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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

ARTIFICIAL INTELLIGENCE AND FUTURE TECHNOLOGIES THAT WILL SHAPE THE NEXT PRODUCTION REVOLUTION: A CONTENT ANALYSIS[1]

YAPAY ZEKÂ VE BİR SONRAKİ ÜRETİM DEVRİMİNİ ŞEKİLLENDİRECEK OLAN GELECEĞİN TEKNOLOJİLERİ: BİR İÇERİK ANALİZİ

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ABSTRACT

In this paper, emerging technologies of the Fourth Industrial Revolution are discussed in terms of OECD's concept of "The Next Production Revolution". The purpose of this paper is to raise awareness for the forthcoming production revolution and the significance of new technologies for production. Recently, various studies are addressing new technologies and the latest technological revolution. The main difference of this study is its comprehensive view unique to the production and it addresses the effects of new technologies on production. This paper includes a qualitative approach and uses a content analysis method. Artificial intelligence, additive manufacturing, biotechnology, nanotechnology, advanced materials and blockchain are discussed in terms of the next production revolution. The nature of production has been transformed in many dimensions over recent years. We confirm these technologies are expected to reshape the entire production process and global value chains. The next production revolution triggered by these technologies will have a profound impact on employment, skills, environment, inequality, wages, and productivity. Technology in smart factories significantly boosts productivity and growth. Technological developments also lead to skill shifts in the industries.

Keywords: Artificial Intelligence, 3D Print, Biotechnology, Nanotechnology, Advanced Materials.
Jel Codes: L60, L65, O14, O25.

ÖZ

Bu makalede, Dördüncü Sanayi Devrimi'nin yeni teknolojileri, OECD'nin "Bir Sonraki Üretim Devrimi" kavramı açısından tartışılmaktadır. Bu makalenin amacı, önümüzdeki üretim devrimi ve yeni teknolojilerin üretim için önemi hakkında farkındalık yaratmaktır. Son zamanlarda, çeşitli çalışmalar yeni teknolojileri ve son teknolojik devrimi ele almaktadır. Bu çalışmanın diğerlerinden temel farkı, üretime özgü kapsamlı görünümü ve yeni teknolojilerin üretim üzerindeki etkilerine değinmesidir. Bu makale nitel bir yaklaşım içermekte ve içerik analizi yöntemi kullanmaktadır. Yapay zekâ, katmanlı imalat, biyoteknoloji, nanoteknoloji, ileri malzemeler ve blok zincir, bir sonraki üretim devrimi açısından tartışılmaktadır. Son yıllarda üretimin doğası birçok boyutta değişmektedir. Bu teknolojilerin, tüm üretim sürecini ve küresel değer zincirlerini yeniden şekillendirmesinin beklendiği doğrulanmaktadır. Bu teknolojilerin tetiklediği bir sonraki üretim devrimi; istihdam, beceriler, çevre,

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eşitsizlik, ücretler ve verimlilik üzerinde derin bir etkiye sahip olacaktır. Akıllı fabrikalardaki teknoloji, üretkenliği ve büyümeyi önemli ölçüde artıracaktır. Teknolojik gelişmeler aynı zamanda sektörlerde beceri değişimlerine yol açmaktadır.

Anahtar Kelimeler: Yapay Zekâ, 3B Baskı, Biyoteknoloji, Nanoteknoloji, İleri Malzemeler.
Jel Kodları: L60, L65, O14, O25.

1. INTRODUCTION

Manufacturing is changing dramatically in recent decades. Emerging technologies are radically changing the way how we produce things and how we innovate them. Manufacturing systems become more and more digitalized today. Industry 4.0 is characterized by smart factories in the industries. Smart factories point out digitalization and developments at the cutting edge of technology in manufacturing. In this paper, we use the OECD's concept of "The Next Production Revolution" to reflect the recent technological breakthroughs in production. It means new technologies such as artificial intelligence, additive manufacturing (3D printing), cyber-physical systems, big data, cloud computing, advanced materials, nanotechnology and biotechnology that are expected to reshape the entire production process and global value chains. So, in this paper, we emphasize the impact of these technologies on manufacturing systems.

Rapidly developing new technologies become a significant challenge to manufacturers, workers and policymakers as well. The scale of this change promises many opportunities but at the same time, it brings many challenges like unemployment and skill shifting. The new technologies in production suggest greener production, safer jobs, faster productivity growth and customized goods and services. However, they also have possibilities of job replacement, job polarization, unemployment, wage polarization and inequality. Emerging technologies reshape the nature of traditional production and employment. The integration of these technologies in smart factories has the potential to enable a range of new processes and new markets. And the convergence between all of these new technologies is inevitably to ignite the next production revolution.

