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THE EFFECT OF AUTOMATION AND DIGITALIZATION ON EMPLOYMENT IN EU COUNTRIES

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LIST OF ABBREVIATIONS

EU - European Union
UNIVAC - Universal Automatic Computer
ICT - Information Communication Technology
DESI -Digital Economy and Society Index
R&D - Research and Development
CAGR- Compound annual growth rate
ERP - Enterprise resource planning

INTRODUCTION

"If we continue to develop our technology without wisdom or prudence, our servant may prove to be our executioner."

-Omar Bradley; US army general

Today, few aspects of our daily lives remain untouched by innovations in robotics and information technology as they penetrate numerous aspects of our daily lives and create a new kind of workplace. Accessible communication and the liberalization of information have been the backbone of the information era. According to Nordqvist (2017), the definition of automation is the use of machines to accomplish tasks once performed by human beings or tasks that would otherwise be impossible. The general purpose of this thesis is to find out how the nature of employment has been changed by the continuous and rapid growth of industry 4.0 technologies, specifically in the field of automation and digitization. Limiting the scope of these effects to industries that this change has significantly impacted is crucial. According to Prašnikar, Redek, and Koman (2017), the occupation structure will change significantly; some will become wholly obsolete by automation and digitization, while some aren't expected to be replaced.

In this thesis I provide historical context to waves of automation, which still echo today. I take a macro cross-country approach in deconstructing the pillars of an era dominated by rapid automation and digitalization and how such trends correlate with types of employment. Finally, I attempt to dissect otherwise broad terms of what it means to automate and digitalize within an industry using a set of variables. I will be exploring a range of industries and how automation and digitization have affected the employment rate of industries by analyzing past data. In summary, this thesis will attempt to conceptualize the degree to which new technologies are modifying the labor force in European countries.

My research will center around the following research questions:

- Do higher rates of automation and digitization in the specified industries lead to lower employment in those industries?
- Do higher rates of automation and digitization lower the employment rate of people with elementary education?
- Do higher rates of automation and digitization have a complementary or substitution effect on employment?

The findings of this study may be helpful to researchers and policymakers evaluate what kind of impact automation and digitalization could have on the labor market. Innovation in some fields could have a substituting effect on the labor force, such as advances in robotics allowing increasingly complicated tasks performed by machines. Other innovations could accelerate the demand for labor as entirely new industry sectors are created. The development of this research is aimed to facilitate further understanding of how automation and digitalization distort the labor market

Technological development is a broad term that requires conceptualization to capture its effect across EU countries and industries. These countries include Germany, France, Italy, Spain, and The Netherlands due to their substantial share of GDP to the EU economy and reasonable degrees of heterogeny in economic, geographic, social, and political terms. In order to assess changes in types of employment, research will be presented in specific industries. These industries are chosen because of their sizable employment numbers within a country's economy and somewhat quantifiable way of measuring how inputs are transformed into value, allowing for higher data availability. These include manufacturing, construction, and the accommodation and food service sector.

In the next chapter I discuss the history of automation and digitization through the framework of Industrial Revolutions. The third chapter discusses the research methodology and provides descriptions of our proxy variables used to operationalize automation and digitalization. Finally, the fourth chapter presents our results, which discuss the correlative strength of our variables with employment.

2 HISTORICAL CONTEXT OF AUTOMATION AND SOCIAL CONSEQUENCES

The ability of humankind to create and utilize tools is perhaps one of the most defining aspects of what sets our species apart from the rest of the animal kingdom. Our survival is predicated on our ability to adapt and reshape the harsh environment around us. According to Leakey and Clark (1951), the earliest known human technology is a tear-shaped stone-chopping tool dating back two million years. Despite its primitive nature, the tool's simple shape allowed for chopping branches off trees, scraping meat off the bone, skinning the hide of animals, chopping wood, cracking nuts, and breaking a bone, revealing its nutritious marrow. Additionally, and perhaps most importantly, it was used as a tool to create other such tools, making it a self-propagating instrument.

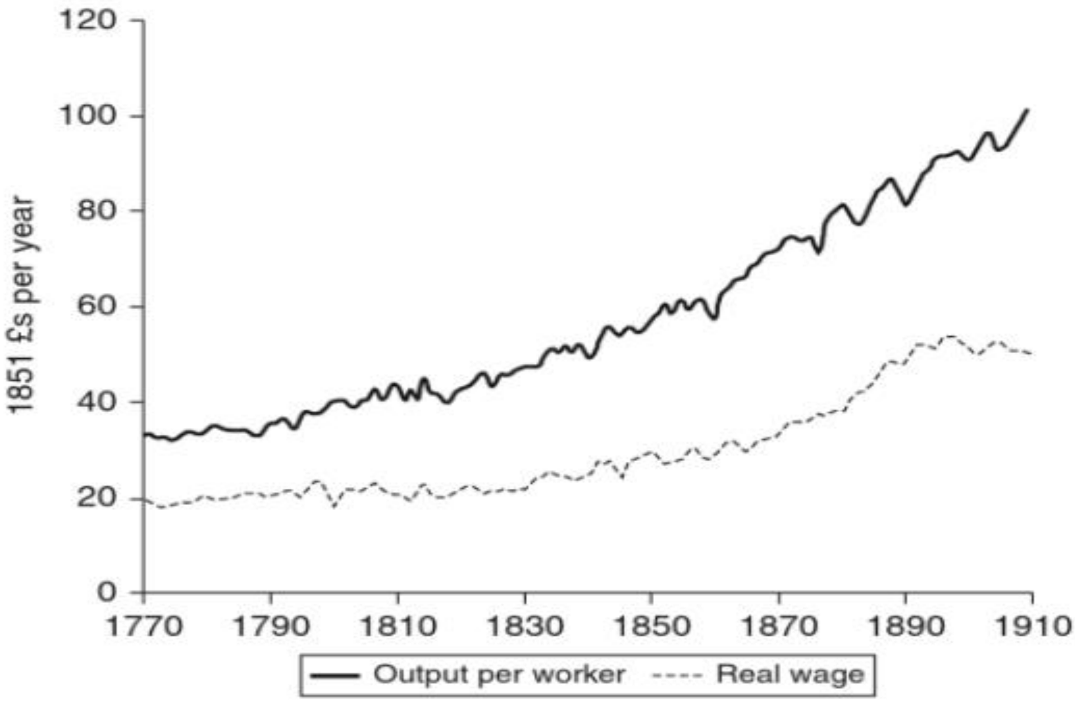
Jumping ahead millions of years to mid-18th century Britain, an unprecedented transformational shift in manufacturing technology led to a revolution in productivity. Incorporating the same ancient principles of leveraging technology for our benefit came the 'First Industrial Revolution.'

During the First Industrial Revolution, a wide range of industries arose. At the time, there were several technical advancements. For example, the Watt steam engine, Cort's puddling and rolling method for manufacturing iron, and Crompton's mule for spinning cotton. The overall factor of production was enhanced as a result of these developments. (Khan, 2008)

A worker using a machine with 100 spindles may spin 100 cotton threads faster than 100 employees operating antiquated spinning wheels.

Britain became known as the "world's workshop" during this period. (Ashton, 1948) Coal kickstarted access to cheap energy, which powered rapidly expanding manufacturing facilities. This led to revolutions in adjacent industries such as transportation, construction, medicine, communication, mining, and textile. Populations in cities skyrocketed as industry and commerce replaced traditional agricultural activity leading to an urban revolution. As shown in Figure 1, between 1770 and 1870, the income per capita doubled, and output per capita nearly tripled. (Allen, 2017)

Figure 1: Growth of Output and Real Wages 1770-1910



Source: Allen (2017).

During the Industrial Revolution, the societies of capitalism and socialism were founded. Capitalism is an economic system in which the manufacturing system relies entirely on the factory owners. It was firmly argued that salaries would be forced down as the population grew.

Adam Smith (1723–1790), a Scottish social philosopher, was the first economist to describe the workings of a modern economy in terms of specialization and labor division, efficient market transactions, and increased productivity. (Timetoast, 2016) He argued for an economic system centered on accessible business, private ownership of industrial assets, and little government intervention. The economy is built on laissez-faire, which promotes free commerce without government intervention. According to this philosophy, factory owners could establish working conditions as they saw fit. As a result, society adopted mercantilism. (Ashton, 1948).

The three political economists Adam Smith (1723–1790), Thomas Malthus (1766–1834), and David Ricardo (1772–1823) mostly backed laissez-faire. (Mohajan, 2019) These three economists opposed the government's initiatives to assist disadvantaged employees. According to Malthus, population growth outpaces food production. Handcrafting was replaced by machines, which allowed the production of larger quantities at a faster rate. According to the principles of supply and demand, when there was a greater production of commodities, their prices decreased, and they became more widely available.

With rapidly expanding population centers, the risk of infectious diseases grew exponentially while medical infrastructure and health laws lagged. In addition, burning coal and expanding populations led to widespread pollution, declining air quality, and environmental degradation. Profit maximization and production amongst factory owners ran rampant, resulting in dangerous and inhumane working conditions. Furthermore, child labor and nonexistent worker rights translated into horrendous living standards for most of the population. (Rafferty, 2017)

Industrialization also allowed for numerous medical advances, resulting in higher average life expectancy rates; however, these gains were not apparent early on. Time and labor-saving inventions allowed for increased professional specializations leading to leaps in expertise and quality of work. However, such rapid development proved to be two-sided. Greater access to food processed with salt and sugar, accompanied by machines displacing physical work, led to increased obesity, heart disease, diabetes, and cancer. With all its advances and drawbacks, it is sure that the first industrial revolution paved the way for the second, third, and fourth.

Technological progress is rarely characterized as an untorn upward-sloping line. Often, significant improvements depend on much more minor, cumulative changes built upon those from the first Industrial Revolution. The Second Industrial Revolution is based on these principles. Inventions identified by this period often do not directly impact levels of productivity or output but rather increase the effectiveness of research and development capability in industrial activity. (Mokyr, 1990)

The Second Industrial Revolution began taking shape in the late 19th century (1870-1914) and is characterized by technological advancements in production and mobility. Automotive, aerial, and naval capabilities expanded our capacity to move people and cargo cheaply and efficiently. The telegraph allowed for instant communication along long distances, which had far-reaching consequences for economic development. Quick information transmission facilitated the rapid expansion of railroads, reduced information costs between and within firms, and hastened the development of commodity and financial markets. It also produced other significant inventions such as the automobile, the airplane, the lightbulb, and the telephone – cornerstones of modern life even today. These new technologies facilitated a shift from traditional fuel methods such as coal superseded by petroleum and electricity. (Roberts, 2015).

The Digital Revolution, which started in the second part of the 20th century, marked a profound change in the technical capacities of humankind. Digitization can be, in its original form, dated back to 1679 with the German polymath Gottfried Wilhelm Leibniz and his development of the binary system. However, the continuous adoption of digital computers that only came to fruition in the 20th century was the catalyst that shifted us from mechanical and analog technologies to digital electronics. This technological leap ushered in the era of the Information age. (Schoenherr, 2004).

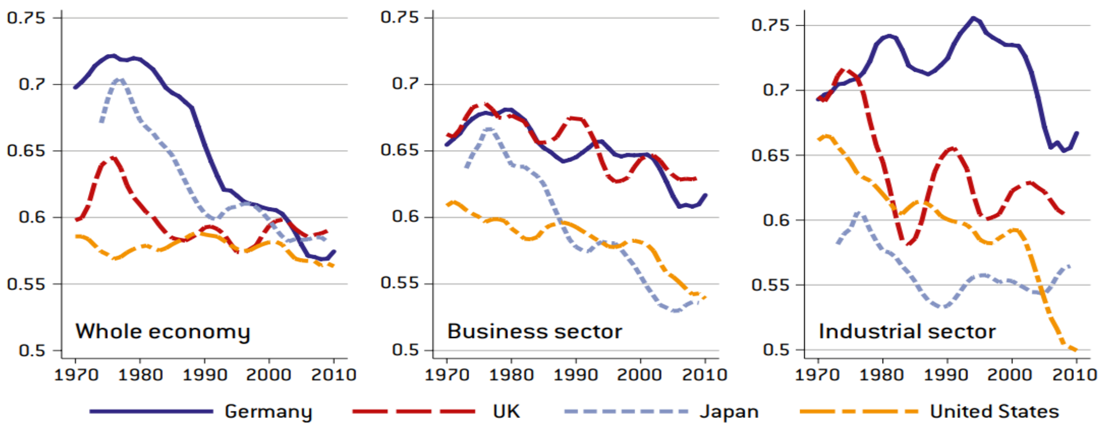
Like previous revolutions, the third industrial revolution is characterized by technological advances in manufacturing, distribution, transport, and energy-related advancements such as the increased adoption of nuclear energy. After the end of World War II, a team of Bell Telephone Laboratories scientists led by Mervin Kelly invented the digital transistor, otherwise known as the “nerve cell” of the Digital Revolution. In the 1950s, as it began to replace vacuum tubes, the transistor was the technological precedent that allowed microprocessors and integrated circuits to become available. The first commercially viable computer, UNIVAC (Universal Automatic Computer), was invented by J. Presper Eckert and John Mauchly in 1951. The UNIVAC, which only allowed for simple arithmetic and was utilized in payroll, is recognized as the ancestor of all of today’s digital technology. With this leap from analog to digital being utilized in a corporate environment, we are, for the first time, able to speak about digitalization in the modern sense.

One of the most significant advancements which characterized the third industrial revolution is the development of the internet. The Advanced Research Projects Agency Network (ARPANET) developed what would become the precursor to today’s modern internet. Although ARPANET was a major success, only a small number of academic and research institutions having contracts with the Defense Department were allowed to participate. As a result, various networks that offer information exchange were developed. (Roberts, 2015) The project was conceived initially as early as 1962 and was originally rejected by the United States Department of Defense. In 1965 the project was rekindled and ultimately implemented in 1969. It was commissioned by the US Air Force and led by researchers at the Massachusetts Institute of Technology and the US Department of Defense. Connected by so-called gateways or today’s routers, a group of computers was run together, with the first data transfer taking place in October 1969 between the Stanford Research Institute and the University of California. (Savio, 2011) The first digitally sent message was meant to say “Login”; due to an unforeseen system crash, the message was received simply as “Lo.” Two years later, computer engineer Ray Tomlinson successfully sent the first email reading “QWERTYUIOP.” Tomilson combined the logic behind the programs named “SNDMSG” and “READ EMAIL,” allowing users to leave messages for each other and created a program called CYPNET, which allowed for file transfers between computers; A discovery that was the precursor to modern email. (Centre for Computing History, 2018) The Economist magazine Markillie (2012) said of the third industrial revolution:

“As manufacturing goes digital, a third great change is now gathering pace. It will allow things to be made economically in much smaller numbers, more flexible and with a much lower input of labor, thanks to new materials, completely new processes such as 3D printing, easy-to-use robots, and new collaborative manufacturing services available online. The wheel is almost coming full circle, turning away from mass manufacturing and towards much more individualized production. And that in turn could bring some of the jobs back to rich countries that long ago lost them to the emerging world. “

Fueled by fast communication and the advent of the Internet, the reliance on physical labor for company output has shifted significantly. As a result, since the early 1980s, the global labor share and the capital ratio have declined precipitously in developed economies. According to OECD (2015), numerous studies have documented the fall in the labor income share since the 1980s. One significant determinant is that shifts determine trends in the labor share from labor-intensive to more capital-intensive sectors, where labor shares are lower.

Figure 2: Share of labor and capital 1970-2010



Source: Breugel (2017).

The stark decline in labor share observed in Figure 2 can be ascribed to a shift away from agriculture into high-value-added industries. The International Labor Organization (2010) found that the shift in sectors was the main contributing factor to lowering labor shares in many countries. However, in advanced economies, most of the decline resulted from falling shares within as opposed to between sectors.

