Aalto University
School of Business

Digitalization and Work Life: How new technologies are changing task content and skill demand for five selected occupations.

Economics

Master's thesis

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Abstract of master's thesis

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Objective of the Study

The objective of this study is to understand how digitalization and new technologies are changing task content and skill demand for five selected occupations: business managers, technology innovators, higher education teachers, healthcare professionals and cybersecurity experts. The aim is to study how the productivity of the work of these occupations can be increased by realizing the benefits offered by digitalization. Consequently, this study examines the future division of work between humans and computers and provides recommendations on the required skills and changes in the nature of work that will be increasingly in demand in the near future due to the changes induced by digitalization.

Methodology and Theoretical Framework

In this study a theoretical framework based on the bottlenecks to computerization was used to predict future skill demand for the occupations under study. The research was conducted using qualitative multiple case study approach in which each occupation represents one case. The data for the study was collected using semi-constructed interviews with representatives of each of the occupations. There were altogether 26 interviews which were analyzed using theoretical propositions and cross-case comparisons between the different occupations.

Findings and Conclusions

The main findings of this study indicate that despite of technological advancements, in the occupations under study humans still have a comparative advantage over computers in skills that require analytical and critical thinking, creative intelligence and social and emotional intelligence. Moreover, the common opportunities and challenges of digitalization among the occupations were identified and divided into three following main areas: information efficiency, technology efficiency and people efficiency. The benefits of digitalization can only be realized by tackling the identified challenges that prevent the increase in the efficiency of work for the occupations under study.

The role of digitalization in each of the occupations differed depending on how digitalization has changed the efficiency of work and nature of work. For cybersecurity experts, who are diginatives, the changes in both work efficiency and nature of work have and will be constantly increasing. On the other hand, higher education teachers and healthcare professionals are emerging digitalists on the verge of digital transformation, as the needed changes in the nature of work have not yet occurred to increase the efficiency of work accordingly. For business managers, who are efficient digitalists, the increase in the efficiency of work has been significant. However, the changes in the nature of work have been relatively small. Lastly, for technology innovators the changes in the nature of work have been tremendous while the change in work efficiency has not yet been realized. Therefore, they are named as being digital reinventionists. In order to make the work more productive for these five occupations, it is necessary to have the right skills in place and change the nature of work to fit to the needs of the new digital economy.

Keywords digitalization, technological change, task content, skill demand, future of work

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1 Introduction

The aim of this master's thesis is to understand the relationship between recent technological development and occupation-specific skills, which are typically measured with the level of education within economics. Based on the literature, technology increases the productivity of all workers, but especially of high-skilled workers (e.g., Katz and Murphy, 1992; Acemogly and Autor, 2011). However, it has been also argued that exposure to technology depends mainly on the occupational tasks, not on the education of the worker (Autor, Levy and Murnane, 2003). Accordingly, whether or not technology can substitute or complement human labor differs between occupations depending on the tasks that these occupations include. In order to get a comprehensive picture of the skill demand it is necessary also to understand the changes in task content.

In a recent study by Frey and Osborne (2013) the future division of labor between humans and computers is studied by predicting the future of employment based on bottlenecks to computerization. These bottlenecks, which are such that computers still have a hard time to accomplish, are perception and manipulation, creative intelligence and social intelligence related tasks. They find that due to the recent advancements in machine learning and mobile robotics, up to 47 % of total US employment is in the high risk category and thus susceptible to computerization in the near future. According to Pajarinen and Rouvinen (2014), the corresponding figure for Finland is 36 %. The jobs that will remain include tasks that require knowledge of human heuristics, usually required in generalist occupations, and the development of novel ideas and artifacts required in specialist jobs. The generalist occupations include, for example, all managerial jobs, whereas specialist knowledge is required in such fields as health care, education, arts and media and computer science jobs. Needless to say, these occupations also tend to require a high level of education, thus indicating the importance of having the right skills in the labor market shaped by technological advancements.

Consequently, this study aims to expand our knowledge of how task content of five selected occupations has been affected by digitalization and new technologies and what are the implied results on the skill demand. These five selected occupations are business managers, technology innovators, higher education teachers, healthcare professionals and cybersecurity experts. All of these are listed in the low risk category in the study by Frey and Osborne (2013) meaning that their work has a low probability of being replaced by computers in the near future. These occupations also tend to require a high level of education. Nonetheless, their study does not take into account how the task content of these occupations changes due to development of new technologies. This study tries to fill in this gap and provide recommendations on the skills that will be increasingly in demand in the near future. Furthermore, the aim is to study the role of digitalization in the work life of the selected occupations under study and provide recommendations how to increase the productivity of their work by exploiting the benefits of digitalization.

1.1 Background

The division of labor between humans and computers has been a topical issue in the public discussions as well as in economics ever since the invention of computers. The exponential speed of technological development expressed by Moore's law, the doubling of computational power every 18 months, has vast implications on labor markets and the way humans work (Levy and Murnane, 2004; Brynjolfsson and Mcafee, 2014). Computers and Internet are gradually creating complementary innovations and replacing human labor in tasks in which they have a comparative advantage over human labor (Autor, Levy and Murnane, 2003; Frey and Osborne, 2013). This new division of labor between humans and computers is becoming ever more evident as computers and robots are becoming not only better but also cheaper than human labor. As a result, many economists have started to call the emergence of the new digital economy the third industrial revolution, which is changing the underlying politics of the labor market and forcing us to rethink the nature of work (e.g., Greenwood and Yorukoglu, 1997; Brynjolfsson and McAfee, 2011; 2014).

This new division of labor invokes a question of skills that humans should obtain in order to stay competitive in the labor market. In fact, the relationship between skills and technology was first recognized in economics with the development of skill-biased technological change theory, SBTC, in the early 1990s. The theory was built to explain how due to technological change the demand for skills, measured in years of schooling, has increased over multiple decades albeit a concurrent increase in the supply of skills in the US (Katz and Murphy, 1992; Autor, Katz and Krueger, 1998; Acemoglu and Autor, 2011). The skill-biased technological change has resulted in an increased wage premium for the high-skilled workers aggregating wage inequality between high- and low-skilled workers not only in the US, but also in various developed countries in Europe with different institutional settings (Berman, Bound and Machin, 1997; Machin and Van Reenen, 1998). This is what Goldin and Katz (2009) refer to as the race between education and technology.

However, contrary to the SBTC theory, in the 1990s employment shares and relative earnings rose both in the low- and high-skilled jobs across developed countries, which led to U-shaped relationship between skill levels, employment and wage growth called job polarization (Autor, Katz and Kearney, 2006; Spitz-Oener, 2006; Goos and Manning, 2007). This hollowing-out of middle-skilled workers has also been observed in the egalitarian Nordic countries, including Finland (Asplund et al. 2011; Mitrunen, 2013). As a result, the workers in the middle, mainly in routine manufacturing and office jobs, have moved down in the ladder towards low-skilled jobs, further increasing wage inequality due to the augmented wage premium for the highly skilled (Autor and Dorn, 2013).

To explain the job polarization effect, Autor, Levy and Murnane (2003) created a model in which they showed how the task content of jobs has changed due to technological advancements. They argued that especially the routine tasks, both manual as well as interactive and analytic tasks, are substitutes to computer capital. Hence, as computers are better at completing routine tasks than humans, task content has shifted towards more non-routine tasks. Building on to the task model, Frey and Osborne (2013) predict the future of work based on how susceptible jobs are to computerization. They concluded that in the near future humans still remain to have comparative advantage over computers in tasks that require perception and manipulation, creative intelligence and social intelligence skills. They called these tasks as the bottlenecks to computerization. Their results indicate that 47 % of total US employment is in the high risk category, which included jobs, e.g., in manufacturing, logistics and in service. Therefore, it is highly probable that these jobs will be done by computers in the near future as technology advances. According to Pajarinen and Rouvinen (2014), the corresponding figure for Finland is 36 %.

Despite of these gloomy pictures, it is worth noticing that the role of technology in changing the labor market is by no means a new phenomenon. The invention of new machines in the Industrial Revolutions in the 19th and 20th century revolutionized work by moving workers from agriculture to manufacturing, from fields to factories. However, these technologies took decades before they appeared in the productivity statistics, which has also been the case for computer-based technologies (Syverson 2013; Brynjolfsson and McAfee, 2014). Brynjolfsson and Hitt (1998) study the causes of productivity paradox and conclude that it is important to realize that computerization does not automatically increase productivity by itself, but is an essential component of a broader system of organizational changes which do increase productivity. Just as in the Ford manufacturing factory in the electrification era, the benefits of electric motors were realized only when the engineers redesigned the work process to match the needs of the new machines. Hence, it appears that in order to truly exploit the productivity gains of digital technologies, it is time to restructure the way work is done to make computerization more effective. This is not only important for firms but also for national economies, including Finland, which is experiencing alarming trends of decreasing productivity growth (Pohjola, 2007; Statistics Finland, 2014).

Therefore, it might be that the threat of technological unemployment, caused by the effect of technological advancements on middle- and low-skilled jobs, is a result of the inability of our skills, organizations, and institutions to keep pace with technological change, as argued by Keynes (1933). Brynjolfsson and McAfee (2014) state that it is essentially a matter of supply and demand. By reducing the supply of low-skilled workers and increasing the supply of educated workers the shortages in both of these areas can be overcome. This can be done by enhancing opportunities of the entire society and fostering the right educational settings, focusing on teaching people the skills that humans are originally better at: creativity, complex communication and human interaction. After all, as stated by Goldin and Katz (2009), the role of human capital in increasing labor productivity is essential in order to gain higher rates of nationwide aggregate growth. Based on these arguments, it is highly important to study how workers' skills should be developed and how work should be organized in order to realize the benefits of digitalization, which is the aim of this study.

1.2 Research Objectives and Questions

Despite of the novel predictions of Frey and Osborne (2013), it should be noted that the changes in the labor market depend on the predicted technological advancements in machine learning and mobile robots. However, the exponential speed of technological progress highlights the difficulty of making predictions about technological progress, as argued by Armstrong and Sotala (2015). Moreover, they do not take into account the changes in task content nor the development of new tasks or even completely new jobs due to the new technologies. Consequently, the aim of this study is to fill in this gap in the literature and explore how task content and skill demand change due to digitalization and the invention of new technologies. Digitalization and new technologies are used to refer, not only to computer based technologies, but also all types of new digital technologies and tools being used increasingly in the work life. In other words, digitalization in this study aims to capture the recent technological advancements which were initially initiated by the invention of computers and Internet, but is now focusing on the development of digital technologies and other intelligent information systems.

The recent results of Frey and Osborne (2013) and the replicated analysis of Pajarinen and Rouvinen (2014) indicate that there is serious need also in Finland for understanding how task content within certain occupations is changing in order to react to the effects of technological progress on labor. This was also recently noted by the largest Finnish newspaper Helsingin Sanomat[1] in their article, which raised the question of the disappearing occupations based on the results of Pajarinen and Rouvinen (2014), pointing out the high topicality of the research topic. Additionally, in Finland, the labor and national productivity growth rates have decreased since 2000 as presented by Statistics Finland (2014) and thus it is of high importance to address the possible reasons for barriers in productivity increase.

By building on the results of Frey and Osborne (2013) this study aims to test the hypothesis that skill demand is changing towards tasks in perception and manipulation, creative intelligence and social intelligence. This is done by focusing on the changes in task content in five selected occupations within the low risk category. These occupations are business managers, technology innovators, higher education teachers, healthcare professionals and cyber security experts. Therefore, the following research question is proposed:

RQ: How digitalization affects task content and skill demand for five selected occupations?

Furthermore, to gain an in-depth picture of digitalization and its effects on task content and skill demand, it was considered important to understand the opportunities and challenges related to digitalization. This was also considered to be useful in order to provide valuable recommendations on how to realize the productivity benefits offered by digitalization. As a result, the following sub-questions were developed:

SQ1: What are the opportunities and challenges of digitalization in the work life of these five selected occupations?

SQ2: How to increase the productivity of work for these five selected occupations?

The phenomenon is thus studied by reflecting the past task content changes induced by digital technologies to the expected future changes. Moreover, though the term digitalization is being used vastly in this study, the focus is not only on the digital technologies, but also on the role of technological development in the work life. As a result, the study aims to analyze the

[1] Helsingin Sanomat, 27th of September, 2015

development of task content in the past decade as well as the future trends due to technological advancements related to automation, robotization and new digital technologies.

The research was conducted using qualitative multiple case study research method with focused face-to-face semi-structured interviews consisting of open-ended questions. The interviews were done with representatives of each of the chosen occupational roles, which will be defined more in detail in the methodology chapter of this study. The selection of the interviewees was based on their innovative approach towards new technologies and their relatively long experience within their respective fields. The research approach is based on the assumption that the interviewees are experts of their own work and thus they are the best judges in evaluating the changes in task content and skill demand for their own occupational roles. Moreover, based on the results of the conducted 26 interviewees, a model for the future task content and the subsequent required skills was developed. It will also serve to test the validity of the bottlenecks presented by Frey and Osborne (2013) and give implications on the skill demand for business managers, higher education teachers, technology innovators, healthcare professionals and cybersecurity experts.

1.3 Structure of the Thesis

The first chapter of this study introduces the topic and the research questions and objectives, thus also providing motivation for the study. Chapter 2 presents the literature review that discusses work in the new digital era based on the implications of Moore's law and the productivity paradox. Moreover, in this chapter the theories of skill-biased technological change and the different task models developed by Autor, Levy and Murnane (2003) and Frey and Osborne (2013) will be explained more in detail. Chapter 3 provides the description of the used methodology which is the basis of the empirical findings.

The empirical findings are presented in chapter 4 by first focusing on the common changes across different occupational roles. This is followed by an occupation-specific analysis on changes in task content and their implications on skill demand. These changes are divided into changes in work efficiency and nature of work in order to get an in-depth understanding of the type of changes digitalization and new technologies cause in task content. Furthermore, the chapter is concluded with a summary of the results that presents the current situation of digitalization in the work life of each occupation. Finally, in chapter 5, the conclusions and the practical implications of the study are presented.

2 Literature Review

In this chapter the relevant literature for this study is presented. The chapter is divided into three following sections and topics: work in the new digital era, increasing wage inequality and skill returns and job polarization. The first section will discuss the exponential speed of technological advancements and the implications of Moore's law on work using the analogy from previous industrial revolutions. Additionally, the productivity paradox relating to the gap between technological advancements and increase in productivity will be discussed in more detail ending up with the new division of work between humans and computers. The next section will cover the increasing wage inequality and returns to skills explained by the theory of Skill biased technological change. Section three will conclude by explaining the causes of job polarization with two different task models developed by Autor, Levy and Murnane and Frey and Osborne (2013).

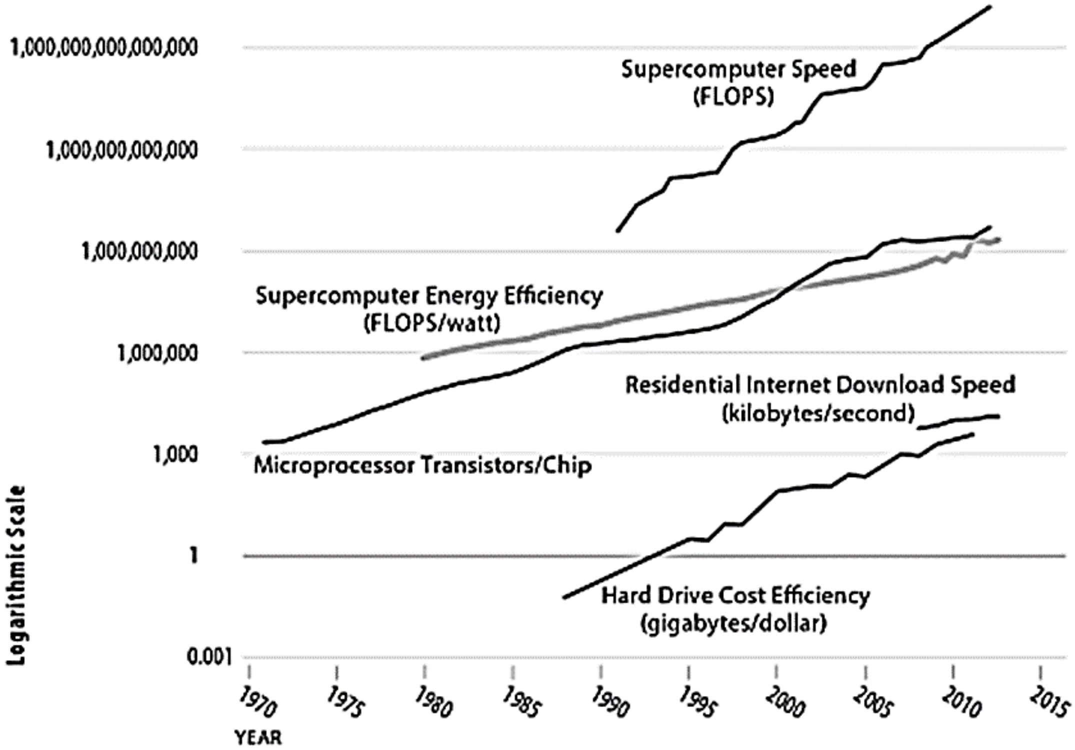
2.1 Work in the New Digital Era

2.1.1 Moore's Law and the Digital Progress

There are two things that are speeding up the drastic changes aroused by the inventions of computer, the Internet and other digital innovations. These are the exponential progress of ICT technologies and the drastic decrease in the cost of computer power. Firstly, the exponential progress of technologies was first discovered in 1965 by Intel's co-founder Gordon Moore who detected that as transistors in Intel computer processor chips got smaller, the number of transistors that fit onto an integrated circuit grew exponentially. This was based on the proposed challenge by Moore that the semiconductor industry was to continue this exponential growth that requires innovation, capital expenditure and risk taking. The result has been that since the 70s the computing power of an integrated circuit, a microchip, has doubled every 18 months, a rule that is called the Moore's law (Atkinson and Mckay, 2007).

Additionally, this exponential progress is continuing across many other IT technologies as argued by Brynjolfsson and McAfee (2014) who look at the progress of several digital innovations, such as supercomputer speed and microprocessor transistors. They state that these technologies have been improving at exponential rates for a long time as seen in Figure 1, which is expressed in logarithmic scale. In other words, looking at Figure 1 it is evident that digital progress is doubling approximately every two years, thus following the Moore's law, and this progress has been in force for a long time and applies to many types of digital progress. This is the underlying reason why the development of not only ICT technologies but also many other technologies, such as Artificial Intelligence, seems to speed up constantly and thus continuously changing the way humans work, interact and operate. Moreover, due to the exponential speed of development, some technological breakthroughs that seem impossible today can be easily achieved in the near future.

Figure 1: Moore's Law Realized in Digital Innovations (Brynjolfsson and McAfee, 2014).



Moreover, Moore's statement did not rely upon the speeding up for the progress alone, but it also put forward an idea that the cost of machinery will decline rapidly. Accordingly, Moore (1965) states that the complexity for minimum component costs, i.e., the amount of integrated circuit computing power one can buy for one dollar, will increase at a rate of roughly a factor of two per year. This law of doubling has been verified since then by many scholars and statistics. For example, Nordhaus (2007) analyses the computer performance and the development of real cost of performing a standardized set of computational tasks by measuring real cost as relative to the labor cost of performing the same calculations. He concluded that the real costs fell by 1.7 trillion-fold between 1850 and 2006 and, moreover, the majority of this decline occurred in the latest three decades after the World War II. Moreover, Van Reenen (2006) suggests that the real price of network servers fell approximately 30 % per year between 1996 and 2001. In the meanwhile, hard drive storage capacity has doubled every 19 months while the cost of a stored megabyte of data has fallen 50 percent per year. Consequently, the cost of storing one megabyte of information fell from $5,257 in 1975 to less than 1/10th of a cent in 2007 (Atkinson and McKay, 2007). Thus, it is needless to say, that the power of constant doubling is big and has tremendous effects on the use, adaption and application of these digital technologies.

However, there are also constraints in transistors and computing elements which are related to the laws of physics. Many have argued that at some point Moore's Law must slow down or even come to its end due to the fact that there is limits to how many electrons per second can be put through a channel etched in an integrated circuit, or how fast beams of light can travel through the fiber-optic cable (Brynjolfsson and McAfee, 2014). Transistors have gradually decreased in size over the years and are now approaching the size of atoms. Consequently, Intel has recently faced trouble in doubling the processor performance in every two years, as it has been difficult to migrate from 22nm to 14nm process technology used in the transistors[2]. This is proving the fact that the doubling of transistor performance has been merely a successful strategic goal implemented by Intel and now it seems that there are no more benefits to be realized in shrinking further.

However, it is not to say that Moore's law is slowing down, but that the benefits of making systems on a chip cheaper, faster with better and smarter design can enhance the law even further in the future. As Brynjolfsson and McAfee (2014) state, the constraints in the digital technologies are much looser, as the laws of physics do not apply for them. Additionally, Kurzweil (2005) criticizes Moore's law's narrow reference to the number of transistors on an integrated circuit of fixed size. Instead, he argues that the most appropriate measure to track price-performance of computers is computational speed per unit costs. This way many levels of innovative technological evolutions can be taken into account that include also the multiple layers of improvement in computer design that are also highly relevant in analyzing the computational power of computers.

Kurzweil (2005) projects these computational performance trends for the next century and states that personal computing will achieve human brain capability by around 2020 depending how conservative estimation of human brain capacity is used. Additionally, he argues that by around 2045 computational power will even exceed the power of all human brains, which would be the ultimate singularity for the creation of superintelligence. In fact, human brain is at least one million times slower carrying out bulks of its calculations in the interneuronal connections than contemporary electronic circuits. However, brain's enormous power comes from its

[2] *The Economist Technology Quarterly*, September 5th, 2015

extremely parallel organization in three dimensions. In other words, the interaction between interneurons allow the brain to perform its different complex functions, such as learning and decision-making. Consequently, as the doubling of processor performance seems to reach its natural limit, the new paradigm may lie in the three-dimensional circuits. Whilst these estimates may seem radical, Kurzweil's (2015) remarkable calculations of supercomputer power development compared to the brain's functioning highlight that the "third industrial revolution" induced by the computer based technologies is much more radical than the previous industrial revolutions. However, due to productivity paradox, these radical changes might have not yet fully occurred as explained in the next section.

2.1.2 Productivity Paradox

The invention of powerful technologies are central to economic progress. Prior to 1750, on the brink of the first Industrial Revolution, there was almost no economic growth for four centuries. However, the invention of steam engine together with other machinery tools turned the economic growth and social development into an upward trajectory and thus it was one of the most significant event in the economic history of the world (Gordon, 2012; Cowen, 2011). The second Industrial Revolution followed with new inventions, such as the electricity, the internal combustion engine and indoor plumbing with running water. In fact, as Gordon (2012) argues, the great inventions of the industrial Revolution were so important that they took full 100 years to have their main effect, lasting until the late 20th century. However, the growth of productivity measured in output per hour slowed after 1970 which according to Gordon (2012) was a result of the fact that the benefits of the great inventions and their spin-offs had already occurred and only second-round improvements remained.