Recently, various studies are addressing new technologies and the latest technological revolution, mostly known as "Industry 4.0". Alternatively, this paper takes a more comprehensive view, unique to production and the effects of new technologies on production. This paper aims to raise awareness for the forthcoming production revolution and the significance of new technologies for production. This paper includes a qualitative approach and uses a content analysis method. In the following part, artificial intelligence, additive manufacturing, biotechnology, nanotechnology, advanced materials and blockchain are discussed in terms of the next production revolution. In the last part of this paper, the effects of these technologies in production are discussed.

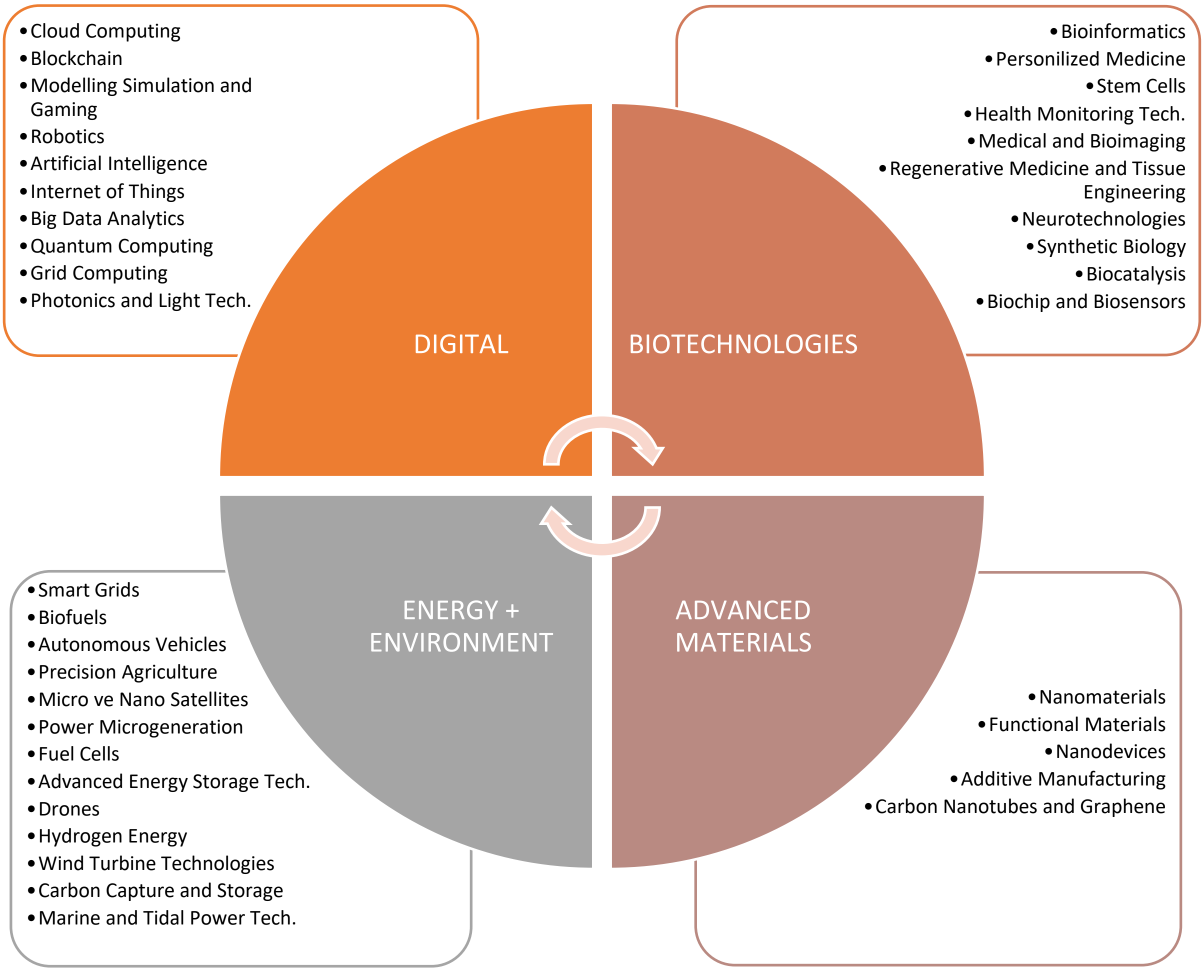
2. THE FUTURE TECHNOLOGIES OF THE NEXT PRODUCTION REVOLUTION

Many emerging technologies are on the horizon and some are already transforming the nature of production in many industries. Even though the precise effects of these technologies are still unknown, they are likely to be huge and effective. The data source is increasing day by day and big data along with data analytics support machines to be smarter and more functional. Cloud technologies offer cheaper solutions to keep and secure the data. Advanced robots are more intelligent and do not need continuous human control, meaning autonomous. Synthetic biology offers natural solutions to the energy problem and suggests greener production like producing petroleum-based products from sugar-based microbes. 3D printers are more common and allow to build larger objects even a building. Nanotechnology and biotechnology offer new materials which are lighter and stronger.

Artificial intelligence, machine learning, biotechnology, internet of things, big data, nanotechnology, synthetic biology, 3D printing, advanced robotics, cloud technologies, 5G, autonomous vehicles, virtual and augmented reality, implant technologies, and new materials are all future technologies that will shape the future of production revolution (see Figure 1). It is mainly believed that the next production revolution will occur thanks to the confluence of these technologies (OECD, 2017: 6). New processes in the production line and new materials that new technologies supply will affect the nature of traditional production overall.

The Fourth Industrial Revolution (also known as Industry 4.0) welcome us with smart technologies and smart solutions even in our daily life. Smart factories that embody new technologies will be the future of the manufacturing sector. Industrial robots which are highly autonomous will work 7/24 in smart factories and radically drive down costs. In the following parts, some of these new technologies that are likely to be crucial for production and their potential will be examined.

Figure 1. 40 Key and Emerging Technologies



Source: OECD (2016a).

OECD (2016a: 86) defines Artificial Intelligence (AI) as *"the ability of machines and systems to acquire and apply knowledge and to carry out intelligent behavior. This means performing a broad variety of cognitive tasks, e.g. sensing, processing oral language, reasoning, learning, making decisions and demonstrating an ability to move and manipulate objects accordingly"*.

