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THE IMPACT OF TECHNOLOGICAL ADVANCEMENT ON UNEMPLOYMENT

Yüksek Lisans Tezi

MELİS ZEREN

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ÖZET

Endüstri 4.0, aslen imalat sanayinde dijitalleşmenin önünü açmak için Alman hükümeti tarafından başlatılan bir yüksek teknoloji projesi olup icatçılık, inovasyon ve yenilikçiliğin yanında Yapay Zekanın (AI), Nesnelerin İnternetinin (IoT), Büyük Verinin, yeni algoritmaların, sensörlerin, kontrolörlerin, giyilebilir teknolojilerin ve robotların yaygınlaşan kullanımı ile karakterize edilmiştir. Bu çalışma, Yaratıcı Yıkım ve Sektörel Değişim Teorilerini baz alarak Endüstri 4.0 değişkeniyle işsizliği açıklamaya çalışmaktadır. Çalışmada kullanılan veriler WEF (Dünya Ekonomik Forumu), UNIDO (Birleşmiş Milletler Sınai Kalkınma Teşkilatı) ve Dünya Bankasından elde edilmiş olup 2003-2016 zaman aralığını kapsamaktadır. İşsizliği ve sektörel değişimleri tahmin etmek için kullanılan ülkeler Kanada, Fransa, Almanya, İtalya, Güney Kore, Polonya, İspanya, Birleşik Krallık ve Amerika Birleşik Devletleri'dir ve bu ülkeler görece yüksek nüfusa sahip olan Endüstri 4.0 indeksinde ilk sıralarda yer alan OECD ülkeleridir. Ampirik sonuçlar göstermektedir ki Gayri Safi Sabit Sermaye Oluşumu (%GSMH), İmalat Sanayi Katma Değeri (%GSMH) ve "Networked Readiness Index" (Endüstri 4.0 hazırlık indeksi)'inin, beklenenin aksine, işsizlik üzerinde negatif etkisi vardır, yani işsizlik oranını azaltmaktadır. Buna göre, Endüstri 4.0 yeni iş olanakları yaratarak işsizliği düşürmektedir.

GENERAL KNOWLEDGE

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ABSTRACT

Industry 4.0 is a term originally used for a high-technology project German government started up, which facilitated computerization of the manufacturing process and is characterized by the promotion of the innovativeness, invention, and innovation as well as the pervasion of usage of Artificial Intelligence (AI), Internet of Things (IoT), Big Data, new algorithms, sensors, controllers, wearable technologies and robots. This study tries to explain the unemployment rate change via Industry 4.0 basing upon two main theories, namely, Creative Destruction Theory and Sectoral Shifts Theory. Data used for this study are obtained from WEF, UNIDO and World Bank with a time range from 2003 to 2016. OECD countries with relatively high population rates, which rank at the top of NRI (Networked Readiness Index) such as Canada, France, Germany, Italy, Korea Republic, Poland, Spain, United Kingdom, and the United States are used to estimate unemployment and sectoral shifts and NRI proposed by World Economic Forum (WEF) is utilized as the technological advancement level. Empirical results show that Gross Capital Formation % of GDP, Manufacturing Value Added % of GDP and Networked Readiness Index (NRI) seem to have

a negative and statistically significant impact on Unemployment Rate, which means that in contrary to expectations, Industry 4.0 doesn't decrease the level of employment, rather it creates new job opportunities decreasing the level of unemployment.

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LIST OF ABBREVIATIONS

AI - Artificial Intelligence

EI - Emotional Intelligence

GDP - Gross Domestic Product

ICT - Information Communication Technologies

IMF - International Monetary Fund

IoT- Internet of Things

NEG - Job Destruction

NET - POS-NEG, net job creation-destruction

NRI - Networked Readiness Index

OECD - Organization For Economic Co-operation And Development

PLC - Programmable Logic Controllers

POS - Job Creation

SUM - Total Employee Reallocation

UNIDO - United Nations Industrial Development Organization

WEF - World Economic Forum

1. INTRODUCTION

Industry 4.0 is the name generally attributed to rapid technological advancement starting from the 2000s. The term Industry 4.0 is originally used for a high-technology project German government started up, which facilitated computerization of the manufacturing process. The term is, then, generalized and its meaning is broadened. Articles, researches and newspapers often refer to Industry 4.0 as the Fourth Industrial Revolution. The reason for using the term ‘Revolution’ is related to the high speed of technological advancement and rate of change of technology level. Another reason for calling this technological advancement a revolution is that scientists and researchers consider that there is a tremendous jump beginning with the late 1990s and early 2000s.

Industry 4.0 is characterized by the promotion of the innovativeness, invention, and innovation (Bergström and Venema, 2018), as well as the pervasion of usage of Artificial Intelligence (AI), Internet of Things (IoT), Big Data, new algorithms, sensors, controllers, wearable technologies and robots. Mass production, product differentiation, and customer satisfaction have become the center of firms following the changes in the technology levels. Changing communication facilities have changed the company structure and organizational hierarchy, too. The pervasion of computer usage has introduced opportunities to improve product design and production processes. Industry 4.0 is also identified with increased automation of the manufacturing process (Zhong, Xu, Klotz and Newman, 2017).

Industry 4.0 is assumed to create new jobs as well as destroy old ones. The Future of Jobs Report (2018) estimates that 0.98 million jobs to be destructed due to the transformation of the job market structure, but meanwhile 1.74 million additional jobs are expected to be created during this process. Jobs such as Application Developers, Software Specialists, Data Analysts, Social Media Experts, Customer Service Employees, Sales and Marketing Experts, Organizational Development Experts, Innovation Managers, Artificial Intelligence Specialists, Big Data Professionals, Data Security Specialists, Human-Machine Task Designers, Robotic Engineers, Blockchain Experts and Product and Process Automation

Professionals are occupations, which are expected to increase in future demand. Approximately 54% of employees will need to update their skills. Qualifications such as innovativeness; being open to learning; ability for analytical thinking; flexibility; computer programming; problem solving in complex environments, paying attention to details; having higher EI (Emotional Intelligence); having better social and communication skills, ability for technology and algorithm design are anticipated to be in higher demand in the near future.

According to World Economic Forum (WEF) (2018), some companies are assumed to survive whereas others are considered to be thrown out of the play during the Industry 4.0 process (WEF Report, 2018). In the survey done by World Economic Forum (2018), it is reported that 85% of all businesses opt for adopting new technologies such as Data Analysis, Data Mining and Big Data utilization (WEF, 2018). The adoption rate of new technologies by businesses and governments is anticipated to strengthen the competitive advantage of the institutions any kind. For example, distributed ledger technologies are going to be adopted by sectors such as Healthcare and Financial sector. On the other hand, some sectors and jobs are expected to reduce in demand or disappear totally: For example, Financial Service Management, Data Entry Specialists, Secretaries, tasks requiring physical strength as well as routine and manual jobs, Cashiers, Craft and Plant Workers, Stock Keeping Staff, and Accounting Clerks are some of the occupations which are anticipated to be replaced by machinery and algorithms. Employees working in industries such as Aircraft, Tourism, Financial Sector, Health, Biotechnology, and Chemistry will need to update their skill and know-how via further education and training (WEF, 2018).

The motivation for this research comes from the curiosity about how the Technology 4.0 Revolution will really affect the unemployment rate and sectoral shifts in countries such as Canada, France, Germany, Italy, Korea Republic, Poland, Spain, the United Kingdom, and the United States within the time range of 2003 and 2016. These nine countries are OECD economies, which are considered as in the top of Networked Readiness Index (advancement in Industry 4.0) and do have relatively high population numbers. And this study asks the following questions: Does Industry 4.0 affect sectoral shifts in sectors such as agriculture, industry, and services? Does Industry 4.0 affect sectoral shifts within the manufacturing sector? Do Manufacturing Value Added, Gross Capital Formation and Industry 4.0 have impact on unemployment rate? Do sectoral shifts have an impact on the unemployment rate? Do sectoral shifts in agriculture-industry-service sectors have a different effect on unemployment rate than those within manufacturing sector?

To estimate the possible answers to these questions, this investigation is based upon the theories of Creative Destruction and Sectoral Shifts. Creative Destruction Theory originates from Schumpeter's (1942) study and hypothesizes that jobs and products are created and destroyed during the technological advancement process. Sectoral Shifts Theory, on the other hand, grounds on Kuznets' (1973) and Lilien's (1982) studies. Sectoral Shifts Theory fundamentally explains that there are shifts between sectors due to different reasons, which then culminate into sectoral composition changes and a different labor market structure. In this context, Kuznets and Lilien have different point of views about how sectoral shifts occur. Kuznets (1973) assumes that sectoral shifts are employment shifts between agriculture, industry and services sectors whereas Lilien (1982) expresses sectoral shifts as the standard deviation of the growth rates in different sectors between two periods.

The rest of the thesis is organized as follows: 'Section 1' addresses a brief presentation of what Industry 4.0 is, what its outcomes will be as well as the 'question and motivation' of this research. 'Section 2' reveals the theories this study grounds on to support the findings. These theories are Creative Destruction and Structural Change Theories. 'Section 3' contains previous research related to opportunities and threats connected to Industry 4.0; changing skill requirements; emerging and disappearing occupations; the impact of investment, manufacturing value added and structural change on unemployment. 'Section 4' displays descriptive statistics and basic facts about unemployment and sectoral shifts. 'Section 5' focuses on the sources and characteristics of the data and regression models. 'Section 6' addresses the findings of this study. And 'Concluding Remarks' section reveals the conclusions to be inferred from the findings. Finally, APPENDIX A, APPENDIX B and APPENDIX C present, empirical test results; Networked Readiness Index explanation and calculation; sectoral coverage, respectively.

2. THEORETICAL BACKGROUND

Following the literature of Schumpeter (1942); Kuznets (1973); Lilien (1982); Syrquin (1988); Haltiwanger (1999); Davis and Haltiwanger (2009) and Abramowitz (1983) this thesis tries to understand how unemployment rate and sectoral shifts change via technological advancement. There are many factors possibly affecting the unemployment rate increase/decrease, however, recent researches try to relate unemployment rate to technological advancement. This thesis tries to explain the unemployment rate change via Industry 4.0 basing upon two main theories, namely, Creative Destruction Theory and Sectoral Shifts Theory. The main idea, which originates from Schumpeter (1942), is that as capitalization increases via new investments and companies get alarmed in order to survive the technological changes. Companies, which can keep up with the technological changes and make necessary renewals, obtain a competitive advantage in the market and survive the tough competition, however, companies, which cannot keep up with the technological differentiation, cannot hold on to the market and fail (Creative Destruction Theory). These ideas are also supported by Haltiwanger (1999); Davis and Haltiwanger (2009), who investigated job creation and job destruction leaning on the Creative Destruction Theory. The demand increases for capital and skilled labor related to job creation and destruction are assumed to lead to unemployment rate changes and sectoral shifts (Structural Change/Sectoral Shifts). There are mainly two different point of views to Structural Change or Sectoral Shifts Theory. Kuznets (1973) assumes that the Structural Change occurs due to the employment shifts from the agriculture sector to the manufacturing sector and from the manufacturing sector to the services sector, on the other hand, Lilien (1982) assumes that sectoral shifts occur due to the demand for certain labor skills.

Previous literature calculated structural change using different ways. For example, Lilien (1982) measured structural change using an index, which is then called by his name, the Lilien Index. Lilien (1982) relate changes in the labor force size to product demand and cost of input factors. He argues that workers leave Low-wage sectors and shift to higher-waged sectors, which results in a continuous and positive unemployment rate. Demand changes via wars, oil boycotts, and price differentiation lead to dramatic demand shifts and resulting labor market

shifts. According to him, there are two factors affecting the unemployment rate, one is the size of flows of the labor force and the second is the duration of the unemployment (Lilien, 1982).

Briefly stated, Creative Destruction (Schumpeter,1942) process creates pressure on employers who are willing to survive the increasing capitalization and incrementing demand for skilled labor. This process is assumed to lead employers to invest in new capital and hire skilled labor. This preference change is anticipated to create structural change in the labor market (Lilien, 1982). Demanded skill change and raising productivity via technological advancement are expected to shift employment from the agriculture sector to sectors with higher productivity such as industry and services.

2.1.The Concept of 'Creative Destruction'

The Austrian economist, J. Schumpeter (1942), who was born in 1883, added a new concept to the literature at his time. The concept is called Creative Destruction and is introduced in his study named '*Capitalism, Socialism, and Democracy*'. In his article written in 1942, Schumpeter defines this concept as follows (in his own words):

"*The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation–if I may use that biological term–that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism*." (Schumpeter, 1942, p 82-85)

Schumpeter (1942) states that Creative Destruction is a process through which the non-stationary capitalist system progresses, where new products and processes develop due to technological advancement and old ones are destroyed simultaneously since they are obsolete in terms of functionality, design or technological advancement level. He further suggests that capitalism can consume itself through its very creative process and classifies this process as the change in the production function through the creation of new technologies, new markets, and reorganization of the existing industries through the discovery of new raw material (Schumpeter, 1942).

Schumpeter (1942) argues that certain firms are going to survive the Creative Destruction process, whereas others are going to fail. What does the success of firms depend on during this Creative Destructive process? Tripsas (1997) argues that the success of incumbents and new entrants are dependent upon the balanced interconnection between three factors, namely, *investment behavior*, *technology level* and *complementary assets* possessed by already established firms. She suggests that established companies have concrete procedures, settled processes and an already known chain of command between employees. Therefore, they are sometimes unable to compete with radical technology changes, because they don't prefer to invest in radical technological advancements due to the rigidness of their investment behavior. This incapability to invest into new technologies is attributable to the '*investment behavior*'. When established firms don't invest in radically new technologies, they might fall behind the technological competence and their products and processes may obsolete. This is attributable to the '*technology-level*' incompetence. And *complementary assets* possessed by already established firms are products and know-how held by other firms, which may enable new entrants to create new products. For example, computers sold by certain companies may enable new software developers to develop extraordinary software, and incrementally advancing technology facilitates new products to be developed more easily (Tripsas, 1997).

Andersson, Braunerhjelm, and Thulin (2011) explain in their working paper that the entries and competition among the entrepreneurial class is the main driving force enhancing the Creative Destruction process. They exhibit that the productivity level of new-entry-firms is significantly higher than the old ones. Caballero (2008) tested the functionality of the Creative Destruction Theory and confirmed the existence of this concept in real life. He further argued that the impediments to this process can have crucial short-and-long-term negative outcomes.