These powerful technologies, such as the steam engine and electricity, are those what many economists call the General Purpose Technologies (GPTs) that spread throughout many industries. GPTs are highly important because they accelerate the normal march of economic progress. The general consensus among different researchers is that GPTs should be pervasive, improve over time and be able to generate new innovations (Cowen, 2011). Brynjolfsson and McAfee (2011; 2014) and Bresnahan (2010) argue that digital technologies meet all of these three requirements for GPTs. GPTs generally start with small economic benefits but as they improve and complement other technologies that spur of the GPTs, after a long period of time the economic growth will increase. This is similar to the recent technological development which started already decades ago with the invention of computer and later the Internet.

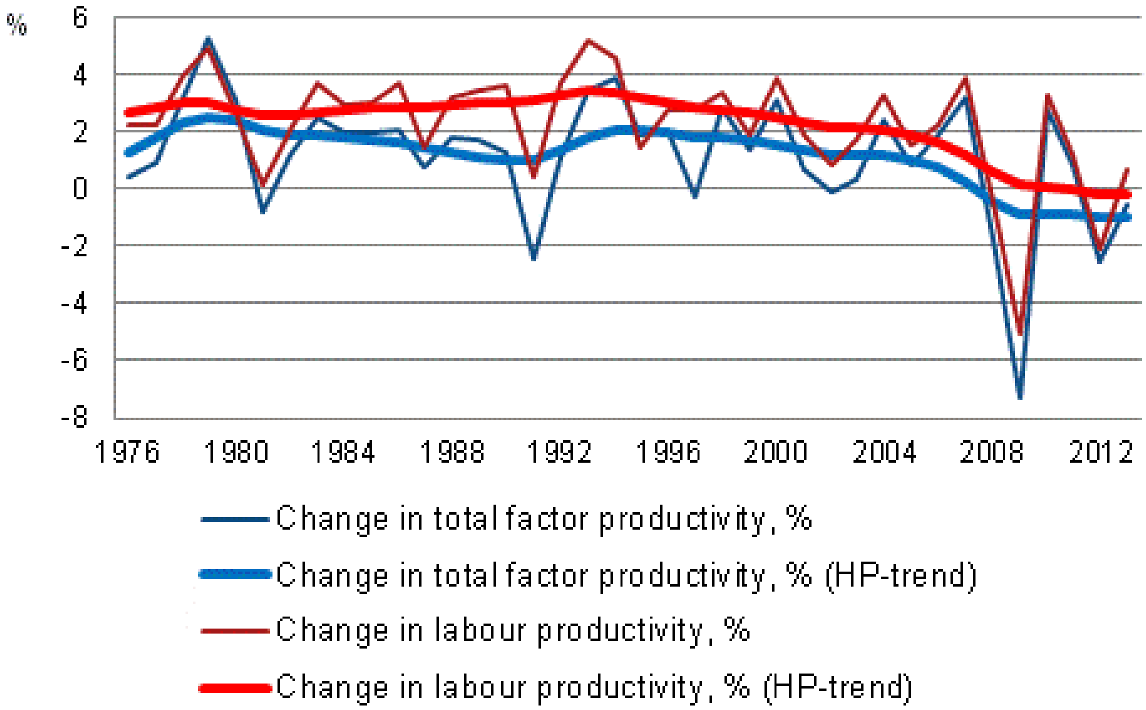
Furthermore, what is so special about the digital technologies and the GPT of ICT is that it enables a drastic amount of new ways to combine and recombine ideas (Weitzman, 1998).

Productivity growth, the increase in GDP per person, comes partly from using more resources. However, the main source for growth in productivity comes from the ability to get more output from the same input. In economics, productivity is commonly measured by labor productivity, the output per worker, but it can be also measured by multifactor productivity, called the "Solow residual" which is output divided by a weighted average of capital and labor inputs. From these equations one can see that increasing the amount of hours worked increases productivity. Additionally, growth in labor productivity depends on three main factors: Investment and saving in physical capital, new technology and human capital, which in economics refer to expenditures on education, training and medical care, etc. Nonetheless, the main source for productivity growth comes from innovations in technology and techniques of production, from new technologies with which it is possible to get more from the same input.

Considering the tremendous changes in work induced by computers, the invention of computer should have increased the productivity substantially during the 1970s and 1980s. However, in US the period of 1970-1985 was a period of slow productivity growth, thus the term productivity paradox emerged. In fact, the benefits of computer technologies were only visible in the national statistics in the mid-1990s. This indicates that there was a clear lag, around two decades, between the introduction of computer technology and its productivity benefits (Brynjolfsson and McAfee, 2014). Interestingly, Syverson (2013) finds the surprisingly well matching analogy in the slow start and subsequent acceleration of productivity growth in the electricity era. He states that the slow start and subsequent acceleration of productivity growth in the electricity era matches well with the speed-up that began in the 1990s related to the computer-based technologies.

While in US productivity growth accelerated after the mid-1990s, in most countries in Europe the productivity growth slowed down after the mid-1990s (Van Ark, Inklaar and McGuckin, 2003). Though these differences in productivity growth rates may be a result of different business cycles and different macroeconomic conditions, Van Ark, O'Mahony and Timmer (2008) argue that the difference is mainly due to the slower emergence of the knowledge economy in Europe compared to the United States. Similar to Europe, in Finland the development of productivity growth has steadily slowed down after the mid-1990s after a relatively steady productivity growth during the previous two decades as seen in Figure 2. Since 2000 both total factor productivity and labor productivity growth trends have clearly slowed down. These observations are verified by Pohjola (2007) who states that though the productivity growth still remains positive, it is the direction of the trend which is alarming. Although there is much more to be said about the productivity of an economy, considering the recent digital innovations related to ICT-technologies that should have enabled higher productivity growth rates, it seems that so far the productivity benefits related to ICT-technologies have not been realized.

Figure 2: Development of Productivity in the Whole National Economy in Finland 1976-2013[3] (Statistics Finland, 2014)



Brynjolfsson and Hitt (1998) try to understand the underlying reasons why it has been hard to prove the productivity growth of IT investments. Firstly, they argue that the measures of output and input are not proper measures. In the new digital economy, value depends increasingly on product quality, timeliness, customization and other intangibles which should be included in the measure of output. Similarly, inputs should include quantity and quality of capital equipment used, materials consumed, the amount of organizational capital and worker training and education. Secondly, Brynjolfsson and Hitt (1998) argue that due to the organizational structures that do not support the made IT investments, IT has turned out strangely unproductive in the long-term. This is because organizational factors that unlock the value of IT are costly and time-consuming. Consequently, there has been enormous amount of variation between the

[3] The figures for 2012 and 2013 are based on preliminary information

relationship of IT investments and productivity across firms, as some firms with high IT investments are also highly productive, while others with similar investments have low productivity.

As Brynjolfsson and Hitt (1998) conclude, in order to gain substantial productivity growth, the research is increasingly focusing on how to make more computerization effective. They argue, that computerization does not automatically increase productivity, but it is an essential component of a broader system of organizational changes which does increase productivity. Just as in the Ford factory in the electrification era, the benefits of electric motors were realized only when the engineers redesigned the work process to match the needs of the new machines. Therefore, it appears that in order to truly exploit the productivity gains of ICT-technologies it is time to restructure the way work is done to make more computerization effective. This is not only important for firms but also for the national economies, including Finland.

2.1.3 The New Division of Labor

The implications of the exponential speed of progress of digital innovations and the use of the Internet have vast amount of implications on the labor market. However, controversial to the technological change in the Industrial Revolution which sharply increased demand for human labor and human cognition, digitalization of work is simultaneously increasing the demand for information processing tasks while it is also better able to automate these tasks. Levy and Murnane (2004) argue that this ultimately means that the division of labor between digital capital and human will change so that humans will focus more on those tasks which are still hard for the computers to do, in other words, on those tasks in which humans have a comparative advantage over computers.

One main source of comparative advantage for computers over human labor is scalability. This is further highlighted albeit the use of big data which helps the networks of machines scale better than human labor (Campbell-Kelly, 2009). Unlike photocopies of books, bits cloned from bits are usually exactly identical to the original version and copying bits is extremely cheap, fast and easy to do due to the cero marginal cost of reproduction. Furthermore, computers are not restricted to labor laws with strictly determined working hours and they can handle large datasets that enable them to manage big calculations (Kahneman, Slovic and Tversky, 1982). In addition, as Frey and Osborne (2013) state, one crucial comparative advantage for computers in cognitive tasks is that algorithms are not subject to some human biases. For example, in many situation involving decision-making, such as in customs when trying to catch drug traffickers or in court rulings ruled by experienced judges, humans can be biased to physical appearances or their own experiences. On the contrary, impartial algorithmic solutions are not bias, and hence they are better at the job than humans.

Subsequently, during the last years, more and more technologies, such as payroll processing software, factory automation computer-controlled machines, automated inventory control and word processing, have been deployed for routine work (Autor, Levy and Murnane, 2003; Brynjolfsson and McAfee, 2014). As a result, computers have substituted number of jobs in clerical tasks, on the factory floor and other routine task related jobs, including bookkeepers, cashiers and telephone operators (Bresnahan, 1999; MGI, 2013). Nonetheless, still many jobs that humans do go on being too difficult for the computers or robots to do. This follows from the argument that computers are good at repetition and following explicit rules but very lousy at pattern recognition (Frey and Osborne, 2013; Brynjolfsson and McAfee, 2014).

Accordingly, Moravec (1988) argues that it is relatively easy to make computers exhibit high-level reasoning, whereas low-level sensorimotor skills relating to perception and mobility require enormous computational resources. This statement has later been summarized as the Moravec's paradox, which still remains to be a relevant issue among artificial intelligence and robots researchers. However, several recent innovations, such as Google's driverless cars, Amazon's Kiva robots[4], IBM's Watson computer and various other innovations have proved Moravec's paradox wrong, indicating that there are more such innovations up and coming (Frey and Osborne, 2013; Brynjolfsson and McAfee, 2014).

The capability of computers or machines to substitute human labor in some tasks is familiar already from the first industrial revolution which reshaped labor. However, the uniqueness of the digitalization is its exponential speed of advancements, of which we have only seen the first glimpse as economies are still on their way to reach the full potential of it. As Brynjolfsson and McAfee (2014) conclude, digitization enables the use of massive amount of data relevant to almost any situation, and this information can be infinitely reproduced and reused because it is non-rival. As a result of these two forces, the number of potentially valuable digital platforms together with network effects is exploding around the world and the possibilities are multiplying unforeseeable. As Weitzman (1998) argues, in the early stages of technological development economic growth is constrained by number of potential new ideas, but later on it is constrained only by the ability to process them. This view is also shared with Brynjolfsson and McAfee

[4] Kiva robots are Amazon owned advanced warehouse logistics automations that move around warehouses safely, quickly and effectively.

(2014) who state that growth is not over, it is just being held back by our inability to process all the new ideas fast enough.

2.2 Increasing Wage Inequality and Returns to Skills

There are always winners and losers in the economy subject to radical technological advancements but as Manning (2004) argues, the losers tend to be more visible than the winners. He points out that in the 19th century the introduction of mechanical loom dramatically increased the productivity of weaving lowering the cost of clothing. This led to mass layoffs of weaving workers despite the fact that the demand for clothing. These workers, the losers, ended up blaming the machines for their misfortunes. On the other hand, the winners were all the people consuming clothes for whom there was more money left to be spent in other goods due to the lower prices of clothing.

The recent evidence points out that in the new digital era the overall gains to the winners have been larger than total losses for the losers. In 2011 OECD (2011) published a report on increasing income equality throughout the developing countries. The surprising findings indicated that in the 2000s income equality rose for the first time in the traditionally low-inequality countries, such as in the Nordic countries. Although income inequality differs in its definition from wage inequality, the OECD report (2011) states that the changes in the distribution of wages and salaries account for 75% of household incomes among working-age adults, which has also been the main driven factor in the increasing income inequality in the developing countries in the 2000s.

In the US, according to the report of Economic Policy Institute (2012), the median hourly wage grew only 0.1 percent per year between 1973 and 2011 amid a productivity growth of 1.56 percent per year during 1973-2000 and accelerating to 1.88 percent per year from 2000 to 2011. As Mishel and Bivens (2011) point out in the report, 59.9 percent of the gains from 1970-2007 have gone to the top 1 percent of households while only 8.6 percent of income gains have gone to the bottom 90 percent. This trend is also apparent in Finland since 1990, where according to Riihelä, Sullström and Tuomala (2010) the top 5% and 1% deciles of real disposable incomes grew the fastest between 1990 and 2007 with corresponding growth rates of 6.3% and 12.3%. Moreover, during the same time, the lowest 10th decile grew 0.5% while the highest 10th decile grew 4.9%, indicating that the winners of the new digital economy are becoming ever richer also in the highly egalitarian Nordic country, such as Finland.

As Greenwood and Yorukoglu (1997) put it: “Setting up and operating new technologies often involves acquiring and processing information. Skill facilitates this adoption process. Therefore, times of rapid technological advancement should be associated with rise in the return to skill.” Furthermore, they assume that the adaption to new technology is easier for educated people. Milgrom and Roberts (1990), on the other hand, argue that as information technology reduces information and monitoring costs within firms, it allows for reorganization with fewer vertical layers and with workers performing a wider range of tasks. This also gives a competitive advantage for educated workers. Consequently, Greenwood and Yorukoglu (1997) further state that the advances in information technology has resulted in increased inequality. This causal increasing effect of technological advancements on skill demand has been widely acknowledged already early on in the 20th century by several researchers (Nelson and Phelps, 1967; Welch, 1970; Schultz, 1975; Tinbergen, 1975) during the switch to electricity from steam and water-power energy sources. This switch reduced the demand for unskilled manual workers, especially in many conveying and assembly tasks, and increased the demand for skills in capital-intensive industries (Goldin and Katz, 1998).

Based on Tinbergen’s (1975) pioneering work with linking supply and demand of skills to wage differentials, Goldin and Katz (2008) called the recent changes in the labor market throughout the 20th century the race between education and technology, arguing that human capital is the main contributing factor of economic growth. In the literature skills are measured with years of schooling or the level of education and thus whether a person has received university education or not defines her a skilled or unskilled workers. Wage level thus measures the returns to skills or schooling. Accordingly, Becker (1962) stated that investment in human capital, be it schooling, on-the-job training or medical care, has tremendous effects on earnings, employment and other socioeconomic variables in the long-run. Moreover, Goldin and Katz (2008) argue that increases in supply of human capital can bypass the increasing inequality between different skill groups caused by technological progress. Consequently, the increasing inequality in developed countries is a result of slowing pace of accumulation of human capital which has not met the demands of the recent technological developments. It seems that the winners in this era of new technologies are those who have accumulated higher quantities of capital, be it nonhuman capital, such as equipment, intellectual property or financial assets or human capital, such as education, training and skills (Brynjolfsson and McAfee, 2011).

In order to explain how technological change is related to wage inequality it is first important to study the changes in skill supply and skill premia in the recent decades. Skill premia and relative skill supply measure the relative wages and quantities between skilled and unskilled workers. What has been puzzling in the labor market changes during the last decades, is that the skill premia has increased while there has been immense rise in educational levels in all developed countries as seen in Table 1 (see, e.g., Autor, Katz and Krueger, 1999; Cahuc and Zylberberg, 2004; Barro and Lee, 2010). In fact, Appendix 1 shows that the share of college graduates from all employed workers in the US has increased from 6.4% in 1940 to 28.3% in 1996 (Autor, Katz and Krueger, 1998). Therefore, we can see that there has been substantive increase in supply of college educated graduates, especially in the 1970s. Only a decade later in the 1980s there was also a substantive shift towards higher wage premium for these highly skilled workers, which can be seen in Figure 3 which presents the adjusted college/high-school log weekly wage ratio in the US. This wage premium for college graduates in the US has been growing much faster than for the high-school graduates since the 1980s, causing increasing wage inequality (Goldin and Katz, 2008).

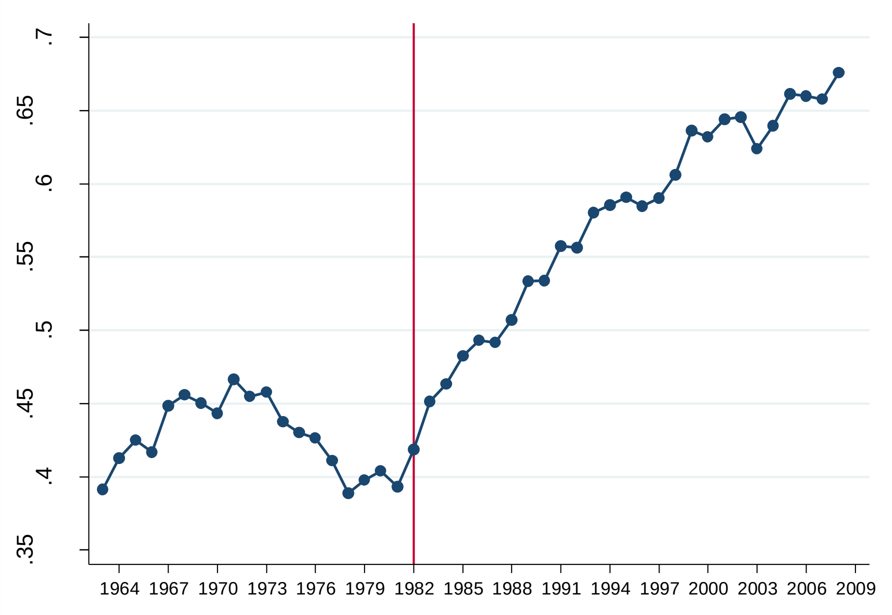
Table 1: Educational levels of total population aged 15 or over in the developed countries 1950-2010 (Barro and Lee, 2010).

Highest level attained (% of population aged 15 or over)

Year	Population aged 15 or over (million)	No schooling	Primary		Secondary		Tertiary		Avg years of schooling
			Total	Completed	Total	Completed	Total	Completed	
1950	428	9.2	60.1	38.1	25	12.7	5.7	2.8	6.22
1960	476	7.8	54.1	34.5	31.1	16.8	6.9	3.5	6.81
1970	541	6.2	45.3	31.7	38.6	21.8	9.9	5.1	7.74
1980	614	5.5	34.2	24.6	44.4	26.7	16	8.3	8.82
1990	683	5.5	27	19.7	44.9	25.9	22.6	11.6	9.56
2000	746	3.4	19.1	14.8	49.5	31.7	28	15.4	10.65
2010	805	2.3	14.2	11.5	57.9	37.7	25.6	14.5	11.03

Note: Developed countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, USA, United Kingdom.

Figure 3: Composition Adjusted College/High-School Log Weekly Wage Ratio, 1963-2008 (Acemoglu and Autor, 2011).



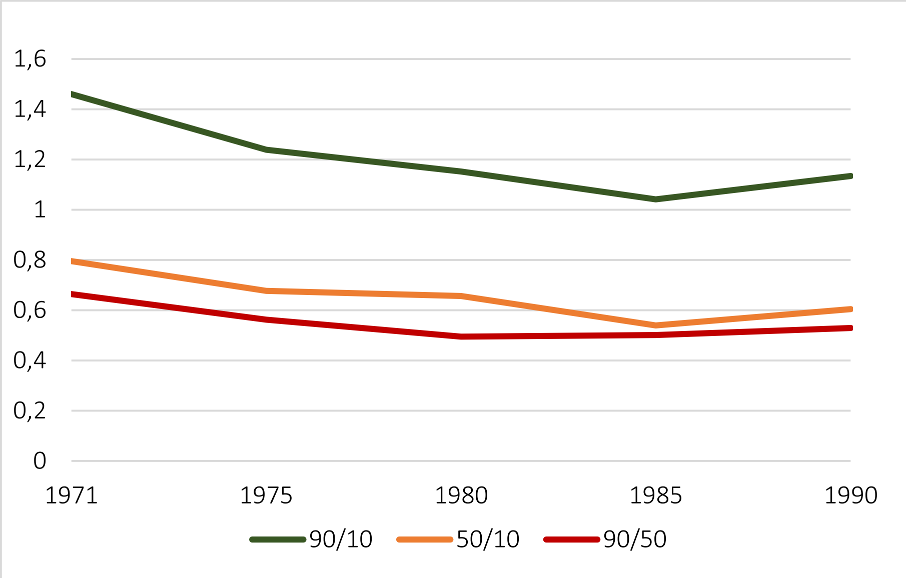
Source: March CPS data. Log weekly wages for full-time, full-year workers are regressed in each year on four education dummies, a quartic in experience, interactions of the education dummies and experience quartic, and two race categories. The compoisition-adjusted mean log wafe is the predicted log wage evaluated for whites at the relevant experience and relevant education level. The mean log wage for college and high school is the weighted average of the relevant composition adjusted cells using a fixed set of weights equal to the average employment share of each group. The ratio of mean log wages for college and high school graduates for each year is plotted.

Based on the law of supply and demand, when the supply of college workers increases, the wage premium for college workers should decrease as it did in the US in the 1970s when there was the sharpest increase in the supply of college graduates. However, as in the 1980s the wage premium turned to a sharp increase, the theory of skill-biased technological change, SBTC, emerged (see e.g., Katz and Murphy, 1992; Katz and Krueger, 1998; Acemoglu and Autor, 2011). The argument of the theory is that technology favors people with more human capital, thus inducing more demand for skilled workers.

While the evidence for increasing skill premia and increasing wage inequality for the US during the 70s and 80s is clear, there have been big differences among the OECD countries in terms of the changes in wage structures. For example, in the UK and Sweden the wage differentials between educated and less educated workers have increased, while in Italy and Germany the dispersion in wage levels has decreased together with education differentials. In Denmark and Norway, on the other hand, wage dispersion has been stable throughout the 80s, whereas in Finland the change in skill premia remained relatively constant. Eriksson and Jäntti (1997) studied the distribution of earnings in Finland between 1971 and 1990 and found that earnings inequality dropped extensively between 1971 and 1975, and continued to decrease up until

1985. From 1985 to 1990, on the other hand, there was substantial increase in the inequality of earnings, which is also comparable to the magnitude to increases observed in the UK and the US in the 80s. Figure 4 shows the changes in inequality of earnings in Finland between 1971 and 1990 measured in 90/10, 50/10 and 90/50 decile ratios.

Figure 4: Inequality of Earnings in Finland 1971-1990 Measured in Decile Ratios (Eriksson and Jäntti, 1997).



Moreover, during the period from 1971 to 1990, the labor force shares of workers with university and vocational education in Finland grew steadily. When looking at the skill premia, during the same period it first fell substantially in the early 70s and decreased moderately up to 1985, but from 1885 to 1990 the skill premia remained almost constant. Consequently, in the 80s there was a simultaneous increase in supply of educated workers and relatively stable skill premia (Asplund, 1995; Eriksson and Jäntti, 1997). Considering the demand side, the implicated demand shifts towards more skilled workers due to SBTC as shown by Katz and Murphy (1992) do not apply to Finland, as the growth in relative demand for educated workers was fast in the 70s and slow in the 1985-1990.