AI research has accelerated in recent years, and recent advances have increased investments in artificial intelligence. For example; Microsoft company invested $ 1 billion in the "Azure AI" artificial intelligence project, which it will carry out with OpenAI (Microsoft, 2019). Today, robots can develop themself thanks to machine learning. Thus, the ability of robots is no longer limited to only routine jobs. Furthermore, advances in artificial intelligence and other following technologies might soon expand these capabilities.

Big data can store the collected data on the cloud using the internet of things technology and transfer it over the internet. Artificial intelligence can only be smart, up-to-date and functional when it reaches this data. It is expected that artificial intelligence, which makes use of many technologies and at the same time prepares the ground for the development of many new technologies, will surpass Moore's Law and grow twice more than computer processing power (Leonhard, 2016: 27). With the advances in big data, internet of things, machine-to-machine communication, cloud computing, increasing data and number of sensors and processing power, access capacity and speed have greatly improved AI in the last decade. The fact that artificial intelligence is intertwined with many technologies makes it the technology of technologies in a sense, and the technology that will mark the next century greatly increases the possibility of being artificial intelligence. In the World Economic Forum's "2017 Global Risk Report", artificial intelligence is listed among the top three technologies expected to offer the greatest advantages (WEF, 2017).

With the advancements in deep learning, AI is more useful with the use of artificial neural networks. AI can be applied to most industrial activities. The Fourth Industrial Revolution is characterized by widespread and mobile internet, powerful and cheap sensors, artificial intelligence and machine learning (Schwab, 2016: 16). However, AI is expected to create the biggest revolution in the next production revolution. TUBITAK (2016: 3-6) has identified; cyber-physical systems, AI/ sensor/ robotics, internet of things, big data, cybersecurity, cloud computing and space technologies, as the leading technologies for Turkey. While buying tickets, choosing movies, e-shopping or internet searches, we always take advantage of the guidance of artificial intelligence without realizing it. Likewise, it is possible to encounter the traces of artificial intelligence almost in every sector. To illustrate:

- Using algorithms derived from neuroscience, the artificial intelligence research firm Numenta has achieved a 50x-fold improvement in speed in deep learning networks without any loss in accuracy (Numenta, 2020);
- Pantanowitz et al. (2020), researchers from the University of Pittsburgh, have announced that using an artificial intelligence program, it reached an accuracy close to 100% in recognizing and characterizing prostate cancer;
- Researchers at the Massachusetts Institute of Technology have succeeded in their research to discover a new antibiotic using artificial intelligence. The computer model, which can scan 100 million chemical compounds, identified a powerful new antibiotic compound using a machine learning algorithm (Stokes et al., 2020);
- British biotech firm Exscientia and its Japanese partner Sumitomo Dainippon Pharma have announced that a new drug created with artificial intelligence is moving to human clinical trials to treat patients with obsessive-compulsive disorder (Sumitomo, 2020);
- Arab banking company Bank ABC, in collaboration with New Zealand technology company Soul Machines, has announced the launch of "Fatema", a fully autonomous AI personality that will assist customers online (Soul Machines, 2018).