The Fourth Industrial Revolution, like the previous revolutions, has the potential to boost global income levels and increase global living standards for everyone. Most of the benefits have so far gone to consumers who can afford it and access the internet; technology has made it possible for new goods and services that improve our everyday lives. These tasks may now be completed remotely, including ordering a cab, booking a flight, purchasing a product, making a payment, listening to music, viewing a movie, or playing a game. (Schwab, 2016)

Technological progress will lead to a supply-side miracle in the future, with long-term increases in efficiency and productivity. As a result, transportation and communication costs will decrease, logistics and global supply chains will improve, and trade costs will decrease, all of which will open new markets and spur economic growth. (Schwab, 2016)

As with every major leap in technological advancements, the pros accompany the cons. The rapid pace of change and the necessity to adapt, rising cyber hazards that drive us to increase cybersecurity, heavy reliance on technology, and the so-called digital gap, a shortage of skilled workers. In terms of the latter, it is important recalling that one of the Fourth Industrial Revolution's main problems is the severe impact of Industry 4.0 on employment. A McKinsey Global analysis published at the outset of the process predicted that by 2030, up to 800 million jobs would have been lost due to automation. However, this might be an opportunity since as new technology arises, so will new professions, resulting in millions of new opportunities in new industries. (Iberdrola, 2019)

The inventors, stockholders, and investors who supply intellectual and physical capital are the biggest benefactors of innovation, which explains the growing wealth disparity between those who rely on capital and those who rely on labor. Therefore, technology is one of the key reasons why salaries in high-income nations have remained stagnant, if not declined, for most of the population (Schwab, 2016).

Artificial Intelligence is expected to be one of the most important technologies in the transformation of the economy, society, and labor market. According to Kurzweil (2004), Machine intelligence will surpass human intellect within a few decades, ushering in The Singularity, a period of technological advancement that will cause a rift in the course of history. The dizzying speed of growth will undoubtedly produce fundamental shifts in how we view employment in the face of the 'smart industry.' Smart industry can be summarized by the following general-purpose technologies.

Internet of Things

A variety of businesses have undergone radical change as a result of the Internet of Things (IoT), which promises to connect the physical and digital worlds. Today, billions of gadgets are connected and communicating, and the number is growing rapidly. (Iberdrola, 2019)

Cobots

Cobots, which are expressly built to engage physically with humans in collaborative contexts, will be critical to the industry as robotics evolves. They optimize productivity and relieve employees of boring and risky activities. (Iberdrola, 2019)

Big Data

Information is a powerful tool. We will be able to transform data into information thanks to the full-fledged Fourth Industrial Revolution. Big data enables the administration and understanding of large amounts of data for business reasons, which is especially useful for developing corporate plans or making choices. (Iberdrola, 2019)

3D and 4D Printing

With 3D and 4D printing, we can now build prototypes — or sellable goods — fast, correctly, and affordably. In design, architecture, and engineering, this technology is becoming increasingly important. (Iberdrola, 2019)

2.1 Skill Based Technological Change

Rapid technological progress continues and has been a major driving force in reshaping the face of our planet, and how we live and work. However, similarly to the first Industrial Revolution, rapid technological development does not come without its pitfalls. In 1930, the economist John Maynard Keynes foretold the potential and scope of widespread detrimental effects of rapid technological progress. “We are being afflicted with a new disease of which some readers may not have heard the name, but of which they will hear a great deal in the years to come, namely, technological unemployment” (Keynes, 1932). In the early 1950s, the economist Wassily Leontief made a similar claim regarding widespread labor force redundancies. “Labor will become less and less important. More and more workers will be replaced by machines. I do not see that new industries can employ everybody who wants a job” (Leontief, 1952). Although the predictions did not come true in the following decades, the rapid pace of modern technological advances in automation and digitalization have undoubtedly rekindled the concern in labor markets.

It is anticipated that many of the critical transformational forces now influencing global sectors will significantly influence employment, including considerable job displacement and creation, increased labor productivity, and growing skill gaps. Moreover, many of today’s most demanded jobs or specialties did not exist a decade ago, and the pace of this is set to accelerate.

It is essential to realize how incorporating such a rapid pace of automation and digitalization will affect our lives. Some authors believe that employment stagnation and weak employment growth after recessions, especially among the lower and middle-skill workers who are replaced by machinery, are due to technological development. (Graetz & Michaels, 2017) Human jobs that involve intensive routine tasks and are more exposed to automation are more susceptible to being replaced by industry robots. (Schwab, 2017) In most industries, efficiency increases from digitalization are evident in dimensions of revenue generation, improved costs, and better risk management. (Fernández-Olano, Castedo, González, Opitz,

& Pfirsching, 2016) Such profound effects on the processes of companies undoubtedly affect the nature and level of qualification required for employment.

While some ‘traditional’ jobs will be replaced, this cannot be generalized. Namely, the U.S. Bureau of Labor Statistics projects that between 2014 and 2024, most of the projected job openings will be in traditional occupations like salespersons, cashiers, food preparation workers, servers, customer service representatives, laborers and similar. These jobs are also part of the service sector with high technical feasibility, but the mentioned jobs still have projected average growth of two to eight percent per year. For now, these traditional jobs are unlikely to be replaced by new technology; workers will more likely work alongside machines, robots, and digital technology, making their work easier. (U.S. Bureau of Labor Statistics, 2015)

However, while technology has made certain occupations and industries redundant, it has caused a wide array of new occupational fields and complemented human labor, helping workers become more productive. (Spandas, 2016). The rise of robotic manufacturing will bring several difficulties for the EU labor market, including the loss of low-skilled employment and a shortage of highly competent individuals. (Maccrory et al., 2014).

2.2 Societal impact and policy implications of technological progress

Both technology and society are interconnected, interdependent, and interdependent. Technology affects society, including its potential for advancement or decline, for better or worse. Human society and technology have become inextricably linked as technical systems such as mobile phones, computers, television, etc., that are artificial and reflect the basic needs and lifestyles of the population. Although technology has improved people's lives, this remains a serious problem for future generations.

Direct empirical effects of technological progress on society are difficult to present in a generalized framework. For example, according to the (EU Agenda for New Skills and Jobs and Digital Agenda for Europe) the framework of employment creation and the improvement of employment quality through the advancement of Information Technology. The issues that affect how technology and employment interact are discussed below.

2.3 Polarization

The polarization of work into high and low-paid professions to the detriment of medium-paid ones has entered the debate and has been widely reported in contemporary literature. (OECD, 2011) The increased demand for high-skill and high-education level workers compromises the possibility of low-skill individuals with lower degrees of education finding work.

This rapid change may result in more inequality, significantly if technology disrupts labor markets. As automation increasingly replaces labor across the economy, the net displacement of employees by machines may widen the gap between capital and labor returns. On the other hand, the technological displacement of employees may result in a net increase in safe and satisfying occupations. We cannot predict which scenario will emerge at this time, but history shows that it will most likely be a hybrid of the two. It can be assumed; however, that skill and not capital will be the most critical component in future production. As a result, the labor market will become increasingly separated between "low-skill/low-pay" and "high-skill/high-pay" divisions, leading to increased societal conflicts (Schwab, 2016).

The accessibility of high-skill positions will not change into better employment outcomes except if governmental policy frameworks and job-seeking through organizations do not adjust to new requirements. This focuses on one of the issues that the polarization hypothesis raises, namely the mismatch of skills required by the labor market compared to the ability of societies to supply such individuals. Skill mismatches thus stunt the revitalization of labor markets.

The main point of interest is thus quicker schooling and training of the labor force at all employment levels, thus making employees more adaptable to the rapid pace of technological change. Creating a more adaptable workforce that is better prepared for the demand for changing skill sets would curb the effects of polarization in labor markets.

2.4 Rising income inequality

Another issue, firmly connected with the polarization patterns in the European work markets, is the rising pay disparity through weakened wages earned by the lower- and middle-income labor force. No industry remains untouched by substantial productivity gains further magnified by ICT (Information Communication Technology) innovations. However, these gains were not translated into similar gains in real wages. (European Commission, 2011).

Income redistribution through tax systems can prove to alleviate the effect of rising income inequalities. Higher minimum wages, especially in industries where wages lag behind productivity improvements, would increase the participation of low-wage earners in the workforce. However, according to European Commission (2011), the Directorate-General for Employment, Social Affairs, and Inclusion, income redistribution approaches have limitations within most EU countries' current financial and political frameworks.

2.5 Empowering public and private users

Encourage the establishment and structuring of markets for ICT and new ICT-based products, for example, through empowering the public and private ICT users, as another way of integrating supply and demand variables. To reap the benefits of ICT, most citizens must possess the necessary skills to engage in the digital economy. Simultaneously, the importance of focusing education policy on the use of digital technology is underlined. This appears to be a crucial aspect in examining ICT's employment implications since it allows the economic policy to enhance demand for ICT products and services from both public and private end users at home and abroad.

2.6 Restructuring hourly working times

The structural issue of job destruction can be addressed by redistributing current jobs and lowering working time per employee. According to Spiezia and Vivarelli (2000), the evidence of a pattern of job destruction has not progressed into job loss due to the gradual decline in a yearly per capita working hours in four European countries. However, according to the study, if time spent working were used as a metric of employment, some European countries would experience a long-term increase in unemployment. Furthermore, according to the findings of another study by, Fernández-Macías (2012), the majority of EU member states had the highest percentage of long working hours in the wage distribution throughout this period.

Furthermore, the authors point out that, between 1995 and 2005, the quality of work in most European countries improved. While shrinking the workforce can be unproductive if it does not result in job loss, reducing the overall number of hours worked while enhancing the amount and quality of employment and well-being has negative socio-economic repercussions. Furthermore, it advocates political interventions in the form of institutional modifications, such as a progressive reduction in an individual's annual working hours, as has been done in several European countries.

2.7 Imbalances between industries

Despite the increasing number of ICT job openings, Europe has historically struggled to develop an economic structure capable of competing with the United States, Japan, India, and China. This is primarily because non-ICT sectors with lesser employment potential are overrepresented in the sector mix of European industries.

According to Antonucci (2007), data over the last three decades demonstrated that employment in Europe's industrial sector had endured periods of low growth or unemployment. The primary justification was a lack of product innovation and remarkable labor-saving process innovation. (Antonucci & Pianta, 2002; Evangelista & Savona, 2003; Mastrostefano & Pianta, 2009; Vivarelli, Evangelista, & Pianta, 1996). According to various empirical studies that support both incentive and reimbursement schemes, product and process innovation are significant predictors of employment outcomes in ICT. (Garcia, Jaumandreu, & Rodriguez,2004; Harrison., Jaumandreu, Mairesse, & Peters, 2005; van

Reenen, 1997) A fresh viewpoint is provided by the link between product-oriented and process-oriented innovation. Compared to Europe and the United States, this highlights the importance of economic infrastructure and the fact that product-oriented sectors that develop and deploy ICT-based innovations are the primary drivers of employment creation in the medium to long term.

According to various empirical studies that support both reward and reimbursement schemes, product and process innovation are significant predictors of employment outcomes in ICT. (Garcia, Jaumandreu, & Rodriguez, 2004; Harrison, Jaumandreu, Mairesse, & Peters, 2005; van Reenen, 1997) According to empirical research, most real employment increases in Europe are attributable to a growth in the service sector's relative proportion of employment compared to the industrial sector. In the usual approach of using industrial policy instruments like taxes and subsidies to favor one industry over another, this job-creating resource might be combined with the job-creating potential of product innovations spurred by ICT.

3 RESEARCH METHODOLOGY

The methodology incorporated in my research consists of quantitative sources of information. To begin, I will describe my data sample. Then, to test my hypothesis, I will present a set of variables that attempt to operationalize the degree of automation on a per-industry basis for European countries. Due to the recurring nature of this topic, quantitative data is widely available from sources such as the Eurostat and OECD databases; however, it is not yet structured in a manner that would adequately encompass the terms automation and digitization. Furthermore, I will incorporate segments of the European Commission's DESI (Digital Economy and Society Index) into my findings on automation to detect degrees of digitalization in EU countries. DESI's sub-dimensions, such as 'business digitization,' allow further understanding of the nature and intensity of digitalization of enterprises in particular EU countries.

Once the degree of automation and digitization are identified at the industry level, I apply a comparative approach based on calculating correlation coefficients between the growth rates of variables that serve as indicators of rising/falling rates of automation and digitization and the growth rates of employment. I then take the same approach concerning the employment of people with elementary education.

3.1 Research Questions

Incorporating this set of techniques for different industries provides a glimpse into how new digital and automation technologies transform employment. Due to the intricate and multi-faceted nature of employment, this thesis does not attempt to control for all variables that would explain their oscillation across time but to uncover patterns, no matter how subtle, between employment and our variables.

It will attempt to uncover a coherent conclusion, at least in part, to this set of research questions:

- Do higher rates of automation and digitization in the specified industries lead to lower employment in those industries?
- Do higher rates of automation and digitization lower the employment rate of people with elementary education?
- Do higher rates of automation and digitization have a complementary or substitution effect on employment?

To track changes of automation and digitization over time this thesis will analyze the following proxy variables:

- ICT Patents per hundred thousand employed,
- High tech exports in € per employed person,
- Operational robots per hundred thousand employed,
- Digital Economy and Society Index.

Moreover, I would also analyze how higher labor productivity measured by the Labor productivity Index or Value added per thousand employees affect the change in employment rate in general and people with elementary education.

According to Frey and Osborne (2013), a higher degree of industrial automation would reduce the low-skilled workforce and cause a substitution effect in the labor force. In other words, more low-skilled employees would lose their jobs and would thus stress the importance of middle and high-skilled jobs. Incorporating this set of techniques will present critical contributions to this thesis and allow for a conclusion to this set of research questions. The industries covered in this thesis include construction, manufacturing, accommodation, and food service. These particular industries were chosen as they represent roughly a quarter to a third of all employment within our analyzed countries.

Additionally, it is relatively easy, particularly in the construction and manufacturing industries, to measure how inputs are transformed into value-added outputs, which allows for greater data availability from secondary sources. The five countries analyzed (Germany, France, Italy, Spain, and The Netherlands) together represent almost 70% of the total EU's GDP in 2020, according to Eurostat (2021b). Furthermore, the countries mentioned earlier are sufficiently distinct regarding their degrees of digitalization and automation, and thus more robust comparisons can be made. The Netherlands, for example, exhibits some of the highest rates of digitization in the EU. At the same time, Germany has the highest degrees of robotization, and France is a leader in ICT patents per hundred thousand employed. While on the other hand, Spain and Italy are both Mediterranean countries chosen because they do not particularly excel at any of our main variables and will thus provide better insight into employment dynamics when degrees of digitalization and automation are comparatively lower.

3.2 Description of Data and Variables

In an attempt to operationalize the trajectory of automation and digitization in a specific country per industry basis and through the vastest available time scale, I have mapped the variables mentioned in the previous chapter to line charts. The collected data is organized in a time series wholly dependent on data availability; thus, the periods range from 1995 to 2021 and other iterations of this period. This section deals with finding trajectories of given variables to track the intensity of digitization and automation. Every section describes the variable and why it was chosen. It attempts to explain large deviations from the trend line due to significant market disturbances, such as the 2008 financial crash or other effects.

The variables incorporated in the research are described below.

- ICT Patents per hundred thousand employed: Patent indicators represent the innovative performance of countries, regions, technologies, businesses, etc. Therefore, patents are an essential indication of innovation output. (OECD, n.d.). However, it must be noted that it is difficult to define the ambiguous nature of patents that correlate to automation. Therefore, patent data, in this case, must be subject to scrutiny to obtain those most valid in the case of automation; these can fall under several categories.
- High tech exports in € per employed person: Another measure of a country's level of innovation and technological prowess. "These high-tech products are divided into nine groups: aerospace, armament, chemistry, computers-office machines, electrical machinery, electronics-telecommunications, non-electrical machinery, pharmacy, and scientific instruments." (Eurostat, 2016b)
- Operational robots per hundred thousand employed: Number of industrial machines employed per country per person employed
- Labor productivity Index: Calculated as actual output per unit of labor input measured by the total number of hours worked. (Eurostat, 2011)
- Value added per thousand employed: Value added reflects the contribution of labor and capital to production. (Eurostat, 2017)
- Digital Economy and Society Index: Index that summarizes digital performance indicators of EU countries. A dimension of the DESI called the Integration of Digital Technology and its sub-dimensions: Digital intensity, digital technologies for business, and e-commerce will be incorporated. (Directorate-General for Communications Networks, Content and Technology, 2020)

"Employed people are defined as persons aged 15 years and over who during the reference week performed work, even for just one hour a week, for pay, profit or family gain or were not at work but had a job or business from which they were temporarily absent because of, e.g., illness, holidays, industrial dispute and education and training.” (Eurostat, 2016a)

3.2.1 ICT Patents per hundred thousand employed

Patents represent the innovative performance of nations, regions, technologies, enterprises, and other entities, making patents an essential indication of innovation output. They are also used to measure the amount of information dispersion among technical domains, nations, industries, and businesses, as well as the extent of internationalization of creative activities. In addition, patent indicators may assess the R&D production, productivity, structure, and evolution of a particular technology or sector. The link between patents and R&D inputs as an intermediate outcome has been widely studied. Patents are frequently regarded as an output indication; however, patents may also be considered an input indicator since they serve as a source of knowledge for succeeding innovators. (OECD, n.d.)