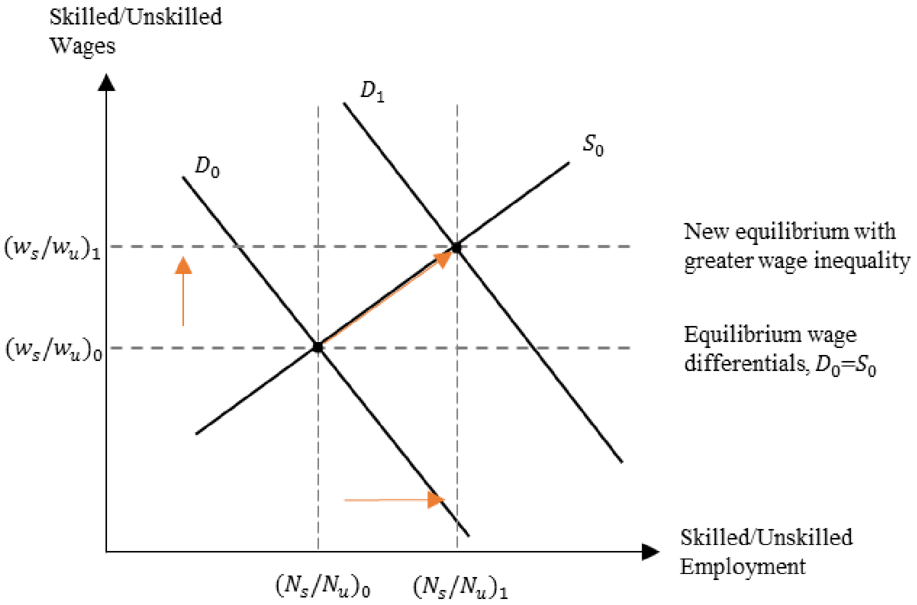
Eriksson and Jäntti (1997) take into consideration the macroeconomic trends in Finland that occurred during the same time in the period of 1985-1990, such as the large drop in trade with Soviet Union prior to its disintegration and the demographic changes relating to the huge after war generation. Nonetheless, they state that these macroeconomic factors are not able to explain the experienced changes in wage inequality. Therefore, Eriksson and Jäntti (1997) conclude that the increase in wage inequality in the 80s most likely appeared due to changes in wage setting policies that occurred during the same time. These policies created a shift towards decentralization and greater power to individual industries and firms. This is because the decrease in earnings differentials in the 70's coincided with the centralized wage-bargaining and solidarity wage policy, whereas the increase in dispersion of earnings coincided with the abandonment of egalitarian and more decentralized wage policy. Nevertheless, these results should be carefully interpreted as the evidence from Finland is rather weak already because there has been lack of individual level data that can be used to examine the development of wage inequality and skill premia more in detail (Asplund, 1995).

Additionally, though the SBTC has been relatively dominant within the vast amount of scholars, alternative hypothesizes have been raised. One is the role of increased international trade in the 1980s which has led to a sharp decline in manufacturing employment and a shift in employment towards sectors that are education and female intensive, thus increasing the demand for skills (e.g., Wood, 1995; Blinder 2009; Autor et al., 2014). Some scholars have also noted the role of institutions affecting wage-setting, such as unions, pay norms and the minimum wage (e.g. Blackburn, Bloom and Freeman, 1989; Freeman, 1991; Acemoglu, Aghion and Violante, 2001). However, there is similar evidence on the relationship of technology and wage premium of skilled workers from many developed countries with different institutional setting (see, e.g. Berman, Bound and Machin, 1998; Machin and Van Reenen, 1998) and hence, the role of wage-setting institutions seems not to be big enough to explain the effect of technology on wage inequality.

2.2.1 The Skill-Biased Technological Change

The theory behind the literature is what Acemoglu and Autor (2011) refer to as the canonical model, which in many scholars is called the skill-biased technological change, SBTC. The basic assumption of the SBTC model is that relative demand for skills increases over time because technological advancements are assumed to be skill biased. To the contrary of the skill-replacing technological advances of the 19th century, most new technologies appear to be skill-complementary inducing greater demand for skills (Katz and Murphy, 1992; Acemoglu, 1998). Consequently, both the increase in demand for skills and the increase in supply of educated workers have been the main source of the increased wage inequality and increasing skill premia in the US. The relationship between relative wage levels and the demand and supply of skills in the SBTC model is presented in Figure 5.

Figure 5: Relative Wages and the Demand and Supply of Skills in the SBTC Model (Machin and Van Reenen, 2007).



In order to study the relationship of technology and skills, employment in the SBTC model is divided into two skill groups, low-skilled workers L and high-skilled workers H who perform two different and imperfectly substitutable tasks. The two factor framework assumes an inelastic short run relative supply function and a downward sloping relative demand function. Moreover, technology is assumed to take a factor-augmenting form and this factor-augmentation can complement either high or low skill workers, thus generating skill biased demand shifts. These demand shifts cause changes in the wage levels between the two skill groups resulting in changes in wage inequality, as seen in Figure 5.

The elasticity of substitution between high and low skill workers plays a pivotal role in understanding the effects technological change in the SBTC model. As all low or high skill workers are not alike, it is worth noticing that in the model each worker is endowed with either high or low skill, but there is a distribution across workers in terms of efficiency units of these skill types. Accordingly, each low skill worker $i \in L$ has l_i efficiency units of low skill labor and each high skill worker $i \in H$ has h_i efficiency units of high skill labor (Acemoglu and Autor, 2011). All workers supply their efficiency units inelastically and hence, the total supply of high and low skill labor is:

$$L = \int_{i \in L} l_i \, di \text{ and } H = \int_{i \in H} h_i \, di$$

To illustrate the changes in wages depending on the skill level, the two factors in the simple CES technology aggregate production function with constant elasticity of substitution is of the form:

$$Y = ([A_l L]^{\rho} + [A_h H]^{\rho})^{1/\rho} \,,$$

where A_l and A_h are efficiency parameters and thus a change in these parameters captures the factor-augmenting technological change increasing productivity of the respective type of labor.

The elasticity of substitution between two production inputs L and H in a generic production function $Y = F(L, H)$ is the following;

$$\sigma = [\frac{\Delta(^{L}/_{H})}{^{L}/_{H}}]/[\frac{\Delta(^{w_h}/_{w_l})}{^{w_h}/_{w_l}}] = \frac{\%\ change\ in\ L/H}{\%change\ in\ w_H/w_L}$$

In the CES model the elasticity of substitution between high-skilled and low-skilled in this CES model is

$$\rho = \frac{\sigma-1}{\sigma}, \text{ where } \rho < 1 \text{ and } \sigma > 0.$$

Consequently, the parameter σ shows how changes in technology A or in supply L and H affect labor demand and wages. If elasticity of substitution > 1 $(or\ \rho > 0)$, then skilled and unskilled workers are gross substitutes, meaning that a reduction in the supply of unskilled workers increases the demand for the skilled workers and vice versa. If $\sigma < 1$ $(or\ \rho < 0)$, then skilled and unskilled workers are gross complements so that a reduction in the supply of the other decreases the demand or the other type of labor. The three other focal cases of substitutability in the CES model can be seen in Appendix 2. Additionally, the demand curve for factor of production depending whether the input is a complement or substitute and how it affects employment of the input can be seen in Appendix 3.

Based on the two optimal wage setting equations derived from the CES technology aggregate production function (see the derivation in Appendix 5), skill premium in logarithmic form is:

$$\log\left(\frac{w_H}{w_L}\right) = \frac{\sigma-1}{\sigma}\log\left(\frac{A_h}{A_l}\right) - \frac{1}{\sigma}\log(\frac{H}{L})$$

Supposing that new technology increases the productivity of skilled workers more than it does that of unskilled workers, then $\frac{A_h}{A_l}$ increases. This type of technological change is called skill-biased technological change and the effect of technological change on the skill premium is either positive or negative depending on the sign $\sigma \lesseqgtr 1$. This effect can be seen in the equation below:

$$\frac{\partial \log({}^{w_H}/_{w_L})}{\partial \log({}^{A_h}/_{A_l})} = \frac{\sigma - 1}{\sigma}$$

In the literature there is a broad consensus that the SBTC model requires that H and L are not gross complements and thus $\sigma > 1$ (see, e.g., Katz and Murphy, 1992; Autor, Katz and Krueger, 1998). Accordingly, SBTC leads to growth in relative supply of skilled workers, H/L, increases the skill premium and contributes to wage inequality.

Based on the results Autor, Katz and Krueger (1998) state that relative demand for more skilled workers measured in college/high-school relative wage grew more rapidly on average during the period of 1970-1995 than during the previous three decades of 1940-1970 (see Figure 3). They argue that this upsurge in skill demand was entirely explained by within-industry changes in skill demand and that this can be further linked to the large diffusion of computers and related technologies. These within-industry changes, rather than between-industry, have been widely demonstrated in several scholars, thus, implying SBTC. There is vast amount of evidence that the demand shifts towards more-skilled workers since 1970 has been mainly a result of more rapid within-industry changes in skill-utilization rather than between-industry employment shifts (Katz and Muprhy, 1992; Autor, Katz and Krueger, 1998; Acemoglu and Autor, 2011).

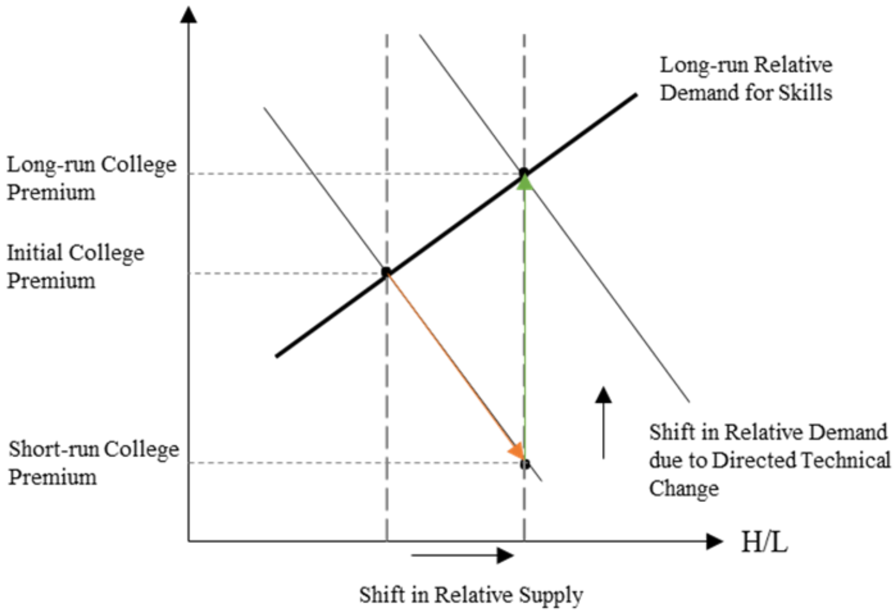
Furthermore, Autor, Katz and Krueger (1998) find that educational and occupational skill upgrading occurred more rapidly in industries with greater computer utilization in the 1980s and early 1990s. Accordingly, Bersnahan, Brynjolfsson and Hitt (2002) find that there is firm-level evidence that greater use of ICT is related to the employment of more skilled workers. They also highlight that in addition to the direct effect of computers on labor demand, computers also induce SBTC indirectly through firm-level organizational changes and new products and services. Nonetheless, some critics have suggested that SBTC fails to explain the evolution of other dimensions determining wage inequality, such as gender and racial wage gaps and the age gradient in the return to education (Card and DiNardo, 2002). Nonetheless, in light of the evidence it is hard to argue against the role that technologies invented in the last decades have had in increasing wage inequality.

2.2.2 Endogenous Skill-biased Technological Change

One deficiency of the skill-biased technological change theory is that it cannot explain how technology responds to the changes in labor market conditions, in particular, changes in labor supplies. Acemoglu (1998; 2003) builds upon the argument and results of Autor, Katz and Krueger (1998) and states that his natural model where the direction of technological change is endogenous can explain why the demand for skills and the college premium first fell in the 1970 with a subsequent large increase in the supply of skills and then increased sharply in the 1980s. Acemoglu (1998) argues that the theory of endogenous technological change implies that an increase in the supply of skills reduces the skill premium in the short run, but in the long-run it induces skill-biased technological change increasing the skill premium.

The impact of an increase in the supply of skills on the skill premium is determined by two forces. These two competing forces are firstly, the substitution effect which makes the economy move along a downwards sloping relative demand curve and secondly, the directed technology effect that shifts relative demand curve for skills as seen in Figure 6. Accordingly, the acceleration in the supply of skills induces a faster upgrading of skill-complementary technologies. This is based on the argument that most technologies are mainly nonrival goods that improve productivity by pushing more effort into invention of new skill-complementary technologies.

Figure 6: Endogenous Technoclogical Change and Dynamics of College Premium (Acemoglu, 1998).

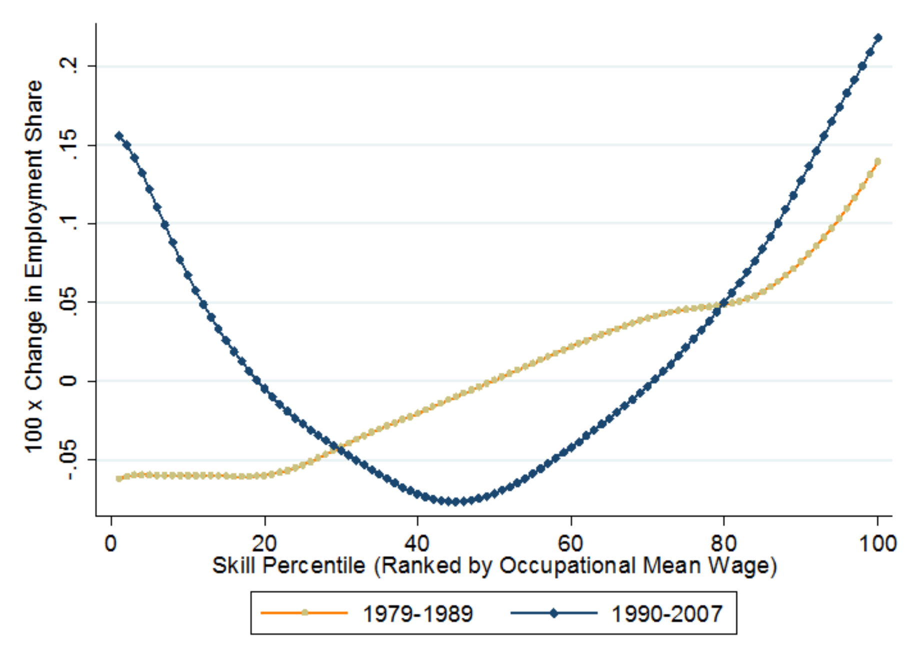


Consequently, Acemoglu (1998) suggests that the model of endogenous technological change implies that technology should become more skill biased following increases in the supply of high-skilled workers, and vice versa. This, on the one hand, explains why in the 19th century technological advancements were skill replacing as it responded to the large increase in the supply of skills into the cities. On the other hand, according to Acemoglu (1998) it also explains why in the 1980s the demand for high-skilled workers accelerated in response to the more rapid increase in the supply of college skills in the late 1960s and early 1970s. Hence, he essentially argues that technological change itself has been the result of a surge in college graduates.

2.3 Job Polarization

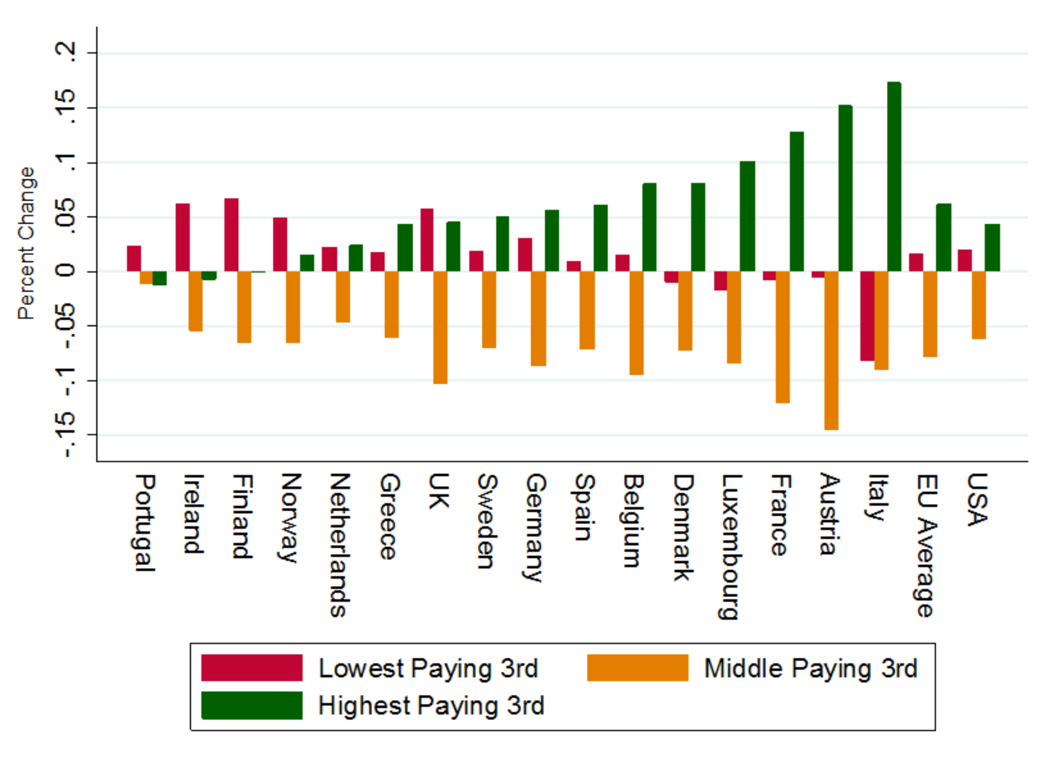
Skill-biased technological change was successful in explaining many decades of data indicating a shift in demand towards more educated and highly skilled workers. However, contradictory to the SBTC model in the 1990s employment shares and relative earnings rose both in the low and high-skilled jobs in the US which led to U-shaped relationship between skill levels, employment and wage growth as seen in Figure 7 (Autor, Katz and Kearney, 2006; 2008; Acemoglu and Autor, 2011; Autor and Dorn, 2013). Thus, SBTC couldn't explain the simultaneous increase both in high- and low-skilled workers' employment shares. This hollowing-out of middle-skilled workers has found empirical evidence also in the UK by Goos and Manning (2007) and in Germany by Spitz-Oener (2006) and Dustmann, Ludsteck and Schönberg (2009) during the same period of time.

Figure 7: **Smoothed Changes in Employment by Pccupational Skill Percentile 1970-2007 in the US (Acemoglu and Autor, 2011).**



Although the evidence for job polarization has been generally weaker in Europe compared to the US, there has been some indications of it mainly in the continental Europe (Goos, Manning, and Salomons, 2009; Michaels, Natraj and Van Reenen, 2014; Goos Manning and Salomons, 2014). The evidence for job polarization from Europe is presented in Figure 8, in which the changes in employment shares by occupation 1993-2006 in several European countries are calculated by Goos, Manning and Salomons (2009).

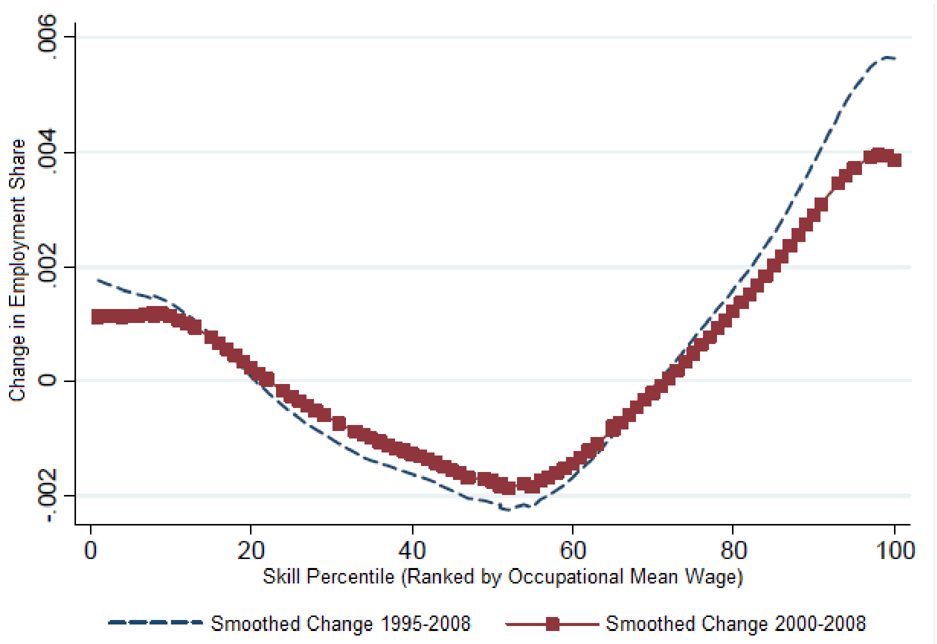
Figure 8: Change in Employment Shares by Occupation in 16 European Countries 1993-2006. Occupations grouped by wage tercile (Goos, Manning and Salomons, 2009; Acemoglu and Autor, 2011).



Occupations are grouped by wage tercile: low, middle and high. The data include all persons ages 16-64 who reported having worked last year excluding those employed by the military and in agricultural occupations. Occupations are first coverted to 326 occupation groups and further grouped into three wage level categories.

In the Nordic countries job polarization has been much weaker, though they are by no means an exception of technological shocks being heavy in ICT-technologies (Asplund et al., 2011). To be precise, according to an OECD report (2004) the contribution of ICT sector to employment in 2000 was the highest in Finland from all OECD countries, reaching up to 11 % of total employment. Nonetheless, in Finland job polarization has been weaker than in other Nordic countries, which is seen in the results of Goos, Manning and Salomons (2009) in Figure 8 above. On the contrary, Asplund et al. (2011) argue that there is relevant increase in the employment shares at the top of the occupational wage distribution in Finland, especially when looking at the 3-digit occupational classification level. These results are reinforced by Mitrunen (2013) who provides clear estimates for job polarization in Finland. He states that between 1995 and 2008 the share of occupations in the middle paying 3rd out of all occupations dropped by 12 percentage points while the share of the lowest and highest 3rd incremented, thus implicating that there is also clear job polarization in Finland. Moreover, Mitrunen (2013) finds out that in the middle paying 3rd especially the industrial manufacturing and clerical jobs have decreased. The evidence of job polarization in Finland is presented in Figure 9 and in Appendix 4. Accordingly, Asplund et al. (2011) argue that despite the rigid wage-setting procedures, there is evidence for job polarization also in Finland, though the increase in the highest paying occupations remains to be clearer than the decline in the lowest paying occupations.