According to Makridakis (2017), to predict possible changes that are caused by AI technologies is much harder for two reasons: *"First, they will depend on the speed that AI technologies will succeed in automating non-repetitive mental tasks currently performed by humans and replacing them in the process, and secondly the extent of the accelerated process of technological change as intelligent computer programs will become available and capable of developing new programs on their own"*.

Additive manufacturing (also known as 3D printing) builds products by adding material in layers in a computer-based control. 3D printing is one of the most discussed technology after AI and the number of 3D printers is increasing day by day. It is commonly used especially for rapid prototyping as well as low-volume production and customized products (OECD, 2015: 10). Thanks to additive manufacturing, it becomes possible to easily produce parts that have holes, pores or bends or that are intertwined and which are difficult or impossible to produce in one piece with traditional methods (Ford, 2018: 208). Some printers can produce with many materials from plastic to rubber and metal to strong alloys.

It is possible to see the use of additive manufacturing in almost every sector. For example; it is possible to find uses in architecture for the construction of plans and models, in the automotive sector for prototypes, in the aviation sector for indicators, and in the defense sector for respirators (Ozdogan, 2017: 82). Since these printers are useful for detecting possible problems that may occur during production process in advance, prototypes and personal designs can be produced perfectly. Furthermore, this technology provides a significant cost advantage by using only one-tenth of the material used in the traditional production process (Oztuna, 2017: 63). This reduction in the cost of producing designs and prototypes will also provide a significant advantage for new inventions and designs.

Nanotechnology is a technology that allows for the manipulation, study or exploitation of very small (typically less than 100 nanometres) structures (OECD, 2015: 11). Nanotechnology basically makes use of the principle of imitating the atomic sequence in nature (Oztuna, 2017: 74). Material science; together with microelectronics, nanotechnology and biotechnology, it has the potential to change and transform the character of production in the manufacturing sector (Banger, 2018: 53). Already, progress in materials science has accelerated progress in the IT sector. The dimensions of the semiconductors in the transistor layers, which are one of the main materials in the informatics sector, have been reduced to atomic dimensions in thickness. This size is so small that behaviors specific to quantum mechanics (Schwab, 2018: 187).

The wisdom of nanotechnology stems from the ability to control matter on a scale where the shape and size of assemblies of individual atoms determine the properties and functions of all materials (OECD, 2016b: 21). Nanotechnology can make products lighter, stronger, cheaper, faster, more resistant, more energy efficient (OECD, 2015: 11). So, the new materials that produced with nanotechnology could be useful in almost every sector and this could affect all existing industrial sectors. For instance, "Graphene" is an advanced nanotechnology product, 200 times stronger than steel and one million times thinner than human hair, has a good heat and electricity conductivity and is now one of the most expensive materials in the world (Schwab, 2016: 26). Nanotechnology is increasingly used in production, because of its ability to replace energy-hungry production processes with low-cost processes (OECD, 2016b: 21).

Biotechnology includes many techniques and technologies such as genetic engineering, genomics, bioinformatics, synthetic biology, tissue engineering, engineering of proteins and molecules, bioenergy and biofuels. Biotechnology uses science and technology to change the natural characteristics of both living and non-living materials (OECD, 2015: 12). Bio-based materials like plastics and some chemicals have great potential as a new raw material source for many industries. Developing biotechnology aims to increase the quality of human life, even to extend the life span and to strengthen human health.

Biotechnology is used to develop plants, animals and microorganisms through genetics and to obtain new substances. In addition to the production of vaccines, pesticides and medicinal plants for agriculture, the production of genetically modified vegetables and fruits with the desired durability and other characteristics are other innovations provided by biotechnology. Low-cost fuels and environmentally friendly bioplastics and cosmetic products are among the industrial benefits of technology (OECD, 2016a: 101-107).