Patent indicators, like every other indicator, offer several benefits and drawbacks. The following are some of the benefits of patent indicators:

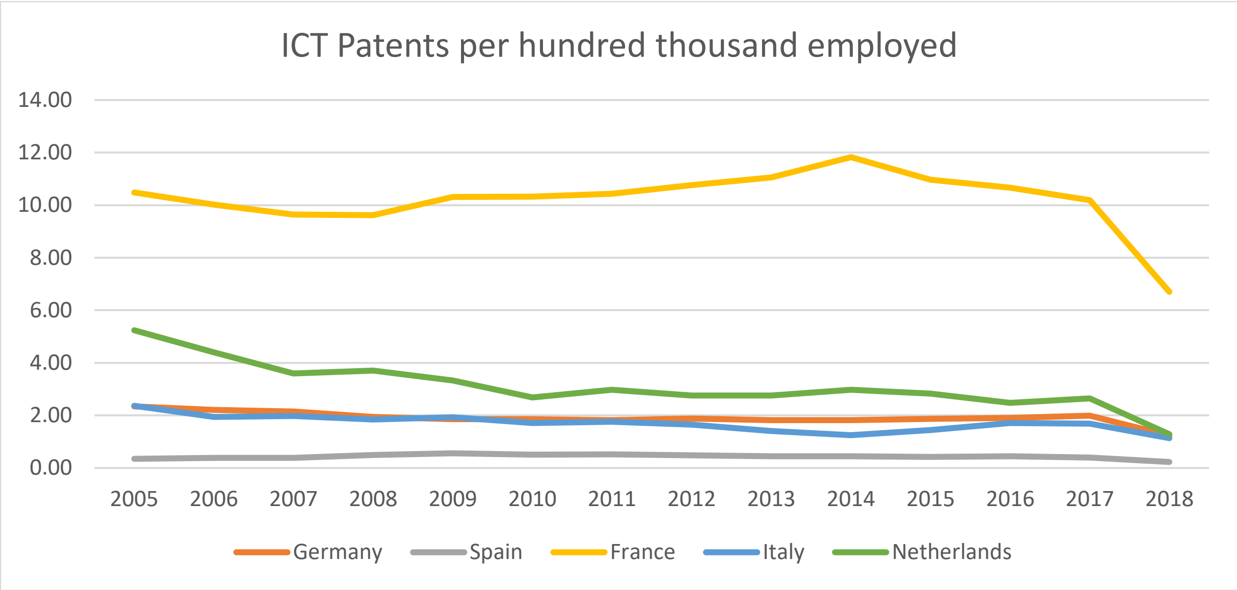
- Patents are closely linked to the invention; patents cover a wide range of technologies for which there are often few other sources of information.
- Patents cover a wide range of technologies for which there are sometimes few other sources of data; patents cover a wide range of technologies for which there are sometimes few other sources of data

On the other hand, patents have several disadvantages:

- The value distribution of patents is skewed because many patents have little industrial application (and so have little societal value), but a few have significant value.
- Many ideas are not patented because they are not patentable or because inventors want to protect their inventions by other means, such as secrecy, lead time, etc.
- The proclivity to patent varies by country and industry.
- Lag times between an issued patent and its industrial application.

Despite the drawbacks, the rate of patents per employed person is considered a valuable proxy to determine a country’s degree of automation and digitization, mainly when the subcategory of particularly ICT patents was chosen.

Figure 3: ICT Patents per hundred thousand employed 2005-2018



Adapted from OECD (n.d.).

We can deduct from Figure 3 a slight downward trend of granted ICT patents per employee. This indicates a 'cooling-off effect in terms of innovation in the field. It should be emphasized, however, that frequently, once a patent is awarded, there is an unforeseen delay before the idea is adopted by a company, an industry, a larger market, or the general public. In real terms, adjusted for hundred thousand employed persons, France is substantially leading the other four countries in patenting for ICT.

According to Figure 3, France in 2018 led the way with 6.70 patents per hundred thousand employed. The Netherlands in 2018 was in second place with 1.28. In 2005 France patented 10.48 patents per hundred thousand employed, while the Netherlands patented 5.24 per hundred thousand employed. This gap between the two countries widened significantly throughout the review period. France's 2-fold lead in 2005 increased to an astounding 5-fold by 2018.

France also exhibited some of the most significant growth from 2008 to peak in 2014, with a 22.89% growth in that period. Spain, Italy, and Germany remained relatively stable with no signs of intense deviation from the trend in the same period. Spain in 2005 exhibited 3.4 patents per hundred thousand employed and fell to 2.3 patents per hundred thousand employed in 2018 while peaking in 2009 with 5.6 per hundred thousand employed. Italy in 2005 exhibited 2.37 per hundred thousand employed, which was also the country's peak, halving to 1.14 per hundred thousand employed in 2018. Germany with 2.34 per hundred thousand employed in 2005 and halving to 1.23 per hundred thousand employed in 2018, with the country's peak also in 2005.

France holds almost 24 times as many ICT patents as Spain in absolute terms and on average from 2005-2018. This dynamic reflects one of the disadvantages of this indicator and its difficulty to compare it between different countries due to different patent laws and institutional barriers. Additionally, according to Llamas (2021), the location of a patent for an innovation, such as a new product, is determined by several variables, including the following:

- What country will the product be made and sold in?
- What are your competition's locations, and what are their primary markets for similar products?
- What are the patenting expenses in each target nation, and how much does it cost?
- How much money is predicted to be made from the product's commercialization in that country?

3.2.2 High tech exports per employed person

High-tech exports are deemed another informative variable in determining a country's trajectory of automation and digitalization. According to Eurostat (2021a), "High-tech products are divided into nine groups: aerospace, armament, chemistry, computers-office machines, electrical machinery, electronics-telecommunications, non-electrical machinery, pharmacy, and scientific instruments." While the industries mentioned earlier cannot be strictly connected with the construction, manufacturing, or service industries, they are a relevant proxy that measures a country's R&D, innovation, and technological prowess in multiple fields.

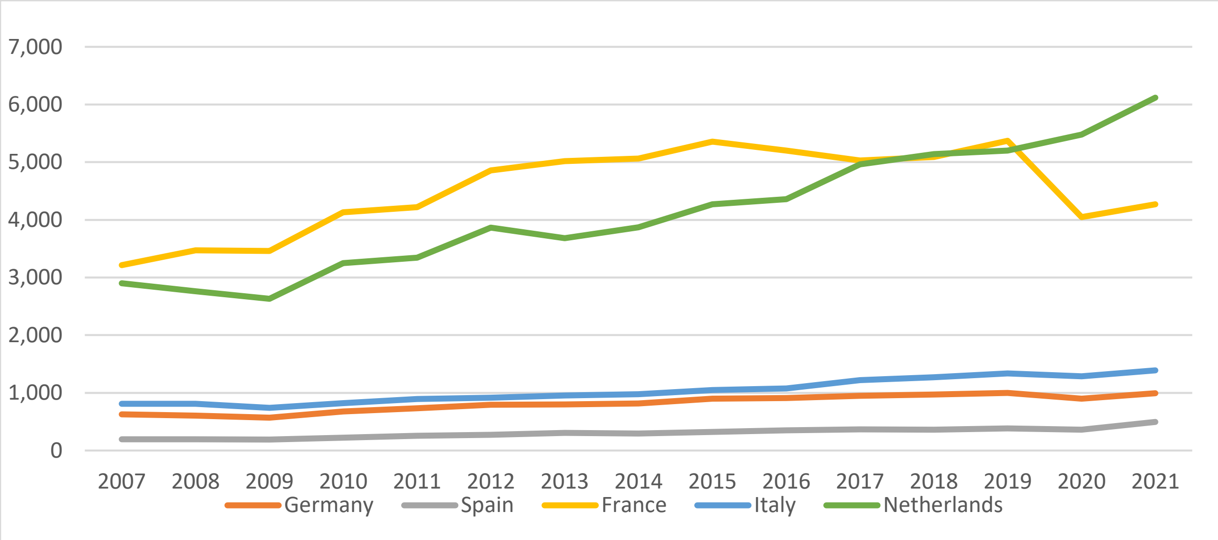
A research paper by Sandu and Ciocanel (2014) explores the correlations between degrees of R&D investment and its effect on high-tech exports in EU countries. Their results were as follows:

- An increase in BERD intensity (R&D expenditure in the business sector as % of GDP) correlates to an increase in medium and high-tech product exports in the same year (as a percent of total products exported). In the short run, a 1% increase in R&D investment in the business sector (as a percent of GDP) leads to a 3.68% increase in high-tech product exports in the same year (as a percent of total goods export).
- With a two-year lag, the intensity of public R&D investment has a beneficial influence on the export of medium and high-tech exports. A 1% increase in R&D Government spending (as a percentage of GDP) positively impacts high-tech exports, with a 5-year lag (lag) and a growth rate of 14.42%. The beneficial effect increases from 14.42% to 16.07% when the latency is increased from 5 to 7 years.

– Increasing the share of employment in knowledge-intensive activities (production and services) in total employment leads to a decrease in the share of medium and high-tech products exported in the short term due in part to the efforts required to integrate, train, and adapt the new workforce to medium and high-tech activities. These efforts may result in a reduction in exports.

The aforementioned establishes a crucial link between R&D and high-tech exports and points out the lag time in medium and high-tech products being ready for export due to an implicit learning curve within the workforce.

Figure 4: High Tech Exports per employed person in the period 2007-2021 (in €)



Adapted from Eurostat. (2008).

Figure 4 points out a stark difference in the value of exports between the Netherlands and France compared to Spain, Italy, and Germany. France, on average, exhibits the highest value exports between 2007-2021 with an average of €4,519.79 per employed person, with Spain having the lowest with an average of €305.05 in millions of € per employed person in the same period. France, on average, exports almost 15 times more high-tech products than Spain. France was leading the way in high-tech exports at the beginning of the review period with €3,214.5 per employed person and ending with €4,269.1 per employed person, with a mere 30% increase in the review period after a drastic 25% drop from 2019 to 2020. Their exports peaked in the year 2015 at €5,355.6 per employed person. The Netherlands began the review period in second place with €2,902.9 per employed person. However, it ended the review period as the highest exporter, doubling its value with €6,118.9 per employed person. In 2008 the Netherlands also achieved peak exports.

Similar to Figure 4, Spain, Italy, and Germany exhibited little deviation from their averages in the review period, with only a slight decline exhibited by all countries in 2009 following the financial crash. Spain exhibited €194.5 per employed person in 2007 and reached €495.7

per employed person, an almost 150% increase in the review period. Italy exhibited an export value of €811 per employed person in 2007 and reached €1,390.4 per employed person in 2021, slightly more than 70% in the review period. Germany exhibited an export value of €628 per employed person in 2007 and reached €992.3 per employed person, a roughly 60% increase in the review period.

Table 1: CAGR of High-Tech Exports 2007-2021

Countries	**CAGR**
Germany	3.10%
Spain	6.44%
France	1.91%
Italy	3.66%
Netherlands	5.10%

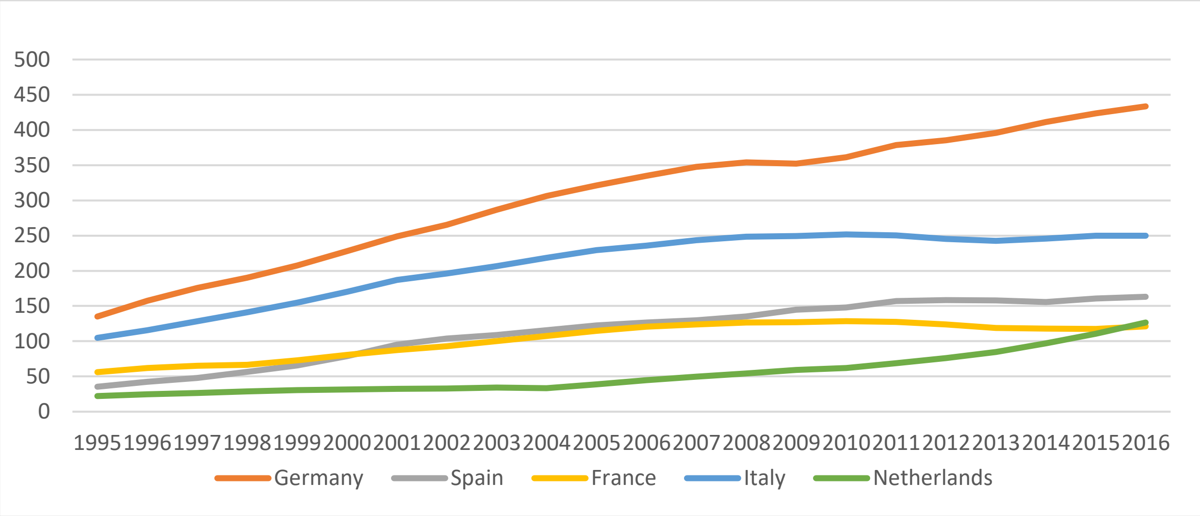
Source: Own work.

Compared to the previous variable of ICT patents per hundred thousand employed persons, the trajectory of high-tech exports, shown in Table 1, exhibits a positive CAGR. Despite Spain having the lowest total exports, it is leading in CAGR with more than triple the rate of France, with Spain exhibiting 6.44% CAGR and France 1.91% in the same period. It is paramount to point out how the bottom three countries of Spain, Italy, and Germany in real export value terms seemingly stagnated concerning export growth relative to France and The Netherlands. However, this does not directly translate into stagnation in the high-tech sectors for the bottom three.

3.2.3 Operational robots per hundred thousand employed

Operational robots per hundred thousand employed stands out as a variable most closely correlates to the general degree of automation in a given country. According to Figure 5, all countries exhibit an evident upward trend from 1995-2016. However, France, Spain, and Italy suggest a relative stagnation in automation in the latter periods from 2008-2016. In relative terms, Germany leads the other countries by a significant margin, even widening the gap as we approach 2016. By the same year, Germany has almost 50% more operational robots than Italy, which is in second place.

Figure 5: Operation Robots per hundred thousand employed 1995-2016



Source: Adapted from International Federation of Robotics (2017).

According to Figure 5, Germany exhibits 135.05 robots per hundred thousand employed in 1995 and 433.50 robots per hundred thousand employed by 2016, indicating a 220% increase between 1995 and 2016. Italy exhibits 104.80 robots per hundred thousand employed at the start of the review period and 249.78 robots per hundred thousand employed by the end of the review period indicating a milder 138% growth. The Netherlands started with 22.15 robots per hundred thousand employed and exhibited strong growth from 2010 onwards, ending the review period with 126.58 robots per hundred thousand employed, with a staggering 470% growth. Spain and France both exhibit relatively similar trajectories up to 2008, with France experiencing a slight topping-off effect in 2008 followed by a period of relative stagnation and even decline as we move further towards the end of the review period. Spain began the review period with 35.44 robots per hundred thousand employed and ended with 163.15 robots per hundred thousand employed, exhibiting a substantial 360% increase. On the other hand, France exhibited a milder 116% growth in the review period, starting with 56.14 robots per hundred thousand employed and ending with 121.10 robots per hundred thousand employed.

Despite being the lowest in relative terms throughout the review period, the Netherlands exhibits the highest CAGR compared with other countries. This points to a higher degree of automation in the country, surpassing France in relative terms in the 22 years. On the other hand, France and Italy exhibited the lowest CAGR in the group, with 3.56% and 4.03%, respectively.

Table 2: CAGR of Operational robots 1995-2016

Country	CAGR
Germany (until 1990 former territory of the FRG)	5.44%
Spain	7.19%
France	3.56%
Italy	4.03%
Netherlands	8.24%

Source: Own work.