Figure 9: Smoothed Changes in Skill Percentile in Finland 1995-2008 (Mitrunen, 2013).



It should be noted that in these international comparisons presented here the comparability of the data should be examined critically as mostly the difficulty in these comparisons is the lack of data or the lack of comparability in the data sources across different governmental statistics. Nevertheless, it can be concluded that job polarization is evident in many developed countries among the OECD, though the extent of the phenomenon depends highly on the given institutions of the economy.

2.3.1 The Routinization Hypothesis

To answer to the deficiency of SBTC, Autor, Levy and Murnane (2003) asked what it is exactly that computers do that causes educated workers to be relatively more in demand. They demonstrated that whether or not technology substitutes or complements human labor depends on the different tasks that the job entails. They argued that exposure to technology varies primarily according to occupational tasks, not according to worker's education. Therefore, they created a conceptual approach in which the interactions of workers and technologies are described by job tasks. The underlying assumption is that computer capital substitutes for workers in performing routine cognitive and manual tasks and complements workers in performing non-routine problem-solving and complex communications tasks. This has been further stressed due to the advances in computer technology caused by the declining price of computer capital. Based on the underlying assumption that routine and non-routine tasks are imperfect substitutes, they find that within industries, occupations, and education groups, computerization is associated with reduced labor input of routine manual and cognitive tasks and increased labor input of non-routine cognitive tasks.

Consistent with the findings of Autor, Levy and Murnane (2003), Beadury, Green and Sand (2013) argue that after many decades of increase in the demand for skills, specifically for cognitive tasks associated with higher education, after 2000 the demand for skills has declined albeit continuing increase in the supply of highly skilled workers. According to Beadury, Green and Sand (2013) this has resulted in a deskilling process meaning that middle-skilled workers have moved down the occupational ladder and have begun to perform jobs traditionally performed by low-skilled workers. As a result middle-skilled workers have been pushing low-skilled workers even further down in the occupational ladder and even out of the labor force. This is further associated with a widening gap between high-skilled and low-skilled workers that increases job polarization as wages react to these shifts in the labor market.

Furthermore, Autor and Dorn (2013) argue that the hollowing out of middle-skill occupations and the modest increase in the employment of low-skilled occupations is caused by the rise in employment and wages in the service occupations. The hypothesis of Autor and Dorn (2013) is that job polarization is driven by the interaction between consumer preferences and non-neutral technological progress. Consumer preferences favor variety over specialization whereas non-neutral technological progress reduces the cost of completing routine job task but has a minor impact on the cost of performing in-person service tasks. The results of the study indicate that between 1980 and 2005 the share of hours worked in service occupations among noncollege workers increased by more than 50 percent with wage growth significantly surpassing other low-skill occupations. The explanation is thus consistent with the "routinization" hypothesis of Autor, Levy and Murnane (2003) as Autor and Dorn (2013) conclude that the declining price of computer technology has driven down the wage paid to routine tasks. This induces low-skill workers to reallocate their labor supply to service occupations as service tasks still remain to be relatively hard to automate.

In order to understand the vast implications the "routinization" hypothesis has on the labor market Frey and Osborne (2013) made an in-depth analysis of what exactly does this ability of computers to automate mean for the future of employment. Instead of looking at the historical trends, they identify the bottlenecks to computing in order to better comprehend the division of labor between humans and computers in the future. By building a revisited task model based on Autor, Levy and Murnane (2003), they categorize occupations according to their susceptibility to computerization. On the contrary to the findings of Autor and Dorn (2013) and the recent implications on job polarization, the results of Frey and Osborne (2013) indicate that most of the service jobs, especially those requiring relatively little skills, will be computerized in the near future if and when technological progress will allow for better automation and robotics. Additionally, consistent with the initial hypothesis of SBTC, the results of Frey and Osborne (2013) indicate that the lower the probability of computerization, the higher the required education level and earned wage level of the occupation. Consequently, as computerization threatens jobs especially at the low-skill end, it gives implications on the further increasing skill demands of workers, rather than job polarization.

Next the task model by Autor, Levy and Murnane (2003) will be presented in more detail. Furthermore, the revisited task model by Frey and Osborne (2013) and the implications of computerization to the future of employment will be explained. The findings of the literature offer good insights for understanding what are those skills that humans should require in order to be competitive in the labor markets in the future as technological progress further accelerates.

2.3.1.1 The Task Model with Two Task Inputs

The task model, which is also called the Ricardian model of the labor market, makes a distinction between skills and tasks and tries to capture the changes in skill requirements based on job tasks. In this model the interaction and relationship between skills, technologies and wages is explained with the supply and demand for skills. It is based on the self-selection of workers across different tasks according to the comparative advantage between workers and technology, which substitutes some specific tasks while complementing others. The essential idea of the model is that a skill is a worker's endowment of capabilities for performing various tasks. This endowment can be exogenously assigned or acquired through schooling, training, etc. Furthermore, a task is a unit of work activity that produces output and workers apply their skill endowments to tasks in exchange for wages (Acemoglu and Autor, 2011).

Autor, Levy and Murnane (2003) define a routine task as such that it can be completed by machines following explicit programmed rules. One example of these tasks are manual tasks in an assembly line in a manufacturing factory or cognitive tasks such as bookkeeping. These tasks include systematic and disciplined repetition of a procedure which can be relatively easily programmed into clear instructions and thus performed by machines or robots. However, the prerequisite for programming routine tasks is that the procedures to complete them are well understood and executed in a well-controlled environment. Otherwise they cannot be explained to a computer with uniform and explicit rules. Therefore, the explained prerequisites for programming routine tasks are the main problems and obstacles in programming manual and cognitive tasks and why there is still need for human labor.

This leads to the definition of non-routine tasks, which are such tasks that rules are not sufficiently well understood to be specified in computer code and executed by machines. These tasks are, for example, professional and managerial tasks that require extensive amount of abstract problem-solving and interactive communication. These non-routine type of tasks thus tend to be included in jobs that are in the upper part of the wage distribution. Additionally, non-routine tasks include also manual tasks, such as cleaning jobs and other low-skilled jobs that happen in an unconstructed environment, and are thus hard to automate. Consequently, these low-skilled jobs are not directly affected by technology, but the impact of technology on other jobs in the economy is likely to lead to an upturn in employment in these low-skilled jobs (Goos and Manning, 2007). Table 2 gives examples of different routine and non-routine jobs, which are further divided in the matrix into manual tasks and analytic and interactive tasks. Moreover, the underlying hypothesis of the impact of computerization of each tasks is presented in the table as stated by Autor, Levy and Murnane (2003).

Table 2: Task model for the impact of computerization on four categories of workplace tasks (Autor, Levy and Murnane, 2003).

	Routine tasks	Non-routine tasks
	Analytic and interactive tasks	
Examples	· Record-keeping · Calculation · Repetitive customer service (e.g., bank teller)	· Forming/testing hypotheses · Medical diagnosis. · Legal writing. · Persuading/selling. · Managing others.
Computer impact	· Substantial substitution.	· Strong complementarities.
	Manual tasks	
Examples	· Picking or sorting · Repetitive assembly	· Janitorial services · Truck driving
Computer impact	· Substantial substitution	· Limited opportunities for substitution or complementarity.

Table 2 above implies three main assumptions for the framework by Autor, Levy and Murnane (2003). First, computer capital is more substitutable for human labor in completing routine tasks than non-routine tasks. Secondly, routine and non-routine tasks are imperfect substitutes and thirdly, greater intensity of routine inputs increases the marginal productivity of non-routine inputs. Based on these assumption, Autor, Levy and Murnane (2003) build a general equilibrium model with two task inputs, routine and non-routine task inputs that are used to produce output Q, which sells at price one. The Cobb-Douglas production function with constant returns to scale are assumed in the function below:

$$Q = (L_R + C)^{1-\beta} L_N^{\beta}, \beta \epsilon (0,1),$$

where L_R and L_N are routine and non-routine labor inputs and C is computer capital, all measured in efficiency units. In this model computer capital is supplied at market price ρ per efficiency unit, where ρ is falling exogenously with time due to technological advances. The main assumption is that computer capital and labor are perfect substitutes in carrying out routine tasks. Moreover, the model implies that the elasticity of substitution between routine and non-routine tasks is one, and hence computer capital and non-routine task inputs are relative complements. Regardless of the assumption of perfect substitutability between computer capital and routine task input, which is contradictory to the first two assumptions above, the only requirement for the model of Autor, Levy and Murnane (2003) is that computer capital is more substitutable for routine than non-routine tasks. Therefore, routine and non-routine tasks are q-complements, which means that an increase in the economy's endowment of routine task input leads to an increase in the equilibrium price of non-routine input, and vice versa (Hamermesh, 1985). In other words, the marginal productivity of non-routine task rises with the quantity of routine task input, which is consistent with the third assumption in the previous section (Autor, Levy and Murnane, 2003).

The assumptions include that there is a large number of income-maximizing workers and each worker supplies one unit of labor. Workers have heterogeneous productivity endowments in both routine and non-routine tasks, with $E_i = [r_i, \eta_i]$ and $1 \geq r_i, \eta_i > 0 \; \forall \; i$. Each worker can thus choose to supply any convex combination of r_i efficiency units of routine task input and η_i efficiency units of non-routine tasks input so that $L_i = [\lambda_i r_i, (1 - \lambda_i)\eta_i]$, where $0 \leq \lambda_i \leq 1$. Consequently, workers will choose tasks according to comparative advantage and thus it generates re-sorting of workers across jobs as a result of decline in ρ due to technological advancements.

The market equilibrium in this model is based on the assumption of perfect substitutability of routine tasks and computer capital, so that the wage per efficiency unit of routine task input is equal to the price of computer capital:

$$w_R = \rho \; .$$

Additionally, the market equilibrium requires that workers can self-select among routine versus non-routine occupations.

The relative efficiency of an individual i at performing non-routine versus routine tasks is $n_i = n_i / r_1$, where $\eta_i \in (0, \infty)$ according to the assumptions in the model. At the labor market equilibrium, a worker is indifferent between performing routine and non-routine tasks when $\eta^* = w_R / w_N$, where n^* is the equilibrium relative efficiency units between these two tasks. The worker supplies routine labor if $\eta_i < \eta^*$, and supplies non-routine labor otherwise.

To quantify the total labor supply in an economy, total endowments in efficiency units of all workers performing routine and non-routine tasks are measured at each value of η in the respective functions $g(\eta)$ and $h(\eta)$ so that:

$$g(\eta) = \textstyle\sum_i r_i \cdot I[\eta_i < \eta] \text{ and } h(\eta) = \textstyle\sum_i n_i \cdot I[\eta_i \geq \eta],$$

where $I[\cdot]$ is the indicator function. Assuming that η_i has nonzero support at all $\eta_i \in (0, \infty)$, $h(\eta)$ becomes continuously upward sloping and $h(\eta)$ continuously downward sloping in η. Lastly, assuming that the economy operates on the demand curve, productive efficiency requires that:

$w_R = \frac{\partial Q}{\partial L_R} = (1-\beta)\theta^{-\beta}$ and $w_N = \frac{\partial Q}{\partial L_N} = \beta\theta^{1-\beta}$, where $\theta \equiv (C + g(\eta^*))/h(\eta^*)$.

Thus, θ in this function above symbols the ratio of routine to non-routine task input in production. These equations provide the equilibrium conditions for the Autor, Levy and Murnane (2003) model and its five endogenous variables: $w_R w_N \theta, C, \eta$. Deriving from the equilibrium, it is easy to see how a decline in the price of computer capital affects task input, wages, and labor supply. Firstly, from the equation $w_R = \rho$ it is evident that a reduction in the price of computer capital will reduce the wage level of routine job in the same proportion and thus the demand for routine task input rises as seen in the following equation:

$$\frac{\partial \ln\theta}{\partial \ln\rho} = -\frac{1}{\beta}.$$

From an employer's perspective this rise can be met by either an increase in computer capital or labor input for routine tasks. As routine and non-routine tasks are q-complements, the relative wage paid to non-routine task rises as ρ declines:

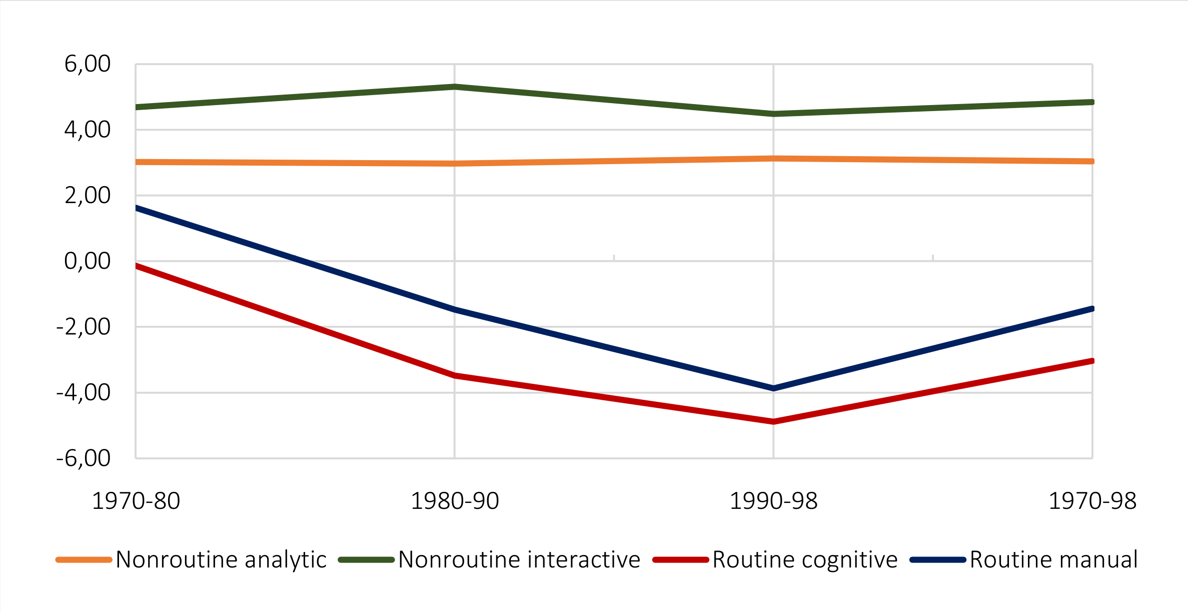
$$\frac{\partial \ln({}^{w_N}/{w_R})}{\partial \ln\rho} = -\frac{1}{\beta} \text{ and } \frac{\partial \ln\eta^*}{\partial \ln\rho} = \frac{1}{\beta}$$

Consequently, workers will reallocate their labor input from routine to non-routine tasks and increased demand for routine tasks must be met entirely by computer capital. To conclude, based on the routinization hypothesis and the model presented here, a decline in the price of computer capital raises the marginal productivity of nonroutine tasks. This leads to workers reallocating labor supply from routine to nonroutine task input. Furthermore, routine tasks are done by computers yielding to a net increase in the intensity of routine task input in production (Autor, Levy and Murnane, 2003).

2.3.2 Shift in Demand towards Non-routine Tasks

Autor, Levy and Murnane (2003) create a novel interpretation of labor market trends affected by the recent advances in computer technology in order to understand the cause of job polarization. By focusing on task content of employment and dividing job tasks into routine and non-routine tasks, they are able to show that the demand for skills has especially risen for the non-routine tasks. Figure 10 shows how throughout the 1970 until 1998 the non-routine analytic and interactive job tasks have increased, while the routine manual and analytic tasks have decreased. This indicates that there has been steady increase for tasks that require more skills since the 1970s.

Figure 10: Shifts in College-equivalents Labor Demand in the US Implied by Changes in Job Tasks, 1970-1998 (Autor, Levy and Murnane, 2003).



The changes in job tasks are measured in observed annual changes in the US DOT occupational task measures, annual changes are presented in percentile changes relative to 1960 task distribution in the US. Figure 8 summarizes the changes in job task input due to cross-occupation shifts in task input. The combined within- and cross-occupation shifts between 1980 and 1998 can be seen in Autor, Levy Murnane (2003).

The “routinization” hypothesis is very intuitive and accurate regarding the predictions based on historic labor market trends, but what will happen in the future in the labor markets still remains unknown. Consistent with the Moore’s law, which explains the exponential speed of technological development in the current digital era, it seems that we are only halfway through in exploiting the full potential of technological innovations to replace human labor with disruptive technologies (Brynjolfsson and McAfee, 2011). Though, making predictions about technological progress is notoriously difficult (Armstrong and Sotala,2015), it does not mean that we should not to be prepared for the changing skill requirements and job content in order to provide a smoother transit to the new digital economy. This is what Frey and Osborne (2013) tried to do in their study by altering the task model of Autor, Levy and Murnane (2003) to predict the impact of computerization on US labor market outcomes. This revisited model will be explained in more detail in the next section.

2.3.3 The Task Model Revisited

Rather than looking backwards into the historic data of employment, Frey and Osborne (2013) take a look at the future aiming to predict the impact of computerization on US labor market outcomes. The objective of the study is to analyze the number of jobs at risk due to computerization. Moreover, it aims to capture the relationship of wages and educational attainment on an occupation’s probability of computerization. By using a methodology that draws on recent advances in Machine Learning, ML, and Mobile Robotics, MR, Frey and Osborne (2013) aim to go even beyond the computerization of routine tasks as in the model by Autor, Levy and Murnane (2003) by combining labor market trends with capabilities of computer-controlled equipment.

The need for this study emerged to add up to the vast discussion among economists on how technological advancements have resulted in higher rates of technological unemployment across the advanced economies, especially after the Great Recession (see, e.g. Katz, et al., 2014). Brynjolfsson and McAfee (2011) argued that the computer-controlled equipment is one possible explanation for this recent jobless growth. It has been noticed now that no longer are only routine manufacturing jobs subject to computerization but also relatively complex tasks requiring mobility and interactivity. In fact, Autor, Levy and Murnane (2003) categorize driving a truck, legal writing and medical diagnosis as non-routine tasks not subject to the threat of computer capital. However, in 2015 IBM's Watson computer is giving medical diagnosis to patients and Google's driverless car has driven 1,011,338 autonomous miles on the road [5](Frey and Osborne, 2013; Brynjolfsson and McAfee, 2014).

The model of Frey and Osborne (2013) uses the Occupational Information Network (O*NET) data, which is an online service developed specifically for the US Department of Labor. The O*NET data is a database containing information on hundreds of standardized and occupation-specific descriptors in the US. Based on the occupation-specific descriptors Frey and Osborne (2013) categorize occupations based on specific characteristics that describe how susceptible the occupations are to computerization. The characteristics are the following defined bottlenecks to computerization: perception and manipulation, creative intelligence and social intelligence. Essentially the overarching feature of all of these bottlenecks is that they include processes that are hard to be understood specifically and thus followed by explicit rules computed for computers by humans. This is the same underlying assumption as in the routine and non-routine task model of Autor, Levy and Murnane (2003), however, to some extent the updated version.

In order to better predict the impact of computerization on task content and employment, Frey and Osborne (2013) develop an altered task model that assumes for tractability an aggregate constant-returns-to-scale Cobb-Douglas production function of the form:

[5] Google Self-Driving Car Project, Monthly Report, May 2015.

$$Q = (L_S + C)^{1-\beta} L_{NS}^{\beta}, \beta \epsilon (0,1),$$

where L_S and L_{NS} are susceptible and non-susceptible labor inputs and C is computer capital. The model assumes that computer capital is supplied perfectly elastically at market price per efficiency unit, and the market price is falling exogenously with time due to technological progress. Moreover, the model assumes that there are income-maximizing workers with heterogeneous productivity endowments in both susceptible and non-susceptible tasks. The alteration to the original task model by Autor, Levy and Murnane (2003) arises from the input L_{NS} which is not confined to routine labor inputs. This results from the recent technological advancements in ML and MR, and the use of big data, which allow for better pattern recognition that enables computer capital to substitute labor also in many different non-routine tasks. Nevertheless, the bottlenecks which prevent the full substitution of the non-routine tasks remain, at least for now. Consequently, the altered model by Frey and Osborne (2013) predicts that the speed at which these bottlenecks can be overcome will determine the extent of computerization in the future.

Combining the ideas of exponential speed of development in ML and MR as described by Brynjolfsson and McAfee (2014) and the already mentioned bottlenecks, Frey and Osborne (2013) describe non-susceptible labor input to be of the following form:

$$L_{NS} = \sum_{i=1}^{n} \left(L_{PM,i} + L_{C,i} + L_{SI,i} \right),$$

where L_{PM}, L_C and L_{SI} are labor inputs into perception and manipulation tasks, creative intelligence tasks, and social intelligence tasks.

Consequently, the task model by Frey and Osborne (2013) predicts that recent development in machine learning will result in reduced aggregate demand for labor input in routinized tasks and increased aggregate demand for labor input in tasks that are not susceptible to computerization. This is a result of the advanced technology which allows for pattern recognitions and enables routinized tasks to be computerized while non-routinized tasks still inhere attributes that are hard to computerize. These attributes are further divided into three concrete capabilities by Frey and Osborne (2013) which are in relative terms easy for a human to do, but hard for the computer. These bottlenecks are explained more in detail in the next section below.

2.3.3.1 Bottlenecks to Computerization

i. Perception and manipulation tasks

Perception and manipulations tasks, for which Frey and Osborne (2003) use O'NET variables Finger Dexterity, Manual Dexterity and Cramped Work Space & Awkward Positions, include such tasks that relate to the sensorimotor skills discussed earlier in conjunction with the Moravec's paradox. Sensorimotor skills are those skills that humans learn by trial and error during the premature years by making sense of all the sensory information they receive from their bodies and the environment through the sensory system, such as vision, hearing, smell, taste, touch and vestibular sensory systems. Creating appropriate movement based on the adequate processing and analyzing of information is still relatively hard for robots despite of the recent highly developed sensors, manipulators and lasers, which would allow robots to perform non-routine manual tasks. Consequently, simple manual service tasks, such as cleaning a house, are still done by humans (Frey and Osborne, 2013).

According to Frey and Osborne (2013) as long as robots are unable to match the depth and breadth of human perception, more complex non-routine manual tasks that relate to an unstructured work environment can make jobs less susceptible to computerization. Nevertheless, this obstacle can be overcome by clever task design, such as Amazon's Kiva Systems did by placing bar-code stickers on the floor to inform robots of their precise location in order to be able to navigate in a warehouse (Guizzo, 2008). On the other hand, manipulation tasks relate to handling of irregular objects, in which robots have still several difficulties with. The main challenges include identifying and rectifying mistakes, planning out the sequence of actions required to move the object around and designing manipulators that have responsive dynamics (Frey and Osborne, 2013). As with the task design these obstacles can be overcome by rethinking the problems, which is what most accomplished industrial manipulation tasks have already done, according to Brown, et al. (2010).

