. This includes the sharing economy, the blockchain in the field of finance. The biological aspect includes the innovations related to the field of biology, such as medicine, genetics and a special field of agriculture (GM). Hermann et al. (2016) identified six design principles for the implementation of Industry 4.0, these are interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity. Based on their literature review, four key components of Industry 4.0 can be identified: Cyber-Physical Systems, Internet of Things, Internet of Services, and Smart Factory. They supposed that Machine-to-machine (M2M) communication and Smart Products are also element of Industry 4.0, but they are not considered as independent component. It's because M2M is an enabler of the Internet of Things, and Smart Products are a sub-component of Cyber-Physical Systems. According to Rüssmann et al. (2015) the driving forces of Industry 4.0 are Big data and analytics, augmented reality, additive manufacturing, the cloud, cybersecurity, the industrial Internet of Things, horizontal and vertical system integration, simulation and autonomous robots. Industry 4.0 makes it possible to gather and analyze a large amount of data to enable faster, more flexible, and more efficient economic processes. Rüssmann et al. (2015) also pointed out that this in turn will increase manufacturing productivity, foster industrial growth, and modify the profile of the workforce.

Why the Fourth Industrial Revolution is so special? This question can be answered by Rostow in the '80s, when nobody knew when this revolution would happen. Rostow (1988, pp. 172-181) pointed out that the following industrial revolution would have four characteristics (quoted by Kozmetsky et al. 2004):

- new technologies are so encompassing that no one country can dominate them completely
- new technologies are linked to areas of the basic sciences that also are undergoing revolutionary changes
- new technologies are immediately transferable to rapidly industrializing nations
- new technologies are key to leapfrogging for basic industries.

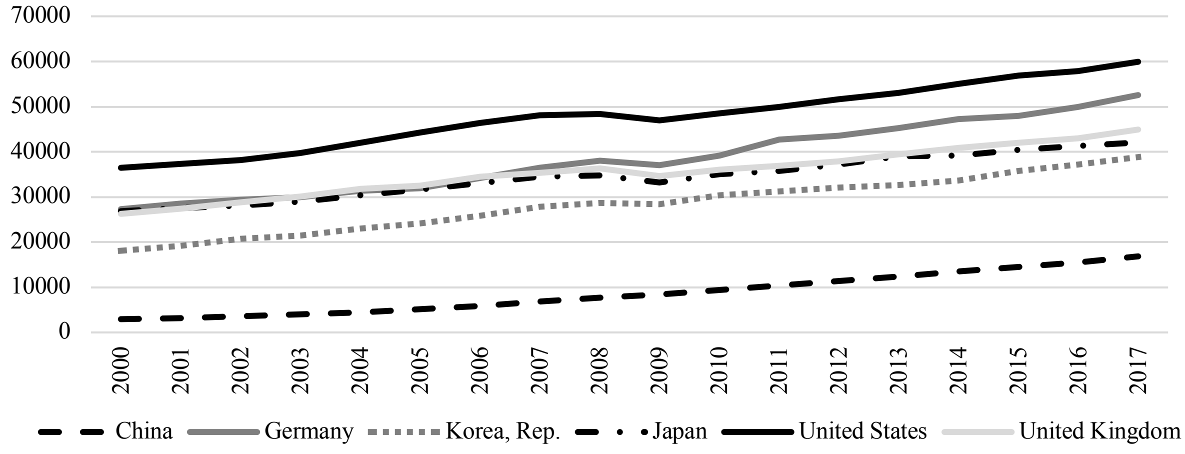
Rostow's findings are still valid today, because there is no one country who can dominate in the world economy. The technological changes are so complex, fundamental changes occur as a result of digitization, which affects almost every area of the economy. In addition, new technologies can adapt more easily to local environment, but the budget constraint prevent the widespread application. Because of this, higher income countries can converge, but it is assumed that technological follower countries will diverge. There is a potential to catch-up with innovation leaders in some imitation-based countries who are not so far behind. According to Balogh (2017), China may be the real winner of the next industrial revolution.