It must be noted, however, that a plethora of other market forces is at play in such assumptions. The 2008 financial crash is apparent in the above graph, with slight stagnation periods evident during and up to 2 or 3 years after. While it is difficult to correlate the number of operational robots directly to the level of automation in our analyzed industries, we assume that the trend of operational robots in any given country trickle throughout all industries. Some industries, however, are more directly affected than others.

The boost in productivity that has been witnessed thus far differs by industry. According to Graetz and Michaels (2015), a 2% increase in the number of robots per million hours worked increased productivity by 3% in the construction industry. In contrast, a 2% increase in the number of robots per million hours worked increased productivity by 43 percent in the utility industry.

According to Graetz and Michaels (2015), the impact of industrial robots yielded measurable economic results, concluding that industrial robots enhanced worker productivity and value-added. Their study consisted of a panel of industries from 17 countries between 1993 and 2007. This result held up to various factors, such as nation and industry trends, prior to growth and changes in labor composition and other capital inputs.

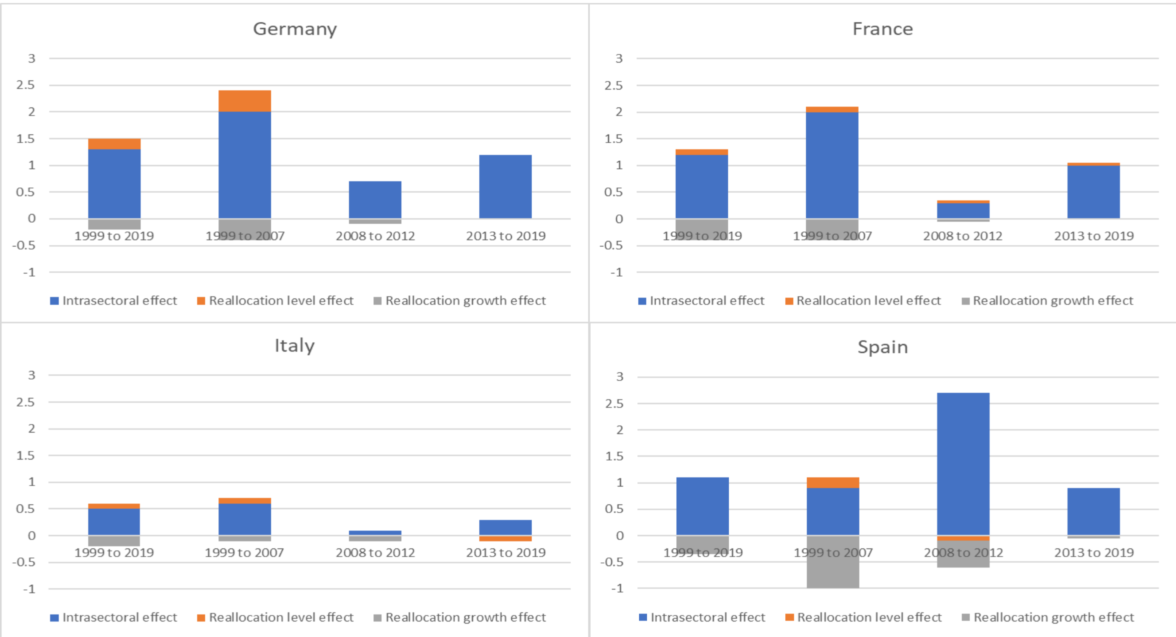
3.2.4 Real Labor Productivity Index

The entire economy's labor productivity is calculated using the price-adjusted gross domestic product and the number of hours worked. Both variables are affected by short-term economic movements that are not always coincidental and can have varying degrees of influence. (Kuntze & Mai, 2020) Labor productivity growth is influenced by three key factors: physical capital saving and investment, new technology, and human capital.

In this section, I will outline a series of factors that impact real productivity growth in the general economy, followed by a more specific approach to the three industries outlined in this thesis. Over the last two decades, the euro area's labor productivity growth has slowed dramatically. This slowdown was widespread across the EU and could be seen in various economic sectors. It can be due to various factors, including a decrease in the productivity growth rates Analyses of the fundamental driving forces reveal cyclical impacts as well as structural variables in particular. (Deutsche Bundesbank, 2021)

There are signs that businesses' ability to innovate and adapt may have deteriorated in some sectors of the economy. Furthermore, inefficiencies in allocating production factors appear to play a more significant role in the productivity decline. Another important influencing factor is demographic changes. The ability of businesses to develop and adapt as a society grows older may be hampered. The fall in labor force growth and the rise in life expectancy can impact company dynamics and hamper aggregate productivity growth. According to an empirical examination of the euro area, population shift has slowed productivity growth. (Deutsche Bundesbank, 2021) The shifting economic structure and the corresponding intersectoral adjustments in production factors can potentially have productivity-dampening impacts. According to a theory by Baumol, Blackman, and Wolff (1985), the proportion of employees working in sectors with relatively low productivity growth suggests a slowdown of company dynamism. However, the workforce in economic sectors with comparatively poor productivity still exhibits positive growth because of consumer preferences.

Figure 6: Average annual change to labor productivity growth in selected EU countries



Adapted from Bundesbank (2021).

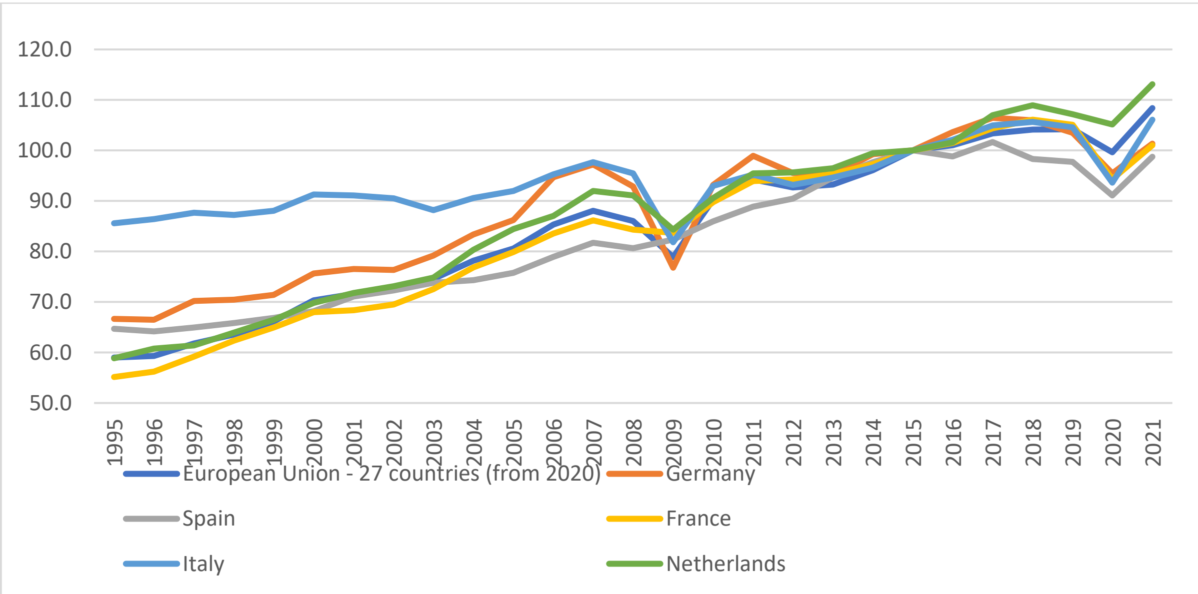
Figure 6 shows to what degree the intersectoral, reallocation level and reallocation growth effect impact the observed countries. Industries considered in Figure 6 are broad but also consider the main three studied in this thesis. They are as follows; Agriculture, Forestry and Fishing, Mining, Manufacturing, Electricity, Gas, Steam and Air, Water Collection, Construction, Wholesale trade, Transportation, Accommodation and food service, Information and communication, and financial activities (their corresponding NACE classifications are B-E, F, G-I, J, K). Breaking down productivity increases into three sub-components demonstrates the impact of this reallocation effect. The contribution to aggregate productivity increase that occurs from a movement in labor input across sectors with different productivity levels is known as the "reallocation level impact." The impact of a change in working hours between sectors with different productivity growth rates is measured by the "reallocation growth effect." Finally, there is also an "intra-sectoral effect," which is measured as the weighted total of productivity increase in the economic sectors under consideration and reflects, among other things, sector-specific productivity growth. When labor input rises (decreases) in regions with positive (negative) productivity growth, the reallocation growth effect causes aggregate hourly productivity to rise. (Deutsche Bundesbank, 2021).

Due to data availability, the following industry sub-chapters are discussed in index terms with 2015=100.

3.2.4.1 Labor productivity index in manufacturing industry

According to Figure 7, the manufacturing industry exhibits a relatively stable slight upward trend throughout the review period. Higher deviations were observed in the first part of the review period (up to 2008) while slowly converging as we move toward the end of the review period in 2021. A noticeable decline was observed during and shortly after the 2008 financial crisis and during the Covid-19 pandemic in 2020. However, Spain, being the exception during the 2008 financial crash, increased labor productivity by 2.1%. Despite the two crises, labor productivity quickly recovered to pre-crash and pre-pandemic levels.

Figure 7: Real labor productivity index per employed person in manufacturing industry 1995-2021



Adapted from Eurostat (2011).

According to Figure 7, Italy exhibited the highest labor productivity per person in 1995, with an index of 85.6 and the lowest standard deviation of 6.56. In 2021 Italy exhibited an index of 106.1. This indicates firm labor productivity in the early review period but fails to establish significant growth as we move toward the end of the review period. The country also exhibits the second-highest drop in labor productivity after Germany's 2008-2009 financial crash, with a decline of -14.28%. Furthermore, it exhibits the most substantial decline of -10.47% during the 2020-2021 pandemic. Germany in 1995 exhibited a labor productivity index of 66.6, falling behind Italy by almost 20 points. However, it exhibited a much higher standard deviation of 13.19, pointing to much more substantial growth as we move toward the end of 2021. The country got hit the hardest during the 2008-2009 financial crash, with the most significant decline of -17.32% in labor productivity from the previous year. A decline much higher than the EU average of -8.33% in the same period.

Spain exhibited a relatively stable upwards trajectory throughout the review period. In 1995 the country exhibited an index of 64.7. The country's growth, however, started to slow and even decline in the period after 2015, with a -0.01% CAGR from 2015-2021. The country's 2021 index is also the only one under 100 in 2021, with labor productivity at 98.8. This indicates a slower recovery than the other countries from the 2020-21 pandemic.

The Netherlands also exhibits a relatively stable upwards growth trajectory throughout the review period. It exhibited a relatively low value of 58.9 in 1995 but up to the highest value of 113.1 in 2021, indicating strong growth in the review period. It also exhibits the highest standard deviation of 16.57, which can indicate solid growth in the review period. The country's -7.44% decline during the 2008 financial crash puts it close to the average decline in real labor productivity of -7.55% amongst the other reviewed countries. Notably, the Netherlands had the mildest labor productivity decline during the 2020-2021 pandemic at -1.94%.

France exhibited the lowest labor productivity index in 1995 with a value of 55.1 but exhibited the second most considerable standard deviation value of 16.18, right after The Netherlands. Despite relatively strong growth in the review period, the country's index remained fourth place at 101 in 2021. However, the country's decline during the 2008-2009 financial crash was relatively low, with a -0.81% decline in labor productivity. While on the other hand exhibited one of the starkest declines of -10.25% during the 2020-2021 pandemic.

According to Table 3, countries exhibit positive upward CAGR in the manufacturing industry, with only the Netherlands having a CAGR rate of 2.45% above that of the European Union average of 2.28%.

Table 3: CAGR of Real labor productivity in Manufacturing industry 1995-2021

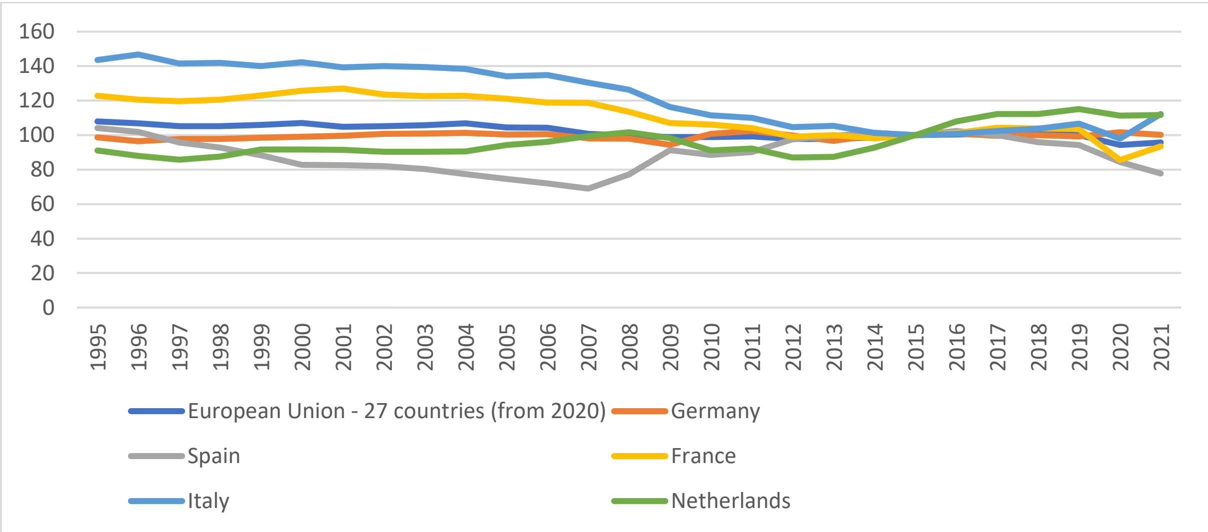
Countries	**CAGR**
Germany	1.56%
Spain	1.58%
France	2.27%
Italy	0.80%
Netherlands	2.45%

Source: Own work.

3.2.4.2 Labor productivity index in construction industry

The real labor productivity index of the construction industry, exhibited in Figure 8, shows a much different trajectory than Figure 7 and Table 3. In this case, most countries, namely Italy, France, and Spain, started in 1995 with a positive index of 100=2015. While the remaining two countries, namely Germany and The Netherlands, started the review period with a negative index. There was a more considerable variance of trajectories during the 2008-2009 financial crash, with labor productivity falling slightly for most countries. In countries such as Spain, labor productivity grew in the same period. While during the 2020-2021 pandemic, Italy's and Germany's labor productivity exhibited growth of 3.2% and 0.44%, respectively. We must bear in mind that the full repercussions of the pandemic may not have yet been fully realized in the construction industry.

Figure 8: Real labor productivity per employed person index in construction industry 1995-2021



Adapted from Eurostat (2011).

According to Figure 8, Italy began the review period in 1995 with the highest labor productivity index at 143.65. In the earlier part of the review period, this value stayed relatively stable until showing signs of slowing down in 2005 and continuing its downward trajectory until a decade later in the index year of 2015, with a noticeably sharper decline of -7.95% during the 2008-2009 financial crash. As we move from 2015 towards the end of the review period, growth is marginal until the 2020 pandemic, where Italy exhibited a relatively sharp decline of -8.11% in labor productivity but a strong uptick of 14.51% the following year. The country manages the review period with the highest labor productivity index, with a value of 112.2.

France also exhibited relatively high labor productivity in 1995, with a value of 122.9. However, similarly to Italy, labor productivity remained relatively stagnant until the 2008-2009 financial crash, where it experienced a relatively sharp downturn of -5.79% from 2007 to 2008. During the latter part of the review period from 2011 to 2020, labor productivity remained relatively stagnant. However, another sharp downtick was exhibited during the pandemic, where it dropped by -17.34% in 2020 and grew by 9.24% in 2021.

Spain's labor productivity is the most volatile, with periods of oscillating growth and decline. The country's labor productivity remained above the index of 100=2015 in 1995 with a value of 104.11. From 1995 to 2007, the country experienced relatively significant declines in labor productivity. Curiously, a year before the 2008-2009 financial crash, the country experienced remarkable growth, which it sustained throughout the crash. Labor productivity grew by a staggering 18.45% from 2008 to 2009. The country peaked in 2016 at 102.4 and sustained a downward trajectory at the end of the review period in 2021, exhibiting the lowest value of 77.85 amongst other countries. Germany's labor productivity remained remarkably stable throughout the review period. In 1995 the country's index was 98.69, and 100.11 in 2021. The country's most significant deviation was observed during the 2008-2009 financial crash, with a decline of -3.68% from 2007 to 2008. Curiously, the country achieved 2.48% growth in labor productivity from 2019-2020, pointing to the industry's resilience during the pandemic. The Netherlands started the review period in 1995 with the lowest labor productivity index of 91.03. The country exhibits relatively consistent growth throughout the review period, ending in second place with a value of 111.65. In the early part of the review period, the country sustained an upward trajectory from 1995 until the 2008-2009 financial crash, with a relatively minor decline of -3.31% from 2007 to 2008. The country's minimum occurred four years later, in 2012, with a value of 86.97. Followed by sharp growth until the 2020 pandemic, exhibiting another relatively minor decline of -3.32% in labor productivity.