Synthetic biology is a new area of research in biotechnology that produces new biobased materials using engineering principles to manipulate DNA in organisms (OECD, 2016a: 104). The ultimate goal of synthetic biology is to create new cells and try to reshape living organisms (De Lorenzo and Danchin, 2008: 823). This area allows the redesign of natural biological systems. The three major sub-sectors created by biotechnology: Biological products (biopharmaceuticals), genetically modified products and industrial biotechnology (fuels, enzymes and supplies) sectors (Carlson, 2017: 51). Thanks to synthetic biology, it is possible to produce proteins, hormones, antibodies, vitamins and antibiotics with the desired properties and beneficial for human health. Bio-based batteries, micro-organisms that produce biofuels and artificial photosynthesis are some other recent breakthroughs in biotechnology (OECD, 2016b: 8). Petro-chemistry has a great potential to change production dramatically by offering unique solutions to dependence on oil and other petrochemicals.

The potential created by biotechnology in the field of health is very promising. Personalized medicine, where the treatment is tailored to the individual, not to the general patient profile, will be possible thanks to biotechnology. Personalized medicine can be applied by obtaining detailed information with a person's genomic, transcriptomic, proteomic, metabolomic and microbiomic profile and molecular structure. Cancer treatment is the most common use of personalized medicine. However, there are studies conducted in asthma, cardiovascular diseases, diabetes and autoimmune diseases (Schwab, 2018: 213). Thanks to synthetic biology, patients' immune cells can be reprogrammed to attack cancer cells, immune cells can be made resistant to HIV, for example, and genetic disorders can be prevented from passing on to next generations (OECD, 2016a: 105).

Advances in computational simulation tools, and technics like atomic-force microscopes and X-ray synchrotrons, make it possible to study materials in more detail for scientists (OECD, 2016b: 24). The achievements in the ability to manage material foundations starting from the atomic level will be a solution to the greatest problems of production. This technology, which is known as material science, advanced material technologies and aims to obtain materials with the desired properties on its basis, will affect many technologies closely.

Potentials such as converting waste heat into electrical energy, producing energy without adding additional burden to global warming, making seawater drinkable or producing drugs that repair cell damage with nanorobots are related to materials science (Schwab, 2018: 183-190). Memory metals that can self-repair or clean, return to their original shape and crystals that can transform pressure into energy have emerged thanks to new material technologies (Schwab, 2016: 26).

Smart materials that can be changed in a controlled manner by external factors such as temperature, humidity, electricity, magnetic energy and light or contain additional properties and are the basis of many applications such as polymers, sensors, and artificial muscles (Banger, 2018: 54). Basic properties targeted in new materials; it is lighter, stronger, transformable and adaptable (Schwab, 2016: 26). Developments in advanced materials reduce time to manufacture and cost as well for manufacturers. Furthermore, it allows novel properties which are perfect for the use of that material.

Blockchain, a distributed ledger technology, is another booming technology in production with its many potential applications in production (OECD, 2018: 58). It is still an immature technology, but very promising for the future. *"However, similar to the 'software as a service' model, "blockchain as a service" is already provided by companies such as Microsoft, SAP, Oracle, Hewlett-Packard, Amazon and IBM"* (OECD, 2018: 58). The fundamental characteristic of this technology is its decentralization and it provides an immutable record of transactions. It might be very useful in many significant aspects of production (OECD, 2018: 59):

- Tracking and tracing in supply chains;
- Resource-planning systems;
- Protect intellectual property and help address counterfeiting with end-to-end encryption;
- Store the digital identity of manufactured parts;

- Proof of compliance with warranties, licenses and standards in production, installation and maintenance;
- Induce more efficient utilization of industrial assets;
- Authenticate machine-based data exchanges, implement associated micro-payments;
- Automate supply chains through the digital execution of "smart contracts".

Smart contracts offer the opportunity to create data for programmable records. These data may indicate that certain rules must be met before the transfer takes place, and in this way, a transaction is performed upon fulfilment of certain conditions (OECD, 2016a: 108-109). For example; when rainfall exceeds a certain range, an insurance contract can be made that pays automatically (Schwab, 2018: 124). Blockchain technology allows for transparent, reliable and traceable transactions, including retrospective. It is a distributed database that can be reviewed by anyone, acts as an open, shared and reliable general ledger (OECD, 2016a: 107). The transparency of the records shows that it is suitable for creating digital identities; Potentially, the ability of this technology to be used in health records, voting and similar public services is emerging (Schwab, 2018: 131).