3. Changes in global power relations as a result of industrial revolutions: methodology and empirical results

In the First Industrial Revolution Great Britain was the technological leader, the continental Europe and the other part of the world were lagging behind. The Second Industrial Revolution was not as concentrated as the first one, Europe, primarily Germany, and the United States played the same leading role (Kapás 2010). Unites States retained its technological leading role in the Third Industrial Revolution, the information and communication technologies were appeared here and have spread to the rest of the world. Now, in the era of the Fourth Industrial Revolution, USA is dominant, but China poses a threat to the US position. In some fields, Japan and Rep. of Korea has a leading role, so they will be also the winner of this era. Rüssmann et al. (2015) concluded that Industry 4.0 create opportunities for innovative economic actors and regions but it also poses a threat to laggards. In spite of this, we will see changes in top positions in case of firms and regions too. Current and former leaders, as well as potential technological leader countries in industrial revolutions such as United Kingdom, Germany, United States as current and former ones, while China, Japan and Rep. of Korea as potential ones, will be compared in several fields related to the Fourth Industrial Revolution.

Firstly, an overall economic performance, measured by GDP per capita and annual growth can be compared in countries. *Figure 1* shows the GDP per capita (PPP, current international $) in recent years. All countries economic performance improved and it is observed that China converge to high-income countries due to its high growth rate.

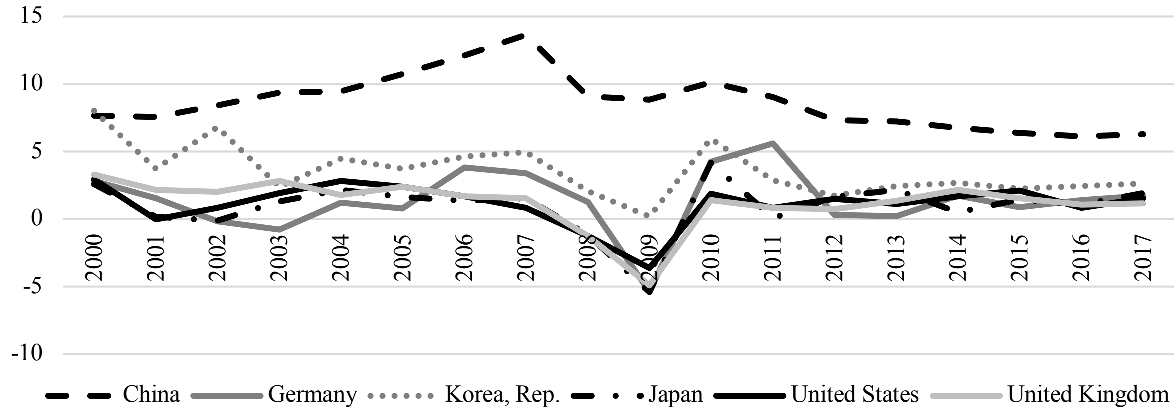
Figure 1: GDP per capita (PPP, current international $) in technological leading countries between 2000 and 2017



Source: World Development Indicators (2019)

Based on Figure 1, we can conclude that the United States' economic performance is constantly improving and keeps the leading position. US is followed by Germany who get ahead of United Kingdom. The economic performance of Japan and UK are so similar but they are lagging behind the leaders. Rep. of Korea is catching up, GDP per capita in 2017 is more than doubled as in 2000. China has the biggest improvement in economic performance, the GDP per capita is more than five times higher in 2017 than in 2000. *Figure 2* shows the annual growth rate of countries.

Figure 2: GDP per capita growth (annual %) in technological leading countries between 2000 and 2017