These challenges in the aptitudes of the robots was seen clearly in the International DARPA Robotic Challenge held in 2015 where the accomplishments of the robots were highly remarkable and innovative considering the starting point of the competition three years before. Nevertheless, the clumsiness of the robots still ended up being the biggest headache for the designers[6]. Accordingly, these perception and manipulation related challenges to robotic computerization remain to be solved in the next decade or two (Robotics-vo, 2013).

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[6] *The Economist,* June 13th, 2015

ii. Creative intelligence tasks

The psychological process relate to human creativity is difficult to specify and it requires using a large knowledge base to create ideas or artifacts that are novel and valuable (Boden, 2004). For Creative Intelligence Frey and Osborne (2003) use Originality and Fine Arts O*NET variables. Originality refers to the creative way of coming up with solutions to problems and clever and unusual ideas, even jokes, whereas Fine Arts refers to knowledge of theory and techniques applied in composing, producing and performing be it music, arts, dance or theatre. The challenge with creative intelligence tasks is that it is still hard for computers to make unfamiliar combinations of familiar ideas that would make sense. However, there are few good examples of premature versions of programmed creativity, for example, automatic creation and designing of statistic models for data, e.g., in Excel, a drawing-program AARON, and EMI software to compose various music.

One of the problems with creativity is that people rarely understand their creative processes, and thus are not able to code them in explicit rules for the computer to do (Boden, 2004). Moreover, creativity is dependent on values, which are by no means static and universal. Human values are constantly changing and they are shaped by ethics, culture and religion. Therefore, as Frey and Osborne (2013) state, it seems very unlikely that creative intelligence tasks will be automated in the next decades.

iii. Social intelligence tasks

Frey and Osborne (2013) define Social Intelligence with four different O*NET Variables: Social Perceptiveness, Negotiation, Persuasion and Assisting and Caring for others. Social Perceptiveness is being aware of others' reactions and understanding the reasons behind the reactions of others, while Negotiation relates bringing others together and trying to reconcile differences. Persuasion, on the one hand, relates to persuading others to change their minds or behavior whereas Assisting and Caring for Others requires skills of empathy and providing emotional support, medical attention or personal assistance. Thus, it is about caring for others, such as coworkers, customers or patients.

Social intelligence is an important skill to have in various work tasks and occupations that involve skills relating to, for example, negotiation, persuasion and care. Despite the active research conducted in the area of Affective Computing (Scherer, et al., 2010; Picard, 2010) and Social Robotics (Broekens, et al., 2009), the main problem in these tasks is the real-time recognition of natural human emotions and the ability to respond intelligently to these emotions.

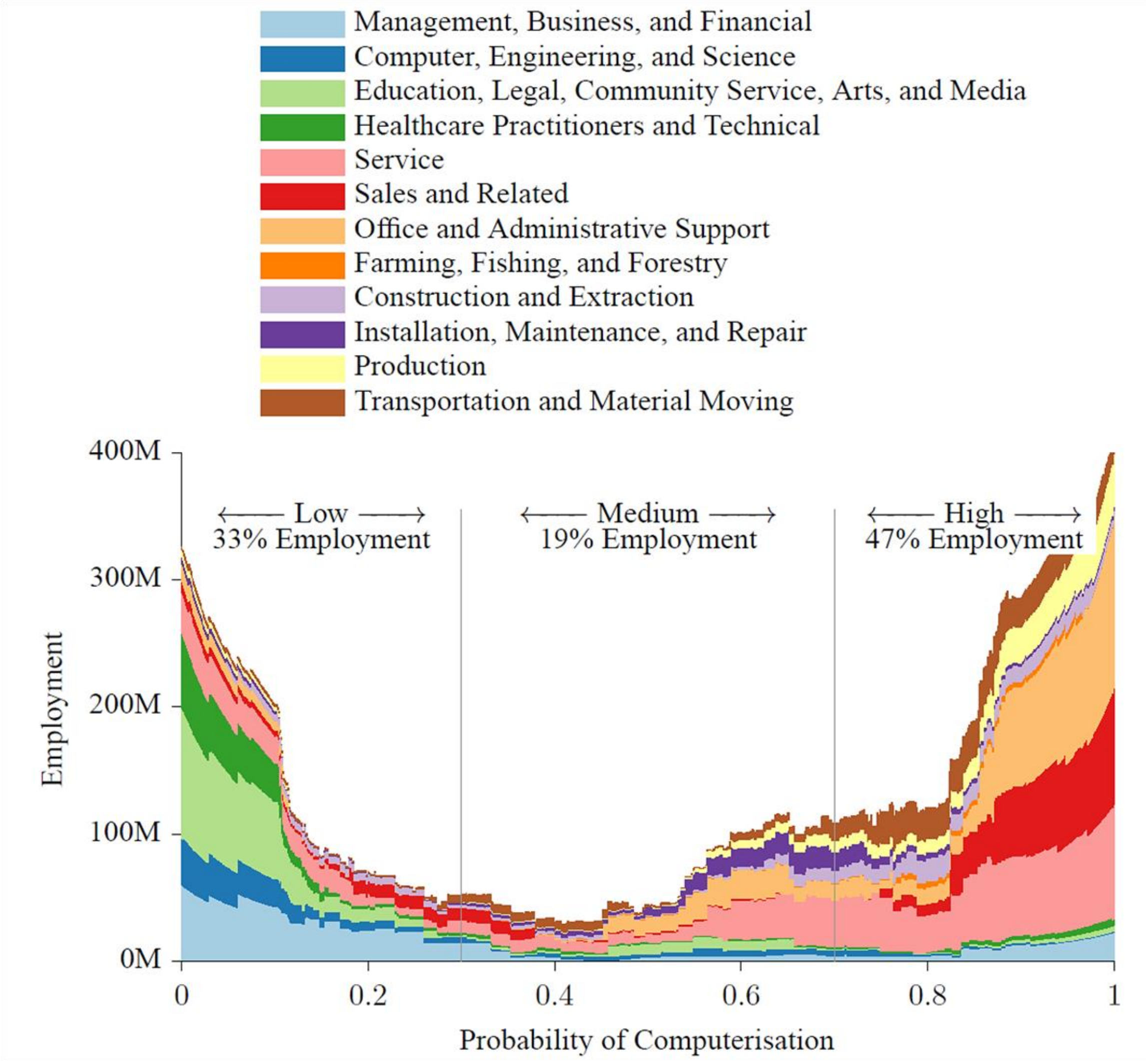
Yet, computers have a hard time resembling humans when it comes to processing common sense information, which is hard for humans to articulate so that it could be encoded for the computers or robots.

As Frey and Osborne (2013) state, brain emulation, i.e., scanning, mapping and digitalizing of a human brain, could enable the robots to obtain improves social intelligence skills. In order to have a fully operational brain emulation a relevant filter of relevant data and the supporting technology is required. However, according to Sandberg and Bostorm (2008) it is very unlikely that brain emulation will be realized within the next two decades, but when they do, the employment impacts is likely to be huge, as Hanson (2001) argues.

2.3.4 The Effect of Computerization on Employment

The summarized results obtained from the analysis by Frey and Osborne (2013) can be seen in Figure 11 below. The expected employment impact is distinguished between high, medium and low risk occupations based on the probability of computerization, with respective boundary probabilities at 0.7 and 0.3. The robust estimate of the analysis indicate that 47 percent of total US employment is in the high risk category, meaning that the associated occupations are potentially automated and replaced by computers during the next decade or two. Hence, the higher the probability of the occupation to be computerized the faster it will be substituted by computer capital. The occupations that are at high risk and high employment category are, for example, service and sales related jobs, office and administrative jobs. The low risk jobs are such jobs that are related to business, engineering, education and healthcare. Furthermore, the extent of computerization will depend on the pace of development at which the described bottlenecks to automation can be overcome. The timespan for the effect is roughly the probability of computerization so that the more higher the probability the sooner the job will be automated or substituted by computer capital.

Figure 11: The Distribution of BLS 2010 Occupational Employment of Total US Employment over the Probability of Computerization (Frey and Osborne, 2013).



According to Frey and Osborne (2013) the first wave of computerization will target first office clerk jobs and jobs in transportation and logistics, which are relatively easy to be substituted by computer capital. Moreover, this is prevalent already today as mentioned earlier. For example, the declining cost of sensors and development of driverless cars will advance the automation of logistics and transportation jobs gradually in the near future. The use of big data will further help in this process as the use of vast amount of information will enable using algorithms to automate even very complex tasks. The development of robotics, specifically industrial robots, will further enable the automation of several non-routine manual tasks in production occupations. For example, the market for personal and household service robots is already growing by about 20 percent annually worldwide while the prices of the robots is constantly decreasing (MGI, 2013). This will further accelerate the substitution of service jobs by computer capital, depending on the relative prices and thus the comparative advantage of computers versus humans.

The somewhat surprising factor is that sales occupations, such as cashiers, telemarketers and counter and rental clerks, are one of the highest risk occupations despite of the fact that they include substantive amount of interactive tasks. Nevertheless, they do not require high degree of social intelligence, which stresses the implications of the underlying assumptions on the computerization bottlenecks. Moreover, the jobs in the medium risk category are mainly jobs that depend on perception and manipulation challenges, thus highlighting the extreme difficulty to create human-like pattern recognition for computers and robots. In the low risk category are all those tasks that require knowledge of human heuristics, usually required in generalist occupations, and the development of novel ideas and artifacts required in specialist jobs. The generalist occupations are, for example, all managerial jobs, whereas specialist knowledge is usually required in health care, education, arts and media and computer science jobs.

Pajarinen and Rouvinen (2014) employ Frey and Osborne’s (2013) calculations of probabilities of computerization and replicate the analysis for Finland. Their findings implicate that, similar to the US, there are in relative terms more jobs that are either in low risk category or high risk category than there are in the middle of the distribution. Moreover, the corresponding share of employment in the high risk category for Finland is slightly less than in the US at 35.7%. Consequently, due to the differences in the occupational structure the impact of computerization is around ten percentage points less in Finland than in the US. Nevertheless, also in Finland the better paid occupations are in the low risk category, those being the ones that also require a higher level of education.

Pajarinen and Rouvinen (2014) thus conclude that the employment effect of computerization in Finland is of great concern and requires increasing attention as technological progress evolves. It might be possible that the increased churn in the labor market caused by the threat of computerization leads to a higher natural rate of unemployment because increasing share of individuals are engaged in job search or acquiring new skills. In the short run, there seems to be worrying amount of job destruction and not enough job creation. This creates big challenges that can be overcome with increasing emphasis on education and training.

It is worth noticing the underlying assumptions in the analysis of Frey and Osborne (2013). The subject of speculation in the study is how technology, especially digital technology which is only in the early stages of its development, will affect jobs that existed in 2010 in the US Bureau of Labor Statistics. This means that the analysis is limited to the substitution effect of future computerization and does not analyze the creation of new jobs nor the complementary effect technology has within-occupation, liberating more time to focus on the more interesting job tasks. Relating to this, the hand-labelling of occupations based on the determined bottlenecks of computerization is very much subject to the interpretation of Frey and Osborne (2013) that should be taken into account when interpreting the results of the study. Moreover, in terms of technological progress and the timespan of increased automation, the actual speed of technological development will depend on many things, which are not accounted for in the study. Firstly, the comparative advantage which defines the division of labor between humans and computers, depends on future wage levels and capital prices that also affect the timeline of the predictions. Moreover, institutions related to the labor market still remain to be highly regulated in developed economies and hence, much of the development regarding automation of work will be highly dependent on the regulatory changes on labor and the public opinion of technological progress.

Nonetheless, the results of Frey and Osborne’s (2013) study are very alarming as they suggest that job polarization is only a transient phenomenon in the labor market. It gives implications on further increasing skill demand towards those skills in which humans still have a comparative advantage over computers, thus leaving a large number of people without these skills unemployed. The recent developments in ML will arguably reduce aggregate demand for labor input in routine tasks due to better pattern recognition, while increasing the demand for tasks that are not susceptible to computerization. These tasks not susceptible to computerization in the near future are such that tend to require long years of schooling and high skills. This strengthens the original theory of skill-biased technological change, indicating that the education system might be of high importance in responding to the potential future labor market demands as argued by Goldin and Katz (2008).

Although it remains to be seen how accurate these predictions are and how fast technological development will be in the near future, in the meanwhile it is important to react to these potential changes in the labor market induced by the exponential speed of technological progress. Therefore, this study aims to fill in the gap in the literature following the theoretical proposition of Frey and Osborne (2013). The aim is to study how task content changes within five selected occupations in the low risk category changes due do digitalization and new technologies. These five occupations are business manager, technology innovator, higher education teacher, healthcare professional and cybersecurity expert. Next chapter will explain the methodology of this study and the choice of these occupations in more detail.

3 Methodology

In this chapter the study's research design and approach are presented. Additionally, the data collection and analysis methods will be discussed in detail. The chapter is concluded with in the research evaluation section, which discusses the credibility of the research.

3.1 Research Design and Approach

The used method for this research was a qualitative multiple case study as it is based on a constructivist paradigm in which reality is socially constructed and thus the truth is considered to be relative and dependent on one's perspective. The paradigm recognizes the importance of the subjective human creation of meaning, but doesn't reject the notion of objectivity (Stake, 1995; Yin, 2009). The main advantage of this approach is the collaboration between the researcher and the participant which enables the participants to tell their stories and thus describe their view of reality (Carbtree & Miller, 1999).

Consequently, the qualitative multiple case study method was concerned the right approach in investigating the phenomena of how digitalization and new technologies affect skill demand and task content within five selected occupations: business managers, technology innovators, higher education teachers, healthcare professionals, cybersecurity experts. The individuals representing these occupations are assumed to possess the right knowledge based on the extensive experience they have of their own work and thus the examination of the view of reality of the interviewees enables to also better understand the actions of participants.

As Yin (2009) states, case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. However, Creswell (1998) adds that a case study is a bounded system, which can be defined in terms of an event, activity, individuals or groups of people. Accordingly, it can be concluded that while the boundaries can be hard to define in a case study which aims to study a phenomenon in a certain context, it can be defined in terms of groups of people under study. Considering the phenomenon under scrutiny in this study, it is rather difficult to define the boundaries of how digitalization and new technologies affect task content. In order to investigate this in depth, it was considered useful to focus on the mentioned five specific occupations which are highly relevant in the digital economy. These five occupations have low risk of computerization and embed number of tasks which are considered as bottlenecks for computerization according to Frey and Osborne (2013).

The strength of a case study research approach is its ability to deal with a various different forms of evidence, such as documents, artifacts, interviews, and observations. Consequently, a case study is highly suitable research approach when the research questions consists of explanatory questions asking about a contemporary set of events over which the investigator has little or no control. As Yin (2009) states, case studies are the preferred method when “how” and “why” questions are posed, which are also the type of questions that this study aims to answer. However, the challenge is that there are many variables of interest than just data points and thus the case study investigator is required to cope with a technically distinctive situation.

Stoecker (1991) suggest that there are two different tactics to conduct a case study, those being intensive and extensive case study research. According to him, intensive case research design focuses on finding out as much as possible on one or a few cases, whereas the extensive design focuses on mapping common patterns and properties across cases. Additionally, intensive case research design mainly aims to emphasize interpretation and understanding of the case thoroughly developing understanding from the perspectives of the people involved in the case. Extensive case study approach, on the other hand, relies more on the ideals of quantitative and positivist research, focusing on mapping common patterns, mechanisms and properties in a chosen context in order to develop, elaborate or test theory. Thus, in this study the main approach used is the intensive approach, as the focus is on a handful of instances in order to study the phenomenon in depth. Each instance is studied in its own specific context, and in greater detail than in extensive research. However, the aim of this study is to develop an understanding of common patterns in the occupations which are not subject to computerization in the near future and thus test the theory developed by Frey and Osborne (2013). Consequently, it also uses extensive research approach.

Case studies can be further divided into single case studies and multiple or collective case studies as stated by several scholars (e.g., Stake, 2006; Yin, 2009). The distinction is that in a single case study the object of the study is only one individual case that share common characteristics or conditions, whereas multiple case study includes two or more observations of the same phenomenon, thus examining several individual cases that are linked together (Stake, 2006). For example, some scholars argue that you should prefer multiple case studies over single-studies, when you have enough resources (Eisenhardt, 1991; Leonard-Barton, 1990; Yin, 2011). However, not all researchers agree, arguing in favor of the single-case studies (e.g., Dyer and Wilkins, 1991).The multiple case study approach covers several cases drawing cross-case conclusions, whereas single-case study focuses only studying one specific case. Therefore, there will be also increased external validity in the multiple case study approach as it uses replication logic. This is also why the multiple case approach its better suited for the ambitions of this study, as it can better illustrate how task content and skill demand varies between these different occupations.

The theoretical replication design of the multiple case study aims to predict contrasting results for anticipatable reasons in contrast to literal replication which predicts similar results between different cases (Yin, 2009). The replication logic in this research paper occurs by changing the occupation of the individual depending on his or her role in the organization. As the research design consists of more than one individual presenting one occupation subgroup, it means that there is theoretical replications across these subgroups which are complemented by literal replications within each subgroup. This supports the analysis of the differences and the similarities between the occupations' within task content and skill requirements. Moreover, with the multiple case study approach it is easier to study how the underlying hypothesis regarding the bottlenecks to computerization hold for each of the occupations. As a consequence, the multiple case study conducted with in-depth semi structured interviews is able to enlighten the unclear outcome of the vast literature on how jobs will look like in the new digital era and what skills are needed in each of these five different occupations.

As Baxter and Jack (2008) highlight, in multiple case study it very important to put effort into case selection so that similar or contrasting results across cases can be predicted based on the theory. Therefore, the rational of the case selection is based on the prediction by Frey and Osborne (2013), in which the four biggest occupations groups categorized into the low-risk categories are (1) Education, Legal, Community Service, Arts and Media, (2) Management, Business, and Financial, (3) Computer, Engineering, and Science, (4) Healthcare Practitioners and Technical (see Figure 11). Accordingly, each of the five occupations are within each of these groups, as they are the ones least subject to the bottlenecks of computerization and hence, it makes much sense to test the hypothesis of Frey and Osborne (2013) with these occupational roles least subject to computerization.

It should be noted that both technology innovators and cybersecurity experts are under the occupational group related to computer science and engineering. In effect, cybersecurity experts differ from the other roles as it is an occupation created by the new technologies and digitalization, and moreover, the demand for cybersecurity experts is expected to increment continuously within the next decades as technological advancement occurs[7]. Due to the disparity of cybersecurity experts to the other occupational roles, there is a risk of introducing some noise to the results. Nevertheless, it was considered a good example of how digitalization can also create new jobs, which is one of the limitations in the study by Frey and Osborne (2013).

As the aim is to study the future task content and skill requirements, there needs to be some sort of boundary to the time frame. However, as it is almost impossible to predict reliably how technological progress will change task content in the future and how fast these changes will happen, the time boundary is difficult to determine. Nevertheless, the focus is only on the near future, being the next 10 years, which is still assumed to be a comprehensible time frame in terms of understanding technological progress.

Moreover, by focusing on only five occupations, which are the units of analysis, the case study has clear boundaries and the complex research topic can have an in-depth analysis in terms of the mentioned five occupations. Thus, the case study method is a very suitable method to obtain an in-depth understanding of changes in task content and skill demand. This is especially the case in this study, as this understanding encompasses important contextual conditions that the interviewer does not have or know and which are highly relevant in order to understand the effect of computerization. In addition, the case study approach benefits from the prior development of theoretical propositions presented in the literature review, and the theory also guides the data collection and analysis (Yin, 2009).

3.2 Data Collection

Data collection for this research was done with focused face-to-face semi-structured interviews consisting of open-ended questions. Additionally, secondary sources were used to explain the occupation-specific terms that occurred in the interviews and strengthen the findings of the interviews. As Merton, Fiske and Kendall (1990) state, semi-structured interviews allow new ideas to be introduced during the interview as a result of follow-up question based on what the interviewee says. As the interviews were very dependent on the contextual setting of each individual, the semi-structured interview approach allowed for more illuminating questions if something new raised during the interview, which was highly valuable. The interviews were conducted with individuals each representing one of the chosen five occupations under study; business managers, higher education teachers, technology innovators, healthcare professionals

[7] The Washington Post, 2012, 12th May.

and cybersecurity experts. Hence, these occupations are the units of analysis in this research. As these occupation titles can be rather opaque or loosely defined, there was need for more specific definitions of each of these occupations, in order to define the units of analysis more clearly. The more specific definition of these occupation titles are explained below:

i) Business Managers

Business managers are defined as business professionals with a business degree who are working within marketing, sales and customer accounts as well as within such support functions as general management and human resource management. In other words, individuals representing business managers are involved in the core business processes of an organization, either within customer interface or in support functions dealing with different stakeholders of the company.

ii) Technology Innovators

Technology innovators are defined as professionals with strong technical background working within research and development, R&D, either directly in product development teams or in the interface between customers and product development. Therefore, one of the core tasks of technology innovators is to develop and manage innovations.

iii) Higher Education Teachers

Higher education teachers are defined as professors, researchers and university lecturers who are all lecturing in universities. These individuals are thus responsible of higher education teaching together with conducting research within their own respective disciplinary.

iv) Healthcare Professionals

Healthcare professionals are divided into two basic categories, physicians and nurses with medical degree. The specialization area is not separately defined and hence, health care professionals include all physicians and nurses within different specialization areas.

v) Cybersecurity Experts

Cybersecurity experts are defined as professionals working with internet, cyberwarfare, information, mobile and network security. Their work consists of the protection of information systems within hardware and software. These professionals can be either organization's head of cybersecurity or external cybersecurity consultants.

In order to get important insights regarding the research topic from the interviewees it is crucial that the interviewee posits herself in the role of an informant rather than a respondent. This relates to the fact that the interviewees possess the best knowledge of their work and task content, which the interviewee doesn't possess. Moreover, due to role of an informant, it was considered important that the interviewees have also the best possible view over the future changes in task content. Consequently, the interviewees for this study were chosen according to their attitude towards new technological changes so that they are so called innovators or early adopters based on the innovation adoption process model by Beal, Rogers and Bohlen (1957). The selection of the interviewees was based on either their role and title or the employer organization. The positive attitude towards new technologies of the interviewees made them well-informed interviewees with deep knowledge to share in order to maximize their role as informants for the case study research. It is thus important to notice that as the chosen interviewees are relatively open-minded towards new technologies, the results reflect their attitudes and insights, which is not necessarily divided with the whole population representing the same occupations. Nonetheless, in order to get in-depth knowledge of the effects of digitalization it was crucial to choose these type of innovative interviewees.

The rationale for choosing interview as the main source of information is highlighted by Yin (2009) who argues that interviews are one of the most important source of case study information. They are guided conversations rather than structured inquiries in which it is important to follow the line of inquiry of the research and to ask questions in an unbiased manner. This requires that the questions are carefully worded and are not leading, which is of high importance especially when using open-ended questions. Conducting interviews and using them as source of evidence has its weaknesses as it can be biased due to poorly articulated questions or reflexivity and response bias. Nevertheless, interviews can be targeted as they focus directly on the research topic and highly insightful as they provide perceived causal inferences and explanations.