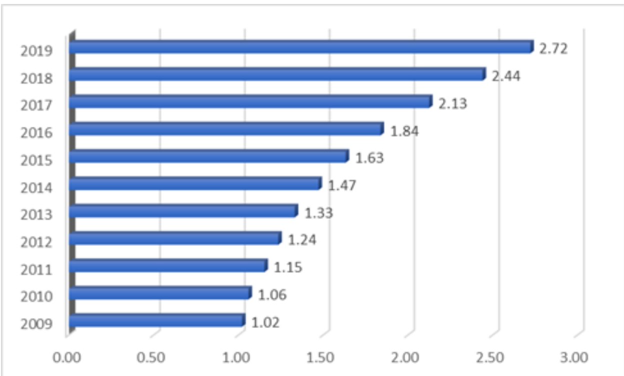
3. THE EFFECTS OF FUTURE TECHNOLOGIES IN PRODUCTION

The nature of production has been transformed in many dimensions both in manufacturing and service sector over recent years. Production is no longer within the borders of the country or city. Neither production nor trade is limited with any borders today. The movement of capital, intermediate inputs, final goods and employers is very obvious over recent decades (Pilat and Nolan, 2016: 118). Technological development allows manufacturers to produce goods and services in different locations and even in different countries. Furthermore, in some cases, different components of the same goods are produced and assembled in different places. The figures for value-added data of OECD indicate the significance of global value chains for international trade and production (Pilat and Nolan, 2016: 118).

The future technologies explained in the previous section, will make a versatile effect on the economy. The next production revolution triggered by these technologies will have a profound impact on employment, skills, environment, inequality, wages, and productivity. In fact, it would not be wrong to accept that these effects have already begun. Key characteristics of future production are complex, rapidly responsive, creative, customized, digital, smart and intelligent, distributed and localized, sustainable and bundling of goods and services (OECD, 2015: 16-18).

According to The International Federation of Robotics (IFR, 2020), the number of industrial robots reached 2.72 million in 2019 (see Figure 2). The number of robots that newly joined the production process last year alone is 375 thousand. The industrial robots replace human workers in smart factories, but that does not mean the robots will leave people unemployed. The first reason for this is the productivity effect of these robots.

Figure 2. Industrial Robots in the Last Decade *million robots



Source: The data is obtained from IFR (2020).

The technology in smart factories significantly boosts productivity and GDP (Gross Domestic Product) as well. Graetz and Michaels (2015) suggest that industrial robots increase labor productivity and added value and contribute approximately 10% to economic growth. Likewise, PWC (2017) finds new technologies could contribute up to 14% to GDP and Digital Europe organization finds these technologies could increase GDP by 6% (DE, 2015).

The effects of new production technologies can affect productivity in many ways (OECD, 2017: 29-30):

- *"The combination of new sensors, control devices, data analytics, cloud computing and the IoT is enabling increasingly intelligent and autonomous machines and systems.*
- *Intelligent systems can almost entirely eliminate errors in some production processes. Among other reasons, this is because sensors allow every item to be monitored, rather than having to test for errors in samples drawn from batches. Machine downtime and repair costs can be greatly reduced when intelligent systems predict maintenance needs. Savings can be had if industrial products can be simulated before being made, and if industrial processes can be simulated before being implemented. Data-driven supply chains greatly speed the time to deliver orders. And digital technologies can allow production to be set to meet actual rather than projected demand, reducing the need to hold inventories and lowering failure rates for new product launches.*
- *By being faster, stronger, more precise and consistent than workers, robots have vastly raised productivity on assembly lines in the automotive industry. They will do so again in an expanding range of sectors and processes as industrial robotics advances.*
- *The mix of industrial biotechnology with state-of-the-art chemistry can increase the efficiency of bioprocesses (most biological processes have low yields).*
- *By printing already-assembled mechanisms, 3D printing could remove the need for assembly in some stages of production.*
- *Progress in materials science and computation will permit a simulation-driven approach to developing new materials. This will reduce time and cost because, in searching for materials with desired qualities, companies will be able to avoid the repetitive analysis of candidate materials and simply build the desired qualities into materials from the start.*
- *Nanotechnology can make plastics electrically conductive. In the automotive industry, this can remove the need for a separate spray painting process for plastics, reducing costs by USD 100 per vehicle."*

Nevertheless, some papers find industrial robots reduce the employment rate (Chiacchio et al., 2018; Acemoglu and Restrepo, 2020). But the compensation mechanisms mainly balance these effects. According to a report of WEF (2020a), by 2025, 85 million jobs might be displaced, while 97 million new jobs could emerge. This means automation process and industrial robots create millions of new jobs due to the rise of productivity with direct and indirect impact in the industries. IFR (2013) finds that the robot industry created 8 to 10 million new jobs worldwide in three years covering 2008-2011.