Pissarides (2000) argues that there is a Reservation Productivity and companies choose to destroy jobs if the actual productivity of that job/task drops below this critical value. Assuming that the reason for a fall in the productivity can be due to an idiosyncratic or a general shock, Pissarides (2000) says that jobs, below this reservation productivity, are chosen to be destroyed by the firm and this causes the employees to be transferred to the unemployed labor force. He assumes that jobs have constant productivity before the shock, shocks are received by a Poisson rate σ and job creation is equal to the job destruction at steady state. At job creation, the firms have the full opportunity to maximize the profits. In the case of falling productivity, the firm can opt for continuing to produce until it can or for shutting down the business or the job. In his model of job creation and destruction, he tries to optimize this process (Pissarides, 2000).

Pagés, Pierre and Scarpetta (2009) attributed job creation and destruction to productivity and output growth. Haltiwanger (1999) defines **Job Creation** as the sum of new job opportunities created by start-ups (entrepreneurs) and the expansion of existing firms. And **Job Destruction**, according to him, refers to the lost employment through contractions and exits of firms. Following Schumpeter's Creative Destruction idea, Davis and Haltiwanger (2009) calculated the employment-level statistics of POS (job creation), NEG (job destruction), NET (POS-NEG, net job creation-destruction) and SUM (total employee reallocation). In their article, they revealed descriptive statistics of job creation, destruction, and reallocation.

This thesis employs Creative Destruction Theory to explain the results of the study and the impact of Industry 4.0 on unemployment.

2.2.Structural Change and Technology

Structural Change is defined differently by different researches. Kuznets (1973) defined Structural Change as the change in the share of the industry (Kuznets, 1973) and Lilien (1982) calculated sectoral employment considering different industries and regions utilizing an index, called by his name, the Lilien Index. Researches reveal a connection between structural change, technological advancements, and unemployment levels. For example, Dogruel,

Dogruel and Ozerkek (2018) utilized Lilien Index as a determinant for the unemployment level and assumed Lilien Index as an indicator for the level of regional adjustments to endogenous shocks. Betts (1994), on the other hand, argues that technological progress differentiates requirements for certain skills and this differentiation increases productivity and labor force inequality, where more skilled labor force shifts to more productive and innovating sectors.

As abovementioned, Structural Change might happen in various ways: Kuznets (1973) explains it as the labor shift from agriculture sector to manufacturing and from manufacturing to the services sector. Kuznets (1971) explains that economic growth can't occur without structural change via alteration in beliefs and in social institutions. However, Lilien (1982) explains Structural Change as the differentiation in the labor market composition. Lilien related it to demand and input factors, however, compositional features might also be related to age, gender, education, skill or experience. Lilien (1982) suggests that an important percent of 'cyclical unemployment' is attributable to 'frictions' (frictional unemployment), where friction here refers to mismatches between availability time of the job and the search-time of the worker for a job.

Hoskins (2000) attributes the shifting tendency of educational attainments and skill obtainment to biased technological progress. He argues that skill requirements have changed over the last four decades, where there is a dislocation from manual tasks to non-manual tasks. And workers who accomplish manual jobs and non-manual jobs have different skill levels.

According to M. Syrquin (1988), structure indicates the composition of the total of something and is generally used in economics to explain the relative significance of sectors considering the factor use and production. The 'Structure' also indicates some ratios related to employee behavior and technological change (Syrquin, 1988). To Syrquin, structural change mostly happens due to the process of industrialization. Syrquin (1988) further argues that structural change in the final consumption occurs when demand for food consumption (agricultural products) decreases and demand for industrial goods increases.

Abramowitz (1983) proposes that structural change happens via a change in employment and production. According to him, reallocation of human capital and physical capital serves to a better match of resources to the needs and more efficient utilization of them. To him, this consequently increases productivity and economic growth. In the process of industrialization, the combination of manufacturing goods highly differentiates according to the endowments of the country and the technological advancement level of it.

Chenery (1986a) explains Structural Change slightly different. Structural change, as mentioned by Chenery (1986a), occurs in final-and-intermediate demand, trade, employment, and production. He suggests that in developing countries the use of intermediate goods relative to final goods rises while the composition of the intermediate goods differentiates.

In this research, Lilien Index for three sectors is discriminated from the Lilien Index for the Manufacturing sector in order to show the effect of the Manufacturing sector in separation with three-sector Lilien Index. Bahrin, Othman, Nor, Nor and Talib (2016) argue that **‘***robotics and automation technology is the basis of industrial manufacturing and an important driver for Industry 4.0***’.** Thus, manufacturing is assumed to be connected to Industry 4.0. Additionally, as manufacturing sector is considered to be more related to Industry 4.0 then agriculture-industry-services sectors, this thesis employs the Three-Sector Lilien Index and Manufacturing Lilien Index separately.

3. LITERATURE REVIEW

Industry 4.0 is considered to change the organizational structure, create new jobs and new products, and destroy existing ones. The ongoing process of innovations of new products, services and processes also lead to a destruction of dysfunctional and out-of-date products and firms (Schumpeter, 1942). Firms are highly directed to be innovative and open to new progress.

Innovation creates new facilities and opportunities, however, old products are dismissed and replaced by new ones. Previous literature has examined the concept of creative destruction empirically and tried to test the consistency of this concept with reality. For example, Brandt, Van Biesebroeck and Zhang (2009) investigated the Chinese manufacturing sector and found evidence that the Chinese economy outscored other world economies with a very high output growth (approximately 8%). They showed that during this process of economic and technological growth, besides the new entrants into the market, there are many companies exiting the industries by facing a substantial productivity decline. This meant that while the economy and output grow, existing job opportunities are destroyed simultaneously to the creation of new jobs. They also indicated that there was a tremendous shift from agriculture-dependent economy to the non-agriculture-dependent economy between the 1980s and 2000s. This has been seen as a by-product of industrialization and technological progress (Brandt, Van Biesebroeck and Zhang, 2009)

Aghion and P. Howitt (1989) developed an endogenous growth model based on the idea of Schumpeter's creative destruction, where technological advancement is the driving force, which is fostered by research and development activities, competition as well as innovations. According to Aghion and Howitt (1989), there are fundamentally two sources of economic growth, namely the innovations and the know-how accumulation via learning-by-doing. They showed that economic growth can be generated through technological advancement and innovative competition.

Additionally, Hart and Milstein (1999) argue that destruction of old products and new combinations of outputs are inevitable to counterbalance the emerging needs in the developing markets and global sustainability is catalyzed through the creative destruction process. A concrete example of creative destruction is realizing in the healthcare industry, where digital technologies and genetic improvements drive individualized medical care (J. A. Kim, 2013). In this context, technological progress leads to the obsolescence of collective medical health care and fosters customized treatments.

Frey and Osborne (2013) suggest that 47% of the 702 jobs in the USA under consideration is in jeopardy of being destroyed in the following 10-15 years. This indicates the importance of the acquisition of new skills and knowledge as well as training. On the other hand, World Bank (2013) reports that 600 million new jobs have to be created until 2030-3035 and that most of the jobs have to be established in Sub-Sahara and Asia (The World Development Report 2013). Half a billion in China and India and 11 million workers in Africa are anticipated to enter the labor force in the next 15 years (Jieun Choi, World Bank, 2017).

Mentioning the Fourth Industrial Revolution also implies that there have been three previous revolutions. Brettel et all. (2014) define the three former industrial revolutions as follows:

First Industrial Revolution is the introduction of manufacturing items working with steam-power at the end of the 18^{th} century in Britain. Thomas Savery proposed the first machine, the steam pump, in 1698, which used steam-power to throw the water out of a mine. Years from 1750 to 1850 are characterized by heightened industrial activity, especially in the textile industry. People started to use coal in the construction of houses, to operate big machines such as ships and to manage heating and cooking (Brettel et al., 2014). Britain had great coal deposits at that time and the government supported commercially productive projects. In addition to these, government intervention was limited and the literacy rate was relatively high. All these reasons are argued to cause the First Industrial Revolution to start in Great Britain (Thomas Savery,1698).

The Second Industrial Revolution occurred between 1870 – 1914. Mokyr (1998) argues that in this era the scientific inventions have translated into manufacturing relatively more than in other eras and that the inventions of Thomas Edison (1847 – 1931) and Felix Hoffman (1868 – 946) had contributed to the development process a great deal. Just to remind, Edison has invented the light bulb, and F. Hoffman has discovered the famous medicine Aspirin (Mokyr, 1998).

The Third Industrial Revolution, between 1969 – 2000, was rather related to computers and the internet. Brettel et al. (2014) suggest that the main invention corresponding to this era is the Programmable Logic Controllers (PLC), which are used to automate the manufacturing processes.

And lastly, there is the Fourth Industrial Revolution, Industry 4.0 or Technology 4.0. Schmidt et. al. (2015) argue that the Fourth Industrial Revolution is identified by the digital and smart products as well as the pervasion of the IoT (Internet of Things) and Artificial Intelligence. Schmidt et. al. (2015) define the Industrial Revolutions as follows:

i. **First Industrial Revolution:** Is characterized by the pervasion of the usage of the mechanical energy simultaneous with the control systems, which resulted in a massive production increase in the textile industry. Steam power is started to be used to operate certain machines.

ii. **Second Industrial Revolution:** Is characterized by the substitution of steam via electricity following the invention of the electric bulb.

iii. **Third Industrial Revolution:** Is characterized by the employment of electronic devices for mass production. The pervasion of internet usage had a substantial impact in this era.

iv. **Fourth Industrial Revolution:** Is characterized by the employment of IoT (Internet of Things), AI (Artificial Intelligence), the digital and smart products

Schmidt et. al. (2015) explain that smart products facilitate calculations, data storage, communication and interaction between human and environment (Schmidt et. al., 2015). To shortly define, Smart Products interchange information between the environment and the person using it. Sensors are capable to acquire data from the environment and store them. The collected data is so big that it necessitates large storage devices and databases. They summarize the changes via Industry 4.0 as below:

i. Production time gets shorter

ii. Business processes are improved

iii. Automation level increases

iv. Mass customization affects Industry 4.0 in a positive manner

v. Idle data is created via Mobile Computing, Cyber-Physical Systems, Cloud-Computing and Internet of Things

vi. Use of technology such as Mobile Computing, Cyber-Physical Systems, Cloud-Computing and Internet of Things enhances the Fourth Industrial Revolution (Schmidt et. all, 2015)

In the Fourth Industrial Revolution, the internet is utilized as a powerful means to control wastes and delays, which happen occasionally in the production process and obtain feedbacks throughout the production time. The process of manufacturing is becoming more flexible, modularized and cheaper, products are becoming more complex, easier to use and highly differentiated due to the Fourth Revolution. The main concepts of Industry 4.0 are modularization, flexibility, complexity, differentiation, and easiness. Modularization encompasses the division of the production process into many subsystems with low interdependencies to economize the resources and to cope with the increasing complexity (Schmidt et. al., 2015).

The Future of Jobs Report (2018) published by World Economic Forum reports that 23%-37% of all businesses tend to opt for investing in highly advanced technologies depending upon the type of the industry. According to this report, approximately 50% of the firms are expected to reduce their full-time labor force due to automation until 2022. Over 25% of the firms anticipate the creation of new jobs in their enterprises. In addition, most of the companies are planning to employ their labor force with more flexible working conditions, reducing office-oriented working environment and increasing decentralization level (The Future of Jobs Report, 2018). In 2018, approximately 71% of total works done are completed by humans and 29% of the total tasks done are completed by machines. However, this ratio is expected to change until 2022 in such a way that only a 58% of the task will be performed by humans and 42% of the task will be performed by machinery and robots. Even the tasks dominated by humans such as communication, coordination, decision making, development, interaction, reasoning, and management are expected to be completed by robots and machines in the near future (The Future of Jobs Report, 2018).

The pervasion of computer use has introduced opportunities to improve product design and process. Goldhar and Jelinek (1983), Adler (1988), Dean and Susman (1989) told that organizational structure and business strategies have to change during the increase in automation. This new manufacturing system is composed of: Computer-Supported Manufacturing, Computer-Supported Design, Automated Storage; Control; Re-Reorganization systems (Parthasarthy and Sethi, 1992). As a result of the transformation of the manufacturing system, a necessity of the re-design of the business structure and strategy has emerged. Plants have gained new features along with technological advancements. Below is a comparison between the features of the old-version and the new-version of fabrics:

Table 1. Features of Old and New Plants. How Were Plants before, How Will They Be after Industry 4.0 Revolution.

Features of the Old Plant	Features of the New Plant
Predetermined equipment	Flexible and computer-added equipment
Massive inventories	Lesser inventories
Price related to the amount of output	All operators are paid by the same rate
Keeping production line whatever happens	Machines will stop the line if not properly working
Strict investigation of product quality	Operators will be responsible for the level of quality
In-house produced raw material	Raw materials will be outsourced
Narrowly defined task functions	Tasks are more flexible
Fields are divided according to machine type	Fields are divided by working cells
Decisions are made by salaried workers	Any worker can contribute with ideas
Groups work according to their functions	Compatible work of groups
Vertical communication	Horizontal communication
More stages of directorial levels	Lesser directorial stages

Source: Brynjolfsson and Hitt (2000), '*Beyond computation: Information technology, organizational transformation and business performance*'

Opportunities and Threats of Industry 4.0 Revolution

Technological advancement has certain benefits and pitfalls: Companies are enjoying high productivity and production levels, and industries are in a heightened investment mood in the technological progress environment. Manufacturing industry skims this hyper investment framework (Bergström and Venema, 2018). Bergström and Venema (2018) argue that product/process invention and innovation as an important feature in the Fourth Industrial Revolution. According to them, the *invention* is defined as the discovery of an idea, and *innovation* is the application of this idea in a practical way. Fagerberg et al., (2012) comment on product innovation as having three levels: Firstly, the composition of the product can be altered so that the function is changed, this is *Product Innovation* (Arthur, 2007). Secondly, activities can be reconfigured and this is called the *Process Innovation* (Klepper, 1996). And finally, the systematic of the business activities can be differentiated which is called the *Business Model Innovation* (Santos et al., 2009).

Industry 4.0 is characterized by the promotion of innovativeness, invention, and innovation (Bergström and Venema, 2018). This is one of the opportunities of Technology 4.0 when we consider that new job vacancies open and new jobs are created. GeisBauer et. al. (2014) argue that the internet is altering the company structure completely. According to them, companies in Euro-zone will invest in industrial internet approximately $140 yearly and, until 2019-2020, 80% of all companies are anticipated to digitize most of their value chain. They suggest that horizontal expansion is better able to satisfy customer needs and demands, where horizontal growth is an important feature of Technology 4.0 (GeisBauer et. al., 2014). They suggest that industrial internet contributes to the increase in productivity and efficiency.

In this way, the manufacturing sector is capable to produce more output with fewer inputs. Redundancies, errors, and delays are eliminated via self-control mechanisms during the production process. Flexibility in production is becoming more achievable and more important. Data acquisition, storage, and interpretation are believed to become subject to prior interest because information received from sensors and internet is getting larger each second. Digitization is observed to raise the revenues substantially (GeisBauer et. al., 2014), which contribute to profit-maximization and company growth.