These strengths and weaknesses were implemented carefully into the interview process to control the focus and the scope in the interviews. Therefore, an interview guide with set of questions that were the same for all five different occupations was developed. The interview guide can be seen in Appendix 6. The questions were based on the conducted literature review and on the assumptions developed by Autor, Levy and Murnane (2003) and Frey and Osborne (2013). Furthermore, the questions were created following the guidelines developed by Yin (2009) to decrease the biasness due to leading and badly articulated questions, which is often the case especially when the interviewer lacks experience of conducting semi-constructed interviews, which is the case in this study. Hence, to test the first set of questions, a first round of pilot interviews with few selected higher education teachers was conducted after which the interview guide was further developed. The developed version was altered in order to have better suited questions that would allow the interviewees to answer freely to the questions but give them a sense of scope in order to focus truly on how digitalization affects their occupation-specific task content and skill demand. Therefore, the interview questions focus on capturing the individual's experiences on their task content and how it has changed and will change due to digitalization and technological advancements. Furthermore, the guide is divided into two parts, where in the first part the focus is on the present time reflecting on the past events and in the second part the focus is on future events.

The list of the conducted interviews and interviewees are presented in Appendix 7. The interviews were conducted in Finnish during June and October 2015 in Helsinki or Espoo, Finland. The interviewees were briefly informed in beforehand of the subject of the interview, however, they were not asked to prepare for the interview in any way. The interviews were conducted face-to-face, except for four interviews which were conducted via Skype due to convenience matters, and recorded with the permission of the interviewees before being typed out. The interviews were conducted anonymously due to sensitive and subjective nature of the comments and opinions. As a result, all of the companies and individuals were kept anonymous and given pseudonyms. The interviewees were distinguished by their current title and the organizations by the industry in which they operate.

There were in total 26 interviews, with around five interviews per occupation, though due to the pilot interviews, there were up to eight interviews with higher education teachers. Additionally, mainly due to lack of responses and time restrictions, there were only three interviews with cybersecurity experts. However, as the cybersecurity experts were the most specifically defined, the data saturation was lower than with the other occupations for which data saturation was achieved with approximately five interviews. The selection of interviewees was done by using LinkedIn and snowball sampling so that the existing study subjects recruited future subjects from among their acquaintances. Both of these methods were very useful as they helped choosing interviewees that had truly a positive and innovative approach towards technologies.

The interviews were designed to take approximately 50 minutes, thus enabling the interviewee to explore her knowledge and experiences on the given topic and propose her own insights regarding the future task content, skill demand, working life, work environment and the division of work between humans and computers. In real life the length of the interview varied from 30 minutes to 1 hour and 10 minutes across different interviewees due to time restrictions and personality of the interviewees. For example, while some interviewees answered directly to the questions with short answers, some started discussing digitalization in much bigger scale then required. This, however, helped them feel more relaxed in the beginning and get them introduced to the topic before getting into the details.

3.3 Data Analysis

Yin (2009) argues that analyzing case study evidence is difficult and thus it is crucial that all case study analyses should follow a general analytic strategic, defining priorities for what to analyze and why. The used analytic strategy in this multiple case study is based on the theoretical propositions of Frey and Osborne (2013), which also led to the choice of case study. As Yin (2009) argues, using theoretical propositions is an appropriate strategy when they are the basis of the objectives and design of the case study and when these propositions are reflected in the set of research questions, reviews of the literature and new hypotheses or propositions. Additionally, it is also the most preferred strategy to follow in the case study data analysis as it can be extremely useful in helping to organize the entire case study and define alternative explanations.

Moreover, Yin (2009) states that there are five techniques to conduct an analysis, those being pattern matching, linking data to propositions, explanation building, time-series analysis, logic models and cross-case synthesis. These techniques are not mutually exclusive and hence, they can be used in any combination when analyzing the data. The techniques used in this study are pattern matching in which the patterns are related to the dependent variables of the study. This pattern matching logic occurs in the analysis as the data is matched with expected patterns, the bottlenecks of computerization, based on the initial hypothesis. This is done so that for each occupation the expected bottlenecks of computerization are matched with the results of the analysis based on the respective coding system, so that the initial hypothesis can be either verified, declined or further developed. This coding system is done so that a matrix of categories related to the different bottlenecks to computerization is created. The evidence is then under the corresponding categories. This enables an in-depth analysis of tasks that are embedded in each of the bottlenecks for the different occupations under study.

In addition to the pattern matching technique, also cross-case synthesis technique applicable to multiple cases is used in the analysis of this study. This technique occurs as the data from the individual cases are displayed according to the same uniform framework for each of the occupations. This makes the data comparable between the different cases and thus can strengthen the findings even further as it enables the comparison between different occupations. This way the analysis can probe whether different occupational roles under study appear to share some similarities.

In conclusion, the general strategy used in the analysis of this study is based on the theoretical propositions using the pattern matching and cross-case synthesis analysis. Due to the vast amount of data that enables using both of these techniques, this study has an effective base for high-quality case study. Nevertheless, the lack of rival propositions diminishes the validity of the analysis as there isn't a possibility to use an alternative explanation to that of Frey and Osborne (2013). The validity of the research approach will be discussed more in detail in the next section.

3.4 Research Evaluation

A lot of effort has been put to give some guidance to qualitative researches in improving the quality of qualitative researches. This stems from the use of words such as validity and reliability, which are originally developed for the use of quantitative tradition and which do not necessarily fit into qualitative research. As a consequence, qualitative methodologists have created new terms that either substituted or added new ideas to the scientific language of earlier periods (Seale, 1999). There is extensive literature on the strategies to establish credibility, transferability, dependability and confirmability in qualitative research and to assess the trustworthiness and rigor of qualitative data across different fields (e.g., Krefting, 1991; Sandelowski, 1993). Hence, proving the trustworthiness of qualitative research may seem difficult, as there is no universal framework to assess the quality. Nevertheless, it is crucial to evaluate the quality of the research in order to critically interpret the final results of this study.

Moreover, as Yin (2009) states, case studies have faced criticism due to the lack of rigor, which occurs when systematic procedures are not followed and equivocal evidence or biased views are allowed to influence the direction of the findings and conclusions. Secondly, critics argue that case studies provide little basis for scientific generalization. In effect, case studies are not generalizations of the populations or universes, but generalizable to theoretical propositions. Consequently, case study does not present a "sample", but it aims to expand and generalize theories analytically, not statistically. Thirdly, some have also criticized that case studies are not able to prove true causal relationships, which is an important aspect of academic research.

Nevertheless, as Yin (2009) argues, case studies can offer important evidence to complement experiments.

This is also the aim of this case study, which is not aiming to be a generalization of the entire population, but aims to expand and generalize the theory developed by Frey and Osborne (2013). Additionally, the aim is not to prove the causal relationship between new technologies and skill demand, as the related evidence is already presented in the extensive literature review of this study. Thus, this study aims to expand the presented theory and apply it to the chosen set of occupational roles. However, there is a risk of novice researchers, as the researcher of this study has only some previous experience from conducting qualitative research. This attenuates the requirements of a successful case study with systematic procedures and unbiased views in the analysis that come with the experience of conducting research.

There are few issues that should be reviewed carefully in the research. Firstly, it should be noted that qualitative research is a rare and unpopular research method used within the field of economics, which already makes this study rather unique. One of the main reasons why qualitative research is not perceived very reliable within the field of economics is because it does not meet the standards of the widely used econometric theory, such as random sampling and quantifiable results. However, as Piore (1979) states, qualitative research in economics is not without its antecedents, especially in labor economics where trade unions and wage setting procedures have been studied with qualitative methods already in the 1930s. Interestingly, Piore (1979) also used qualitative method in his own study which aimed to solve whether technological change was increasing or decreasing the skill requirements of jobs in manufacturing. For him, just as in this study, one of the defining points in choosing a qualitative method was that there was lack of data, especially data that could be comparable across cases.

Additionally, the focus is on the future, thus aiming to anticipate the future outcomes of technological advancements that have not occurred yet and that, most importantly, are very hard to predict even with novel approaches (Armstrong and Sotala, 2015). This is especially a concern as not all of the interviewees were highly familiar with the exponential speed of technological progress, though the selection criteria aimed at focusing on choosing interviewees that were mainly very informed of digitalization. Taking into consideration the causal relationship between digitalization and new technologies on skill demand and task content, it is not always so clear whether the changes were due to digitalization or, e.g., globalization. Nevertheless, the vast amount of interviews and the occurrence of similar issues and topics in the different interviewees increases the credibility of the results.

Moreover, in many cases the interviewees started to dwell on the subject with excitement, thus using the interview questions only as supporting questions. This was very useful as afterwards it was easy to then code the answers in an unbiased manner based on the theoretical propositions to see whether or not they can be verified. These answers came across either inherently or explicitly and thus at times the coding was again subject to interpretation, which is why the terms that the interviews used are already used when presenting the results. However, in some cases the conversation remained in a rather general level, though towards the end of the interview the answers got more personal.

The data gathered for this case study is rather extensive, already because there are five different occupational roles under study. This increases the possibility to triangulation, which is the process of gaining assurance to the researchers own impressions as well as those of others (Stake, 2006). The triangulation occurs thus as each important findings has at least three confirmations and assurances that the right information and interpretations have been obtained. Therefore, triangulation is mostly a process of repetitious data gathering and critical review of what is being said. This is of high importance due to the varying roles of the interviewees within the same occupational role. Additionally, the attitude and exploitation of technologies was also highly dependent on the organization in which the interviewees worked at, hence the triangulation was an important factor to consider as the contextual setting had a high impact on the answers. However, the extensive amount of data requires careful reviewing of data which requires substantive amount of time, thus inducing time challenges into the research process.

To conclude, though the research was highly subjective to the researcher’s own interpretation as well as to the interviewee’s attitudes towards digitalization and new technologies, these challenges can be deteriorated with careful triangulation and assessment of the results. Consequently, the theory developed in this study can be successfully generalizable to the chosen occupations and thus give important implications on their task content and required skills in the near future.

4 Empirical Findings

In this chapter the results of the conducted interviews with the representatives of each occupational roles will be presented. The aim is to answer the study's main research question in evaluating how digitalization affects task content and skill demand for five selected occupations: business managers, technology innovators, higher education teachers, healthcare professionals and cybersecurity experts. This is done by following the theoretical research by dividing task content of these selected occupations into the bottlenecks of computerization and thus testing the initial hypothesis developed by Frey and Osborne (2013).

The empirical findings of this study argues that in addition to the bottlenecks of computerization described by Frey and Osborne (2013), analytical and critical thinking emerged as one important skill for each of these occupations. This is related to the mere fact that increasing amount of information and data requires human capability of critically processing and selecting the information. In addition, perception and manipulation tasks were only a relevant bottleneck for healthcare professionals and even for them it was only a bottleneck because of the high degree of flexibility that human sensimotor skills entail. Hence, perception and manipulation related tasks do not increasingly require any specific skills, but they are intuitive skills that humans have. Though among the occupational roles some skills were highlighted as being more important than other skills, it can be verified that across all occupational roles, task content is changing towards more need in analytical and critical thinking, creative intelligence and social and emotional intelligence, thus verifying the initial hypothesis with small revision.

Moreover, in many cases the interviewee's saw that there is clear increase in skill demand in the near future due to the increased variation of different tasks and degree of complexity of the tasks. In the analysis of the interview data it came clear that the changes in task content can be divided into changes in work efficiency and nature of work. In other words, digitalization and new technologies can at their best increase the working efficiency significantly but they also change the nature of work. Based on these observations the results are summarized for each occupation separately in the sections below.

The chapter is organized so that first the opportunities and challenges of digitalization in work life are presented. These results thus embed the common changes for all interviewee's. This will be followed by the verification of the hypothesis related to the bottlenecks of computerization and skill demand. After the summarized results for each of the occupations are presented, the chapter is concluded with a summary analysis that concludes what is the current role of digitalization in the work life of all of the occupations and what could be done to better exploit digitalization's efficiency gains.

4.1 The Effect of Digitalization on Work Life

Irrelevant of the different work that the different occupational roles have, there were many common opportunities and challenges related to digitalization, automation and new technologies that emerged in the interviews. These results are summarized and grouped into information efficiency, technology efficiency and people efficiency related topics in Table 3.

Table 3: Opportunities and Challenges of Digitalization in Work Life for All Occupations

	Opportunities	Challenges
Information Efficiency	• Revelation of new causal relations and solving root cause problems with data • Improved predictability enables a shift from reactive to proactive services increasing reaction time • Quality and cost effectiveness improvements with digitalization	• Increasing information overload • Securing data protection and information security • Focusing only on what the measures and meters reveal • Lack of long-term digital vision and strategy and perseverance in decision-making
Technology Efficiency	• From routine to creative and intellectually challenging work • Increased level of flexibility due to place and time independency of work	• Increasing skill demands and global competition • Increasing amount of routine "secretary" work due to automated tools causing noise in everyday work • Accentuating the humanity of technology
People Efficiency	• Increased meters and measures enabling individual feedback of one's own performance and skills • The importance of information sharing increases and enables creation of more novel ideas	• Time management skills and well-being at work • Polarization of work force due to their knowledge or lack of "digi skills" • Old organization models prevent better exploitation of digitalization

4.1.1 Information Efficiency

Firstly, it was evident that the increase in information and data availability enables realization of many new causal relationships, even such causal relationship that would have never before occurred. This makes problem solving much more efficient, as the causal relationships can reveal true underlying root causes for many different problems that the customers themselves didn't even know that existed. This view is highlighted in the quote of interviewee 9 below. Alternatively, in the case of healthcare professionals the increased availability of data and information can reveal important information of major causes of wrong diagnosis or failures in patient treatment, as argued by interviewee 21m a healthcare professional.

"Nowadays we can collect a lot of data from almost anything. This makes it possible to find and analyze completely new relations between different things, which creates completely new kind of information. Thus, we can better find hidden things"

(Interviewee 9, Technology Innovator)

Additionally, the wider availability of information and the corresponding analysis of data enables a shift from reactive to proactive customer service and patient treatment, as predictability of future events comes ever easier. This means that together with the revelation of new causal relationship and the availability of real-time information and data, it is faster to fix problems, to react to customer's requirements and understand the patient's underlying symptoms, to name few examples. As many of the interviewees argued, this creates more business opportunities in the case of technology innovators and business managers and significant increases in the quality of teaching and patient treatment. Consequently, it enables better knowledge management[8]. In other words, both the revelation of new causal relationships and the shift from reactive to proactive services enable significant improvements in quality and thus in cost-effectiveness, exactly in this order. As interviewee 19, a healthcare professional, argued, especially in the context of hospitals, it is important to focus on improving the quality of patient treatments, and by achieving better quality better cost-effectiveness can be achieved, not the other way around.

The increasing amount of information comes with many challenges according to the interviewees. One of the most evident challenge is the question related to data protection and information security, which on the other hand explains quite well why there is explosive increase in demand for cyber security experts. This question is increasingly embedded into the everyday work life no matter what the occupational role is and thus there is lack of knowledge and definition of data protection practices. Moreover, the shift towards knowledge economy, which is giving increasing amount of focus on information management, has induced a feeling of information overload among many interviewee's. This information overload was a topic that all the interviewees raised by accentuating the need for conceptualization of the vast amount of data and information processing skills. Additionally, many of the interviewees argued that there is a risk of only focusing on those things that the meters and measures reveal, as different kinds

[8] Knowledge management refers to better exploitation of organizational knowledge through effective sharing, developing and using of knowledge.

of meters to measure performance are being used ever more widely in organizations. For example, interviewee 16 argued the following:

> *"Related to digitalization, I see that because there is more computing power available, there is increasing amount of measuring and exploitation of data, which has led to this sort of managing with numbers to a certain degree. Increasingly, we like to set goals that can be converted into numbers so that we can then clearly see whether or not we have achieved these goals. This easily affects our way of working because we start to, so called, get what we meter."*
>
> (Interviewee 16, Higher Education Teacher)

Though the increasing availability of different meters and measures is a big opportunity in increasing efficiency, there are also challenges embedded in this. For example, a recent article about Amazon in the *New York Times*[9] argued that the thriving Internet retailer company is constantly measuring its workers and those who fail to outperform the required numbers are ruthlessly eliminated. Thus, the writers of the article argued that the company is using classic Taylorist techniques to achieve efficiency regardless of personal strategies of their employers. This was a concern expressed also by the interviewee 4, a business manager working within HR function, who stated that there is risk of giving too much emphasis on data and thus losing focus on the humans. "After all humans are the most important thing in the work," argued the interviewee 4.

Lastly, one of the challenges deals with organization's capability to manage information, which is related to the shift from reactive to proactive service due to availability of real-time data. This was especially highlighted among business managers, but across the occupational roles there were several notes of concern regarding the hype related to digitalization and the new technologies. As interviewee 14, a higher education teacher, stated: *"All in all there is a lot of hype in this digitalization. People think that technology is an absolute value rather than an aid tool."* Consequently, this causes incoherence as people rush into making decisions related to, for example, different information system investments without critically thinking whether or not it is truly beneficial for one's own operational environment and how it fits into the overall picture. Interviewee 2 highly stressed the importance of determining a digital vision within organization and argued that there is a clear lack of these sort of activities across the business life in Finland. Additionally, interviewee 14 argued the following:

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[9] *The New York Times,* September 1st, 2015

"Then this sort of strategic planning and support is also very important, meaning that the management of the teaching staff should have a clear vision where to aim at with this exploitation of digitalization. We need a clear vision and an action plans. With the help of these methods we can then have an influence on the coherence and integrate these [goals] into the pedagogical goals and plan good indicators, with which we can evaluate the success and development in these matters."

(Interviewee 14, Higher Education Teacher)

This does not only apply only to the higher education organizations, but also to all other organizations, as stressed by many interviewees.

4.1.2 Technology Efficiency

"Well, then I would end up doing the job that I am actually meant to do."

(Interviewee 8, Technology Innovator)

This was a view that was not only said by the interviewee 8 but also several others when asked about their changing task content due to technological advancements. This highlights the fact that many of the interviewees saw that automation and technological advancements are able to make their work more interesting and meaningful as well as intellectually challenging. According to the interviewees, automation has freed time from routine work thus liberating time to focus on the increasingly complex problem solving. This is thus aligned with the results of Autor, Levy and Murnane (2003). *"I do not believe that problem solving disappears, quite the opposite, problems as well as problem solving will become more challenging and complex"* argued interviewee 24, a cyber security expert.

However, it should be noted that in most of the interviews, when interviewees were asked about automation and how it has affected their job task content, many didn't know how to reply to that question as it was altogether hard to see the role of automation. The conclusion for many was that it is not precisely automation that has affected their task content, but the different tools that enable automatic information and data acquisition and reporting. This indicates that automation has played very minor role in automating some specific tasks that the interviewee's have. Nonetheless, different available automatic tools have increased efficiency of work as information sharing can be done much quicker than before.

Additionally, many mentioned that due to the advanced communication tools, such as Skype and Office Lync, especially recently there is more both internal and external meetings held online and thus less need for travelling. Wireless connections and cloud storage has enabled a more flexible time schedule as work is less dependent on place and time, and thus *"one can be constantly online*[10]*."* As interviewee 6, a technology innovator, stated: *"This kind of Finnish eight-to-five job no longer exists in practice really. The work is done whenever there is work and whenever the customer wants the work to be done, which causes time difference challenges as well."* There is no difficulty in serving global customers as there are so many tools to share documents, information and meet online, however, this also loosens the definition of work hours. In general, the time spent travelling to customer meetings and etc. is decreasing every day, which has caused significant increase in efficiency of work.

Increased automation has not decreased all routine work entirely, and in some cases it has even increased it. Many complained about the number tasks relating to doing travel expenses, booking of travel tickets and making time and other reports. The interviewees argued that these "routine-like duties" create added unnecessary noise in the everyday work, thus shifting the focus from what should be actually doing. These tasks were named as "secretary work" in this study, as these types of tasks were previously done by one's own secretary that almost no one has today. Today it is very easy and fast to do these types of tasks, however, as there are many different systems being used for all the different reports, it creates chaos among workers and sometimes double or triple the amount of work. Even emails were considered very time-consuming and a clumsy way of communicating by some of the interviewee's, but still emailing takes up rather big chunk of working hours currently.

This is a worry that is being noticed by the big tech companies who are developing solutions to tackle the problems related to the increasing amount of secretary work. According to *the Economist*[11], there have been substantial developments made in the area of virtual personal assistants recently. For example, Apple's personal assistant technology Siri is already able to respond to voice commands. In addition to Apple, many other tech firms have recently invested a great deal in developing "software secretaries" that would be able to create reminders for appointments, look up information and complete other similar tasks. Consequently, there might be big breakthroughs done in this area very recently, which can further improve the efficiency of workers. However, whether or not they are truly able to replace these sort of tasks in the near future depends highly on the development of the technology.

Furthermore, the increasing amount of different systems with which one hast to operate these days is not making the situation any better. One of the most extreme cases of this occurred

[10] Interviewee 15, a higher education teacher
[11] *The Economist*, September 12th, 2015

among healthcare professionals who at the moment have to in some cases operate with several different patient data systems. According to interviewee 21, a healthcare professional, as these systems do not have common interfaces, one has to enter the same information into all of the systems separately. This highlights the importance of user experience design in all fo the technologies used in work across all occupational roles, which was mentioned several times in many interviews. There is an increasing need to simplify the way technology and information systems are being used today in work so that they take the user into account. In other words, there is clear need for designing technology for humans, not the other way around. One answer to this is to accentuate the humanity of technology by making technology and software more user friendly. *"Technology should not become the master of all this, instead it should just be a mere aid tool"*, argued interviewee 21, a healthcare professional.

Consequently, as digitalization is making the place and time more irrelevant, competence and skills can come from wherever. This leads to increasingly intensive global competition which highlights the importance of having top know-how. At the same time, there is need for ever wider skillsets among all of the occupations under study. Business managers have to understand digitalization and control the decision-making based on vast amount of information. Technology innovators have to be both specialist of their own discipline as well as know about business and user experience. Higher education teachers have to obtain deep discipline knowledge due to their research work and possess high level pedagogical skills. Healthcare professionals have to understand information systems and cyber security experts have to know about various amount of different technologies, business and legal issues. Though there is need for wider skillsets, specialized knowledge is still highly valuable, which increases the importance of team and social skills. Moreover, as there is limits to how much one individual can acquire information and thus information sharing becomes ever more important. The skill demand will be discussed later in this chapter in more detail.