According to Table 4 CAGR in the construction industry exhibits relatively low rates of growth or decline among the five countries. In the 27-year review period, The Netherlands exhibited the most robust CAGR of 0.76%, while Spain was the weakest at -1.07%. Only two of our five countries exhibit a CAGR above the European Union value of -0.44%, namely Germany and The Netherlands, with 0.05% and 0.76%, respectively.

Table 4: CAGR of Real labor productivity in Construction industry 1995-2021

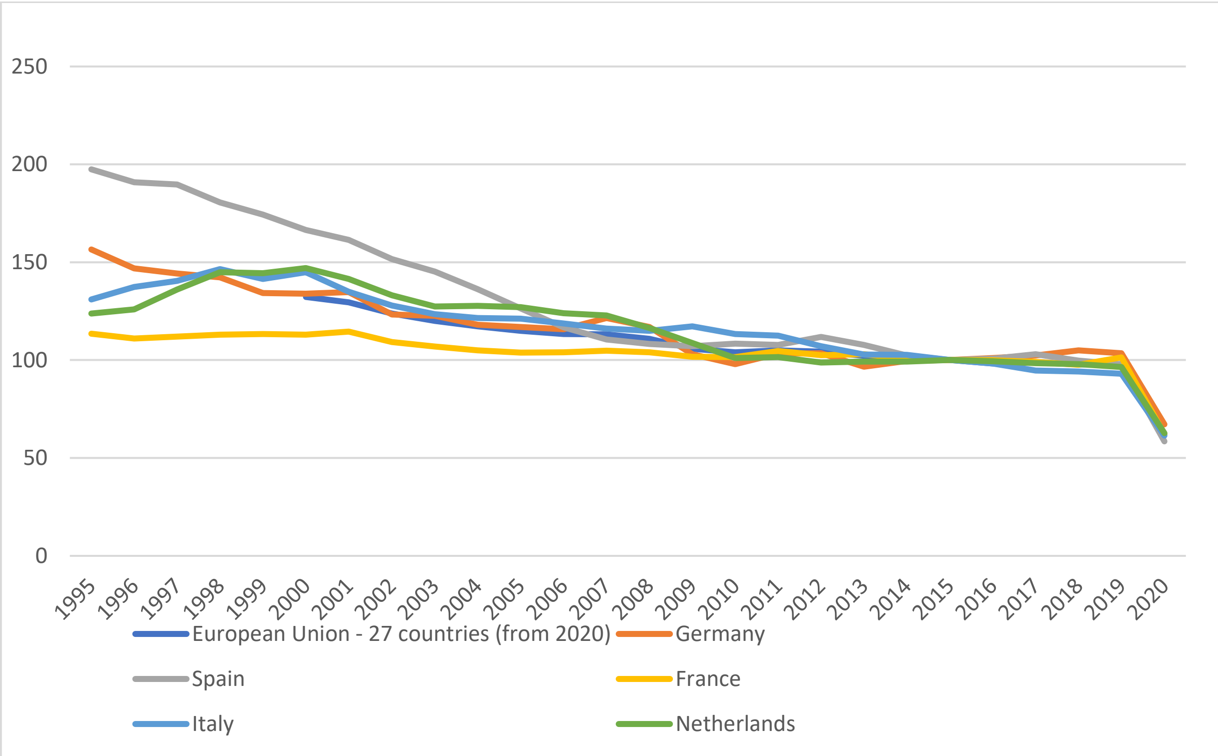
Countries	CAGR
Germany	0.05%
Spain	-1.07%
France	-1.01%
Italy	-0.91%
Netherlands	0.76%

Source: Own work.

3.2.4.3 Labor productivity index in accommodation and food service

If labor productivity in manufacturing (Figure 7) generally exhibited an upward slope and construction (Figure 8) remained relatively flat, the accommodation and food service industry exhibited a stark downward slope throughout the review period. All countries in this thesis started the review period in 1995 with positive indices with 100=2015.

Figure 9: Real labor productivity per employed person index in accommodation and food service industry 1995-2021



Adapted from Eurostat (2011).

According to Figure 9, small shocks were realized during the 2008-2009 financial crash by all countries except Germany, exhibiting a decline of -11.93%. However, the same cannot be said for the 2020 pandemic, where all countries exhibited a sharp downward turn in labor productivity, averaging a decline of -36.57%. This was likely due to the nature of closures and restricted travel during this period, which hit the accommodation and food service industries particularly hard. A period of convergence became noticeable following 2006 when all countries started moving closer to the index year of 2015.

Spain began the review period in 1995 with a substantial lead of labor productivity of 197.47 over the second-place country, Germany. In the early review period, Spain exhibited a relatively stark decline until 2008, when the downward trend became milder. In the latter part of the review period, the country peaked in 2012, exhibiting an index of 111.87. However, the country's sharpest downturn was exhibited during the 2020 pandemic, where its decline of -40.41% was the starkest among the others reviewed. The country finished the review period with the lowest labor productivity of 58.50. Germany's labor productivity started the review period with an index of 156.52 while exhibiting a relatively milder decline than Spain. However, during the 2008-2009 financial crash, the country exhibited some of the most substantial declines of -11.93% while exhibiting relatively high growth two years before the crash. During the review period's latter part, Germany's labor productivity growth remained relatively stagnant. The 2020 pandemic resulted in a decline of -35.09%, which remains below the average decline of -36.57% of the other countries. Germany ended the review period with an index of 67.19, making it the highest performer in 2020. Italy began the review period in third place, exhibiting a labor productivity index of 130.91. In the next three years, Italy exhibits strong growth in the sector, peaking at an index of 146.50 in the year 1998. The country then continues a consistent downward trajectory, with the only year of growth being from 2008 to 2009, with a marginal growth rate of 1.90%. During the 2020 pandemic, labor productivity in Italy exhibited the smallest decline of -34.03% compared with other countries. Italy finishes the review period in fourth place with an index of 61.43. The Netherlands started the review period in 1995 with an index of 123.78. Similar to Italy, The Netherlands began the review period with a period of relatively strong growth, with the peak being in the year 2000 with an index of 147.03. Following its peak, the country exhibited a consistent downward trajectory in labor productivity throughout the review period. In 2020 The Netherlands achieved a relatively small decline of -35.03%. The Netherlands ended the review period in second place with a labor productivity index of 62.69. France began the review period in 1995 in last place with labor productivity with an index value of 113.56. Since then, it began a consistent downward trend throughout the review period. The country achieved its peak of 114.56 a few years later, in 2001. It also exhibited some of the highest decline of -38.61% during the 2020 pandemic. Well above the average of -36.57% exhibited by other countries. France ended the review period in 2020 with an index of 62.29, putting it in third place amongst other countries.

Table 5 provides a clear overview of the negative growth of labor productivity in the accommodation and food service industry. While some of the negative CAGR can be attributed to the sharp downturn in the sector, that dynamic paints only a part of the picture. France exhibited the mildest CAGR of -2.28% in the review period, while Spain exhibited more than double with -4.57%. Germany, Italy, and The Netherlands remain well above the

EU CAGR of -3.53%, exhibiting -3.20%, -2.87%, and -2.58% CAGR in labor productivity, respectively.

Table 5: CAGR of Real labor productivity Accommodation and food service industry 1995-2021

Countries	**CAGR**
Germany	-3.20%
Spain	-4.57%
France	-2.28%
Italy	-2.87%
Netherlands	-2.58%

Source: Own work.

3.2.5 Value Added per Industry

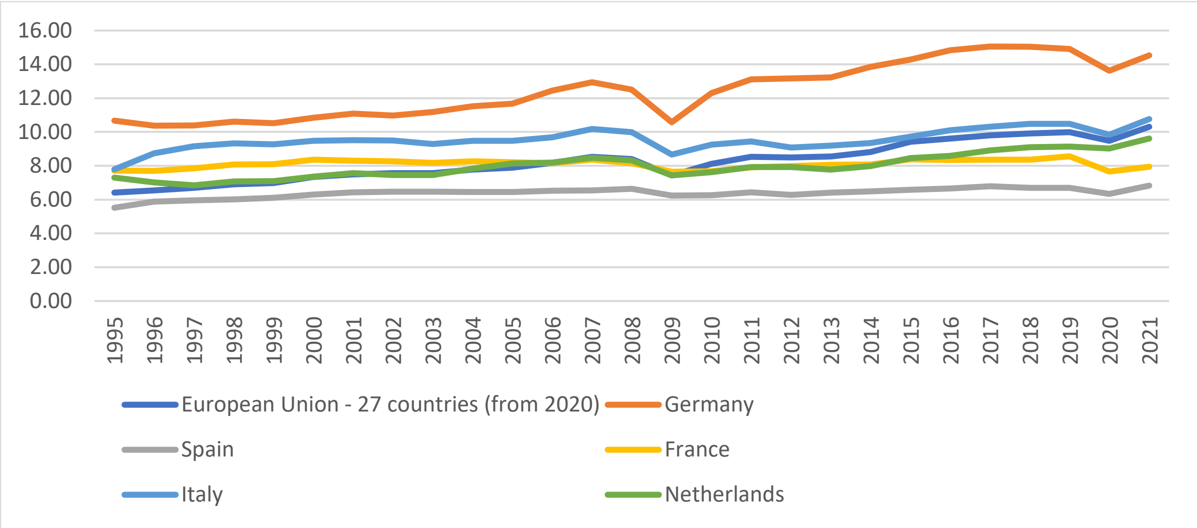
The difference between an industry's gross output (sales or revenues, other operating income, commodity taxes, and inventory change) and the cost of its intermediate inputs (energy, raw materials, semi-finished items, and services obtained from all sources) is known as value-added. Value added happens when a business adds extras to an actual product's value during production or by putting on other goods, offers, and services. When clients are prepared to pay more for the additional output, it is classified as a value-added activity.

In the context of automation and digitization, this indicates the degree of growth or decline within our evaluated industries. The paper by United Nations Industrial Developmental Organization (2019) explores the connection between value-added and robotization. "Growth in the stock of industrial robots among suppliers of an industry that is accumulated along the domestic supply chains. Moreover, growth in the stock of robots in international forward linkages reduces real value-added growth." In our context, we will explore the trajectory of added value per industry in our five countries and attempt to find linkages with the state of employment within those industries.

3.2.5.1 Value Added per thousand employed in manufacturing Industry

Figure 10 depicts similar trajectories of all our countries; relatively weak growth throughout the review period, a sharp drop during the 2008-2009 financial crash, and a milder one following the 2020 pandemic. A correction effect occurred following the financial crash, followed by relatively weak growth until 2014.

Figure 10: Value Added per thousand employed in manufacturing industry 1995-2021



Adapted from Eurostat (2017).

All countries retain their position in value-added terms, except The Netherlands and France; France exhibited a value-added of 7.71 in 1995 and 7.94 in 2021, resulting in a low growth rate of 2.97% throughout this period. The Netherlands exhibited a value-added of 7.31 in 1995, growing strongly to a value of 9.61 by 2021, resulting in a relatively high growth rate of 31.57% in this period. Italy exhibited the highest growth in the review period, starting with a value-added of 7.79 in 1995 and 10.76 in 2021, a 38.19% growth. Germany is also amongst the strongest growth countries. In 1995 it had a value of 10.68, and 14.54 in 2021, a growth of 36.14%. Spain achieved relatively benign 23.73% growth between 1995 and 2021 with a value of 5.52 and 6.83, respectively.

Table 6 depicts CAGR over the 27 years of data availability. Again, all countries exhibited positive CAGR in the review period. However, Spain and France exhibit the lowest growth, 0.79%, and 0.11%, respectively. On the other hand, Italy, Germany, and The Netherlands, France experience higher growth with CAGR values of 1.21%, 1.15%, and 1.02%, respectively.

Table 6: CAGR of Value Added in Manufacturing industry 1995-2021

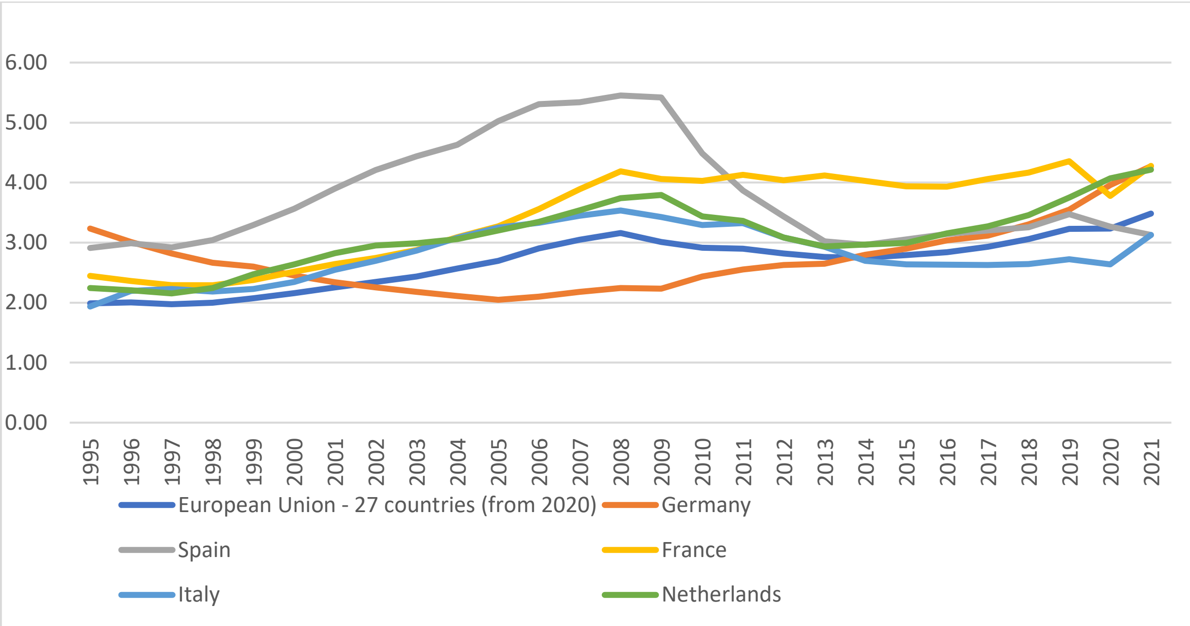
Countries	**CAGR**
Germany	1.15%
Spain	0.79%
France	0.11%
Italy	1.21%
Netherlands	1.02%

Source: Own work.

3.2.5.2 Value Added per thousand employed in construction Industry

Figure 11 depicts value added per thousand employed in the construction industry. Here countries follow very different trend lines compared to the manufacturing industry.

Figure 11: Value Added per thousand employed in construction industry 1995-2021



Adapted from Eurostat (2017).

In 1995 Spain exhibited strong growth of 86.19% from 1995 to 2009, followed by an intense -45.33% decline from 2009 to 2014. The country then stagnated from 2014 until 2021, exhibiting only 2.42% growth. In 2021 Spain exhibited a value of 3.13; a relatively weak growth of 7.41% between 1995 and 2021. Germany exhibited a weak decline between 1995 and 2006; a decline of -35.05% followed by solid growth of 96.25% from 2007 to 2021. Germany exhibited a value of 3.24 in 1995 and increased to 4.27 in 2021, a growth of 32.05%. Italy and The Netherlands follow a similar trajectory from 1995 to 2008. However, Italy began a period of decline from 2008 to 2014, experiencing a stark -23.75% decline, followed by relative stagnation from 2014 to 2020, exhibiting only a -2.21% decline. In 1995 Italy exhibited a value of 1.93, increasing to 3.13, strong growth of 61.64%. On the other hand, The Netherlands exhibited a slightly milder decline from 2008 to 2014 of -20.67%, followed by strong 40.67% growth from 2015 to 2021. The Netherlands began this review period with a value of 2.24 and increased to a value of 4.22 in 2021, strong growth of 87.78%. France follows a growth trajectory from 1995 to 2008, exhibiting strong 71.33% growth. This is then followed by a period of relative stagnation from 2008 to 2019, a growth of only 4.05%. The 2020 pandemic hit the French construction industry the hardest amongst our countries, resulting in a decline of -13.22%, followed by a growth of 13.14% in 2021. France began the review period with a value of 2.44 and ended with a value of 4.28, a substantial increase of 75.03% in the review period.