Smart machines, wearable technologies, product differentiation, customer satisfaction, mass and quick production, and ease of use of goods are some advantages consumers will benefit from. Customer satisfaction is increasingly becoming the ultimate goal of the firms. Countries with high technology level are anticipated to export their value-added and technology-weighted products and take advantage of cheap and abundant production. They will enjoy a higher comparative advantage in the worldwide markets (Heckscher, 1919-Ohlin, 1933). To broaden their markets globally and increase of value-added products as a percentage of GDP are some of the biggest economic opportunities for technology-leading countries.

Kagermann et al. (2016) argue that productivity increment will facilitate countries' global competitiveness. Self-organizing and self-optimizing plants will reduce mistakes, wastes, and delays, and thus enable cheaper and smoother production. New business structures and internet platforms are expected to emerge due to this Industry Revolution. Because the new global system requires modularization and distribution of tasks as well as specialization of labor, companies will expand horizontally.

Government policies have already begun to support innovation and technological advancement, which in turn will lead to an increased number of innovations, start-ups, scientific research, and a heightened business environment. Accelerated business environment means increased employment, differentiated and new products. Small and Medium Sized Enterprises (SMEs) opt for entering the market more easily and there is a big potential for them to transform into Multinational Organizations. Consecutively, new start-up environments and digital platforms will develop. Cost benefits, government incentives and economies of scale accelerate innovative activities and economic growth processes even more (Kagermann et al., 2016).

On the other hand, there are also threats and disadvantages to developing technology levels. Industry 4.0 might create advantageous and disadvantageous parties by changing the labor market structure or by leading to an increase in the unemployment level as Dogruel, Dogruel, and Ozerkek (2018) argued in their research. So, the change in labor market structure and the potential unemployment increase due to the Industrial Revolution might lead to difficulties for some occupations, which don't get automated and for countries, which remain backward in the Industry 4.0 competition.

According to World Bank (2018) reports a list of occupations, which are going to be automated with a high probability and which are most probably going to expire in terms of automation.

Table 2. Likelihood of Computarization of Certain Jobs

Probability of Automation/Computarization in Certain Occupations [1]	
Most Likely Occupations	***Probability of Computarization***
Telemarketer	99,0%
Title Examiner, Summarizer and Researcher	99,0%
Sewers	99,0%
Insurance Underwriter	98,9%
Mathematical Specialist	98,9%
Watch Repairer	98,8%
Freight and Cargo Agent	98,7%
Tax Preparative	98,7%
Photographic Process Employee and Processing Machine Operator	98,7%
Accounts Clerk	98,7%
Library Technical	98,6%

[1] Source: OECD Social, Employment and Migration Working Papers No: 193

Data Entry Specialist	98,5%
Timing Equipment Adjusters	98,5%
Least Likely Occupations	***Probability of Computarization***
Recreational Therapist	0,3%
Supervisor of Machine Repairers and Installers (First Stage supervisors)	0,3%
Emergency Management Executive	0,3%
Substance Use and Mental Health Social Employee	0,3%
Audiologist	0,3%
Vocational Therapist	0,3%
Prosthetist and Orthotist	0,4%
Healthcare Social Employee	0,4%
Some Surgeons	0,4%
Supervisors of Fireman (First stage supervisor)	0,4%
Nutritionists and Dietitians	0,4%
Lodging Director	0,4%
Choreographer	0,4%

Source: Berger and Frey (OECD Report, 2016)

4. BASIC FACTS ABOUT UNEMPLOYMENT AND SECTORAL SHIFTS

This section addresses the basic facts about the analysis of the unemployment rate and sectoral shifts. There are two sub-sections, the first one explains ‘Unemployment Rate’ and the second one reveals basic facts about ‘Sectoral Shifts’. There is a substantial literature attempting to explain the relationships of unemployment and several variables such as technology, investment, manufacturing value added and sectoral shifts. Below are descriptive statistics regarding these relationships employing OECD, UNIDO, World Bank and World

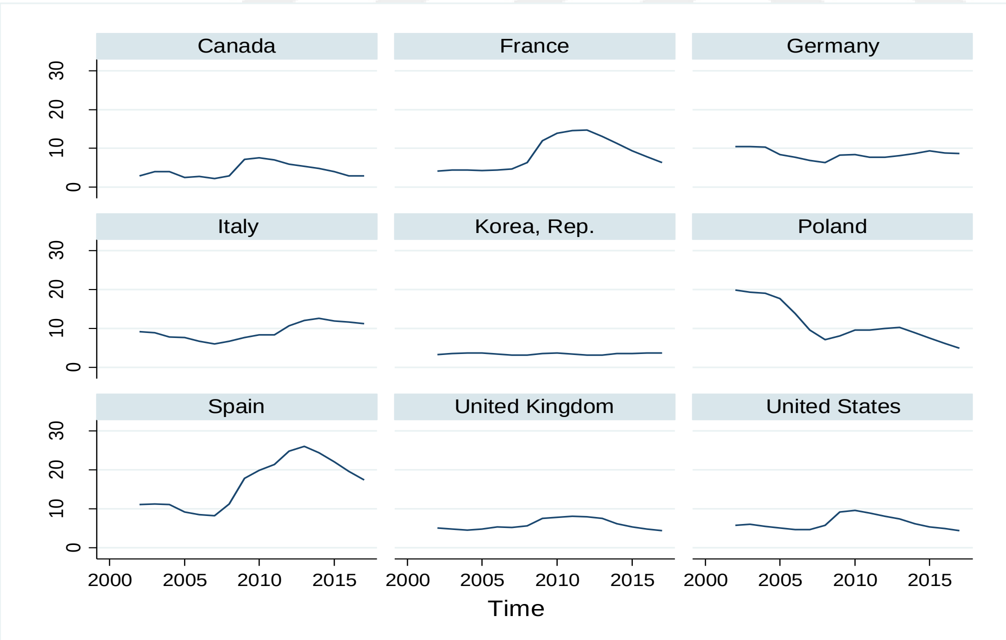
Economic Forum data. Countries considered in this research are Canada, France, Germany, Italy, Korea Republic, Poland, Spain, United Kingdom, and the United States. These countries are OECD economies, which appear at the top of the NRI Rank and which are considered as large countries when the population is regarded. The graphics presented below belong to the variables used in the empirical analysis. There are multi-country graphics revealing each variable between 2003 and 2016 and there are two-variable relationship graphs.

4.1.Unemployment Rate

This section provides some descriptive evidence about unemployment and related variables using nine OECD countries between the time range of 2003 and 2016. There are also relationship-graphs, which reveal connections between unemployment-technology, unemployment-productivity, unemployment-investment, and unemployment-sectoral shifts, considering the years 2003-2016. Relationship-graphs visualize following connections: Unemployment Rate and NRI; Unemployment Rate and Manufacturing (%GDP) Value Added; Unemployment Rate and Lilien Index of Manufacturing sector; Unemployment Rate and Investment.

Figure 1. illustrates the evolutions of Unemployment Rates in 9 relatively highly populated OECD countries between 2003 and 2016. It is observed that Germany, Korea Republic, United Kingdom, and Italy exhibit a relatively non-fluctuating unemployment rate whereas France, Canada, Spain, USA, and Poland reveal fluctuations, especially in the 2008-2009 Global Financial Crisis. Poland shows a steady downward trend whereas Spain and France experience an upward trend after the Global Crisis of 2008 with a consequent decline. Almost all countries seem to have been influenced by the 2008 Global Crisis. Canada, Germany, Korea Republic, United Kingdom, and the United States reveal mostly an unemployment rate below or equal to 10%, whereas France, Italy, Poland, and Spain sometimes increase over 10% in terms of the unemployment rate. Countries experiencing high fluctuations such as Spain and Poland are also backward in terms of NRI (Industry 4.0 readiness).

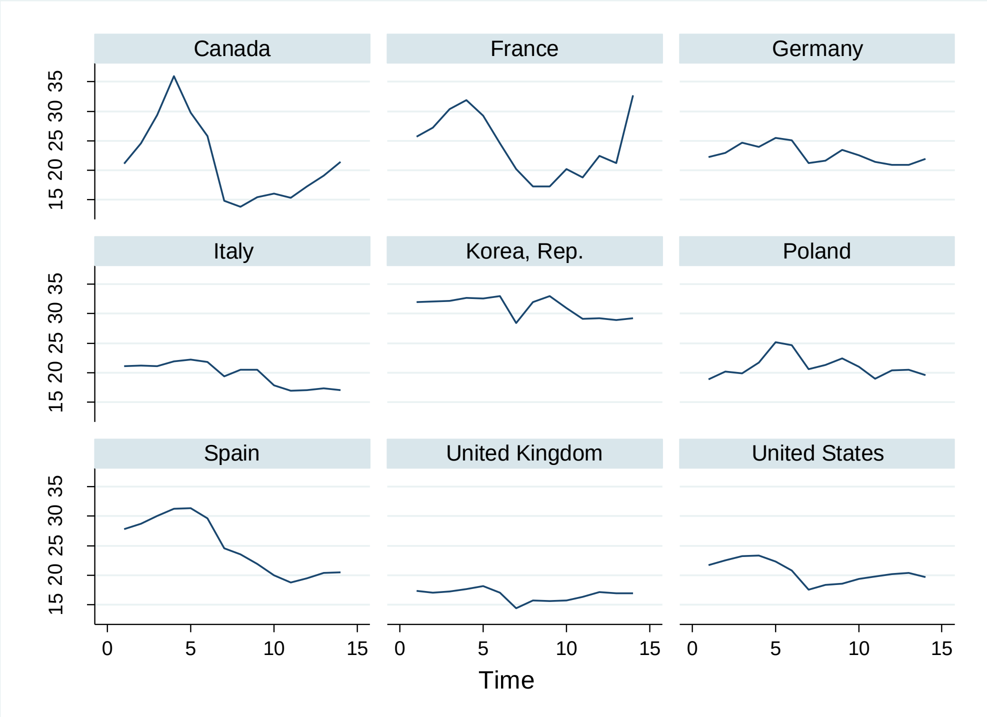
Figure 1. Unemployment Rate-of nine OECD countries between 2003 and 2016



Source. World Bank Database, 2003-2016

Figure 2. reveals Gross Capital Formation (% of GDP) of nine OECD countries between 2003 and 2016. It is observed that Canada, Spain, and France experience a sharp decline in the 2008 Global Crisis in terms of investments. On the other hand, Canada and France recover between 2010-2016 time span but Spain seems to experience a steady decline without recovery. United Kingdom, Germany, and the Korea Republic keep their relatively stable positions between these years but Korea reveals a small decline in the 2008 Crisis. Canada, Spain, and France exhibit the most fluctuations. The United States also show a decline in the 2008 Global Crisis. Canada, Spain, and France reveal Gross Capital Formation levels between 15%-35%. Germany, Italy, and Poland are between the range of 10% and 25%. The United Kingdom has mostly a Gross Capital Formation level of 15%-20%, which keeps the lowest level among all countries. Why are the investment levels of Canada and France this much affected by 2008 Crisis? Government of Canada reports in its official website that Canada has experienced a real GDP contraction by 2.6% in the 2008 Global Crisis and went into a severe recession (Canada.gov, *Canada's State of Trade: Trade and Investment Update*, 2010). France felt the serious impacts of the Global Crisis in 2008 as well and accepted an EU program to stabilize the country's economic state (EU Report, 2008). So, both countries are deeply affected by the Crisis and made provisions against the adverse effects.

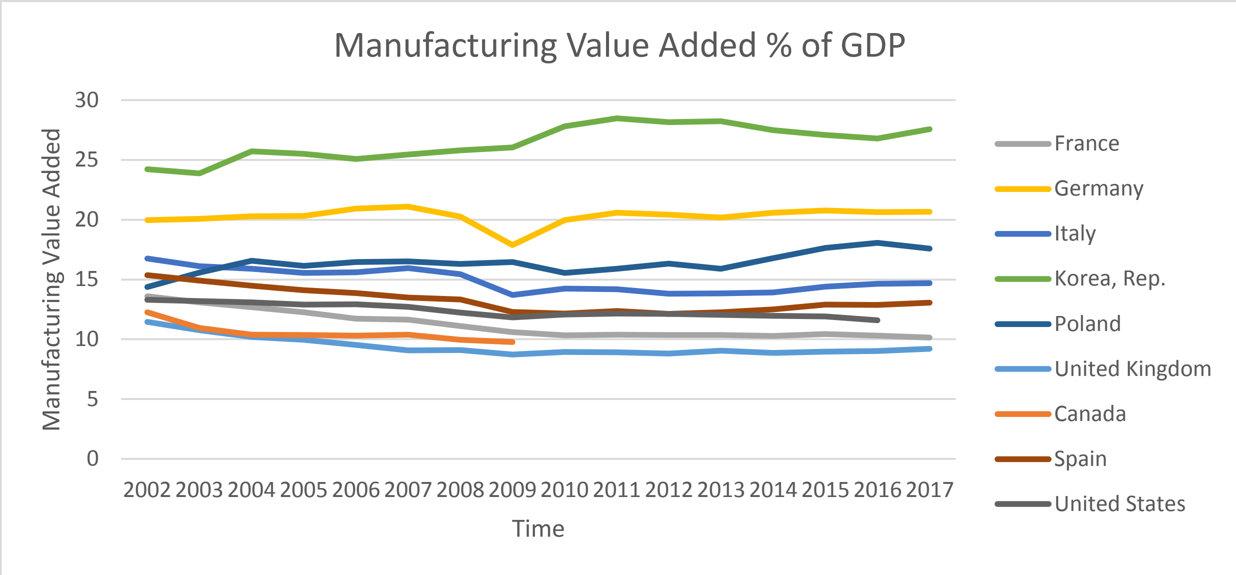
Figure 2. Gross Capital Formation (% of GDP) in nine OECD countries between 2003 and 2016.



Source. World Bank Database, 2003-2016

Figure 3. indicates the evolution of Manufacturing Value Added (% of GDP) of nine OECD countries between 2003 and 2016. According to the graphical representations, Korea Republic, Germany and Poland exhibit relatively higher values of Manufacturing Value Added (% of GDP). This means that Korea, Germany, and Poland gain a higher share of their national income from Manufacturing Value Added. All countries seem to have relatively stable Manufacturing Value Added shares between 2003 and 2016. Only Germany has experienced a small decline in the 2008 Global Crisis.