4.1.3 People Efficiency

Lastly, one of the opportunities related to efficiency in one's own work, which was named as the people efficiency. The increasing amount of meters and measures, which was already discussed earlier relating to information efficiency, enables better individual feedback of one's own work and performance. According to Interviewee 21, a healthcare professional, this enables continuous development of one's own skills and thus can at best develop ever more highly skilled workers. On the other hand, it requires increasingly skills and willingness for self-development, accepting feedback and reflecting on it. As interviewee 8 stated:

"On the one hand, we are continuously trying to get rid of this individualist mentality as we have to be able to work together. But if you cannot as an individual accept feedback and further develop yourself, than in the long run you will not survive."

(Interviewee 8, Technology Innovator)

Moreover, there is significant increase in the importance of sharing information between both co-workers as with external stakeholders. This is related to the observation of interviewee 9, a technology innovator, that there is more need for ever wider skillsets. However, it is not necessary that one person possesses all these skills, but they can exist within a team, in which information is shared extensively. There are great opportunities in this, as it has been widely acknowledge that both internal and external knowledge sharing within diverse work groups result in improved performance (e.g., Cummings, 2004; Mesmer-Magnus and Dechurch, 2009). This is not only relevant for technology innovators and business managers, but also for, e.g., higher education teachers. For example, interviewee 15, a higher education teacher, stressed that: "*it is the collective wisdom and support that is one of the most important factors of all universities, including universities.*" However, the increasing importance of sharing information requires completely different mindset for working, which needs to be reflected in the way work is organized in the new digital economy. This requires increasingly skills for communication and teamwork as work is done more together in projects.

"Knowledge management has become part of everyday life. Things are done together in projects and in common workplaces. This kind of sharing information has increased, so in a way the mindset has changed. It is no good that I have that piece of information, the value truly comes only when I share the information with others and dare to expose my own understanding, even if it is incomplete, for others to pick on so that they can further develop my idea forward. This way the amount information increases and this sort of spiral of information is developed. This is rather a big change in this new world. No one has a readymade answer. There needs to be courage to be on thin ice constantly. You have to be able to look for the best or develop the solution further without giving up".

(Interviewee 5, Business Manager)

Related to the more flexible time schedule and less place and time dependent nature of work, several interviewee's pointed out, that though there are clear benefits in it, such as being able to flexibly fit private life into work life, it also increases the need for controlling one's own working hours. As working around the clock is much easier nowadays, it is increasingly important to manage stress and take care of well-being.

> *"For example, I have myself noticed that this virtual discussion forum makes it possible to work around the clock [...]. It is easy to leave work stage on from morning until evening, which causes additional stress. Students also work quite a lot around the clock, which brings on challenges in controlling your own working hours. "*
>
> (Interviewee 12, Higher Education Teacher)

> "*Also possibilities for remote working have improved and one can work remotely ever more flexibly. Naturally, there's a trap in this that you can work whenever and cannot set limits to yourself. You need certain type of leadership and expertise skills in this so that you can set limits to yourself and not check you emails when you are off duty, etc."*
>
> (Interviewee 4, Business Manager)

The hype related to digitalization and exploitation of new technologies has also induced a worry among the workers, that not everyone is very open-minded towards these changes. Though this is related to resistance to change, it is also partly related to the division between generations that have born and raised with digital innovations and those that have already had an extensive career with and without digital technologies. This is referred to as the polarization of workforce in Table 3. This was brought up especially by healthcare professionals and higher education teachers. Only cyber security experts didn't raise this question, which well describes the fact that cyber security experts are born digital. For example, interviewee 12, a higher education teacher, pointed out that new devices and tools can cause different reactions to different people, and for some it can even create stress. For business managers and technology innovators this is also causing difficulties, as workers who used to be best performers no longer excel in the digitalized work environment and who are not able to cope with the changes that come along with digitalization.

Interviewees 22, 21 and 23, who are all healthcare professionals, pointed out that there is need to focus on updating education and training workers to be digitally skilled in order to not lose those workers who are also very valuable for the organization due to their experience. This seems be in accordance with Becker's (1962) argument that investments in schooling, on-the-job training or medical care, i.e., in human capital, has tremendous effects on earnings, employment and other socioeconomic variables in the long-run. Moreover, due to the rapid increase in requirements of "digi skills" it is of high importance to focus on updating education.

Lastly, many mentioned the importance of understanding the role of organizations and how organizational models can affect one's own work and everyday working life. This is especially important so that it would be easier to question the used organizational models and develop such that would better support the changing work. In other words, the organization of work that was once created for executing million euro investments do not support the solution and customer-oriented selling as expressed by interviewees 5 and 9, a business manager and technology innovator. Furthermore, while the trial and error culture does not fit so well into the work environment of cyber security experts and healthcare professionals, it is increasingly required in the work of the rest of the occupations.

As argued by Brynjolfsson and Hitt (1998) already two decades ago, there is need for dramatic organizational changes that exploit low-cost communications and information processing capabilities created by IT. It is rather astonishing how accurately Drucker (1988) put it already in 1988: "Businesses, especially large ones, have little choice but to become information-based. Demographics, for one, demands the shift. The center of gravity in employment is moving fast from manual and clerical workers to knowledge workers who resist the command-and-control model that business took from the military 100 years ago. Economics also dictates change, especially the need for large businesses to innovate and to be entrepreneurs. But above all, information technology demands the shift." Based on the interview results, it seems that this has not been completely achieved in the today's organizations.

To conclude, it seems that the results of this study are in line with the results of Brynjolfsson and Hitt's (1998) study that studies why it has been hard to prove productivity growth of IT investments. According to them, in the new digital economy the measure of output should include such things as the quality of product, timeliness and customization. The inputs, on the other hand, should include the amount of organization capital and worker training and education. Moreover, using analogy from the earlier industrial revolutions, it is important to reconsider not only with what we do our work, but also how we do our work, so that we could better exploit the opportunities offered by digitalization. In the next section the description of how the hypothesis of Frey and Osborne (2013) is related to the skill demand in the new digital economy is presented. Furthermore, the skills that are increasingly in demand in the near future for all occupations will be discussed in more detail.

4.2 Linking Bottlenecks to Computerization into Skill Demand

When the interviewee's were asked how digitalization has affected and how it will affect their task content, many mentioned such things as innovative thinking and the ability to create something meaningful for others. Additionally, in all of the occupational roles many highlighted the importance of increasing the focus on such tasks that require not only social skills, such as working in a team and coaching subordinates, but also skills that relate to self-management and personal development. As a consequence, it was concluded that it is not only about social but also emotional intelligence skills what is increasingly required from workers across different occupational roles.

As described by Frey and Osborne (2015), social intelligence includes such skills as social perceptiveness, being aware of other's reactions and understanding why they react as they do, negotiation and persuasion skills as well as assisting and caring for others. Emotional intelligence, on the other hand, is the ability to perceive emotions, use emotions to assist thought, to understand emotions and to regulate emotions based on reflective thinking (Mayer and Salovey, 1995). Goleman (2006) divides emotional intelligence, EQ, into the ability for self- and social awareness as well as self- and social management. While self- awareness describes one's self-confidence and accurate self-assessment, social awareness describes the ability for empathy, organizational awareness and service orientation. Furthermore, whereas self-management describes such skills as adaptability, self-control, achievement drive and initiative, relationship management describes ability for developing and maintaining good relationships, conflict management, teamwork and collaboration. These are all skills and abilities that were raised by all interviewee's to be skills that are increasingly important in their work in the near future.

When it comes to perception and manipulation tasks, it was evident that it is only a bottleneck for healthcare professionals whose work includes working with hands. For example, though industrial robots are already widely applied across different fields of technology, it only affects the workers at the production site who are involved with the manufacturing. As perception and manipulation tasks are only a bottleneck for computerization due to the intuitiveness these task embed for humans, it is not really a skill that was highlighted to be of great demand in the near future by the healthcare professional interviewee's. As interviewee 19 stated, *"The robots that are being used today in surgery are merely a fancier tool to do exactly the same thing as we have done before as well."* Thus, the interviewee 19 argues that robotics is still in its infancy, as so far there has been no real added value of robots performing surgeries.

Interestingly, many of the interviewees mentioned that their tasks include increasing amount of tasks related to information processing and structuring. Additionally, the common statement was that as the amount of information available has increased there is more need for understanding causal relationships and drawing conclusions from the vast amount of data. This requires the ability to evaluate information and data, which again requires ability for analytical and critical thinking. Therefore, according to the interviewees, one of the things that humans are needed at workplaces still in the future is their ability to think analytically and critically.

This of course relates to the fact that was well put by the interviewee 24, a cybersecurity expert: *"As long as humans are making software there will be errors made by humans."* Accordingly, as technology is ultimately still made by humans, solving problems related to technology requires human problem solving and logical thinking skills. This is somewhat contrary to the argument that computers are actually much better at information processing than humans, which makes it rather interesting, as well as questionable. Nevertheless, according to the interviewees it is ever more important to have skills related to analytical and critical thinking due to the increasing information overload.

Table 4: Modified Bottlenecks to Computerization Based on Frey and Osborne (2013).

	Perception and Manipulation Tasks	Creative Intelligence	Social and Emotional Intelligence	Analytic and Critical Thinking
Description (O*NET variables)	• Finger dexterity • Manual dexterity • Cramped work space, awkward positions • Human sensimotor skills	• Orginality • Fine Arts • Innovativeness and creativity • Creative application of knowledge	• Social perceptiveness • Negotiation and persuasion skills • Caring for others • Self-awareness and self-regulation • Motivation	• Problem solving and logical thinking • Structuring information and drawing conclusions • Argumentation • Examination of statements • Understanding causalities
However	• Medical robots, military robots • Reorganization of work (e.g., Amazon Kiva system)	• Coded creativity (e.g., statistical images in Excel, AARON drawing composer , EMI composer software)	• Brain emulation enabling social intelligence for computers	• Artificial intelligence and self-taught software • Computers' advantage in information processing

The characteristics of the bottlenecks to computerization based on the O*NET variables described by Frey and Osborne (2013) and the described modifications are summarized in Table 4. The "However" row describes the computational achievements related to each of the bottleneck, thus trying to capture the vulnerability in the assumption. Based on these described characteristics the tasks that are increasingly important for each of the occupations are divided into these four categories based on the interview results. These results are divided into work efficiency and nature of work related changes for each of the bottlenecks, as it was clear that there are changes related to either or of these two categories.

Consequently, the hypothesis built by Frey and Osborne (2013) can be verified with the small modifications explained above. The bottlenecks describe the skill demand in the near future, as all of the mentioned changes in task content require increasing amount of skills related to analytic and critical thinking, creative intelligence and social and emotional intelligence. Whilst perception and manipulation task related skills were relevant only for healthcare professionals in the selected occupations under study, it was not separately highlighted that these skills would be of high demand in the near future. On the contrary, some of the interviewee's argued they might be actually robotized depending on the development of robotics. Thus, they were also dropped from the analysis part.

The results of this study are also emphasized in the recent study by Deming (2015), who finds empirical evidence that in the US employment and wage growth has been strongest in jobs that require high levels of both cognitive skills and social skills. Interestingly, in order to understand these patterns he creates a model of team production where workers "trade tasks" to exploit their comparative advantage. In the model, social skills reduce coordination costs, allowing workers to specialize and trade more efficiently. The next section, in which the effect of digitalization on occupation-specific skill demand and task content is discussed, shows why the model of Deming (2015) is highly relevant for the results of this study.

4.3 Effect of digitalization on Skill Demand and Task Content

In this section the opportunities and challenges and the changes in task content are presented for each of the occupational roles separately. The opportunities and challenges are somewhat already discussed in the first section of this chapter, which is why it will be only briefly explained why some of them are more important for others and vice versa. The changes in task content are explained with frameworks that divide the changes into work efficiency and nature of work related changes as well as into the skills that are based on the bottlenecks of computerization as explained in the previous section.

4.3.1 Business Managers

The interviewees for business managers included individuals who work within human resources, communications and marketing, sales or customer service. The most important findings in the changes in work life due to digitalization for business managers are summarized in Table 5. Moreover, the summarized changes in task content and their implications on skill demand are presented in Table 6 at the end of this section.

Table 5: Opportunities and Challenges in Work Life for Business Managers

	Opportunities	Challenges
1	Increasing efficiency due to more time- and place- independent work	Lack of digital visions and perseverance strategies with short-term operational plans
2	Availability of real-time data and information enables better predictivity and decision-making	Creation of trial and error culture with lean-thinking and greater employee empowerment
3	Larger, easier and faster customer attainment with omnichannel approach	Focusing too much on measures and meters and not on the underlying root causes

Big part of business managers' tasks consists of different meetings, either internal ones with subordinates, management teams and various project teams or external meetings with customers and other external stakeholders. Due to the increased availability and use of digital technologies in communication, there is much less travelling and more online meetings as argued by all of the interviewees. Work can be done increasingly whenever and wherever in virtual working places due to cloud storage, remote connections and availability of different cloud services, as argued by interviewee 5. Moreover, as argued by interviewee 1, the increased use of digital technologies in communication is seen in the increase in the use of different social medias, which has led to managing a fivefold amount of medias with the same work effort. All this means a tremendous increase in efficiency of work.

Furthermore, the speed and pace of work has increased significantly for business managers due to the availability of real-time data and increasing transparency brought by social media. Interviewee 3 pointed out, that this has significantly decreased the reaction time, thus making the work much more hectic. As interviewee 1 argued, the increasing amount of different Medias used in communication and marketing has caused substantial confusion and disarray for companies. This requires analytical and critical thinking as there is need for focus in choosing the right channels and most important Medias to follow and be present in. The same skills should be applied in the choice of meters and measures as the exploitation of data to measure performance increases. As interviewee 1 stated: *"One thing I have noticed, is the importance of choosing the right meters. In other words, when the choice regarding what to measure and with what meter is made, it is then the only truth that the decision-makers see."*

As the everyday work life is becoming increasingly hectic with short-term thinking focusing on quarterly economic performance, there is need for perseverance and coherence in actions.

This has induced a need for long-term strategic thinking with a strong focus on defining a digital vision. Interviewee 2 sees that this is highly critical for Finnish companies who are at the moment losing business to international companies who are simply better at, e.g., online retailing. This is highly related to the fact that there is need for business architecture skills, in order to understand how short-term operational plans and projects fit into the bigger picture, into the strategy and goals of the organization.

In addition, due to the increased transparency brought by social media, a fast reaction time is highly crucial. This means that the old slow hierarchical models do not fit into this new way of operating, as decision have to be made faster. Consequently, there is clear need for greater employee empowerment which requires that employees are increasingly trusted to make good decision on their own as indicated by several interviewees. The increasing transparency can be seen also outside the organization with customers. As there is more information available, there is need for strong customer relationships which are built on trust. This, on the other hand, requires substantial social and emotional intelligence in order to be able to have deeper communication with the customer.

Digitalization is highly evident in the work of business managers due to the increasing application of omnichannel approach, which was raised by the business manager interviewees. Whereas multichannel approach indicates how customers can obtain information by quickly switching between different channels, omnichannel approach indicates how they use them simultaneously meaning that all the channels are connected to each other. In this approach it is, however, increasingly important to build and manage coherence across the different channels in order to best exploit the possibilities of omnichannel retailing, marketing and communication (Pophal, 2015). This again requires skills to exploit these digital channels and networks, a skill that is referred to as “digi skills” in Table 6, and true in-depth knowledge of digitalization, as argued by interviewee 1, 4 and 5. Interviewee 4 added that though the new generation can bring better knowledge of these skills into the company, there is still clear lack of digital visionaries.

Nevertheless, in marketing and communication the nature of work is still mainly about creating mental images by innovating and brainstorming. This cannot be easily replaced by computers, as stressed by interviewee 3. Additionally, though in digital marketing there are shorter and more messages produced than in the printed counterpart, they are merely the result of the same innovative work as before, just in a digital form. The role of automation in marketing was well explained by interviewee 1:

"For example, in the automated marketing and communication, we can set 100 different consumer types and 100 different situation in which a certain type of message is sent. However, someone has to create all these 100 times 100 messages into the system, i.e., create the content. This brings about more proactive planning as you have to proactively go through all the possible situation that might arise and plan the messages beforehand. Then you can press play and see how the automation works out according to the initial plan. After this, someone has to go through all the results of different messages, based on which we can see which ones were effective and which ones not and so plan even better content and tactic for future."

(Interviewee 1, Business Manager)

Consequently, automation can at best increase efficiency, but ultimately it changes the nature of work into more proactive actions based on continuous development of better processes and systems. In the end, someone still has to create the content even though the delivery of the content is automatic and much more effective with the omnichannel approach due to better and larger customer attainment. In the end the continuous development of systems and processes based on measuring can further improve the methods used and thus increase the efficiency of work significantly when the data analysis and measuring is done correctly.

With regards to automation in sales, interviewee 2 pointed out that the more the product is a commodity, the less there is need for social interaction in sales. In other words, the easier the product is to sell online. To the contrary, when the product is, e.g., a solution, there is clear need for human interaction and cooperation. In fact, interviewee 5 also argued, that sales has shifted from product to solution selling, which stresses the need for deeply understanding customers' business logic as well as customer true desires in order to provide them the best possible solution. These both have their implication on creative intelligence and social and emotional intelligence as stated in Table 6.

Finally, due to the ever faster pace of work with short reaction times and omnichannel approach there is clear need for innovative thinking and trial and error attitude. As highlighted by interviewee 5: "*digitalization has sped up customer's business model so that they have to acquire and adopt to the new initiatives enabled by digitalization ever faster and quicker. This requires agile experimenting, which is something that we do too little in Finland."* This can be achieved by greater empowerment of employees, but also by creating a better organizational culture to support this. In superior work, which is increasingly changing into talent management, there is increasingly more efforts put into developing people's own skills and talents. This is done by providing more "stretch assignments"[12], counselling and coaching to the employees. This is crucial in order to continuously develop employee's skills, as mentioned by interviewee 4. Thus, it can be concluded that though digital technologies and information is playing a bigger role in the work life of business managers, while at the same time it enables to have a better focus on customers as well as on employees, in other words, on humans.

Table 6: Changes in Business Managers' Task Content and the Implications for Skill Demand

	Analytic and Critical Thinking	Creative Intelligence	Social and Emotional Intelligence
Work Efficiency	• Choosing the right meters and measures for effectiveness • Increasing amount of medias and channels requires focus	• Choosing the optimal *Omnichannel* marketing and communication • Content planning for digital services, marketing and communication	• Benefitting from information sharing and co-working • Increasing empowerment of employers in decision-making • Exploiting remote connections and networks in sales, marketing and communication
Nature of Work	• Critical interpretation and structuring of data • Problem solving by chopping and structuring information • Fitting short-term actions into long-term strategy	• Continuous development of support processes and systems • Creating mental images with innovation and brainstorming remains • Matching customers business demand to providers supply • Inventing new business and service concepts • From product to *solution selling*	• Increasing transparency requires stronger interaction with external stakeholders • Emphasis on personal encounters that build strong motivation and trust • Customer orientation with deep communication and comprehension • Superior work is more about counseling and developing skills
Implications on Skill Demand	• Information processing skills • Data analysis skills • Project work skills • Business architecture skills	• "Digi" skills, understanding how the new digital economy works • *Omnichannel* marketing and communication skills • Trial and error attitude and innovative thinking	• Organizational skills • People management skills • Communication skills • Teamwork skills

In conclusion, although the efficiency of business managers has increased significantly, there is increasing need for people oriented business managers with "digi skills". In other words, there is great need to optimally exploit the benefits offered by digitalization. Moreover, the importance of social and emotional intelligence skills related to customer relationship management and people management as well as analytical and critical thinking related to managing the information overload should not be undermined.

[12] "Stretch assignment" is a task given to employees which is beyond their current knowledge or skills level. The stretch assignment aims to place employees out of their comfort zone in order to learn and develop their skills.

4.3.2 Technology Innovators

The interviewees for technology innovators included individuals who work within product development and innovation typically with a strong technical background. The most important findings in the changes in work life due to digitalization for technology innovators are summarized in Table 7. Moreover, the changes in task content and their implications on skill demand are summarized in Table 8 at the end of this section.

Table 7: Opportunities and Challenges in Work Life for Technology Innovators

	Opportunities	Challenges
1	Exploitation of global distribution channels make size and place of firm irrelevant	Global competition increases the importance of top know-how
2	Creation of new added value with existing technologies	Current organization models with silos do not support the solution and customer-oriented product development
3	Realization of new causal relationships that create new business opportunities	Definition of ownership and control of information and innovations

The increasing amount of information is impacting the work of technology innovators tremendously given that the core of this work is based on acquisition and application of knowledge. The great opportunity in the new digital economy is that due to the digitally distributable goods it is easier to exploit global distribution channels. Because of the development of business ecosystems, the network of organizations involved in the delivery of a product or service, it doesn’t matter where the big innovative firm comes from or how big it is. However, as the competition shifts from being local to being global, it also means that the competition is much stiffer than before. Additionally, as product development becomes more cross disciplinary and customer oriented it is increasingly difficult to even define the field in which the organization is competing. As interviewee 7 stated, defining competitors is becoming more difficult, as the competitors can be either a multinationals like Google or small startups depending on the product that the customer wants. Thus, interviewees 8 and 7 stressed that it is not by all means self-evident that R&D work is done in Finland, but it can easily be shifted to overseas wherever the top know-how is. This implies that the skill demands for technology innovators have raised substantially and there is great need for top know-how.

Furthermore, due to *Big Data* it is easier to analyze and find new causal relationships which can create completely new business opportunities. As interviewee 9 pointed out: “*Digitalization* *is at its best when we can create totally new value of something that already exists*.” The availability of information enables a deeper understanding of customer’s behavior and her true desires, which again enables solving customer’s root problems. As interviewee 9 continues: “*if we extensively examine customer’s behavior or business model, we can observe that what customer says she wants is something totally different to what she really wants.”* This changes the nature of R&D work so that it is more about starting from the scratch every time as opposed to the old model, in which it was more about further developing and improving the already existing technology or product. As interviewee 10 argues: “*In order to stay on top, there is need for continuous questioning and redeveloping of the current methods used in product development.*”

At the same time, the more information there is, the more complex the problem solving becomes due to resource, time and quality pressures. Interviewee 10 stated that the vast amount of information requires you to increasingly focus and choose the most important things for you. Furthermore, the speed of work has increased significantly and due to the increasing competition one should be constantly innovating and developing new ways of doing things. Concurrently, due to increased transparency, the quality requirements have tightened as companies simply can’t afford to make safety related mistakes, thus increasing the emphasis on quality controlling. Therefore, as argued by interviewee 10 “*this one type of perfection is simply not possible anymore as things get ever more complex and as we are dealing with very wide issues and problems*.” In the end “*it all comes down to what is the most valuable thing for our customers and how we can create maximal value with as minimal efforts as possible*”, as stated by interviewee 8.