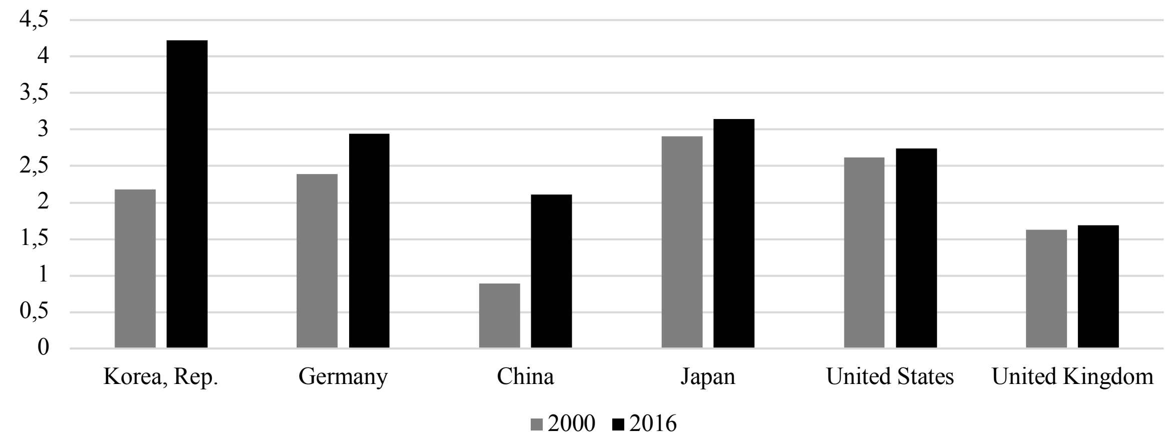


Source: World Development Indicators (2019)

Based on *Figure 2*, we can conclude that China's convergence is explained by the constant economic growth. The annual growth rate was above 10 percent in three years (2005, 2006 and 2007), but this growth slows down from 2010. Besides China, Rep. of Korea is another country where there is no negative growth rate between 2000 and 2017. World's technological leading countries, such as United States, Germany, Japan, and the United Kingdom suffered from the financial crisis in 2009 when they realized the negative growth rate. Germany's recovery was not so long, its economic performance stagnates. In 2017, the annual growth rate of the United States, Germany, United Kingdom, and Japan is below 2%, while Rep. of Korea is 2.62% and the Chinese one is 6.3.

Innovation is the driving force of the economic growth, the two typical indicators which are used to illustrate the innovation performance pf countries are Research and Development expenditures and patent applications. Figure 3 shows the R&D expenditure as a percentage of GDP, while Figure 4 shows the total patent applications in three most patent-intensive countries.

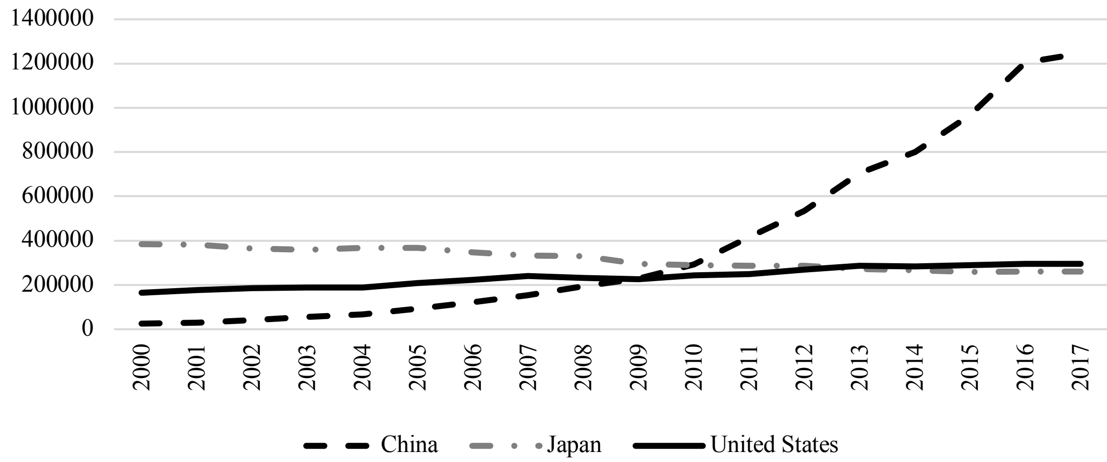
Figure 3: Research and development expenditure as a percentage of GDP in technological leading countries in 2000 and 2016



Source: World Development Indicators (2019)

Based on Figure 3, we can conclude that Rep. of Korea and China increased significantly the R&D expenditures from 2000. The highest share of GDP is in Rep. of Korea, where more than 4 % of GDP is spent on R&D compared to around 2% in 2000. China's R&D expenditure was extremely low in 2000, but in 2016 more than 2% of GDP is spent for this purpose. Germany also increased R&D expenditures in a greater extent between 2000 and 2016, but Japan, United States and United Kingdom spend on R&D almost the same share of GDP in both years. It means that innovation become more important in China and Korea, while remain as important as before in the other countries.