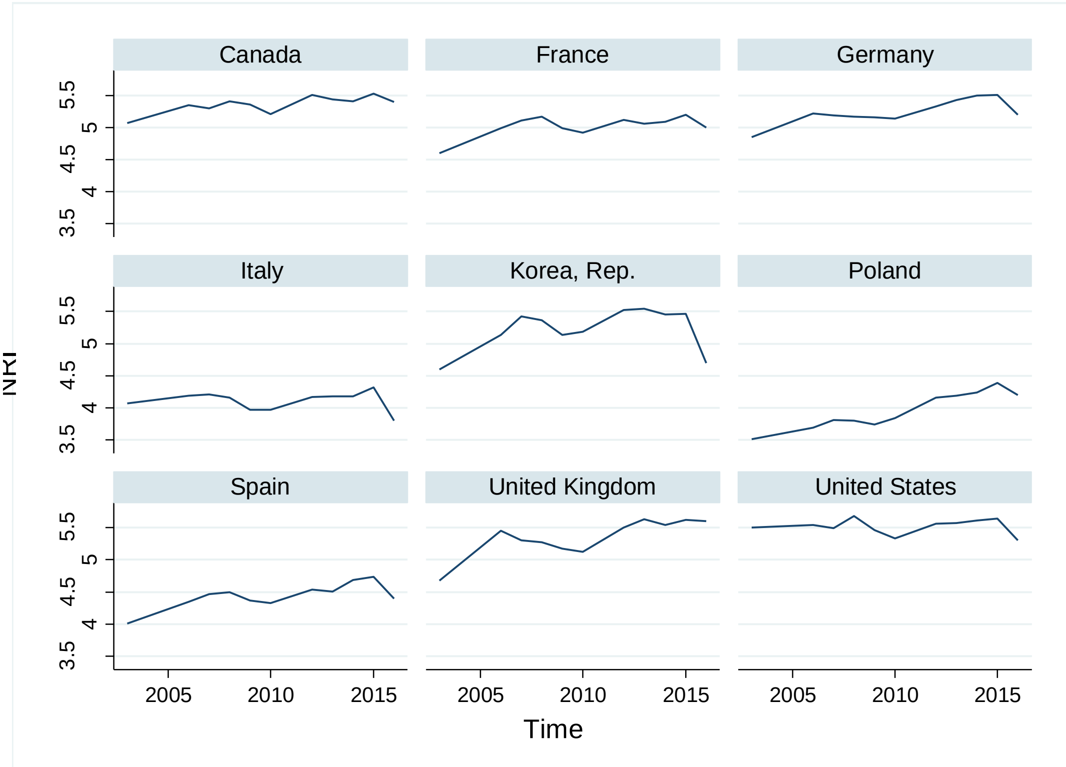
Figure 3. Manufacturing Value Added (% of GDP) of nine OECD countries between 2003 and 2016.



Source. World Bank Database, 2002-2017

Figure 4. exhibits NRI values of 9 countries between 2003 and 2016. Networked Readiness Index (NRI) is an index prepared by the World Economic Forum (2002-2016) and represents the readiness for the Industry 4.0 as well the advancement level in terms of technology. Considering countries on an individual basis reveal that Canada, France, Germany, Korea, the United Kingdom, and the United States exhibit high NRI values whereas Spain and Poland seem to be more backward in the Industry 4.0 competition. All countries experience a slight decrease in terms of NRI values. The Korea Republic seems to be the one, which experienced the most fluctuations with a decline both in the 2008 Global Crisis and after 2015. The United Kingdom and Poland seem to experience a steady increment between 2003 and 2016 with continuous improvement in technological advancement levels. Korea Republic and United Kingdom seem to experience a downturn in terms of NRI during the 2008 Global Crisis but then they collect together. Korea Republic experienced a decline in the Environment Component and Usage Component in NRI during 2008 Crisis. And United Kingdom fall down in terms of Readiness Component in the NRI during that Crisis.

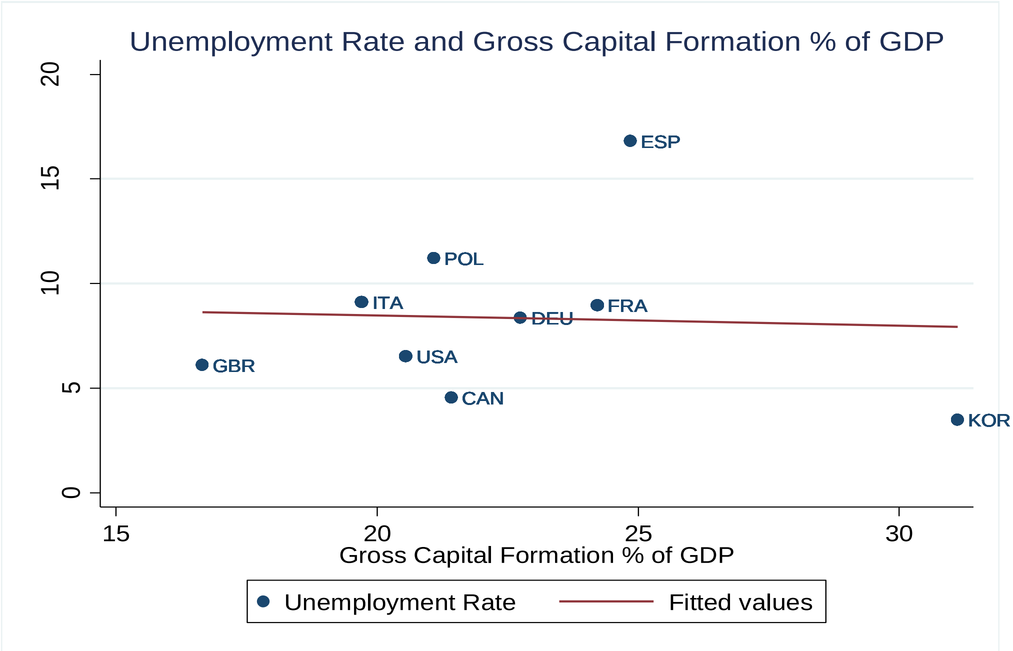
Figure 4. Networked Readiness Index (NRI) for nine OECD countries between 2003 and 2016



Source. World Economic Forum Reports (2003-2011)

Up to this point, each variable, which is assumed to have an impact on unemployment, is depicted graphically for the time range of 2003 and 2016. Now, the relationships of Unemployment and the relevant variables are going to be considered. Thus, **Figure 5.** reveals the relationship between Unemployment Rate and Gross Capital Formation % of GDP in nine OECD countries. According to the graph, it is inferable that there is a slightly negative connection between Unemployment Rate and Gross Capital Formation, which means that an increase in the capitalization level leads to a slight decrease in the unemployment level.

Figure 5. Unemployment Rate and Gross Capital Formation (% of GDP) of nine OECD countries between 2003-2016

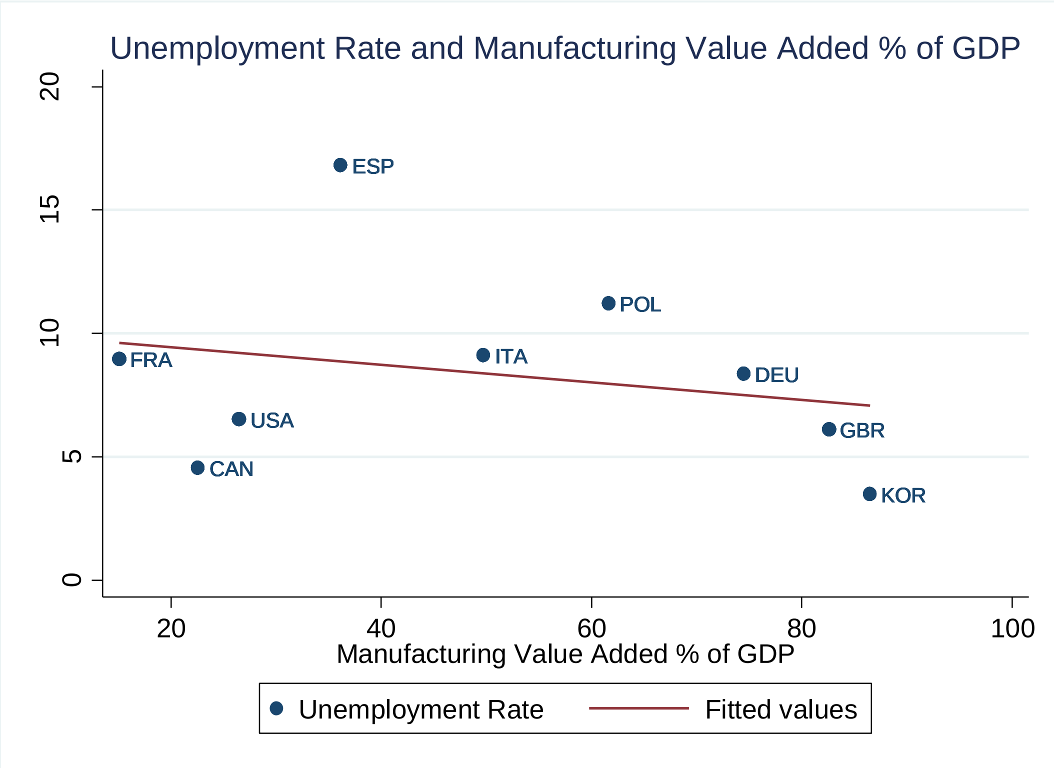


Source. World Bank Database, 2003-2016

Figure 6. Unemployment Rate and Gross Capital Formation % of GDP relationship in nine OECD countries for the time range of 2003-2016.

This thesis considers also Manufacturing Value Added (Share of GDP) as one of the expected influencers of the unemployment rate and **Figure 6.** reveals the relationship between the two. It is observed that the unemployment rate is slightly negatively related to the share of manufacturing in GDP in the nine OECD countries between 2003-2016.

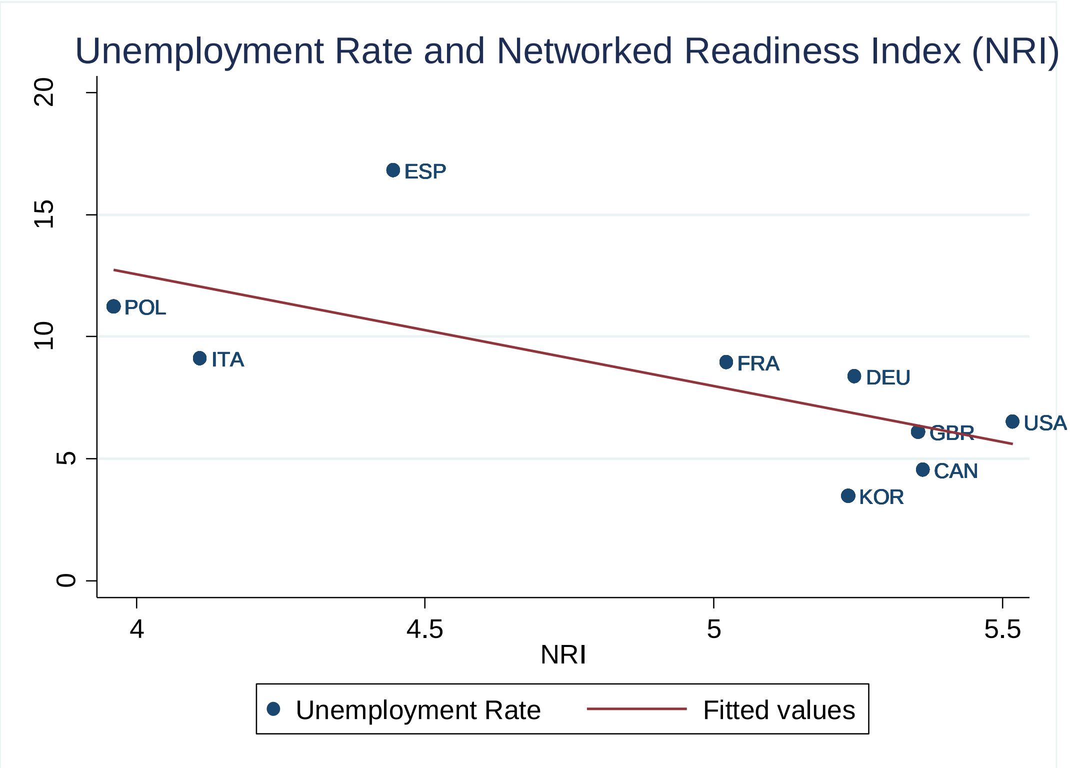
Figure 7. Unemployment Rate and Manufacturing Value Added (as a share of GDP) in nine OECD countries between 2003-2016.



Source. World Bank Database, nine OECD countries, 2003-2016

This thesis employs NRI as an indicator of technology level and Industry 4.0 readiness. **Figure 7.** shows the relationship between NRI and Unemployment Rate between 2003-2016. The graphical illustration reveals a negative relationship between Unemployment Rate and NRI. It is inferable that an increase in the technology level leads to a decline in the unemployment rate. The graphic illustrates that the countries are grouped into two separate clusters. Spain, Poland and Italy are countries more backward in terms of Industry 4.0 readiness, whereas France, Germany, United States, United Kingdom, Canada, and the Korea Republic are more forwards.