Table 7 shows our countries' countries' relatively more variable CAGR than the manufacturing industry. All countries exhibited a positive CAGR value but to different intensities. Spain experienced a relatively low growth of 0.27% in our review period, while The Netherlands and France experienced the highest of 2.36% and 2.09%, respectively, between 1995 and 2021. Germany and Italy exhibited relatively mild CAGR values of 1.03% and 1.79%, respectively.

Table 7: CAGR of Value Added per thousand employed in Construction industry 1995-2021

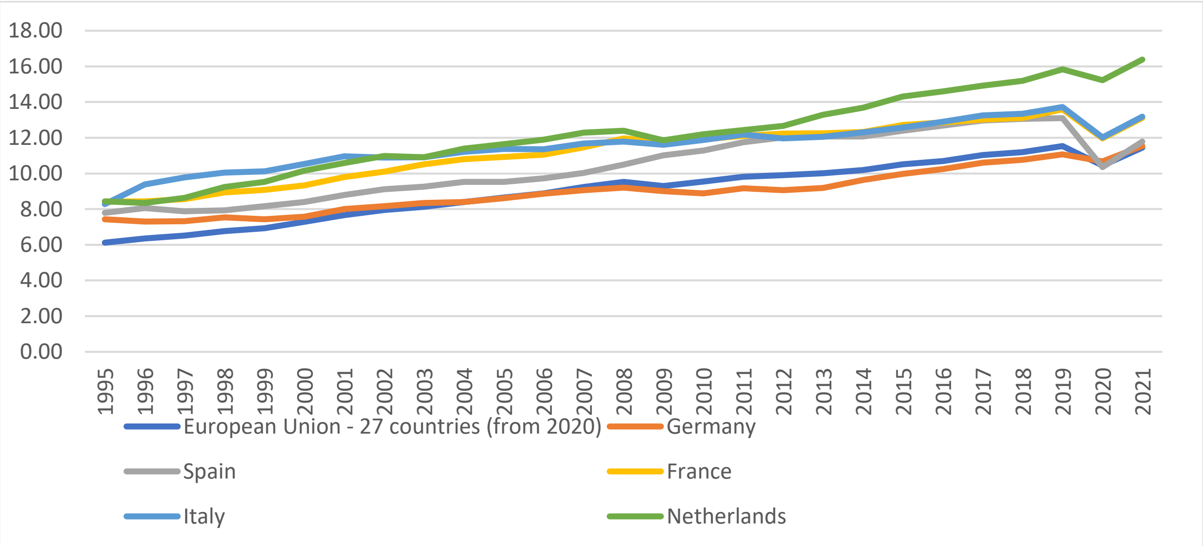
Countries	**CAGR**
Germany	1.03%
Spain	0.27%
France	2.09%
Italy	1.79%
Netherlands	2.36%

Source: Own work.

3.2.5.3 Value Added per thousand employed in Wholesale and retail trade, transport, accommodation, and food service industry

Figure 12 shows the value added per thousand employed in the Wholesale and retail trade, transport, accommodation, and food service industry from 1995 to 2021. Due to the lack of data decoupling from Eurostat, wholesale and retail trade and the transport industry are bundled together with our target industry of accommodation and food service.

Figure 12: Value Added per thousand employed in wholesale and retail trade, transport, accommodation, and food service industry 1995-2021



Adapted from Eurostat (2017).

This industry, in general, exhibits either period of stable yet minimal growth or relative stagnation. For example, the 2008-2009 financial crash caused only minor declines in countries such as France, Germany, Italy, and The Netherlands. In contrast, all countries' declines are the starkest during the 2020 pandemic.

Spain exhibited some of the most robust growth among our countries but suffered the most severe decline of -20.94% during the 2020 pandemic. In 1995 Spain had a value of 7.79, growing by 51.23% to 11.79 in 2021. Germany's growth throughout the review period was relatively mild, with a value of 7.42 in 1995 and increasing by 55.50% to 11.54 in 2021. It must be noted that the country experienced relative stagnation from the financial crash of 2008 to 2013, resulting in a decline of -0.18% in that period. However, Germany exhibited one of the mildest declines during the pandemic, declining by only -3.49% from 2019 to 2020. Italy exhibited relatively strong growth from 1995 to 2001, resulting in a growth of 32.33%. However, this was followed by a relatively mild growth of 25.28% from 2003 to 2020. The country's decline of -12.42% during the pandemic of 2020 was also relatively strong. Italy started the review period with a value of 8.28 in 1995 and ended with a value of 13.18, a growth of 59.23%. The Netherlands exhibited strong growth throughout the 1995-2021 review period, with only a slight decline of -4.47% during the 2008-2009 financial crash and a mild decline of -3.81% during the 2020 pandemic. The country began the review period in 1995 with a value of 8.44 and will almost double to 16.38 in 2021 exhibiting the highest growth of 94.06% amongst our countries.

Similarly, France exhibited a stable upward trajectory throughout our review period, with only a mild -1.53% decline during the 2008-2009 financial crash and a relatively starker decline of -12.03% during the pandemic. In 1995 France exhibited a value of 8.42, which grew to 13.11 in 2021; a growth of 59.23%.

According to Table 8, all countries exhibited positive CAGR values but to different intensities. The Netherlands had the highest CAGR with a value of 2.49%, above the EU value of 2.34%. In comparison, the other countries exhibited relatively homogenous but milder CAGR.

Table 8: CAGR of Value Added per thousand employed in Wholesale and retail trade, transport, accommodation, and food service industries 1995-2021

Countries	**CAGR**
Germany	1.65%
Spain	1.54%
France	1.65%
Italy	1.74%
Netherlands	2.49%

Source: Own work.

3.2.6 DESI Index: Integration of Digital Technology

The Digital Economy and Society Index (DESI) assesses how far EU nations have progressed in their transition to a digital economy and society. As a result, it assembles a collection of pertinent indicators on Europe's present digital policy mix. A dimension of the DESI index, the Integration of Digital Technology, will be central to our analysis of the degree of digitization within our select EU countries. It is comprised of three sub-dimensions; Digital Intensity, Digital technologies for business, and e-commerce. Due to data availability, the index only covers the years from 2016 to 2021. The index is based on Eurostat data and specialized studies and collection methods.

3.2.6.1 Digital Intensity

The Digital Intensity Index is a metric that quantifies how much different digital technologies are used at a company level. A company's score is calculated by analyzing how many of the 12 technologies are employed. Figure 13 depicts the Digital Intensity Index's composition in 2021. It also depicts the degree of penetration and rate of adoption of the various Digital Intensity Index monitored technologies.

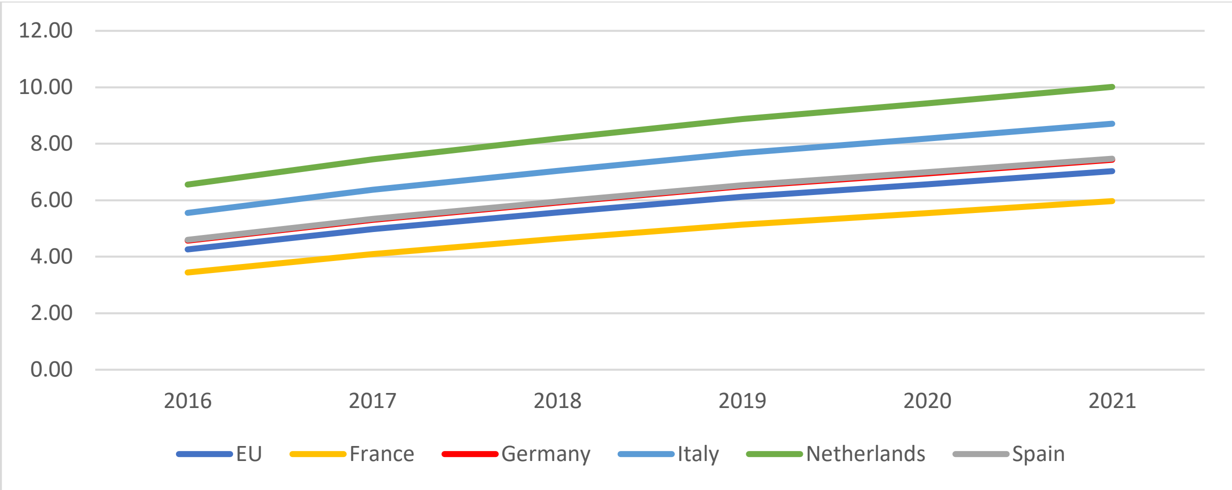
Figure 13: Digital Intensity Composition

Have a website
The maximum contracted download speed of the fastest fixed line internet connection is at 30Mb/s
Website has at least one of: description of goods or services, price lists; possibility for visitors to customize or design online goods or services; tracking or status of orders placed; personalized content in the website for regular/ recurrent visitors
Enterprises where more than 50% of the persons employed used computers with access to the internet for business purposes
Provide more than 20% of the employed persons with a portable device that allows internet connection via mobile telephone networks, for business purposes
E-invoices sent, suitable for automated processing
Buy medium-high CC services
Employ ICT specialists
Enterprises with e-commerce sales of at least 1% turnover
Analyze big data internally from any data source or externally
Use industrial or service robots
Use 3D printing

Source: European Commission (2021).

Digital intensity is measured in Figure 14, which depicts our five countries and their rates from 2016 to 2021. Trajectories of Digital intensity are relatively homogenous, following similar upward trajectories. However, across countries, absolute values vary wildly. In 2016, The Netherlands exhibited the most significant rate of digital intensity, with scores of 6.56, growing to 8.71 in 2021 (growth of 52.73%). Italy, in second place, scored 5.55 in 2016, growing to 8.71 in 2021 (growth of 56.86%). In 2016 Spain exhibited a score of 4.60 growing to 7.47 in 2021 (growth of 62.44%). Germany remains in the middle of digital intensity among our countries, with a score of 4.57 in 2016, growing to 7.43 (62.65%). France is at the bottom of the rate of digital intensity, with a score of 3.44 in 2016 and 5.97 in 2021, exhibiting strong growth of 73.36%.

Figure 14: DESI Dimension - Digital Intensity 2016-2021



Adapted from Directorate-General for Communications Networks, Content and Technology (2020).

According to Table 9, all of our analyzed countries exerted solid and positive growth in our five-year period. France exhibited the highest growth, with a CAGR of 9.6% from 2016 to 2021; the only country with a higher CAGR than the EU's aggregate value of 8.71%. Germany exhibited the second-highest CAGR, followed by Spain, with values of 8.44% and 8.42%, respectively. Italy and The Netherlands exhibited the lowest CAGR among our countries, with values of 7.79% and 7.31%, respectively.

Table 9: CAGR of Digital Intensity 2016-2021

Countries	**CAGR**
Germany	8.44%
Spain	8.42%
France	9.60%
Italy	7.79%
Netherlands	7.31%

Source: Own work.

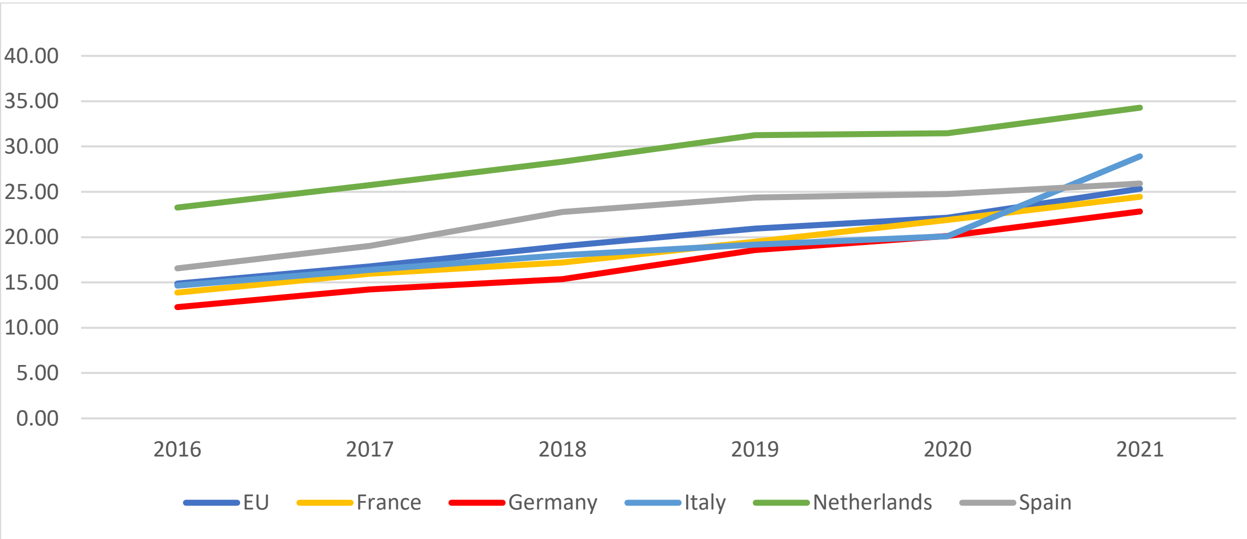
3.2.6.2 Digital Technologies for Business

Our second sub-dimension of the Integration of Digital Technologies Index is Digital technologies for business. According to (European Commission, 2021), large corporations are more inclined to adopt new technology. For example, electronic information exchange via ERP (enterprise resource planning) software is far more utilized in large firms at 80% than in SMEs (small to medium-sized enterprises) at only 35%.

According to Figure 15, this dimension also follows a relatively stable upwards trajectory as we move from 2016 to 2021. All of our countries exhibit relatively stable upward growth from 2016 to 2018. However, countries such as Spain, Italy, and The Netherlands exhibited a period of stagnation from 2018 to 2019. Spain continues this trajectory to 2021, while Italy and The Netherlands exhibit an upward tick from 2020 to 2021. Spain and The Netherlands scored higher than the EU average in the early review period. Italy surges above the EU average following 2020. France and Germany remain below the EU average throughout the review period.

In 2016 The Netherlands exhibited the highest score of 23.26 and ended the review period with a score of 34.28 (growth of 47.37%). Spain follows with a score of 16.56 in 2016 and 25.91 in 2021 (a growth of 56.49%). In 2016 Italy exhibited a score of 14.65, which more than doubled in 2021 with a score of 28.91 (growth of 97.37%). France is in fourth place with a score of 13.88 in 2016 and 24.46 in 2021 (a growth of 76.16%). Germany remains last in the digital technologies for business dimension with a score of 12.28 in 2016 and 22.83 in 2021 (growth of 85.95%).

Figure 15: DESI Dimension – Digital Technologies for Business 2016-2021



Adapted from Directorate-General for Communications Networks, Content and Technology (2020).

According to Table 10, all countries exhibit robust CAGR from 2016 to 2021. Italy and Germany exhibit the most robust CAGR with 12% and 10.89%, respectively. On the other hand, Spain and The Netherlands exhibit the weakest growth of 7.75% and 6.68%, respectively. Finally, France exhibits a moderate CAGR of 9.90% within our review period.

Table 10: CAGR of Digital Technologies for Business

Countries	**CAGR**
Germany	10.89%
Spain	7.75%
France	9.90%
Italy	12.00%
Netherlands	6.68%

Source: Own work.