Figure 4: Patent applications (residents) in China, United States and Japan between 2000 and 2017

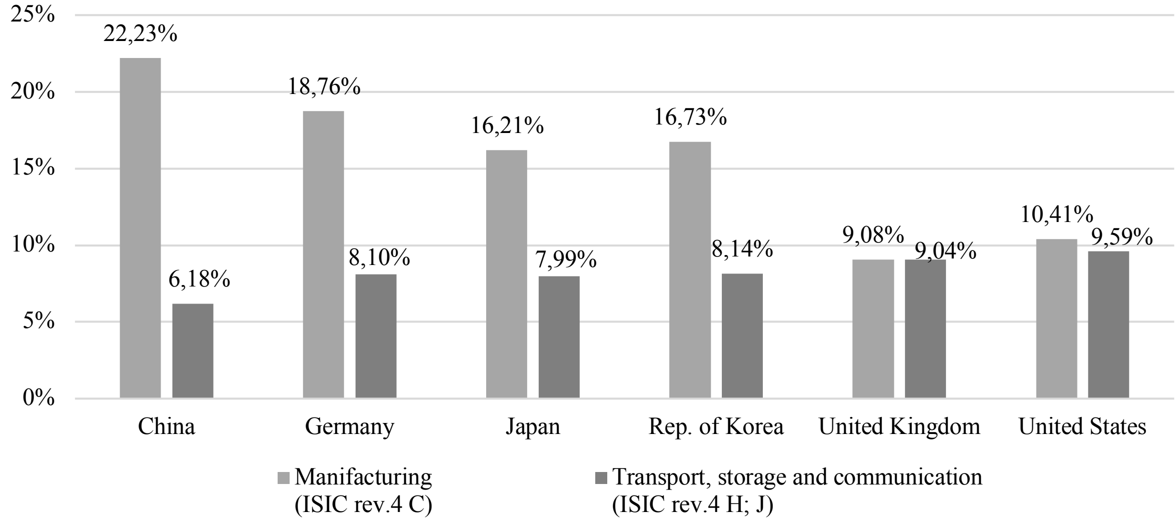


Source: World Development Indicators (2019)

Figure 4 shows that patent applications are significantly grown in China from 2010. This Figure illustrates well the efficiency of the Chinese innovation performance, nowadays most of the patents are related to China. Patenting activity in Japan and the United States is not as important as in China. It's because the innovation become faster while the patenting procedure is slow. The intellectual property rights are important in innovation activity, but the patent is not an optimal solution to protect the owner's rights of the new technologies in the era of the Fourth Industrial Revolution.

Human resources is one of the critical areas how to realize technological progress in a country. Emphasizing the role of human capital in technological progress, Caselli & Coleman (2006) pointed out that the technological differences between countries are due to the qualification asymmetry, because innovation requires more skilled workforce, while the less skilled workforce is suitable for imitation. The basis of the Fourth Industrial Revolution is the IT sector and manufacturing, *Figure 5* shows the employment of these sectors in 2018. The share of manufacturing is so high in China, Germany, Japan and Rep. of Korea, the value is around 20%, while in United Kingdom and United States its share is around 10%. The labour share of transport, storage and communication which includes ICT, is quite similar to manufacturing in UK and US, but much smaller than manufacturing in other countries.

Figure 5: Labour share of manufacturing and transport, storage and communication in total employment (2018)

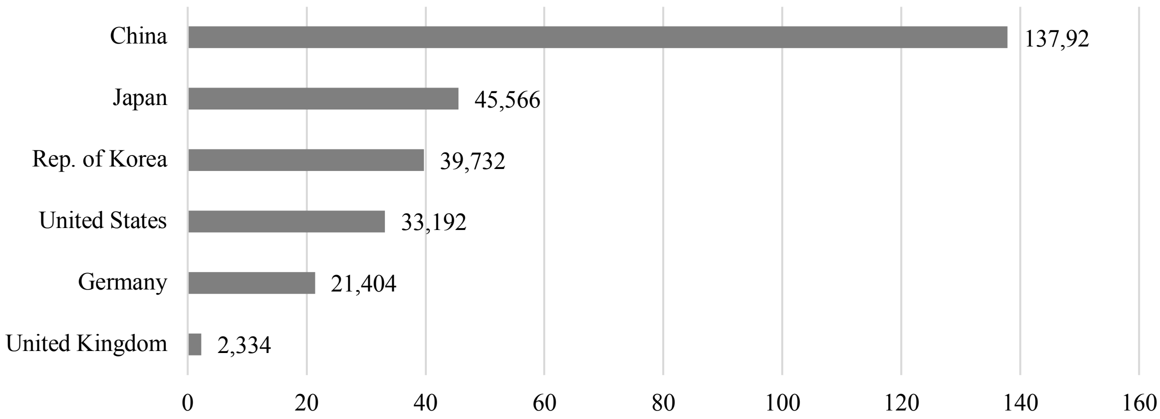


Source: ILO (2019)