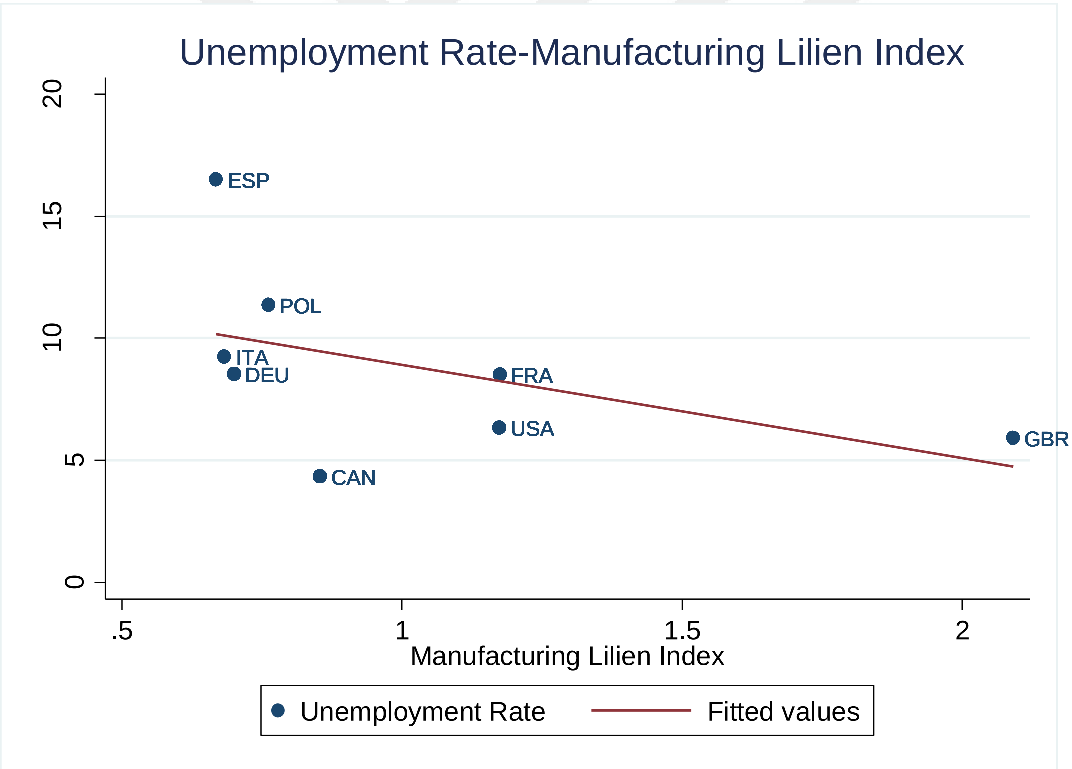
Figure 8. Unemployment Rate and NRI relationship in nine OECD countries between 2003-2016



Source. World Bank Database and World Economic Forum (WEF) Reports (2003-2016)

When we look closer to the relationship between the unemployment rate and Manufacturing Lilien Index, there seems to be a negative connection between the two. **Figure 8.** reveals unemployment rate and Lilien Index relationship, where Lilien Index indicates sectoral shifts in the manufacturing sector in 8 countries between 2003 and 2016. Bahrin, Othman, H. Nor, A. Nor and Talib (2016) argue that '*robotics and automation technology is the basis of industrial manufacturing and an important driver for Industry 4.0*'. Thus, manufacturing is assumed to be connected to Industry 4.0 and technology level. Unemployment Rate seems to have a negative connection to sectoral shifts in Manufacturing in Canada, France, Italy, Poland, Spain, the United Kingdom, and the United States as the negative connection to NRI. This means that an increase in sectoral shifts within the manufacturing sector affects Unemployment level negatively. United Kingdom seems to be experiencing a high degree of sectoral shifts within the manufacturing sector, which is also confirmed by the research made by Robson (2007). According to Robson (2007), UK is going under a substantial sectoral and structural change.

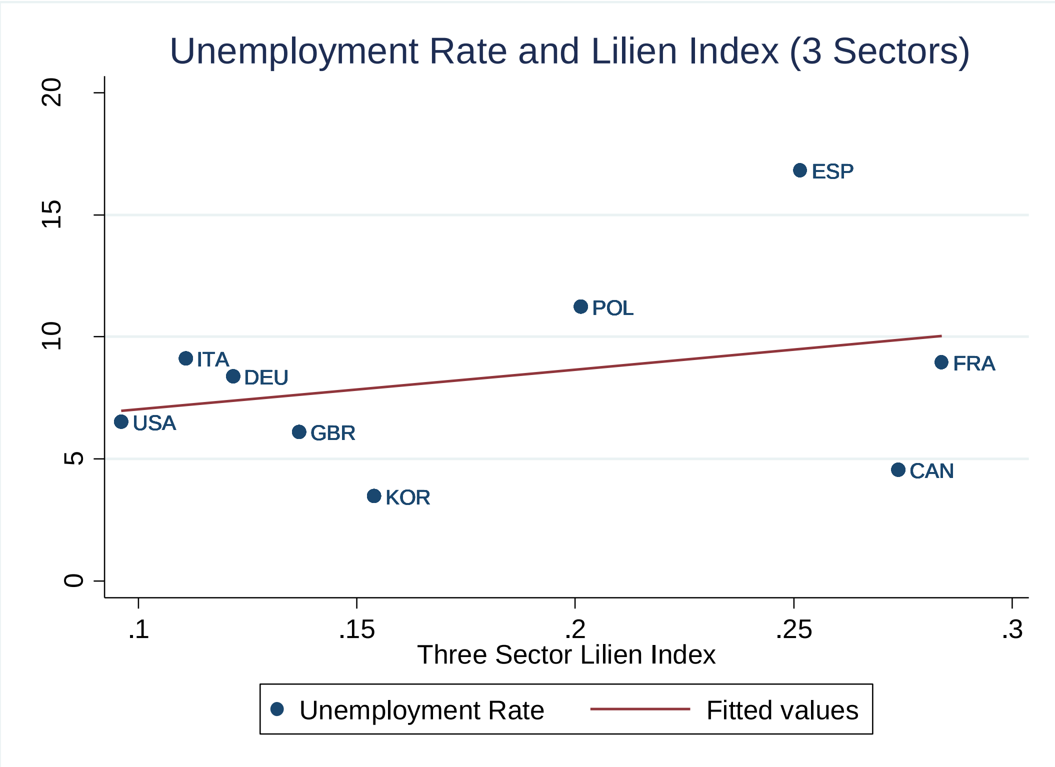
Figure 9. Unemployment Rate and Lilien Index indicating sectoral shifts in Manufacturing sector of 8 countries between 2003-2016



Source. UNIDO 2003-2016 and World Bank Database 2003-2016

Figure 9. reveals the unemployment rate and Three-sectors Lilien Index (agriculture, industry, and services) relationship between 2003 and 2016. The graphical illustration exhibits a positive relationship between the two. This means that sectoral shifts among Agriculture, industry, and services are observed to increase the unemployment rate.

Figure 10. Unemployment Rate and Three-sectors Lilien Index (Agriculture, Industry and Services) between 2003 and 2016.



Source. World Bank Database, 2003-2016 and author's own calculation

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4.2.Lilien Index, Measure of Structural Change

Lilien Index is an often-used tool to calculate the structural change in many areas of economic studies. Components influencing structural unemployment and the formation of employment can be estimated via this methodology. This index originates from the research of Lilien in 1982. Lilien (1982) proposed the index which formulates the standard deviation of the growth rates multiplied by the share of the industry in different sectors between two periods. Lilien index provides the standard deviation of the growth in a sector relative to that of the overall employment. It is remarkable that Lilien (1982) names the sectoral labor reallocation 'Sectoral Shifts', whereas Ansari et. al. (2013) names the reallocation as 'Structural Change', where the same concept is considered from a different point of view. Ansari, Mussida, and Pastore (2014) argue that the variance of the employment level in a sector gives a clue about the change in the demand structure.

McMillan and Rodrik (2012) propose that structural change generally contributes to growth in productivity and an increase in the income level because structural change helps dysfunctional jobs to be eliminated and productive ones to be promoted. The resources in the economy naturally shift from unproductive sectors to productive ones in this way. However, in economies with a relatively large share of raw material in the exports, the structural change generally decrements growth, devaluates exchange rate. According to them, a flexible labor market structure contributes to the increase in economic growth during the structural change process. Lilien (1982) comments on the relationship between unemployment and sectoral reallocation as follows:

'*A substantial fraction of cyclical unemployment is better characterized as fluctuations of the "frictional" or "natural" rate than as deviations from some relatively stable natural rate. Shifts of employment demand between sectors of the economy necessitate continuous labor reallocation. Since it takes time for workers to find new jobs, some unemployment is unavoidable*.' (Lilien, 1982, p. 777)

The formula for Lilien Index (σ) is expressed as follows:

$$\sigma = \left| \sum_{i=1}^{I} \frac{x_{it}}{X_i} (\Delta \log x_{it} - \Delta \log X_t)^2 \right|^{\frac{1}{2}} \qquad [2]$$

Where,

$\frac{x_{it}}{X_i}$ = share of sector i in the local employment at time t

$x_{i,r,t}$ = employment level in sector i, in local area r and at time t

$X_{r,t}$ = overall employment level in local area r and at time t

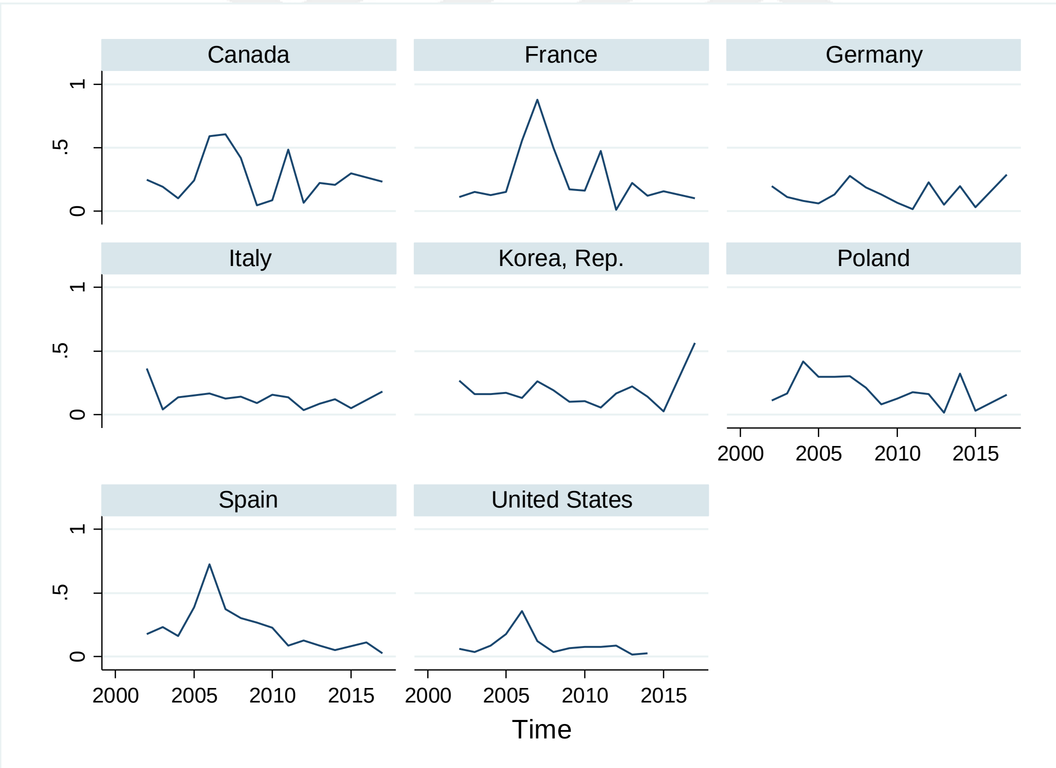
Δ log x_{it} = log($x_{i,r,t}$) - log($x_{i,r,t-1}$) growth of employment in sector i, local area r and at time t

Δ log X_t = log($X_{r,t}$) - log($X_{r,t-1}$) growth in the overall employment level in local area r and at time t (Lilien, 1982).

Sectoral changes are assumed to be affected by the technological advancement levels. This thesis tries to assess sectoral shifts via technological advancement level by employing NRI to foresee Lilien Index. Lilien Index is assumed to reflect dispersion in sectoral employment growth. There are two different Lilien Indexes employed indicating two distinct sector compositions. Firstly, three-sectors Lilien Index is utilized, which consists of the agriculture, industry and services sectors. Grounding on the thought that the manufacturing sector is one of the sectors, which is influenced most by the technological changes, Lilien Index for the Manufacturing sector is also employed. The manufacturing sector is assumed to be affected more by the technological development level compared to agricultural and services sectors.

Lilien Index is another variable assumed to have an impact on the labor market. Thus, **Figure 10.** represents three-sector Lilien Index (agriculture, industry, and services) between 2003-2016. It. shows evolutions of Lilien Index values in nine OECD countries between these years. Graphical presentation exhibits sectoral shifts in Canada, France, Germany, Italy, Korea Republic, Poland, Spain, United Kingdom, and the United States. Canada and France seem to experience high fluctuations in terms of sectoral shifts between 2005 and 2012. Spain, the UK, and the USA seem to experience a peak in 2005, which lasts until 2010. The Korea Republic exhibits an increase after 2015. Poland, Germany, Italy, and the Korea reveal relatively stable paths between 2002-2015. US Bureau of Labor Statistics (2012) report that 3.4% of total employment in the USA consisted of agriculture sector in the 1980s but fell to 1.6% in 2011. Agricultural Sector involves agriculture, hunting, forestry, and fishing. The Republic of Korea and France had larger shares of agriculture in the 1980s but this share sharply declined in 2011. The share of industry, which contains manufacturing, construction and mining sectors, has also declined since the 1980s. On the other hand, the share of the services sector has increased substantially since the 1980s. In the United States, United Kingdom, Canada, and France, every 8 from 10 people are employed in the services sector. In Germany and South Korea in 2011, every 7 people from 10 are employed in Services sector (US Bureau of Labor Statistics, 2012). These all show that the agriculture and industry sectors are in a downward trend, whereas Services sector is in an upward trend in terms of share in total employment. These findings are consistent with Kuznets' hypothesis about the shift of employment from agriculture and industry sectors to the services sector.

Figure 11. Three-Sector Lilien Index (Agriculture, Industry and Services) between 2003-2016

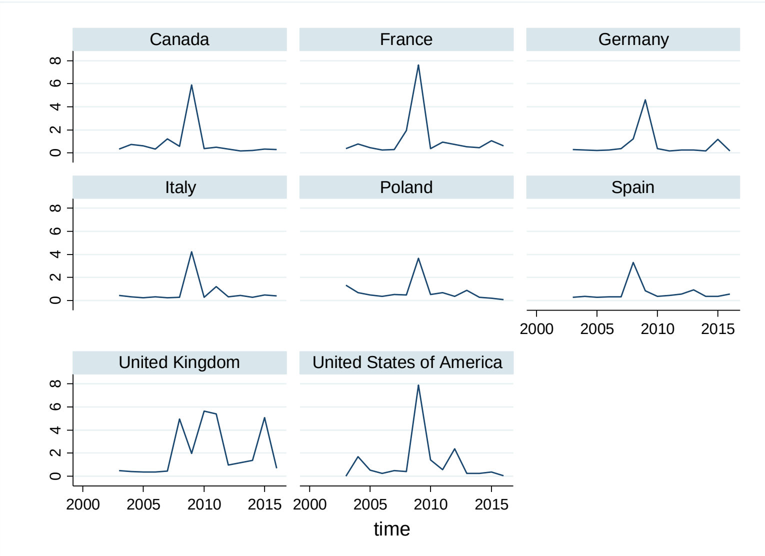


Source. World Bank Database, 2003-2016 and author's own calculation

Manufacturing Lilien Index indicates whether there are sectoral shifts or sectoral reallocation within the manufacturing sector. The manufacturing sector is considered to be affected by technological advancement more than agriculture and services sectors. 20 sectors in the manufacturing industry are utilized in the Lilien Index calculations.