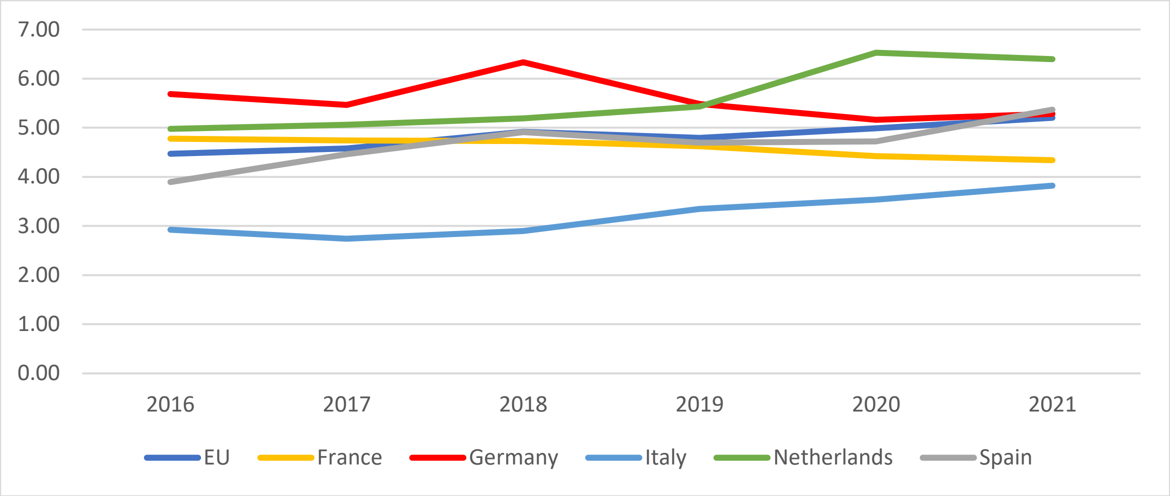
3.2.6.3 E-Commerce

Our final sub-dimension Integration of Digital Technologies Index is E-commerce. According to European Commission (2021), there is a stark divide between large businesses and SMEs within the EU in utilizing e-commerce in daily activities. For example, only 17% percent of SMEs sell online (compared to 39 percent of large businesses), and only 8% sell cross-border internet (24 percent for large enterprises).

According to Figure 16, the e-commerce sub-dimension appears much more volatile in growth (decline) than the previous two. Throughout our review period between 2016 and 2021, several countries change trajectories and their standing. Germany begins the review period in the first place and falls to third place in 2021. France in 2016 exhibited the third largest score and will fall to fourth by 2021. Spain exhibits the highest jump, going from fourth place in 2016 to second in 2021, while Italy consistently remains last.

Germany starts off the review period with a score of 5.69 in 2016 and falls to a score of 5.28 in 2021 (a decline of -7.09%). The Netherlands exhibited a score of 4.98 in 2016 and a score of 6.40 exhibiting strong growth of 28.55% in our review period. In 2016 France exhibited a score of 4.78 in 2016 and fell to 4.34 in 2021 (a decline of -9.16%). Spain exhibited a score of 3.90 in 2016 and grew to 5.37 in 2021 (strong growth of 37.82%). Finally, Italy scored 2.92 in 2016, growing to 3.82 in 2021 (strong growth of 30.74%).

Figure 16: DESI Dimension – E-Commerce 2016-2021



Adapted from Directorate-General for Communications Networks, Content and Technology (2020).

According to Table 11, CAGR varies greatly not only in intensity but trajectory among our countries within the review period. Spain exhibits the highest CAGR of 5.49%, followed by Italy with 4.57% and The Netherlands with 4.28%. Two of our countries, Germany and France, exhibited negative CAGR between 2016 and 2021, with values of -1.22% and -1.59%, respectively.

Table 11: CAGR of E-Commerce 2016-2021

Countries	**CAGR**
Germany	-1.22%
Spain	5.49%
France	-1.59%
Italy	4.57%
Netherlands	4.28%

Source: Own work.

Table 12 shows us the aggregate of all of our CAGR variables throughout our countries. It is clear that most of our variables exhibit an upward trajectory. However, there are some exceptions. The degree of e-commerce in Germany and France, labor productivity in construction in Spain, France and Italy, and finally labor productivity in accommodation exhibit negative CAGR.

Table 12: Summary of our variables with regards to CAGR

Country/Variable	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
Operational Robots	5.44%	7.19%	3.56%	4.03%	8.24%
High-tech exports	3.10%	6.44%	1.91%	3.66%	5.10%
Digital Intensity	8.44%	8.42%	9.60%	7.79%	7.31%
Digital Technologies for business	10.89%	7.75%	9.90%	12.00%	6.68%
E-commerce	-1.22%	5.49%	-1.59%	4.57%	4.28%
Value Added in Manufacturing	1.15%	0.79%	0.11%	1.21%	1.02%
Value Added in Construction	1.03%	0.27%	2.09%	1.79%	2.36%
Value Added in Accommodation	1.65%	1.54%	1.65%	1.74%	2.49%
Real labor productivity in Manufacturing	1.56%	1.58%	2.27%	0.80%	2.45%
Real labor productivity in Construction	0.05%	-1.07%	-1.01%	-0.91%	0.76%
Real labor productivity Accommodation	-3.20%	-4.57%	-2.28%	-2.87%	-2.58%

Source: Own work.

4 RESULTS

The following chapter will present the findings posed by the research questions in the introduction of this thesis. Firstly, do higher rates of automation and digitization in the specified industries lead to lower employment in those industries? Secondly, do higher rates of automation and digitization lower the employment rate of people with elementary education? Lastly, do higher rates of automation and digitization have a complementary or substitution effect on employment? None of our proxy variables exert their effect on employment independently on one another, thus the concept of *ceteris paribus* must incorporated into the subsequent findings.

The numbers in Tables 14-21 were calculated by correlating the growth rates (y/y-1) of our variables with growth rates (y/y-1) of all employment or a specific industry corresponding to the country. The time horizon depended on data availability corresponding to the employment and variable statistics and is seen in Table 13.

Table 13: Time horizons of the CAGR of variables

Variable	**Time Horizon of data availability**
ICT Patents	2005-2018
High-tech Exports	2007-2021
Operational Robots	1995-2016
Labor Productivity	1995-2021
Value Added	1995-2021
Digital Intensity	2016-2021
Digital Technologies for business	2016-2021
E-commerce	2016-2021

Source: Own work.

Figure 18 represents the correlative strength between our variables. The following chapters will frequently reference our findings to this legend.

Figure 18: Legend of correlation strength

Legend
Weak correlation (<0.4, >-0.4)
Moderate correlation (>=0.4 and <=0.7, <=-0.4 and >=-0.7)
Strong correlation (>0.7 and <-0.7)

Source: Own work.

4.1 Research Question 1

The correlations in Tables 14-21 represent the findings of our first research question. It must be noted that the time between innovation represented by patents and their incorporation into the industry often follows a lag time. Our correlations between ICT per hundred thousand employed and employment growth were calculated incorporating five years.

Table 14: Correlations between growth of ICT patents per hundred thousand employed and employment growth rates

Correlated variables/Country	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
All Employment/ICT Patents	0.21	-0.01	0.70	-0.13	0.04
Manufacturing Employment/ICT Patents	-0.50	-0.50	0.48	-0.15	0.44
Construction Employment/ICT Patents	0.06	-0.62	-0.06	0.46	0.20
Accommodation Employment/ICT Patents	-0.45	-0.17	0.37	-0.51	0.06

Source: Own work.

The correlation coefficients in Table 14 show a relatively moderate correlation between growth in ICT Patents per hundred thousand employed and employment levels. France exhibits a strong positive correlation between all employment and the number of ICT patents issued per hundred thousand employed and a moderate positive correlation between employment in manufacturing and our variable. Germany exhibits a moderate negative correlation between manufacturing employment, accommodation and food service employment, and ICT patents per hundred thousand employed. Spain exhibits a moderate negative correlation between manufacturing and construction employment and ICT patents per hundred thousand employed. Italy exhibits a moderate positive correlation between construction employment and a moderate negative correlation between accommodation and food service employment and ICT patents per hundred thousand employed. The Netherlands only exhibits a moderate correlation between manufacturing employment and our variable.

Table 15: Correlations between growth of high-tech exports per employed person and employment growth rates

Correlated variables/Country	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
All Employment/High tech exports	-0.54	-0.58	-0.53	-0.19	-0.30
Manufacturing Employment/High-tech exports	-0.55	-0.48	-0.66	-0.34	-0.30
Construction Employment/High-tech exports	-0.21	-0.25	-0.24	0.21	0.03
Accommodation Employment/High-tech exports	-0.29	-0.74	-0.47	-0.20	-0.36

Source: Own work.

According to Table 15, the correlations are slightly stronger within the variable of growth in high-tech exports in € per employed person and growth in employment. Spain exhibits a strong negative correlation between employment in accommodation and food service and our variable. Germany, Spain, and France exhibit a moderate negative correlation between all types of employment as well as employment in manufacturing and high-tech exports in € per employed person. Additionally, France exhibits a moderate negative correlation between accommodation and food service employment and high-tech exports.

Table 16: Correlations between growth of operational robots per hundred thousand employed and employment growth rates

Correlated variables/Country	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
All Employment/Operational Robots	-0.08	-0.53	-0.26	-0.22	0.48
Manufacturing Employment/Operational Robots	0.69	-0.49	-0.28	0.12	0.57
Construction Employment/Operational Robots	-0.13	-0.59	0.41	0.88	0.35
Accommodation Employment/Operational Robots	0.66	-0.60	0.40	0.20	0.35

Source: Own work.

Similarly, to ICT patents per one hundred thousand, operational robots per hundred thousand employed are subject to a lag between their procurement and reaching total production capacity within the industry. For this study, a one-year lag time was incorporated. According to Table 16, growth in employment and growth in operational robots per hundred thousand employed exhibited stronger correlations with employment levels on average. Germany exhibited a moderate positive correlation between our variable and employment in manufacturing and accommodation and food service. Spain exhibits a moderate negative correlation between all employees and manufacturing, construction, accommodation, and food service employment. France exhibits a moderate positive correlation with employment in construction and the accommodation and food service industry. Italy exhibits a strong positive correlation in the construction industry. The Netherlands exhibited a moderate positive correlation between all employment and employment in the manufacturing industry and operational robots per hundred thousand employed.

Table 17: Correlations between growth of digital intensity employment growth rates

Correlated variables/Country	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
All Employment/Digital Intensity	0.80	0.47	0.24	0.61	0.61
Manufacturing Employment/Digital Intensity	0.73	0.80	-0.08	0.65	0.47
Construction Employment/Digital Intensity	0.18	0.33	-0.86	-0.75	0.55
Accommodation Employment/Digital Intensity	0.80	0.46	0.45	0.77	0.69

Source: Own work.

Table 17 exhibits correlations between growth in digital intensity and employment growth. They exhibit the highest rate of strong correlations among all of our variables. Germany exhibits strong positive correlations between digital intensity and all employment, employment in manufacturing and accommodation, and food service industries. A possible explanation for this lies within Germany's 'Mittelstandsstrategie 4.0', which aims to support the digitization process within German SMEs actively. According to (European Commission, 2019), 63.7% of Germany's workforce is employed in SMEs.

Furthermore, the construction sector accounts for 10.3%, manufacturing for 7.3%, and accommodation and food service for 3.1% of all SMEs, making our reviewed industries a sizable beneficiary of Germany's strategy to digitize (KfW Bankengruppe, 2015). Spain exhibits a strong positive correlation between employment in manufacturing and digital intensity, as well as moderate positive ones between all employees and the accommodation and food service industry. France exhibits a strong negative correlation between our variable and the construction, accommodation, and food service industry. Italy exhibits a strong negative correlation between construction and our variable, as well as a strongly positive one in the accommodation and food service industry. Additionally, Italy exhibits moderate positive correlations between all employment and employment in manufacturing employment and digital intensity. Finally, the Netherlands exhibits a moderate positive correlation between all other employment types and digital intensity. The Netherlands exhibits some of the strongest correlations between all employment types and any of our assessed variables.

Table 18: Correlations between growth of growth of digital technologies for business and employment growth rates

Correlated variables/Country	Germany	Spain	France	Italy	Netherlands
All Employment/Digital Technologies for Business	0.35	0.57	-0.03	0.29	0.97
Manufacturing Employment/Digital Technologies for Business	0.26	0.84	0.10	-0.08	0.68
Construction Employment/Digital Technologies for Business	-0.39	0.60	-0.31	0.86	0.40
Accommodation Employment/Digital Technologies for Business	0.30	0.50	-0.01	0.07	0.94

Source: Own work.

According to Table 18, employment and growth in the digital technologies for business variable show a majority of positive correlations but range widely in strength. Germany exhibits only weak correlations within this variable. In contrast, Spain exhibits strong positive correlations between employment in manufacturing and moderate positive correlations between all employment and employment in construction, and accommodation and food service. Spain thus exhibits some of the strongest correlations between employment and other assessed variables. Italy exhibits a strong correlation between employment in construction and our variables. The Netherlands exhibits a strong positive correlation between all employment and employment in accommodation and food service and a moderate positive correlation in employment within the manufacturing industry and our variable.

Table 19: Correlations between growth of e-commerce and employment growth rates

Correlated variables/Country	Germany	Spain	France	Italy	Netherlands
All Employment/E-Commerce	0.29	0.37	0.74	-0.17	-0.89
Manufacturing Employment/E-Commerce	0.34	0.28	0.04	-0.05	-0.38
Construction Employment/E-Commerce	0.46	0.10	-0.35	0.28	-0.17
Accommodation Employment/E-Commerce	0.28	0.23	0.85	-0.26	-0.78

Source: Own work.

According to Table 19, correlations between growth in e-commerce and employment levels are much like digital intensity polarized in strength. Germany exhibits only a moderate correlation between e-commerce and employment in construction. France exhibits a strong positive correlation between all employment and accommodation and food service employment. Spain and Italy exhibit only weak correlations within this variable. Finally, The Netherlands exhibits a strong negative correlation between all employment and employment in accommodation and food service and e-commerce.

Table 20: Correlations between growth of value added per thousand employed and employment growth rates within specified industries

Correlated variables/Country	Germany	Spain	France	Italy	Netherlands
All Employment/Value Added	0.35	0.63	0.31	0.61	0.44
Manufacturing Employment/Value Added Manufacturing	0.27	0.48	0.31	0.45	0.44
Construction Employment/Value Added Construction	0.33	0.69	0.32	0.79	0.83
Accommodation Employment/Value Added Accommodation	-0.61	0.55	0.72	0.11	0.33

Source: Own work.

According to Table 20, Germany exhibits a moderate negative correlation between employment in the accommodation and food service industry and value-added in accommodation and food service. Spain exhibits a moderate positive correlation between all employment types and all industries with value-added and their corresponding industries. France exhibits a strong positive correlation between employment in accommodation and food service and value-added in the same industry. Italy and The Netherlands both exhibit a strong positive correlation between employment in construction and value-added in construction and a moderate positive correlation between all employment and manufacturing employment and value-added.

Table 21: Correlations between growth of labor productivity and employment growth rates within specified industries

Correlated variables/Country	Germany	Spain	France	Italy	Netherlands
All Employment/Labor Productivity	0.33	0.10	0.79	0.56	0.25
Manufacturing Employment /Labor Productivity Manufacturing	0.13	-0.14	-0.20	0.23	0.07
Construction Employment/Labor Productivity Construction	0.05	-0.70	-0.06	0.49	0.24
Accommodation Employment/Labor Productivity Accommodation	0.95	0.58	0.54	0.72	0.55

Source: Own work.

According to Table 21, all countries exhibit strong or moderate positive correlations between growth in accommodation and food service employment and labor productivity in accommodation and food service. Additionally, Spain exhibits a strong negative correlation between employment in construction and labor productivity in construction, while France exhibits a strong positive correlation between all employment and labor productivity. Finally, Italy exhibits a moderate positive correlation between all employment as well as employment in construction and labor productivity.

4.2 Research Question 2

Table 21 represents the findings for the second research question and exhibits correlations between our variables and elementary-level employment specifically. Within High tech exports, Spain exhibits a moderate negative correlation and Italy a moderate positive correlation between all elementary employment. Regarding operational robots, Spain exhibits a strong negative correlation between elementary employment, and Italy exhibits a moderately positive one. Digital intensity exhibits the strongest correlation between elementary employment Germany and The Netherlands exhibit strong positive correlations between digital intensity and elementary employment, while France and Italy exhibit a moderately positive one. Technologies for business only The Netherlands exhibits a moderate positive correlation. Within e-commerce, Spain exhibits a strong positive correlation between elementary employment, and France exhibits a moderately positive one. According to Table 22, growth in value added per thousand employed, labor productivity in our industries, and growth in elementary employment exhibit weak correlations.