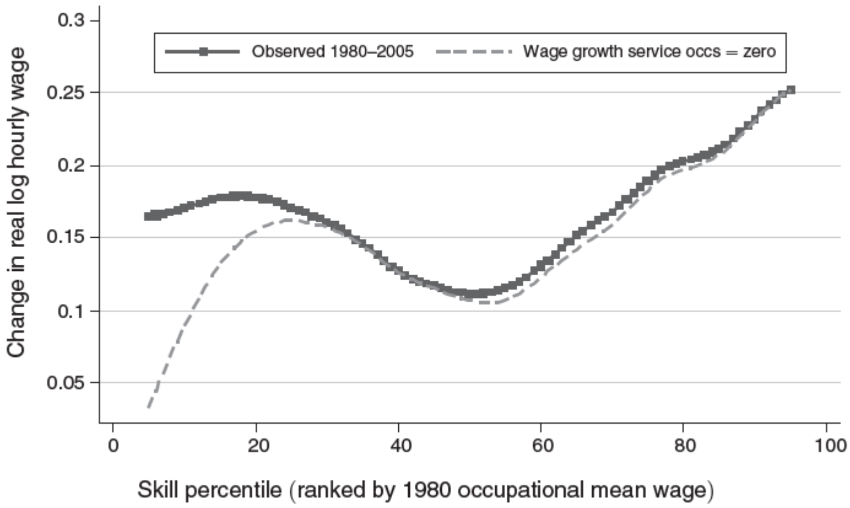
WEF (2017) confirms that estimations and suggests that 133 million new jobs will be created against a loss of 75 million jobs by 2022. Digital Europe report finds a huge potential of automation that could create 400 thousand to 1.5 million new jobs and reduce public expenditures by 15% to 20% (DE, 2015). According to the Boston Consulting Group, automation could increase production speed by 30% and productivity by 25% (BCG, 2015). WEF (2020b) estimates 6.1 million new job opportunities in the next three years.

Technological developments also lead to skill shifts in the industries. The *"Skill-Biased Technological Change"* (SBTC) hypothesis, first developed by Griliches (1969) and Welch (1970) discuss this skill shift in the labor market. The concept of SBTC basically addresses the relationship and complementarity between skilled-labor and technological change and argues that efficient use of technology requires skilled-labor (Haile et al., 2017: 3). Acemoglu and Autor (2010) call the first model of SBTC as a *Canonical Model* which classifies workers as skilled and unskilled workers. The canonical model suggests while the demand for high-skilled workers increases, the demand for low-skilled workers decreases. Hoedemakers (2017: 12) explains this phenomenon by claiming that skilled workers are more capable of adapting to technology.

Following the first canonical model, Autor et al. (2003) propose "*Routine-Biased Technological Change"* (RBTC) hypothesis. The difference between this concept and SBTC is its approaching model. RBTC use task model to analyze the skill shift in the labor market. According to RBTC, the demand for middle-skilled jobs is decreasing, while the demand for both high-skilled and low-skilled jobs are rising. Goos and Manning (2007: 118) call this current phenomenon as *"job polarization"*. SBTC and RBTC are both two trends that cause the rise of inequality (Dachs, 2018: 29).

Despite recession or decline in wages and employment in most of the low-skilled occupations due to job polarization, a significant exception is encountered in the service sector due to growth in low-skilled service occupations (Autor and Dorn, 2013: 1589). In parallel with job polarization, the traces of the wage polarization draw attention with its U shape (see Figure 3). Wage polarization occurs with steep wage growth in the tails and a low wage growth close to the middle.

Figure 3. Observed and Counterfactual Changes in Employment and Hourly Wages 1980–2005



Source: Autor and Dorn (2013: 1557).

Autor and Dorn (2013) find that among noncollege workers, the share of hours worked in service professions rises by more than 50%. According to Autor and Dorn (2013: 1589), an important reason for the polarization and growth in the US employment and wage distributions is the change in the service sector. While machines are complementary for high-educated workers, they are a substitute for workers that work in routine jobs. According to Autor and Dorn (2013: 1590), *"...low-skill workers have reallocated their labor supply to service occupations, which are difficult to automate because they rely heavily on dexterity, flexible interpersonal communication, and direct physical proximity"*.