Figure 11. depicts Manufacturing Lilien Index for 8 OECD countries between 2003-2016. Korea is excluded because of data unavailability. It is observed that all countries, without exception, experienced an increase in the sectoral shifts within the Manufacturing sector during the Global Economic Crisis in 2008. The United Kingdom is the country with the most fluctuations within the 2003-2016 time range. According to Moffat (2013), UK has been experiencing a substantial downturn in Manufacturing employment. Labor costs have increased a great deal and UK is exposed to a 'de-industrialization' in the recent past. 'de-industrialization is the decline of the share of Manufacturing sector. There is a high Unemployment in Manufacturing sector.

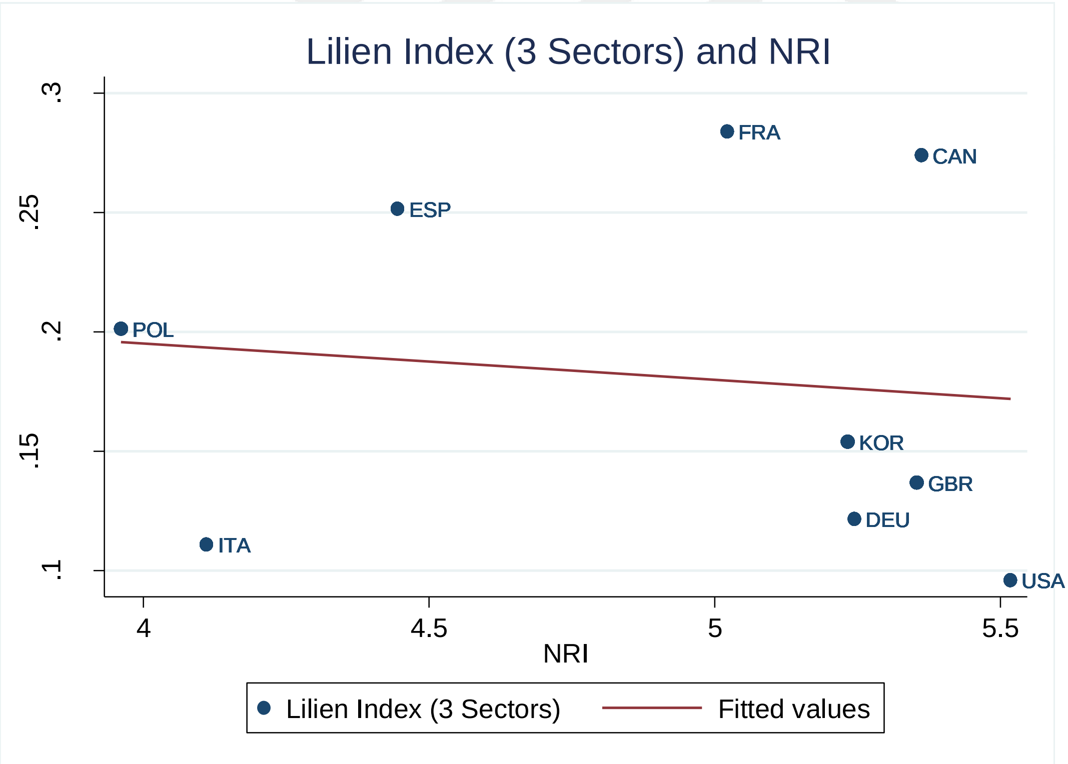
Figure 12. Manufacturing Lilien Index for 8 OECD countries between 2003-2016. Korea is excluded because of data unavailability.



Source. UNIDO, 2003-2016 and author's own calculation.

Figure 12. reveals the relationship between sectoral shifts and technological advancement level. Graphical representation indicates a negative connection between Networked Readiness Index, the indicator for technological advancement, and sectoral shifts. It is inferable that as technological development level increases, shifts between agriculture, industry and services sector tends to decline.

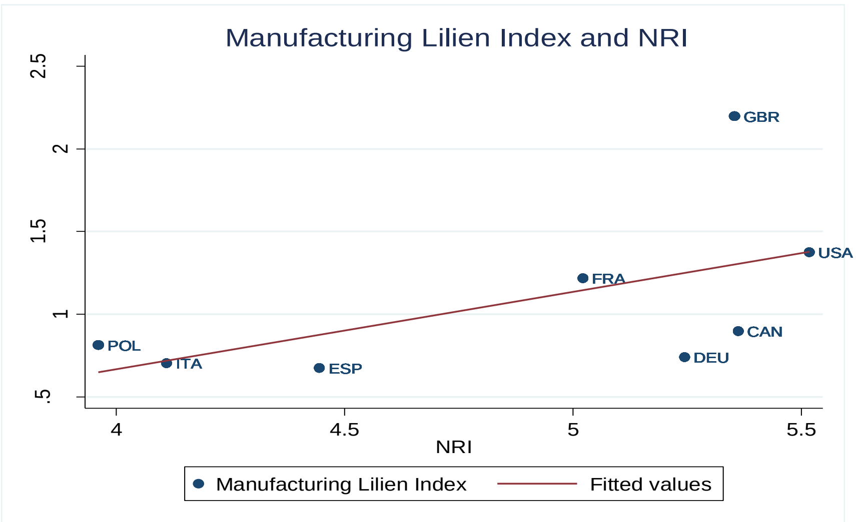
Figure 13. Three-Sector Lilien Index (considering agriculture, industry and services) and NRI relationship between 2003-2016



Source. World Economic Forum (WEF) Reports and database 2003-2016, author's own calculation

Figure 13. depicts the Manufacturing Lilien Index for 8 OECD countries and NRI relationship between 2003-2016. The Korea Republic is excluded due to data unavailability. Alcorta (1992); Bureau of Labor Statistics (Urquhart, 1984) argue that the technological advancements affect manufacturing sector substantially. In the graphical presentation also, Manufacturing Lilien Index is observed to have positively connected to NRI, which indicates the readiness for Industry 4.0.

Figure 14. Manufacturing Lilien Index for 8 OECD countries and NRI relationship between 2003-2016



Source. UNIDO 2003-2016, World Economic Forum (WEF) Reports and database 2003-2016

5. DATA AND METHODOLOGY

5.1.Data

The unemployment rate variable utilized in the analyses regarding the largest countries in OECD (in terms of population) are constructed from the country-level unemployment data of nine OECD countries for the period of 2003-2016. Unemployment Rate data are obtained from the World Bank Database and all assessments are made via Panel data models.

There are nine OECD countries employed in total, which appear in the top 50 in the Networked Readiness Index and which rank at the top of population numbers. The variables utilized for unemployment rate prediction, which are obtained from the World Bank Database are Three-sector employment (sectors are agriculture, industry, and services) to calculate Three-sector Lilien Index, Gross Capital Formation % of GDP and Manufacturing Share (%GDP) Value Added. NRI data is obtained from the World Economic Forum (WEF)[2] Reports (2003-2016) and WEF database. Manufacturing Lilien Index is calculated from employment data obtained from UNIDO[3] (United Nations Industrial Development Organization, ISIC Revision 3) database. 2-Digit Manufacturing data contains 20 sectors (See APPENDIX C).

The data in the unemployment rate and Three-sector Lilien Index analyses covers nine OECD countries for the period 2003-2016. The countries used in the analyses are

[2] World Economic Forum (WEF) is an International Organization, which was established in 1971 as a non-profit organization and it's headquarter is in Geneva, Switzerland. The Forum arranges meetings, publishes reports and articles, gives news and is officially recognized as an international organization in 2015. The impact of Industry 4.0 and the readiness state for the Fourth Industrial Revolution are measured by World Economic Forum annually since 2001. The World Economic Forum has a newly established center called the 'Centre for the Fourth Industrial Revolution' for global dialogue and cooperation to take advantage of the Industry 4.0 Revolution and overcome difficulties related to technological advancement. Besides the Networked Readiness Index (NRI) data this thesis also employs 'The Future of Jobs Report 2018' (WEF, 2018) to gain a general perspective about the jobs, which will emerge or be destroyed throughout the revolution process.

[3] UNIDO (United Nations Industrial Development Organization) is a United Nations agency, which supports industrial development to reduce poverty, enhance globalization and promote environmental sustainability. UNIDO is established in 1 April 2019 and has 170 member states. The agency supports creation of a shared prosperity, enhancing economic competitiveness, protect environment and strengthening know-how and institutions.

Canada, France, Germany, Italy, Korea Republic, Poland, Spain, United Kingdom, and the United States.

The second data used in Manufacturing Lilien Index regression analysis covers 8 OECD countries[4] for the period 2003-2016. The countries are Canada, France, Germany, Italy, Poland, Spain, United Kingdom, and the United States.

The empirical analysis mainly consists of the analysis of the unemployment rate and sectoral shifts, measured using Lilien Index. Lilien Index is supposed to represent sectoral reallocation or structural change. Networked Readiness Index (NRI) represents the readiness for Technology 4.0. Manufacturing Share (%GDP) Value Added is supposed to be proxy for the relative importance of manufacturing sector in GDP. The sectoral content of Manufacturing Lilien Index is presented in APPENDIX C.

5.2.Methodology

In order to forecast Lilien Index, NRI (Networked Readiness Index) is employed with the thought that technological advancement level would have an impact on sectoral shifts. And to anticipate Unemployment Rate, Gross Capital Formation % of GDP (investment), NRI, Manufacturing (%GDP) Value Added, Three-sector Lilien Index and Manufacturing Lilien Index (for 20 sectors) are employed. There are six models, which are estimated via Panel data models such as Driscoll-Kraay (1998) standard errors and Fixed Effect methodologies. Additionally, empirical tests are employed to determine the data structure (See APPENDIX A).

5.2.1. Empirical Models

First model tries to estimate Lilien Index for 3 sectors via NRI (Industry 4.0 Index). The second model predicts Manufacturing Lilien Index via NRI. Third model assess

[4] Due to the unavailability of Korean data, Korea Rep. is excluded from this second country-set.

Unemployment Rate via NRI and Investment levels (Gross Capial Formation % of GDP). The fourth model estimates Unemployment Rate via NRI and Manufacturing Value Added % of GDP. The fifth model forecasts the Unemployment Rate via Manufacturing Lilien Index and investment. And finally, sixth model tries to estimate Unemployment Rate via Three-sector Lilien Index and investment level. The models used in this thesis are summarized below in functional and regression form.

5.2.1.1. Models in Functional Form

Model 1: Lilien Index (3 Sector) = f(NRI)
Model 2: Manufacturing Lilien Index (20 Sector) = f(NRI)
Model 3: Unemployment Rate = f(NRI, Investment)
Model 4: Unemployment Rate = f(NRI, Manufacturing (%GDP) Value Added)
Model 5: Unemployment Rate = f(Lilien Index (2 Digit) Manufacturing), Investment)
Model 6: Unemployment Rate = f(Lilien Index (3 Sector), Investment)

5.2.1.2. Models in Regression Form

$LI_{i,t} = \beta_0 + \beta_1 NRI_{i,t} + \varepsilon_{i,t}$ **(Model1)**
$MLI_{i,t} = \beta_0 + \beta_1 NRI_{i,t} + \varepsilon_{i,t}$ **(Model2)**
$UNEMPR_{i,t} = \beta_{0,i,t} + \beta_1 NRI_{i,t} + \beta_2 I_{i,t} + \varepsilon_{i,t}$ (**Model3)**
$UNEMPR_{i,t} = \beta_{0,i,t} + \beta_1 NRI_{i,t} + \beta_2 MVA_{i,t} + \varepsilon_{i,t}$ (**Mode4)**
$UNEMPR_{i,t} = \beta_{0,i,t} + \beta_1 MLI_{i,t} + \beta_2 I_{i,t} + \varepsilon_{i,t}$ (**Model5)**
$UNEMPR_{i,t} = \beta_{0,i,t} + \beta_2 LI_{i,t} + \beta_1 I_{i,t} + \varepsilon_{i,t}$ (**Model6)**

where,
UNEMPR=Unemployment Rate
I= Gross Capital Formation as a percentage (%) of GDP (investment in capital)
LI= Lilien Index of 3 Sectors regarding Agriculture, Industry and Services
NRI= Networked Readiness Index (NRI) Rank as Technology 4.0 Indicator
MVA= Manufacturing Share (%GDP) Value Added

MLI= Lilien Index of Manufacturing (20 Sectors)

$\varepsilon_{i,t}$ = is the regression error term

6. EMPIRICAL METHODS

6.1.Regression Results

Table 3. Regression Results of 3-Sector Lilien Index (agriculture, industry and services) and Manufacturing Lilien Index (20 Sector)

VARIABLES	(1) Lilien Index (3 sectors) Driscoll-Kraay	(2) Lilien Index (3 sectors) Fixed Effect	(3) Manufacturing Lilien Index Driscoll-Kraay	(4) Manufacturing Lilien Index Fixed Effect
NRI	-0.00949	-0.0822**	0.519*	0.464
	(0.00687)	(0.0316)	(0.249)	(0.801)
Constant	0.207***	0.564***	-1.283	-1.015
	(0.0378)	(0.155)	(0.808)	(3.908)
Observations	86	86	80	80
R-squared	0.002	0.018	0.032	0.003
Number of Country	9	9	8	8

Robust Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4. Regression Results with Unemployment Rate as dependent variable

VARIABLES	(1) Unemployment Rate Driscoll-Kraay	(3) Unemployment Rate Driscoll-Kraay	(5) Unemployment Rate Driscoll-Kraay	(7) Unemployment Rate Driscoll-Kraay
NRI	-3.749***	-3.423***		
	(0.502)	(0.544)		
Gross Capital formation % of GDP	-0.313*** (0.0455)		-0.331*** (0.0469)	-0.216** (0.0809)
Manufacturing Value Added of GDP		-0.0457** (0.0173)		
Lilien Index (3 Sectors)			0.907 (2.759)	
Manufacturing Lilien Index (20 Sectors)				-0.261 (0.164)
Constant	33.90***	27.87***	15.65***	13.91***
	(3.450)	(3.801)	(1.184)	(1.574)
Observations	99	81	113	104
R-squared	0.275	0.262	0.118	0.036
Number of Country	9	9	9	8

Robust Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0

6.2.Empirical Test Results

There are mainly three diagnostic tests employed: These are Modified Wald Heteroscedasticity test, Baltagi and Wu (1999)'s Serial Correlation Test and Breusch Pagan (1980) Cross-Sectional Dependence test. Heteroscedasticity means that the variance of a certain variable doesn't remain constant from the beginning to the end of the data set, rather it shows differing variances and standard deviations. Modified Wald Heteroscedasticity test measures the group-wise heteroscedasticity in the residuals of a fixed effect regression and test results reveal that the data used in this study is subject to heteroscedasticity.