In transport, storage and communication, the share of ICT is 37.36% in Germany, 40.58% in Japan, 35.84% in Rep. of Korea, 43.8% in United Kingdom and 38.14% in United States. There is no available data in this field in China. There is an ICT dominance in employment of United States and Europe whose firms are leading in these fields.

One of the most important fear in the era of the Fourth Industrial Revolution is that robots can substitute human resources. Robotics is a dynamically improved field of the economy. Based on World Robotics Outlook 2019, it was only a 1% increase in estimated worldwide annual shipments of industrial robots, after a 30% increase in the previous year. Europe and America are still growing, but there is a decrease in Asia in a supply of industrial robots. If we look at this at a country level, China remains the largest market, followed by Japan, the United States, Republic of Korea and Germany. In the United States, the estimated annual supply of industrial robots is 15%, the supply of industrial robots has doubled in the last ten years. The largest segments are automotive and electronics where there is a decline compared to previous years. Another interesting statistics is made by International Federation of Robotics (IFR), in terms of robot density by region, Europe has the highest level worldwide, with 106 industrial robots per 10 000 employees installed in the manufacturing industry, but Rep. of Korea is a leader in this field, 710 industrial robots per 10 000 employees followed by Singapore, Germany, Japan, and Sweden, while China is 21st, overtook United Kingdom in 2017 (IFR World Robotics 2018). *Figure 6* shows the annual shipment of multipurpose industrial robots, while *Figure 7* shows the Number of installed industrial robots per 10,000 employees in manufacturing.

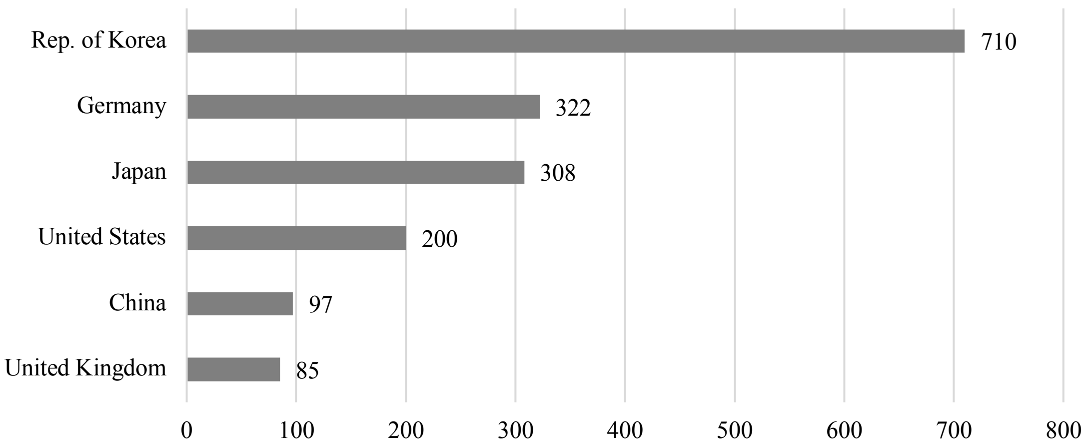
Figure 6: Annual shipments of multipurpose industrial robots (number of units)



Source: IFR World Robotics 2018

China, Japan, Rep. of Korea, United States, Germany and United Kingdom account for almost a three quarters of total shipments of industrial robots (73.47%). China is dominant, because its share is 36.17% followed by Japan (11.95%) and Rep. of Korea (10.42%). In the field of robotics, China has significant advantages.

Figure 7: Number of installed industrial robots per 10,000 employees in manufacturing industry, 2017



Source: IFR World Robotics 2018

Based on Figure 7, Rep. of Korea is the leading in robot density, but only 710 robots are installed per 10 000 employees which reflects that robots cannot substitute completely the human resources. The world average is 85 units which is equal to the value of United Kingdom. Due to the Brexit, UK is lagging behind, China has overtaken. This statistics looks a different picture about countries. Depend on the subfields, different countries perform well which predicts that there is no one country who will dominate in the Fourth Industrial Revolution.