One of the persistent paradoxes accompanying the rise of wage inequality in industrialized economies after the1980s is the steady decline in real wages of less-educated workers (Autor, 2019: 1). The literature shows that the polarization in the demand for changing skills in the labor market has worse performance for workers in the middle of the wage and skill distribution than those at the bottom and top (Michaels et al., 2010: 20). As a result of wage polarization, employees are directed to jobs below their skill levels, with wages that are either at a lower level or with a slower increase compared to the previously existing medium-skill jobs (Schlogl and Sumner, 2018: 9). The effect of the proliferation of artificial intelligence, which is expected to create the biggest revolution in manufacturing technologies on wages depends on the form of total production relations and the flexibility of substitution between human and robotic labor (DeCanio, 2016: 280).

National initiatives for the next production revolution have proliferated in recent years. Turkey's 2023 Industry and Technology Strategy Document (Digital Turkey Road Map), Germany's Industry 4.0 initiative ("Plattform Industrie 4.0"), the People's Republic of China's Made in China 2025 and Internet Plus initiatives, Japan's Robot Strategy, the National Network for Manufacturing Innovation in the United States are some examples of these initiatives (OECD, 2017: 28).

CONCLUSION

In this paper, emerging technologies of the Fourth Industrial Revolution are discussed in terms of OECD's concept of "The Next Production Revolution". New technologies of this era such as artificial intelligence, additive manufacturing (3D printing), cyber-physical systems, big data, cloud computing, advanced materials, nanotechnology and biotechnology are expected to reshape the entire production process and global value chains. Among these technologies, artificial intelligence, additive manufacturing, biotechnology, nanotechnology, advanced materials and blockchain are the most promising ones for the next production revolution. Advanced robots with AI are more intelligent and autonomous any more. Synthetic biology offers natural solutions to the energy problem and suggests greener production like producing petroleum-based products from sugar-based microbes. 3D printers are more common and allow to build larger objects even a building. Nanotechnology and biotechnology offer new materials which are lighter and stronger. These technologies also provide a significant cost advantage. And the new materials that produced with these technologies could be useful in almost every sector and this could affect all existing industrial sectors. AI is expected to create the biggest revolution in the next production revolution.

The achievements in the ability to manage material foundations starting from the atomic level will be a solution to the greatest problems of production. This technology, which is known as material science, advanced material technologies and aims to obtain materials with the desired properties on its basis, will affect many technologies closely. Thanks to synthetic biology, it is possible to produce proteins, hormones, antibodies, vitamins and antibiotics with the desired properties and beneficial for human health. Petro-chemistry has a great potential to change production dramatically by offering unique solutions to dependence on oil and other petrochemicals. Although blockchain is an immature distributed ledger technology, it has many potential applications in production and very promising for the future.

The nature of production has been transformed in many dimensions both in manufacturing and service sector over recent years. The next production revolution triggered by these technologies will have a profound impact on employment, skills, environment, inequality, wages, and productivity. In fact, it would not be wrong to accept that these effects have already begun. Key characteristics of future production are complex, rapidly responsive, creative, customized, digital, smart and intelligent, distributed and localized, sustainable and bundling of goods and services (OECD, 2015: 16-18).

The technology in smart factories significantly boosts productivity and GDP. Nevertheless, some papers find industrial robots reduce the employment rate. WEF (2017) confirms that estimations and suggests that 133 million new jobs will be created against a loss of 75 million jobs by 2022. Digital Europe report finds a huge potential of automation that could create 400 thousand to 1.5 million new jobs and reduce public expenditures by 15% to 20% (DE, 2015). According to the Boston Consulting Group, automation could increase production speed by 30% and productivity by 25% (BCG, 2015). WEF (2020b) estimates 6.1 million new job opportunities in the next three years.

Technological developments also lead to skill shifts in the industries. The SBTC hypothesis suggests while the demand for high-skilled workers increases, the demand for low-skilled workers decreases. According to RBTC, the demand for middle-skilled jobs is decreasing, while the demand for both high-skilled and low-skilled jobs are rising. This current phenomenon is "job polarization". Wage polarization occurs with steep wage growth in the tails and a low wage growth close to the middle. Autor and Dorn (2013) find that among noncollege workers, the share of hours worked in service professions rises by more than 50%.

National initiatives for the next production revolution have proliferated in recent years. That shows most of the countries are aware of the next production revolution. In most of the policy documents, there is a consensus that artificial intelligence, additive manufacturing (3D printing), cyber-physical systems, big data, cloud computing, advanced materials, nanotechnology and biotechnology will the technologies of the future. In this paper, mostly the benefits of these technologies are discussed. So, the challenges, risk and disadvantages and negative advantages of the technologies in the manufacturing sector can be discussed in the following researches. Policies for managing the next production revolution and government interventions and regulations can be another useful work for the literature.

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