Table 22: Correlations between growth of elementary employment and our variables

Correlated variables/Country	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
All Elementary Employment/ICT Patents	-0.32	-0.31	0.08	0.27	0.25
All Elementary Employment/High-tech exports	0.19	-0.47	0.20	0.56	-0.30
All Elementary Employment/Operational Robots	-0.20	-0.76	-0.33	0.43	-0.20
All Elementary Employment/Digital Intensity	0.94	0.10	0.42	0.46	0.80
All Elementary Employment/Digital Technologies for Business	0.26	0.35	0.18	-0.04	0.53
All Elementary Employment/E-Commerce	0.16	0.73	0.49	-0.12	-0.31
All Elementary Employment/Value Added	0.08	0.35	0.33	-0.13	0.00
All Elementary Employment/Labor Productivity	0.16	0.32	0.39	-0.09	0.04

Source: Own work.

4.3 Research Question 3

Table 23 represents the findings of the third research question and exhibits exclusively strong correlations between growth in all employment, employment in different industries, and our represented variables. A complementary effect in employment appears if the strong correlation between our variables and employment is positive (negative), and the CAGR (Table 12) of the corresponding variable is also positive (negative). Follow the same positive or negative trajectory of the variable and the corresponding variable's CAGR (Table 12). On the other hand, a strong substitution effect appears if the strong correlation between our variables and employment correlations is positive (negative) and the CAGR (Table 12) of the corresponding variable exhibits a negative (positive) correlation. Follow the opposite trajectory of the variable and the CAGR (Table 12) of the corresponding variable.

Table 23: Complementary or substitution effect between digitalization, automatization and all employment, employment in the manufacturing, construction, and accommodation and food service industries

Correlated variables/Country	**Germany**	**Spain**	**France**	**Italy**	**Netherlands**
All Employment/ICT Patents	x	x	0.70	x	x
All Employment/Digital Intensity	0.80	x	x	x	x
All Employment/Digital Technologies for Business	x	x	x	x	0.97
All Employment/E-Commerce	x	x	0.74	x	-0.89
All Employment/Labor Productivity	x	x	0.79	x	x
Manufacturing Employment/Digital Intensity	0.73	0.80	x	x	x
Manufacturing Employment/Digital Technologies for Business	x	0.84	x	x	x
Construction Employment/Operational Robots	x	x	x	0.88	x
Construction Employment/Digital Intensity	x	x	-0.86	-0.75	x
Construction Employment/Digital Technologies for Business	x	x	x	0.86	x
Construction Employment/Value Added Construction	x	x	x	0.79	0.83
Construction Employment/Labor Productivity Construction	x	-0.70	x	x	x
Accommodation Employment/High-tech exports	x	-0.74	x	x	x
Accommodation Employment/Digital Intensity	0.80	x	x	0.77	x
Accommodation Employment/Digital Technologies for Business	x	x	x	x	0.94
Accommodation Employment/E-Commerce	x	x	0.85	x	-0.78
Accommodation Employment/Value Added Accommodation	x	x	0.72	x	x
Accommodation Employment/Labor Productivity Accommodation	0.95	x	x	0.72	x

Source: Own work.

According to Table 23, Germany exhibits a complementary effect between all employment, manufacturing employment, and accommodation and food service employment and digital intensity. A substitution effect for Germany exists between accommodation and food service employment and labor productivity in accommodation and food service. Spain exhibits complementary effects between manufacturing employment and digital intensity and manufacturing employment and digital technologies for business. A complementary effect also exists between construction employment and labor productivity in construction. On the other hand, a substitution effect exists between accommodation and food service employment and high-tech exports. Finally, France exhibits a complementary effect between all employment and ICT patents and all employment and labor productivity.

Additionally, a complementary effect exists between accommodation and food service employment and value-added per thousand employed. At the same time, a substitution effect exists for all employment and e-commerce. Furthermore, France exhibits a substitution effect between construction employment and digital intensity, and accommodation and food service employment and value-added per thousand employed in accommodation and food service. Italy exhibits strong complementary effects within employment in construction and operational robots, digital technologies for business, and value-added per thousand employed in construction. This effect exists between accommodation and food service employment and digital intensity.

On the other hand, Italy exhibits a substitution effect between construction employment and digital intensity, and accommodation and food service employment, and labor productivity in accommodation and food service. Finally, the Netherlands exhibits a complementary effect between all employment, accommodation and food service employment, and digital technologies for business. Additionally, between construction employment and value-added per thousand employed in construction. At the same time, a substitution effect exists between all employment, accommodation and food service employment, and e-commerce.

4.4 Limitations of Master’s thesis

This thesis incorporates a wide-ranging set of assumptions to shed further light on a topic as nuanced as digitalization and automation and its’ effects on employment. Firstly, degrees of automation and digitization are precarious to operationalize due to their broad definitions, particularly on the scale of entire countries. New technologies and innovation have always produced a robust effect on the labor market and the nature of work itself, but never at a speed or breadth like that of our modern societies. Technological progress is a moving target changing at an increasingly rapid pace. For this reason, our set of proxy variables serves but as a handful of stone pieces in a vast and fluid mosaic that is digitization and automation. This thesis attempts to make the case that the variables chosen capture the broadest possible surface of our picture. However, a combination of quantitative and qualitative analysis would have to be conducted to capture a more comprehensive portion of the mosaic. Additionally, data analysis on a micro-scale would have to be incorporated to shed light on our research questions further.

Secondly, a range of assumptions was incorporated when analyzing our variables themselves. Most importantly, our variables are proxies in measuring the degrees of automation and digitization within our selected industries. Some appear more evident in their connection, namely operational robots, and digital intensity, while others, such as high-tech exports and labor productivity, are less so. Additionally, ICT patents per hundred thousand employed and operational robots per hundred thousand employed and their effects on employment include arbitrary lag times between their growth and their effect on employment.

Thirdly, while all of our countries are categorized as developed, highly industrialized European nations, their particularities concerning our topic cannot be considered. Cultural, societal, economic, and political differences play vital roles in employment, automation and digitalization. Such differences were primarily omitted from this thesis due to their arduousness in capturing, particularly from secondary sources.

Lastly, the time horizons of our variables were constrained by their availability from our secondary sources. As such, variables such as digital intensity, or e-commerce, span a relatively short period compared to variables whose data collection began decades ago, such as value-added and labor productivity. This also inevitably leads to inconsistencies in measurement within particular variables over different periods and weakens their degrees of comparability between our countries and industries.

CONCLUSION

This thesis studies the effect that automation and digitalization play in labor markets across various EU countries. To assess today's technological trends, this thesis highlights technologies and their societal effects throughout various waves of automation. These so-called Industrial Revolutions provide context into the scope and scale of technological progress throughout early modern history to today.

We are currently in the fourth industrial revolution. An era where the internet touches almost every aspect of our life. From commuting, working, shopping, socializing, and even dating, we live in an era of hyper-interconnectivity. The cost of communication over long distances has dropped precipitously, allowing for greater efficiency and reach of global supply chains. This has lowered costs and spurred growth in most global economies, particularly developing ones. Ground-breaking technologies discussed in our thesis, such as Artificial Intelligence, The Internet of Things, Cobots, Big Data, and 3D and 4D printing, have entered industry at a dizzying pace and are fundamentally changing our societies. Such game-changing technologies catalyze taking a scrupulous look at their effect on employment. Technological employment was already foretold by economist John Maynard Keynes in 1930 and again by economist Wassily Leontief in the 1950s. Despite their predictions holding little water in the labor markets of their time, the exponential pace of technological progress today catalyzed revisiting their ideas of technological unemployment among contemporary scholars such as Georg Graetz, Guy Michaels, Carl Frey, and Michael Osborne.

The research methodology in this thesis makes the case that the incorporated variables serve as a proxy that indirectly measures the degrees and trajectories of both automation and digitization in our selected countries and industries. Most of our proxy variables exhibit a clear upward growth trajectory in their review periods. These include operational robots per hundred thousand employed, high-tech exports in € per person employed, digital intensity, and value-added per thousand employed. In contrast, others exhibit a downward growth trajectory. These include ICT patents per hundred thousand employed, e-commerce (in the case of France and Germany), real labor productivity per employed person in construction (in the case of Spain, France, and Italy), and accommodation and food service. These were then correlated with employment rates in their corresponding country and industry, which yielded mixed findings varying vastly on a country and industry basis in correlative strength.

Despite the limitation mentioned earlier in our thesis, curious patterns have emerged within our research. Our first research question reveals that some of the most robust correlations exist between digital intensity and employment growth rates in all industries within Germany and The Netherlands (except construction employment in Germany) *ceteris paribus*. Digital Intensity also exhibits positive correlations among our countries' accommodation and food service sectors. Furthermore, Spain and The Netherlands exhibit clear positive correlations between digital technologies for business and all employment and employment within all industries (except construction employment in The Netherlands) *ceteris paribus*. Spain, Italy, and The Netherlands exhibit clear positive correlations between value added per thousand employed and all employment and employment in our industries (except the accommodation and food service sector in Italy and The Netherlands) *ceteris paribus*. Additionally, clear positive correlations exist between labor productivity and employment in our countries' accommodation and food service industries *ceteris paribus*.

The most consistent correlations within our second research question exist between all elementary employment and digital intensity in all countries, with Spain being the exception. This indicates that higher degrees of digital intensity may positively affect elementary employment *ceteris paribus*. We consider that most of our correlations between our variables and elementary employment exhibit weak correlative strength, indicating a weak link between degrees of automation and digitization and elementary employment. Our third research question reveals that 16 of our 25 strong correlations exhibit a complementary effect between our variables and employment, while the remaining nine exhibits a substitution effect. This hints that higher degrees of automation and digitization provide more employment opportunities than are displaced *ceteris paribus*.

The decades ahead will undoubtedly mark a turning point in human civilization. It will show us concrete examples of how technological advancement and human evolution are related to whether the alleged wave of automation will indeed replace roughly half of our employment (Frey & Osborne, 2013). Whether artificial intelligence will exist in 2045, having achieved the maximum degree of human intellect (Kurzweil, 2004). Above all, it will likely produce a world with unparalleled plenty and a planet with compelling technologies. Because of this, humans need to discuss and consider how to advance alongside technology in a way that will benefit us rather than turn them into our executioners.

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APPENDIX

Appendix 1: Povzetek (Summary in Slovenian Language)

Magistrsko delo obravnava vpliv avtomatizacije in digitalizacije na trge dela v nekaterih državah EU. Tehnološki razvoj je širok pojem, ki ga je treba natančno opredeliti, da bi zajeli njegov učinek v določenih panogah v državah EU. Za svojo analizo sem izbral Nemčijo, Francijo, Italijo, Španijo in Nizozemsko zaradi njihovega znatnega deleža BDP v gospodarstvu EU ter občutne stopnje heterogenosti v gospodarskem, geografskem, socialnem in političnem smislu. Da bi ocenili spremembe v zaposlovanju, so predstavljene raziskave v posameznih panogah, ki so izbrane zaradi velikega števila zaposlenih v gospodarstvu omenjenih države in ker pretvarjajo industrijske vložke v dodano vrednost na merljiv način. Obravnavane panoge so predelovalna industrija, gradbeništvo in gostinstvo ter hotelirstvo.

Skozi delo smo se podali skozi naslednja raziskovalna vprašanja; Ali višja stopnja avtomatizacije in digitalizacije v določenih panogah vodi k manjši zaposlenosti v teh panogah? Ali višja stopnja avtomatizacije in digitalizacije znižuje stopnjo zaposlenosti oseb z osnovnošolsko izobrazbo? Ali imata višja stopnja avtomatizacije in digitalizacije komplementarni ali substitucijski učinek na zaposlovanje?

Da bi ocenili današnje tehnološke trende, so v tej analizi poudarjene tehnologije in njihovi družbeni učinki v različnih obdobjih avtomatizacije. Te 'industrijske revolucije' omogočajo razumevanje razsežnosti tehnološkega napredka od zgodnje moderne zgodovine ob koncu 18. stoletja do danes.

Trenutno živimo v četrti industrijski revoluciji. V tem obdobju se je internet razširil na domala vsa področja družbenega življenja. Stroški komuniciranja na dolge razdalje so se strmo znižali, kar omogoča večjo učinkovitost in doseganje globalnih dobavnih verig. Takšne tehnologije, ki spreminjajo pravila igre, so razlog za natančen pregled njihovega vpliva na zaposlovanje. Revolucionarne tehnologije, o katerih razpravljamo v delu, kot so umetna inteligenca, internet stvari, koboti, big data, ter 3D in 4D tiskanje, so v industrijo vstopile z vrtoglavo hitrostjo in temeljito spreminjajo našo družbo.

Raziskovalna metodologija v tezi dokazuje, da vključene spremenljivke dejansko služijo kot približek, ki posredno meri stopnje in krivulje avtomatizacije in digitalizacije v izbranih državah in panogah. Večina približnih spremenljivk ima v obravnavanih obdobjih jasen trend rasti. Te vključujejo število operativnih robotov na sto tisoč zaposlenih, visokotehnološki izvoz v evrih na zaposlenega, digitalno intenzivnost in dodano vrednost na tisoč zaposlenih.

Pri drugih proxy spremenljivkah pa je opaziti padajočo dinamiko rasti. Te vključujejo patente IKT na sto tisoč zaposlenih, elektronsko poslovanje (primer Francije in Nemčije), realno produktivnost dela na zaposlenega v gradbeništvu (primeru Španije, Francije in Italije) in nastanitvenih ter gostinskih storitvah. Nato smo jih povezali s stopnjami zaposlenosti v določeni državi in panogi, tako pridobljeni rezultati, pa se glede na obravnavano državo in panogo močno razlikujejo v korelacijski moči.

Kljub omejenosti raziskave so se v njej pojavili pomenljivi vzorci. Prvo raziskovalno vprašanje razkriva, da obstajajo nekatere jasne in nazorne korelacije med digitalno intenzivnostjo in stopnjami rasti zaposlenosti v vseh panogah v Nemčiji in na Nizozemskem (z izjemo zaposlovanja v gradbeništvu v Nemčiji). Digitalna intenzivnost je pozitivno povezana tudi z obravnavanimi državami nastanitvenem in gostinskem sektorju. Poleg tega sta Španija in Nizozemska pokazali jasno pozitivno korelacijo med digitalnimi tehnologijami za poslovanje in vsemi zaposlenimi ter zaposlenostjo v vseh navedenih panogah (razen zaposlenosti v gradbeništvu na Nizozemskem). V Španiji, Italiji in na Nizozemskem so opazne jasne pozitivne korelacije med dodano vrednostjo na tisoč zaposlenih ter vsemi zaposlenimi ter zaposlenostjo v obravnavanih panogah (razen v nastanitvenem in gostinskem sektorju v Italiji in na Nizozemskem). Poleg tega v omenjenih državah obstajajo jasne pozitivne korelacije med produktivnostjo dela in zaposlenostjo v nastanitvenih in gostinskih dejavnostih.

V okviru našega drugega raziskovalnega vprašanja obstajajo najbolj dosledne korelacije med vsemi osnovnimi zaposlitvami in digitalno intenzivnostjo v vseh naštetih državah, z izjemo Španije. To kaže, da ima višja stopnja digitalne intenzivnosti lahko pozitiven učinek na zaposlovanje delavcev z osnovnošolsko izobrazbo. Glede na to, da ima večina korelacij med navedenimi spremenljivkami in osnovnošolskim zaposlovanjem šibko korelacijsko moč, kaže, da obstaja razmeroma šibka povezava med stopnjo avtomatizacije in digitalizacije ter zaposlovanjem delavcev z osnovnošolsko izobrazbo.

Naše tretje raziskovalno vprašanje razkriva, da 16 od 25 močnih korelacij kaže komplementarni učinek med spremenljivkami in zaposlovanjem, medtem ko preostalih 9 kaže substitucijski učinek. To pomeni, da višja stopnja avtomatizacije in digitalizacije zagotavlja več zaposlitvenih možnosti, kot pa je izgubljenih.

Prihodnja desetletja bodo nedvomno pomenila prelomnico v razvoju civilizacije. Prikazal nam bo konkretnejša razmerja med tehnološkim napredkoma in družbeno evolucijo. Zato je za nas nujno, da se pogovarjamo in razmišljamo o tem, kako napredovati skupaj s tehnologijo in sicer na način, da bo le-ta koristila človeštvu, ne pa da bo postajala naš krvnik.