Cross-Sectional Dependence indicates that the data are likely to reveal substantial cross-sectional dependence in the errors and the reason for this might be common shocks, spatial dependence and unobserved components that become part of the error term (Hoyos and Sarafidis, 2006). The effect of Cross-Sectional Dependence leans on the strength and the nature of the correlation across cross-sections. Test results reveal that the data is subject to Cross-Sectional Dependence because most of the countries are selected from EU region, which means that they are under a common spatial effect such as EU agreement. Breusch-Pagan's Cross-Sectional Dependence test uses Langrange Multiplier and is suitable for panel data models with T>N. And finally, to assess whether there is a serial correlation among the error terms, Baltagi and Wu (1999)'s AR(1) test, which is suitable for panel data showing first order autocorrelation, is employed. Baltagi and Wu test can be used for fixed effect and GLS random effect models. Results show that there is autocorrelation in all datasets except for the regression with Manufacturing Lilien Index as the dependent variable.

To state clearly, the dataset is subject to Heteroscedasticity, Serial Correlation and Cross-Sectional Dependence. Therefore, Driscoll-Kraay (1998) standard errors are used to assess the dependent variables. Driscoll-Kraay is suitable for large-T (time) datasets. Hoecle (2007) summarizes Driscoll-Kraay model as follows:

'*Driscoll and Kraay (1998) propose a nonparametric covariance matrix estimator that produces heteroskedasticity- and autocorrelation-consistent standard errors that are robust to general forms of spatial and temporal dependence*.' (Hoechle, 2007, p.281) '*Since autocorrelation, heteroskedasticity, and cross sectional dependence exist in the models, the models are estimated by employing regressions with Driscoll and Kraay (1998) standard* *errors*.' (Hoechle, 2007, p.282) In addition to that, heteroscedasticity-robust Fixed Effect model is also utilized to predict Lilien Indexes.

6.2.1. Sectoral Shifts (Agriculture, Industry, Services and Manufacturing)

To assess sectoral shifts, World Bank, UNIDO and WEF data with a time range of 2003-2016 are used. To assess Three-sector Lilien Index, countries such as Canada, France, Germany, Italy, Korea Republic, Poland, Spain, United Kingdom, and the United States are investigated. Due to data unavailability, Korea Republic is excluded from the Manufacturing Lilien Index forecasting. Estimations for Three-sector Lilien Index and 20-sector Manufacturing Lilien Index are made using NRI data as independent variable.

Table 3. states the regression results with Lilien Index (3-Sector Lilien Index and Manufacturing Lilien Index) as dependent variable and NRI (Industry 4.0 readiness) as independent variable. Confirming M Syrquin (1988); Chenery (1986a); Caroleo and Pastore (2010); Pasinetti (1981), the Fixed Effect model with Driscoll-Kraay standard errors provide evidence for a positive significant (at 10% level) relationship between sectoral shifts in the manufacturing industry and technological advancement level (Industry 4.0 readiness), which is indicated by NRI. There is also a significant (at 5% level) relationship between Three-sector (agriculture, industry, and services) Lilien Index and technology level using Fixed Effect model with heteroscedasticity robust standard errors but this time the relationship is negative.

The findings provide evidence that the advancement in technology level probably leads to an increase in sectoral shifts within the manufacturing sector, whereas a decrease in the sectoral shifts among the abovementioned three sectors. It can be referred to as Industry 4.0 being highly connected to the manufacturing sector itself and the productivity level in that sector. NRI seems to revive the sectoral shifts within the manufacturing sector because the structural change is more related to the manufacturing sector.

The results show that NRI leads to an increase in the Manufacturing Lilien Index and this might be related to the relationship between Industry 4.0 and intelligent manufacturing techniques, which altered the demand for labor and new machinery within the manufacturing sector. Zhonga, Xu, Klotz and Newman (2017) provide evidence that the manufacturing industry changed drastically with intelligent production machines and techniques. This might be differentiating the labor force composition and demand for skilled labor (Krusell et. al., 1997).

On the other hand, Industry 4.0 leads to a decline in the Three-sector Lilien Index, but a decline in the sectoral shifts between agriculture, industry and services sectors in the industrialized countries is already expected due to the saturation of the sectors in those countries.

6.2.2. Unemployment Rate

Data used for this study are obtained from WEF, UNIDO and World Bank with a time range from 2003 to 2016. Companies explored in this study are Canada, France, Germany, Italy, Korea Republic, Poland, Spain, United Kingdom, and the United States. The unemployment rate is estimated using Driscoll-Kraay standard errors.

Table 4. states regression results with the unemployment rate as the dependent variable. In order to assess the Unemployment Rate, variables such as Three-Sector Lilien Index, Manufacturing Lilien Index, Gross Capital Formation and Manufacturing Value Added, are employed. Findings reveal compatible results with the previous literature. For example, consistent with the results found by Young and Pedregal (1999); Sigurdsson (2013); and Holte (1987), this thesis finds a negative significant relationship between Unemployment Rate and Gross Capital Formation (%) of GDP. This indicates that as capitalization via investments increase, the level of unemployment would decrease.

Approving the researches made by Fern´andez-de-C´ordoba and Moreno-Garc´ıa (2006); and Kreickemeier and Nelson (2005), there is evidence for a significant connection between the technology level, measured by NRI (Networked Readiness Index) and Unemployment Rate. Evidence supports that technology level leads to a decline in the unemployment level, which is in contrary to the findings of Prat (2006) and compatible with the studies of Mincer and Danninger (2000); Benigno, Ricci, and Surico (2015); Gallegati et. al. (2014).

Additionally, approving Zagler (2000) and in contrary to Mills, Pelloni and Zervoyianni (1995); Bakas, Panagiotidis and Pelloni (2016), this research finds positive insignificant effect of Three-sector Lilien Index on Unemployment rate. Manufacturing Lilien

Index seems to have a negative impact on the unemployment rate and the effect is also insignificant. Gallipoli and Pelloni (2014) and Panagiotidis and Pelloni (2014) find similar results for their studies and explain the results by saying that higher rates of job reallocation is more associated with higher unemployment rates.

In addition, empirical results show that the connection between the Manufacturing Value Added % of GDP and the Unemployment Rate is negative and significant. This means that increase in Manufacturing Value Added (% of GDP) leads to lower unemployment rates. Manufacturing Value Added is associated with Industry 4.0 and with high productivity growth rates, so this might be the reason of Manufacturing Value Added leading to a lower unemployment rates. Consistent with IMF (International Monetary Fund, 2018) Report, which states that the '*Technological Unemployment'* is '*unwarranted*', this study provides evidence that the unemployment rate is negatively related with technological advancement level.

The empirical results in Table 4 show that as NRI increases, Unemployment rate declines. Flynn et. al. (2017) point out that are increasing education opportunities available in the internet reachable from all over the World. Industry 4.0 facilitates the availability of the educational material and educating staff, which then enables people to improve themselves and find new jobs.

The relationship between Unemployment and sectoral shifts can be explained by Lilien's idea. Lilien (1982) relates sectoral shifts to fluctuations in business cycles by saying that 'Cyclical Unemployment' might be connected to sectoral shifts. According to Lilien (1982), a decline in the unusual ups-and-downs in the sectoral shifts may lead to lower Unemployment rates.

In this study, it is shown that the Three-Sector Lilien Index has a negative connection to Industry 4.0. If Industry 4.0 leads to a decline in Three-sector Lilien Index, it might be decreasing the fluctuations of sectoral shifts. This decrease in the fluctuations might be leading to lower Unemployment rates. Lilien explains this by saying that Cyclical Unemployment is related to the ups-and-downs of sectoral shifts.

6. CONCLUDING REMARKS

The investigation mainly explores the effect of Industry 4.0 on the unemployment rate and sectoral shifts by using nine OECD countries within the period of 2003-2016. Empirical results show how Unemployment Rate is affected by technological advancement, Manufacturing Value Added, Gross Capital Formation, and Structural Changes as well as how Sectoral Shifts are affected by Industry 4.0 readiness state. The unemployment rate seems to be significantly affected by Manufacturing Value Added, Investments and Industry 4.0 activities, however insignificantly affected by the sectoral changes both regarding three sectors (agriculture, industry, and services) and the manufacturing sector with 20 sub-sectors.

Gross Capital Formation % of GDP, Manufacturing Value Added % of GDP and Networked Readiness Index (NRI) seem to have a negative and statistically significant impact on Unemployment Rate. Besides that, sectoral changes have differing effects on the unemployment rate regarding of which sectors are considered. Sectoral shifts regarding agriculture, industry, and services sectors have a negative impact on Unemployment Rate, however, sectoral changes regarding Manufacturing sector have a positive impact on Unemployment. But both of the measures have a statistically insignificant effect, the reason of which is explained by Gallipoli and Pelloni (2014): Panagiotidis and Pelloni (2014).

Gallipoli and Pelloni (2014) argue that there is an asymmetric relationship between sectoral shifts and unemployment when we employ Lilien Index. In their work, they utilize quantile regression and say that when we consider the lower unemployment levels, Lilien Index is insignificant and that this index is only significant in the higher quantiles of unemployment. As this thesis employs mainly developed countries, the unemployment levels are generally lower than 10%, which might have led to insignificant results. Panagiotidis and Pelloni (2014) make an investigation on the impact of Lilien Index on unemployment and conclude that

'*Lilien's dispersion index is significant only for relatively high levels of unemployment and becomes insignificant for lower levels suggesting that reallocation affects unemployment only when the latter is relative high. More job reallocation is associated with higher unemployment.*' (Panagiotidis and Pelloni, 2014, p.1)

Variables such as Gross Capital Formation (% of GDP), Manufacturing Value Added % of GDP and Networked Readiness Index (NRI) seem to decrease Unemployment levels in the empirical results. Technological development measured by the Networked Readiness Index also affects sectoral shifts but sectoral shifts don't seem to have a significant connection to Unemployment levels between 2003 and 2016 in these nine OECD countries. These findings are consistent with the findings of the Bureau of Labor Statistics (2017) and the World Economic Forum's *The Future of Jobs Report (2018).*

The Bureau of Labor Statistics (Works, 2017) reports that increasing technological advancement increases the productivity and decreases cost of production, which leads to a reduction in labor cost and an increase in labor demand. The report of Bureau of Labor Statistics states that '*There are an estimated 1.5–1.75 million robots in operation, with the number expected to increase to 4–6 million by 2025*.' (Works, 2017, p.1). According to this report, they are expected to decrease production and labor costs substantially.

This thesis explored the impact of Industry 4.0 on the labor market, considering the unemployment rate and sectoral shifts. However, this research did not regard the labor force skills, education and experience levels. Further research might be made on how low-middle-and-high skilled labor are affected separately by the Industry 4.0 and a more detailed research might be on how Industry 4.0 affects individual sectors within agriculture, industry and services sectors considering subsectors and different labor skill levels.

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APPENDIX A. Empirical Tests

Tests:	Breusch and Pagan's and Frees' Cross-Sectional Dependence Tests		Baltagi and Wu (1999) Autocorrelation (Serial Correlation) Test		Modified Wald Heteroscedasticity Test	
Reegression Variables:	Statistic	p-value	Statistic	p-value	Statistic	p-value
Lilien Index (3 Sectors) and NRI	0.257 (Frees' Test)	0.0000 (Frees' Test)	2.68	0.0128	2268.91	0.0000
Manufacturing Lilien Index (20 Sectors) and NRI	130.133	0.0000	1.21	0.3089	21.31	0.0064
Unemployment Rate with NRI and Gross Capital	75.763	0.0001	8.92	0.0000	450.65	0.0000

Formation)						
Unemployment Rate with NRI and Manufacturing Value Added % of GDP	81.259	0.0000	4.42	0.0003	682.54	0.0000
Unemployment Rate with Lilien Index (3 Sectors) and Gross Capital Formation	138.173	0.0000	5.12	0.0000	1941.00	0.0000
Unemployment Rate with Manufacturing Lilien Index (20 Sectors) and Gross Capital Formation	101.461	0.0000	5.13	0.0001	1562.09	0.0000

APPENDIX B. NRI

B.1. NRI

Networked Readiness Index (NRI) is an index which indicates the state of readiness for the Fourth Industrial Revolution, the Industry 4.0. It measures indicators such as public, individual and private usage of latest technological machines and devices, effects of technological advancement on the society, whether new products are affordable by the average-income households, whether business environment is open for innovations and inventions, state of country infrastructure in terms of latest technological facilities, human capital quality and state of the regulatory environment. The more pervasive the usage of the new technology, the more democratic the regulatory environment, the more affordable the new products, the better the infrastructure and the qualified the human capital, the lower (better performing or at the top) ranks the country in the Industry 4.0 competition.

Kang and Liu (2014) show in the IMF Working Paper that efficiency of the judicial system has great impact on the rate of investments where inefficient regulatory systems lead to a decline in the investment level of the country. They argue that delays, malfunctioning products and impediments for the regulatory proceedings lead to observable reduction in the investments, be it domestic be it foreign. Countries on the top of the ladder have a strong and trustable judicial system. And confidence in the government as well as in the courts are perceptible in every area of the country.

Singh (2002) suggests that infrastructure constraints in India affect growth rates and applications such as e-government, computer-empowered registrations or bill-payments have a positive impact on the development of IT infrastructure. In the Technology Report (2016) of World Economic Forum it is said that ICT (Information Communication Technologies) products and services are qualified and commonly used in those countries with lower ranks in terms of Networked Readiness Index. Sullivan (1985), Matthews (2007), Raymond et al (2005), Qiang et al (2006) indicate that there is evidence of the impact of Information Communication Technologies sector on economic growth.

Growth generally influences job market in a positive manner except for the Jobless Growth case (Caballero, Hammour, 1998). To mention Jobless Growth case: It refers to the situation, where worldwide technology diffusions accelerate investment and economic growth but labor market doesn’t benefit from it due to strict regulatory environment. One example is Argentina. In Argentina, production growth was 40% in 1995, however, unemployment has risen slightly and productivity has declined also.

The qualification of the human capital is measured in terms of the skill levels. And skills are measured in terms of the qualification of the educational system, especially in terms of math and science education, the level of secondary education enrollment, and adult literacy rate. Cheaper ICT products and services are more acceptable as the price affects the pervasion of the usage (World Economic Forum Technology Report 2016). Consequently, there is evidence that the technological advancement level has a positive impact on economic growth and employment levels. The readiness for the Industry 4.0 Revolution measured in terms of NRI is expected to indicate a positive contribution on labor market and employment.

NRI consists of four main categories (sub-indexes), 10 further subcategories and, 53 different indicators under these 10 subcategories, showing the readiness state of countries for the Fourth Industrial Revolution. NRI is published by the World Economic Forum in order to enable countries to utilize the Industry 4.0 Revolution at the highest possible capacity. The NRI grounds on 6 main necessities:

1. high-quality government and business environment is vital to benefit from the advancements in ICT sector
2. utilization from the ICT sector is evaluated by 3 factors:
    a) ICT-product affordability,
    b) skills,
    c) infrastructure
3. full-capacity utilization from the ICT sector requires social endeavor
4. ICT usage is not the end-point itself
5. There are 3 factors interacting with each other and developing together
    a) Environment,
    b) Readiness for the Industry 4.0,
    c) usage
6. NRI should provide guidance for the countries willing to utilize from the technological advancement.