4. Conclusion

Nowadays we live in the era of the Fourth Industrial Revolution or Industry 4.0, when digitization transforms our life and all sectors of the economy. There is a consensus in economics that technological progress is the driving force of economic growth, so innovation is essential to increase the standard of living in a country. The Industry 4.0 create possibilities to improve efficiency which lead productivity growth. The main question is which country can be the winner of this new technological era, as well as how global power relations can change. In this research six, current, former and potential technological leading countries, i.e. United Kingdom, Germany, United States, China, Japan and Rep. of Korea are included in the analysis. Summarizing the empirical results, we can conclude that the United States preserve its technological leading role, but there is a severe threat of China and Rep. of Korea in the field of robotics. In ICT sectors, US is dominant, its firms are the most competitive in the world economy, but Asian companies improve their competitiveness. To answer the question, in the era of the Fourth Industrial Revolution, the global power relationships will change, more countries have a technological leading role, and there will not only be one country who dominate. United States will remain technological leader, while China and Rep. of Korea will join the US at the top. Due to the rapid technological changes, it is possible that an imitation-driven country whose innovation performance does not seem to be well, catch-up to innovation leaders.

Acknowledgement

This research is supported by the Hungarian National Talent Program.

References

Balogh, L. S. (2017). Lehet-e Kína a következő ipari forradalom nyertese? [Can China be the winner of the next industrial revolution?] *Hitelintézeti Szemle*, Vol. 16(January), pp. 73-100.

Caselli, F. & Coleman, W. J. (2006). The World Technology Frontier. *The American Economic Review*, 96(3), 499 – 522.

Hermann, M., Pentek, T. & Otto, B. (2016). Design Principles for Industrie 4.0 Scenarios. 2016 49th Hawaii International Conference on System Sciences (HICSS), pp. 3928-3937. DOI: 10.1109/HICSS.2016.488

International Federation of Robotics (2019). World Robotics 2018. Retrieved from https://ifr.org/ifr-press-releases/news/brexit-uk-falling-back-in-global-automation-race-robot-sales-down-3 (30 May, 2019)

International Federation of Robotics (2019). World Robotics 2019 Preview Retrieved from https://ifr.org/downloads/press2018/IFR_World_Robotics_Outlook_2019_-_Chicago.pdf (30 May, 2019)

International Labour Organization, ILO (2019) [database]. Retrieved from https://www.ilo.org/global/lang--en/index.htm

Kapás, J. (2010). A technológiai és intézményi fejlődés kölcsönhatásai – az elmúlt ipari forradalmak tapasztalatai [Interactions between technological and institutional development - the experiences of the recent industrial revolutions]. In: Kapás, J. (ed). *Technológiai fejlődés és intézmények [Technological progress and institutions]*. Competitio Books 10., Debrecen, Hungary.

Kovács, O. (2017). Az ipar 4.0 komplexitása – I. rész [The Complexity of Industry 4.0 – Part 1]. Közgazdasági Szemle, Vol. XIV. (July-August), pp. 823 – 851.

Kozmetsky, G., Williams, F. & Williams, V. (2004). New Wealth: Commercialization of Science and Technology for Business and Economic Development. Praeger Publishers, Westport.

Mokyr, J. (2004). A gazdagság gépezete – technológiai kreativitás és gazdasági haladás. [The Lever of Riches: Technological Creativity and Economic Progress]. Budapest: Nemzeti Tankönyvkiadó.

Mokyr, J. (2005). Long−term Economic Growth and the History of Technology. In: Aghion, P. – Durlauf, S. (eds): Handbook of Economic Growth., The Netherlands, Amsterdam, Chapter 17, pp. 1113 – 1180.

Rüssmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Pascal, E. & Harnisch, M. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. http://www.inovasyon.org/pdf/bcg.perspectives_Industry.4.0_2015.pdf (1 June 2019)

Schwab, K. (2016). *The Fourth Industrial Revolution*. World Economic Forum, Geneva, Switzerland.

Williamson, S. D. (2009). *Makroökonómia [Macroeconomics]*. Osiris Kiadó, Budapest.

World Development Indicators (2019) [database]. Retrieved from https://data.worldbank.org/