Four Sub-Indexes Used in Networked Readiness Index:

1. **Environmental Sub-Index:** It refers to the achievement of the country to support the ICT environment, it’s development, promotion of innovation and facilitation of entrepreneurship.
    - **Political and Judicial Environment:** It contains the ability of a country to enable ICT spillover and innovation through government policies and regulations.
    - **Working and Innovation Environment:** Measures the level of facilitation of businesses in terms of procedures to start a business up, level of free competition, funding innovative products and processes, the level of demand for high technology products and taxation.
2. **Readiness Sub-index:** Measures the state of the infrastructure promoting and facilitating the ICT products and services.

- **Infrastructure:** It refers to the abundance of infrastructure supporting Information Communication Technologies such as mobile coverage, internet access and services, electricity production and internet bandwith.
- **Affordability:** This pillar measures the costs of mobile technologies, internet access and ICT services
- **Skills:** This pillar contains the ability of the public to utilize ICT products and services. Skills are measured in terms of enrollment rate for secondary education, education quality and adult literacy rate.

3. **Usage Sub-Index:** This sub-index gives the pervasion of the usage of ICT products and services.
    - **Indıvidual Usage:** Indicates the usage of mobile phone, internet, PC and social networks
    - **Business Usage:** Exhibits the usage of business-to-business (B2B) and business-to-consumer (B2C) internet facilities, innovative capacity of companies, density of patent applications, employees with innovative skills
    - **Government Usage:** Measures the extent of employment, support and promotion of ICT products and services
4. **Effect Sub-Index:** Exhibits the social and economic effects of ICT usage

- **Economic Effects:** Measures the level of free and fair competition in terms of latest technologies, density of patent applications, development of new organizational models due to technological change
- **Social Effects:** Exhibits the availability of healthcare, financial services and education, savings in energy sector, usage of internet in education, quality of ICTs, participation of household to regulatory process

As mentioned, Networked Readiness Index has 10 sub-categories and they are composed of 53 different indicators The World Economic Forum uses data obtained from organizations such as UNDESA, WIPO, OECD, ILO and UNICEF. Remaining gaps in the data are filled by the World Economic Forum-Executive Opinion Survey. This survey is conducted in 139 countries and approximately 14,000 business managers are involved in it. Answers given to the Executive Opinion Survey are rated from 1 to 7, where 1 is the worst situation and 7 is the best situation.

In ‘The Global Information Technology Report’ 2001-2016, countries are ranked according to the state they are, in terms of the readiness for the Fourth Industrial Revolution.

Long-term best performing countries have been Finland, Norway, Sweden, Switzerland, Singapore, United States, United Kingdom, Korea and Germany between the time range of 2002-2017. And Singapore, Finland, Sweden, Norway, United States, Netherlands, Switzerland, United Kingdom, Luxembourg and Japan are reported as top ten technology-leading countries in 2016. Hungary, Slovak Republic, Czech Republic, Poland and Italy are observed as worst performers with higher ranks in the long-run. Lower ranks are considered as better performances in the Industry 4.0 readiness competition because lower ranks are at the top of the downward ladder.

The Global Information Technology Report 2016 indicates four main results of the research:

Firstly, people in the business environment opt for making innovations and increasing technology level with an increasing rate. Although ICT products are increasingly adopted by business environment and innovativeness is rising, patent applications are decelerating. This implies that there are imitations with a rising trend.

Secondly, there are seven economies leading the technology competition. These are: Netherlands, Finland, Singapore, Sweden, United States, Switzerland and Israel. Most of these economies are performing better in the utilization of digital technologies in business environment. In addition to these, pioneering in the Industry 4.0 contest requires high skill levels and competency in the digital technologies.

Thirdly, the utilization of digital technologies by public and private sector are quite inadequate for most of the countries. The employment of internet is rising, however, there are nine countries with decreasing internet utilization. To fully benefit from the Industry 4.0 Revolution, public and private sector should be in such a state, which enables them to respond as quickly and as daringly as possible. There is an increasing trend in the Developed Economies, Eurasia, the Caribbean, Developing Asia and Latin America in terms of Networked Readiness Index, the readiness for Industry 4.0 Revolution. Sub-Sahara is at the lowest rank of the countries with an increasing trend.

And finally, social and economic dynamics are differentiating, especially labor market dynamic and firm-level competition dynamics. Government can play an active role in this process by promoting innovativeness, competition and embracement of ICT products.

There are benefiters and disadvantageous parties in this process, where high-skilled and low-skilled employees are promoted in terms of wages and, routine and middle waged employees are demoted via decreasing wages.

Calculations of and details about the NRI[5] and the sub-indexes are available in APPENDIX B. Below are the evolutions of the rankings of 26 OECD countries in terms of NRIs (Networked Readiness Index) between 2002-2016.

The 10 sub-indexes and the 53 indicators employed in the Networked Readiness Index are as follows:

1. **Political and legislative framework in the country**

a) Effectiveness of legislative bodies:
   1 = not effective at all
   7 = extremely effective
b) Legislations related to ICTs:
   1 = not developed at all
   7 = extremely developed
c) Judicial detachedness:
   1 = not detached at all
   7 = extremely detached
d) Success of legal bodies in settling disputes:
   1 = not successful at all
   7 = extremely successful;
e) Success of legal bodies in challenging laws:
   1 = not successful at all

[5] Sources: United Nations Department of Economic, Social Affairs (UNDESA); UN E-Government Development Database; International Labor Organization (ILO), ILOSTAT; World Intellectual Property Organization (WIPO) PCT Data, sourced from Organization for Economic Co-operation; Development (OECD), Patent Database, January 2016; World Economic Forum, Executive Opinion Survey, 2014 and 2015 editions; International Telecommunication Union (ITU), ITU World Telecommunication/ICT Indicators Database 2015; United Nations Children's Fund (UNICEF), Education Statistics; SITEAL - Sistema de Información de tendencias Educativas de América Latina; national sources; Authors' calculations based on International Energy Agency (IEA), World Energy Statistics and Balances 2015 /; World Bank, World Development Indicators (retrieved January 4, 2016), US Central Intelligence Agency (CIA), The World Factbook; World Bank/International Finance Corporation, Doing Business 2016: Measuring Regulatory Quality and Efficiency, World Bank/PwC, Paying Taxes 2016: The Global Picture; The Software Alliance (BSA), The Compliance Gap: BSA Global Software Survey (June 2014).

7 = successful efficient

f) Are intellectual properties protected?

1 = not at all

7 = to a great extent

g) Software products piracy rate: Unlicensed software products as percentage of total software units in desktop units, laptops, and portables

h) Number of procedures to prosecute a contract: number of stages in a procedure

2. Business and innovation framework in the country

a) Employability of latest technologies:

1 = not at all

7 = to a great extent;

b) Reachability if venture capital:

1 = extremely difficult

7 = extremely easy

c) Tax rate: profit tax, labor tax and social contributions, property taxes, turnover taxes, and other taxes, as a percentage of profits

d) Time span necessary to start up a business: Number of days

e) Number of steps to start up a business

f) Concentration of regional competitiveness

g) Enrollment rate of tertiary education

h) Qualification of management schools

1 = extremely poor

7 = excellent

i) Supplement of high technology products by government: Do government purchasing decisions accelerate innovation

1 = not at all

7 = to a great extent

3. Infrastructure in the country

a) Electricity production (kWh) per capita

b) Mobile technology encasement rate: Share of population covered by a mobile system signals
c) International Internet bandwidth: (kb/s) per internet participant
d) Safe Internet servers, per million people

4. Affordability of ICT products

a) The mean per-minute cost of mobile calls (PPP $)
b) Monthly fee for the broadband Internet service (PPP $)
c) Internet and phone-communication sectors rivalry index

5. Skills of Labor Force

a) Does education cover the needs?
   1 = not well at all;
   7 = extremely well
b) Does mathematics and science education cover the needs?
   1 = extremely poor
   7 = excellent
c) Enrollment rate of the secondary education
d) Literacy rate of adult population

6. Personal use

a) Mobile-phone subscriptions
b) Share of people using Internet
c) Households with a PC
d) Households with Internet access
e) Fixed broadband Internet subscriptions
f) Mobile broadband Internet subscriptions
g) Usage of social media
   1 = not at all used;
   7 = used extensively

7. Business use

a) Technology adoption by firms

1 = not at all;

7 = adopt extensively

b) Innovativeness

1 = not at all;

7 = to a great extent

c) Patent Cooperation Treaties (PCT) per million people

d) ICT usage for B2B transactions

1 = not at all;

7 = to a great extent

a) Internet usage in B2C transactions

1 = not at all;

7 = to a great extent

8. Public use

a) Projection of ICT by government

1 = there is no plan;

7 = there is a clear plan

b) Qualification of government online services

0-to-1 (best)

c) Success of government in promoting the usage of ICTs

9. Economic effects

a) Do ICTs facilitate new business models?

1 = not at all;

7 = to a great extent]

b) Patent Cooperation Treaties (PCT) made for ICT (patent applications per million people)

c) Do ICTs facilitate new organizational models?

1 = not at all;

7 = to a great extent

a) Percentage of labor force in activities requiring knowledge and cognitive skills

10. Social Effects

a) Does ICT enable access to basic services?

1 = not at all;

7 = to a great extent

b) Internet availability in schools

1 = not at all;

7 = to a great extent

c) Public sector efficiency in ICT usage

1 = not at all;

7 = to a great extent

d) E-Participation Index

0-to-1 (best)

B.2. NRI Calculation

Calculation of Networked Readiness Index (NRI)

NRI is composed of 4 main categories and these four sub-indexes are divided into different indicators. All formulations are weighted equally as follows:

NRI = $\frac{1}{4}$ Environment sub-index + $\frac{1}{4}$ Readiness sub-index + $\frac{1}{4}$ Usage sub-index + $\frac{1}{4}$ Effect Sub-index

Calculation of Sub-indexes

Environment sub-index = $\frac{1}{2}$ Political and Legislative Framework + $\frac{1}{2}$ Business and Innovation Framework

Usage sub-index = $\frac{1}{3}$ Personal Usage + $\frac{1}{3}$ Business Usage + $\frac{1}{3}$ Government Usage

Readiness sub-index = $\frac{1}{3}$ Infrastructure in the Country + $\frac{1}{3}$ Affordability of ICT products + $\frac{1}{3}$ Skills of Labor Force

Effect sub-index = $\frac{1}{2}$ Economic Effects + $\frac{1}{2}$ Social Effect

Table 5. Top 50 of NRI (Networked Readiness Index) 2016

Top 50 of NRI (Networked Readiness Index) 2016			
Rank	Country	NRI-Value	Income level
1	Singapore	6.0	HI
2	Finland	6.0	HI-OECD
3	Sweden	5.8	HI-OECD

4	Norway	5.8	HI-OECD
5	United States	5.8	HI-OECD
6	Netherlands	5.8	HI-OECD
7	Switzerland	5.8	HI-OECD
8	United Kingdom	5.7	HI-OECD
9	Luxembourg	5.7	HI-OECD
10	Japan	5.6	HI-OECD
11	Denmark	5.6	HI-OECD
12	Hong Kong SAR	5.6	HI
13	Korea, Rep.	5.6	HI-OECD
14	Canada	5.6	HI-OECD
15	Germany	5.6	HI-OECD
16	Iceland	5.5	HI-OECD
17	New Zealand	5.5	HI-OECD
18	Australia	5.5	HI-OECD
19	Taiwan, China	5.5	HI
20	Austria	5.4	HI-OECD
21	Israel	5.4	HI-OECD
22	Estonia	5.4	HI-OECD
23	Belgium	5.4	HI-OECD
24	France	5.3	HI-OECD
25	Ireland	5.3	HI-OECD
26	United Arab Emirates	5.3	HI-OECD
27	Qatar	5.2	HI-OECD
28	Bahrain	5.1	HI-OECD
29	Lithuania	4.9	HI-OECD
30	Portugal	4.9	HI-OECD
31	Malaysia	4.9	UM
32	Latvia	4.8	HI
33	Saudi Arabia	4.8	HI
34	Malta	4.8	HI
35	Spain	4.8	HI-OECD
36	Czech Republic	4.7	HI-OECD

37	Slovenia	4.7	HI-OECD
38	Chile	4.6	HI-OECD
39	Kazakhstan	4.6	UM
40	Cyprus	4.6	HI
41	Russian Federation	4.5	HI
42	Poland	4.5	HI-OECD
43	Uruguay	4.5	HI
44	Costa Rica	4.5	UM
45	Italy	4.4	HI-OECD
46	Macedonia, FYR	4.4	UM
47	Slovak Republic	4.4	HI-OECD
48	Turkey	4.4	UM
49	Mauritius	4.4	UM
50	Hungary	4.4	HI-OECD

Source: World Economic Forum Report, 2016; HI = high-income countries, HI-OECD=High Income OECD countries, UM = upper-middle-income countries, Table is taken from World Economic Forum, Classification is made by World Bank (2015) and Table refers to the Year 2016.

APPENDIX C. Sectoral Coverage

Definition of Employment: Employment is defined by World Bank Group as persons of working age who were employed in any activity to produce goods or services for payment or profit, be it at work during a certain period or be it at work due to temporary absence from a job, or to working-time agreement

Agriculture Sector: The agriculture sector is composed of activities in agriculture, forestry, hunting, and fishing

Industry Sector: The industry sector is composed of mining, manufacturing, quarrying, construction, and public utilities (electricity, gas, and water)

Services Sector: The services sector is composed of hotels and restaurants; wholesale and retail trade; real estate, financing, and business services; storage, transport, and communications; community, personal and social services.

Manufacturing Sector: includes 2-digit sectors, which appear under the Manufacturing main sector. The sectors in Manufacturing Industry are shown below:

Table 6. 20 Sectors in Manufacturing Industry

Sectors in Manufacturing Industry
15 Food and beverages
16 Tobacco products
17 Textiles
18 Wearing apparel, fur
19 Leather, leather products and footwear
20 Wood products (excl. furniture)
21 Paper and paper products
22 Printing and publishing
23 Coke, refined petroleum products, nuclear fuel
24 Chemicals and chemical products
25 Rubber and plastics products
26 Non-metallic mineral products
27 Basic metals
28 Fabricated metal products
29 Machinery and equipment n.e.c.
30 Office, accounting and computing machinery
31 Electrical machinery and apparatus
34 Motor vehicles, trailers, semi-trailers
35 Other transport equipment

36 Furniture; manufacturing n.e.c.

Source. UNIDO (United Nations Industrial Development Organization) ISIC Rev. 3