As pointed out by interviewee 8, many small or mid-sized firms can outperform bigger firms in several areas. However, though these firms have some specific expertise or knowledge that the bigger firms need, these smaller firms have trouble in seeing the complex system concepts, in which bigger companies are better at. This highlights the importance of partnering, which was brought up by several interviewees as being the way innovation work is done in the future. Partnership models, in which the end user is linked to not only the producer company but also to its partners, who bring in the required skills into the product development, is increasing strongly. Consequently, the role of a big company shifts from being an independent product developer to a product integrator, putting existing components and pieces together. This complicates the determination of who owns the end product and is responsible from it and thus requires an increased level of trust between different partners and customers. Additionally, it induces big changes in the nature of work, as argued by interviewee 9:

> *“The entire product development begins to be water under the bridge and we must completely rethink what product development means and how it should be organized. Things don’t work out so that we do strategic decisions by putting wise heads together and then we go to the basement to develop it for a year. We need to be working together and we do not necessary know how to do everything technically ourselves. It is not worthwhile to think that we have all the required know-how. Know-how can be acquired by partnering up and finding the right doers, so that we can cut and glue pieces together in a way that they are truly valuable for the end user.”*
>
> (Interviewee 9, Technology Innovator)

Consequently, due to the fact that the required know-how does not necessarily rely on individuals within a specific organization, there is more need for combining in depth knowledge and generalist knowledge. This should be combined either within an individual or within a team, so that there are as much different know-hows and skills presented as required. In other words, R&D work is conducted increasingly by sharing information within teams which requires not only teamwork skills and social skills, but also the ability to communicate your own knowledge to others. Thus, many mentioned that is far more important to have socially skilled and teamwork-oriented employees that are eager to learn new things and apply their in-depth knowledge in new areas and even try out something completely new. Hence, for technology innovators there is increasingly need for the same type of trial and error culture as for business managers.

Although in-depth knowledge, which is the basis of state-of-the-art technology, remains to be very important, it was rather clear that in Finland there is lack of generalists who can operate in any field and apply their knowledge in these new fields, especially in the field of business. As several interviewees argued, R&D is becoming more customer oriented and therefore, also customers are more involved in the development process in order to assure that the product produced creates true value for the customer. For technology innovators, who are typically specialist in their own strictly defined field, this requires understanding customer’s business logic and how it fits into the offering so that there can be true value generated. For example, Interviewee 6, who was this type of generalist, stressed the importance of combining business knowledge to technological knowledge. This is crucial as in the end, it is the customer for whom the product is being developed, and if she doesn’t like it, there’s no point in putting effort in it, as stated by interviewee 7. These explained results regarding the changes in task content are summarized in Table 8 below.

Consequently, in the work of technology innovator, the skills related to creative intelligence are of high importance due to the dramatic changes in the nature of work induced by digitalization. These skills are especially highlighted due to the increased amount of information as there is

Table 8: Changes in Technology Innovators' Task Content and the Implications on Skill Demand

	Analytic and Critical Thinking	Creative Intelligence	Social and Emotional Intelligence
Work Efficiency	• Prioritization and acceptance of imperfection in R&D becomes ever more crucial	• Revealing new causal relationships with the help of more data • Creating max. added value with min. efforts • Exploiting global distribution channels	• Information sharing and partnership modeling requires emphasis on trust • Working with more diverse teams with various different skills • Benefitting from global teams and information sharing
Nature of Work	• Increasing complexity of problem solving • Continuous questioning of used methods • Continuous information acquisition and processing • Tightening quality controls due to increased transparency	• Innovation work is increasingly about integrating current components • Solution-oriented R&D • Linking product development to customer's business reality • More recreation of R&D vs. further development	• Shift towards customer oriented product development • More communication and team work • Understanding of people's true needs • Co-creating with teams through information sharing
Implications on Skill Demand	• Information processing skills • Deep discipline knowledge skills • Continuous learning through new information acquisition	• Creative application of deep discipline knowledge combined with business knowledge • Generalist skills • User experience skills • Productization and conceptualization of R&D work	• Social skills • Communication skills • Motivation and enthusiastic attitude to strive towards common goals

need to make sense of it all and create novel ideas and products that create added value for customers. In-depth knowledge of a technology still remains very important, but it is increasingly about applying this knowledge to new context and environment. Moreover, due to the increasing complexity of problem solving, there is high need for understanding the most important causal relationships revealed by the data. When all these skills are combined with social skills with which the end user and the customer are taken into consideration, there are very big opportunities to be achieved.

4.3.3 Higher Education Teachers

The interviewees for higher education teachers included individuals who work in universities as professors, lecturers and researchers, thus being responsible of higher education teaching as well as conducting research within their own disciplinary area. The most important findings in the changes in work life due to digitalization for higher education teachers are summarized in Table 9. Moreover, the changes in task content and their implications on skill demand are summarized in Table 10 at the end of this section.

Table 9: Opportunities and Challenges in Work Life for Higher Education Teachers

	Opportunities	Challenges
1	Increasing motivation due to more individualized learning with diverse teaching methods and materials	Better learning quality not guaranteed with digitalization, content still matters the most
2	Exploitation of existing resources frees time to focus more on personal guidance and feedback of students	Increase in demand for pedagogical skills among higher education teachers
3	Improved learning quality due to better measures of teaching quality	Finding the optimal level of mass online courses and interactive tutorial teaching

In the work of higher education teachers digitalization is on the brink of changing the nature and efficiency of work significantly. Why it has not necessarily done this already is very much related to the environment and context of universities in Finland. For example, as interviewee 12 mentioned: "*in universities many employees are primarily researchers and thus some speak even of "teaching obligation", which represents the situation quite well. Teaching is seen as something negative, as an obligation, which takes time from something much more meaningful, from researching, you see.* " Additionally, many spoke of the effectiveness of the "speaking head" [13] referring to the mass lectures which are still rather common method used in the universities. On the other hand, it was clear that universities are at a crucial turning point in which they need to transform themselves to more modern institutions which increasingly exploit the possibilities of digitalization. Nowadays students have higher expectations of their education as more information is available online for free and there are more MOOCs offered by world's top universities, as stressed by interviewees 11 and 17. At the same time MOOCs and online courses can be distributed to big masses irrelevant of the place and time, which gives

[13] "Puhuva pää" in Finnish

them a significant competitive advantage in comparison to the physical mass lectures. Therefore, it is becoming highly necessary to define the role of higher education as there are more expectations and demands for higher quality learning experiences and outcomes.

Consequently, all interviewees spoke of the great possibilities of more individualized learning. This is based on the idea that *"everyone learns in a different way[14]"* to which digitalization gives great tools to as there are more diverse teaching methods and materials available. *Blended learning* and *flipped classroom* were terms that were brought up in the interviews several times, thus questioning the effectiveness of old-fashioned mass lectures. Blended learning refers to combining online learning experience through Internet and digital media with face-to-face learning in classrooms that require physical co-presence of teacher and students (Garrison and Kanuka, 2004). Flipped classroom method, on the other hand, is one form of blended learning in which students study the content online outside of the classroom as homework and inside classroom the instructor acts as a facilitator to students who engage in different activities based on the studied material (Milman, 2012). Thus, as interviewee 11 argued: "*We are perhaps just now switching to "just-in-case" education to "just-in-time" education, which means that in the future it is not degrees that are valued but the competences that the education provider offers and which are also useful in the work life.*"

Just-in-time education refers to a flipped classroom method where teaching is tailored to students' prior knowledge and interests so that the level of teaching is consistent with students understanding (Simkins and Maier, 2010). This is done with web-based platforms that provide various meters and measures to evaluate the quality of teaching and its outcome on learning quality. This way, as argued by several interviewees, there are great possibilities in achieving the right level of teaching so that students are in the state of flow, meaning that they are highly engaged and motivated in their learning as the teaching is challenging enough but not so hard that students would give up. Therefore, as the work of higher education teachers is shifting from information distributor to an information facilitator, it requires substantially more pedagogical skills than before. Additionally, due to the diverse possibilities to make learning more individualized, there is need for continuously developing the methods and materials used based on the analysis of measures and meters studying the quality of learning. This is where the mentioned shift from reactive to proactive teaching is present in the work of higher education teachers. In this setting, the planning of the pedagogical process takes up much more time than before when professors went about teaching the same material year after year with a more

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[14] Interviewee 13, a higher education teacher

standardized approach. Moreover, it requires more innovative approach from higher education teachers as the trying out of different teaching methods requires a culture of trial and error.

Due to these changes in the task content, there is need for more effective information sharing and support from the organization and co-workers as explained by interviewee 14:

> *"I would see that here the support for higher education teachers is important. When this [work] changes towards development work, it requires more time and energy […].For this we need more support in terms of getting help when something is not working out. Teachers should not be thus merely producers of content but also the planners of the pedagogical process and the latter will take much more time especially as the teaching turns ever more diverse with digitalization."*
>
> (Interviewee 14, Higher Education Teacher)

Additionally, the role of increasing information sharing was presented by interviewees 16 and 17 who highlighted the role of social media in sharing information, such as sharing the results of recent studies. They both argued, that there is significant need for higher education teachers who firstly, know how to use social media in a correct manner and secondly, are willing to actively be present in the Media and thus take part on the societal discussion based on their academic knowledge. The information sharing works also inwards, as pointed by interviewee 18: "*I especially long for these sort of tools that increase community spirit and swarm work. For example, there are tools with which you can add experts into your swarm through an online platform. Whenever you have a question you can ask them questions that you are desperately looking answers for. This type of platform can save you at best time equivalent to one week's worktime. This could increase the efficiency of work significantly and it is very useful in the work of researchers and teachers.*" Hence, it can be concluded that due to digitalization there are many efficient tools available in order to acquire and analyze information rapidly and to evaluate the quality of the information, which has significant impact on the efficiency of the work. However, as for business managers, in order to fully exploit these possibilities brought by digitalization it is increasingly important for higher education teachers to have the required IT and "digi skills".

Automation is present in higher education teacher's work especially in such subjects as mathematics, physics and computer science, as it is much easier to create online courses that give automatic feedback for the completed numeric exercises. Nevertheless, the interviewees argue that there are increasingly more tools to automatically evaluate students' essays and reports which frees time to give more personal feedback and guidance for students. In effect, this is an area that should be emphasized and improved with the help of digitalization as argued by interviewee 17. Moreover, the feedback should not be only going from teachers to students, but also from students to teachers. "*I expect that there is increased amount of interaction in these new digital tools meaning that both teachers and students could give feedback to each other and have conversations, e.g., on the course website. It would be highly useful.*" Furthermore, interviewee 12 added that there should be more student-teacher cooperation which could decrease the workload of the teacher and give more responsibilities for students. For example, students can themselves evaluate other group works, present some topic themselves as well as record, edit and publish videos of lectures on the course website. Consequently, the role of the teacher would be to manage the overall picture and planning of all the important topics and competences that need to be covered during a course. Students, on the other hand, could participate in producing the content of the course thus reducing the workload of the teacher.

Finally, despite all of the changes in the task content of higher education workers, there was the following worry mentioned by some of the interviewee 15: "*the role of a higher education teacher is not to be an entertainer*." This was addressed by interviewee 13 as well: "*One thing that will not change is that there is no shortcut to learning. Digitalization does not speed up learning, but it makes it more pleasant. A student needs to thoroughly understand what she is learning and this requires time and information processing.*" Therefore, higher education teachers still need to possess in-depth knowledge of their own disciplinary and teach this to the students. Although there are more resources to be exploited to make students more motivated and excited to learn, it doesn't change the fact that it takes time to obtain that in-depth knowledge, especially of those things that are very difficult.

Table 10: Changes in Higher Education Teacher's Task Content and the Implications on Skill Demand

	Analytic and Critical Thinking	Creative Intelligence	Social and Emotional Intelligence
Work Efficiency	• Evaluation and analysis of data and information is faster • New visual infographic tools for more efficient data quality analysis	• Creating and exploiting mass online courses, e.g., MOOCs • Exploiting the possibilities of *blended learning* • Achieving *the state of flow* and the right level of difficulty with measuring and metering	• From information distributor to information facilitator (*flipped classroom)* • Remote teaching and meetings • Information sharing within global networks
Nature of Work	• Acquiring and teaching in-depth knowledge requires time and information processing • Segregation of quality in information and data	• Planning of pedagogical process and teaching content • Continuous improving of quality of teaching material • Exploiting student feedback in teaching development • Diversifying teaching to gain best possible learning outcomes • Evaluating students' skills with right meters	• From mass lectures to tutorials with interactive teaching and dialogues • Increasing professor-student cooperation • Improving individual teaching with student guidance and feedback • Human help and support in learning remains to be crucial • From *Just-in-Case Teaching* to *Just-in-Time Teaching*
Implications on Skill Demand	• Information processing skills • Deep knowledge of the taught disciplinary area • Data quality evaluation skills	• Pedagogical skills • IT and "digi" skills • Innovative trial and error culture • Constant creative development of teaching methods and materials	• Soft skills • Communication skills • Accepting and giving constructive feedback

The explained changes in task content for higher education teachers are summarized in Table 10. Based on the results, higher education teachers are on the verge of transformation due to digitalization that changes both the efficiency of work and nature of work significantly. Higher education teachers need to have stronger pedagogical skills as their work is more about planning and developing the pedagogical process. Furthermore, in order to exploit the increasing amount of information, there is need to innovatively explore the possibilities that different digital tools provide to improve the quality of teaching. Nevertheless, as for all occupations, as there is more information available, there is also need to critically evaluate the quality of the information.

4.3.4 Healthcare Professionals

The interviewees for healthcare professionals included individuals who are either physicians or nurses. The most important findings in the changes in work life due to digitalization for healthcare professionals are summarized in Table 11. Moreover, the changes in task content and their implications on skill demand are summarized in Table 12 at the end of this section.

Table 11: Opportunities and Challenges in Work Life for Healthcare Professionals

	Opportunities	Challenges
1	Improvement of quality and safety in patient treatment	Development of intelligent user friendly healthcare systems
2	Creation of effective patient treatment processes based on increased interaction with the patient	Effective exploitation of healthcare systems due to polarization of workforce based on one's IT skills
3	Substantial improvement of cost effectiveness of healthcare services	Careful planning of patient's privacy protection with increased information sharing

For healthcare professional the situation regarding the exploitation of digitalization is quite similar to that of higher education teachers. Healthcare professionals are also on the verge of digital transformation, which will have dramatic improvement effects on healthcare services, if the transformation is done properly. The big impact digitalization can have on the work is related to the fact that documentation and detailed information of patient's medical history and other physical or genetic background is an essential part of a healthcare professionals work. Hence, with the increasing amount of information of all these there are vast possibilities to improve the quality of patient treatment, which can then substantially improve the cost-effectiveness of healthcare services. With automatic information retrieval and documentation there is also increased safety of patient treatment as argued by interviewee 21:"*the most mistakes come from documentation mistakes, according to the research*." Patients have increasingly better access to the best possible expertise regarding their treatment as the diagnosis is becoming automatic and thus all the unnecessary steps of the current treatment processes can be skipped, as argued by interviewee 19. Consequently, the patient treatment processes can be completely redefined so that the patient is at the center of the process, giving more focus on the dialogue and interaction between the doctor and patient, which is an important part of achieving high quality patient treatment.

All this can be achieved with increased digital healthcare services and exploitation of intelligent healthcare systems, which operate as support tools for decision-making. Nevertheless, as pointed out by all of the interviewees, this is not the current situation yet, though there are big investments made in these areas at present. As some of the interviewees mentioned, early 90s there were big improvements of efficiency of work as documentation transferred from printed to electronic version. However, the same has not still happened with the digital technologies.

Though there are various different information systems being used, and different automatic information retrieval tools, they are not yet such that would intelligently support decision-making. Moreover, digital healthcare services are currently being used in the area of therapy, though they are gradually spreading to other areas within healthcare, as explained by interviewee 20 and 19.

The reason why healthcare professionals have lagged behind in the digital process in comparison to other fields, as stated by interviewee 23, is the role of patient's privacy protection and the related legislation. Additionally, some interviewees highlighted that the biggest challenge has been the vast amount of resources that are needed in implementing intelligent systems and technologies, while some stressed that it is due to the lack of required development of the technology itself. Nevertheless, all of the interviewees stressed that as some of these technologies are already available or becoming available very soon, it is increasingly about the exploitation of these technologies what is the biggest challenge. Regarding the latter point, there were two things especially highlighted as the main causes for this. Firstly, there is a great and increasing need for user friendly healthcare systems. Secondly, there is a clear polarization of workforce regarding their information systems knowledge and IT skills.

The increasing need for user friendly healthcare systems is highlighted by interviewee 20:

> *"Those who develop digital healthcare services don't often times have a clue about the core content and the nature of the work, but quickly think that this is done so and so. As a result these [digital healthcare services] often fail, as they are too superficial. In this exploitation of technologies it is very important that one understands very thoroughly what is the content and nature of the work and based on that plan the digital services."*
>
> (Interviewee 20, Healthcare Professional)

This was also stressed by interviewee 19, who stated that there will be more positions in the future that combine clinicians and data scientists work. He argued the following: "*There exists a risk that these position are becoming two separate ones. For example, it is important the individuals who develop these [intelligent healthcare] systems are all the time at least partly doing clinical work so that we can truly develop such systems that in reality support the everyday work of a healthcare professional."* Consequently, there is increasing need for healthcare professionals with user experience designer skills who can continuously improve the intelligent systems to be better at supporting decision-making of healthcare professionals.

On the other hand, the polarization of workforce was especially stressed by interviewee 22 and 23, who both concluded that there are many levels of digital experts in the organization, and it is thus crucial that this issue is addressed with training. Additionally, interviewee 22 pointed out that *"while the newcomers are excited about exploiting new systems and technologies, we cannot afford to lose the people that have extensive amount of experience but see technology as an enemy."* Accordingly, the importance of experience in the work of healthcare professional is very crucial, as argued by interviewees 20 and 22. As interviewee 20 pointed out: "*You don't want to go to a doctor who has just started and doesn't have any experience or practice. It is the long experience which is very necessary for a doctor, but at some point that experience gets a bit old-fashioned, and there is need for more updated information.[…]In our field it is mostly so, that people are at their best in the middle of their career."* This again highlights the importance of the combination of information and experience in healthcare professionals work and the importance of problem-based learning.

One of the big trends related to digitalization within healthcare is the increase of *quantified self*, which refers to the acquisition of data on one's own personal daily life, thus providing information on, e.g., blood and oxygen levels as well as mental and physical performance. Hence, in the context of healthcare, people can increasingly measure their health with the availability of such technologies and sensors that make this possible. This, on the one hand, makes patients active players within their own healthcare as they are true experts of their own healthcare. On the other hand, it changes the work of healthcare professionals more to that of a healthcare coach. As argued by interviewee 19 and 22, already today patients come to receptions with some information they have googled beforehand. This increases the importance of people skills as well as information processing skills, as stated by interviewee 19:

> *"I see that there is more demand for this sort of combination of good people skills and information processing skills. Now we have those, who have either or of these skills, but in a certain way this digitalization will decrease the need for both of these skills. You don't do anything with this idle communication and, on the other hand, if you are a strong analyst who only knows things, it won't be enough as in fact computers are much better at it. […]The importance of people skills can be seen already today as the value of patient experience has increased for patients."*

(Interviewee 19, Healthcare Professional)

Moreover, interviewee 20 adds: "*You can increasingly focus on interaction and communication with the patient as well as planning and guiding patients' meta-level strategic patient* *treatment.[…] Some therapists are very good therapists: they treat their patients very emphatically and systematically."* Therefore, as there will be more information available, healthcare professionals are no longer superior to patients purely with their knowledge. This increases the importance of people and empathy skills. Additionally, in order to plan effective and high quality patient treatment processes, there is need for systems thinking, which unlike analytical thinking, refers to understanding how different parts of a system can influence one another within a whole.

Table 12: Changes in Healthcare Professionals' Task Content and the Implications on Skill Demand

	Analytic and Critical Thinking	Creative Intelligence	Social and Emotional Intelligence
Work Efficiency	• Combining information and causality with automated information retrieval • Intelligent decision support systems require strong critical thinking • Automatic medication robots cannot dull critical thinking and basics of physics	• Reshaping of patient processes with technology • Increased access to specialists knowledge • Effective exploitation of intelligent healthcare systems	• *Quantified self* is increasing, healthcare professionals become healthcare coaches • Increasing digital services and interaction with patient • Patients become active players in their own health • Better technology frees time to focus on patient
Nature of Work	• Understanding the role and capabilities of technologies • Integrating information and controlling the coherent whole • Abstraction of important information is very important • Core physiology knowledge cannot be deteriorated	• Continuous development of intelligent healthcare systems • Combination of experience and scientific knowledge based know-how is hard to replace • Clinical research examination is highlighted due to human complexity and individuality • *Systems thinking* becomes crucial in planning patient treatments	• Improving trust and interaction between patient and doctor • Dialogue between patient and doctor crucial part of treatment • Reacting and responding to patients feelings • Personal relationship with patient is important • Increasing the value and quality of patient experience
Implications on Skill Demand	• Information processing skills • Understanding the limitation and capabilities of technology	• Innovative attitude towards healthcare technology • Information system and IT skills • Healthcare professionals with user experience design skills • Experience- and problem-based learning skills • Systems thinking skills	• Empathy skills • People skills • Ethical skills related to patient privacy policy

Lastly, though automation and intelligent systems will play a bigger role in the work of healthcare professionals in the future, interviewee 21 stressed that this cannot, however, dull the critical thinking and the core physiology knowledge of a healthcare professional. It is increasingly important to understand in what areas computers are better than humans and in what areas not. Moreover, due to the increasing exploitation of information, it is still highly important to control patient's privacy protection implying that doctors should be ever more aware of the ethical issues they are faced against in their work. All these changes in the task content of a healthcare professional are summarized in Table 12 above. As already explained earlier, though it was mentioned that a doctor's touch and observation is a crucial source of important information, it was not included in the table, as it is something very intuitive for human beings rather than a skill that was especially highlighted by the interviewees to be more in demand due to digitalization.

To conclude, the role of digital services and intelligent healthcare systems will significantly increase in the near future in the work of healthcare professionals, thus requiring healthcare professionals to truly understand the benefits of these systems. In order to exploit the quality and efficiency gains brought by these systems, there is need for healthcare professionals who possess good information systems knowledge and user experience design skills. Furthermore, as digitalization reduces the amount of pointless patient reception visits, there is increasing need for a combination of good empathy and people skills as well as systems thinking skills.

4.3.5 Cybersecurity Experts

The interviewees for cybersecurity experts included individuals who are either organization's head of cybersecurity or external cybersecurity consultants. Cybersecurity in this study is used to describe issues that relate to information, network and computer security, which are all terms that are being used in this section. The most important findings in the changes in work life due to digitalization for cybersecurity experts are summarized in Table 13. Moreover, the changes in task content and their implications on skill demand are summarized in Table 14 at the end of this section.

Table 13: Opportunities and Challenges in Work Life for Cybersecurity Experts

	Opportunities	Challenges
1	Internet of things induces explosive increase in demand for cybersecurity products and experts	Problem solving gets ever more complex due to the dispersion of cybersecurity field
2	Automation and remote connection enable substantial increase in problem solving efficiency	There is no room for mistakes as risks become more serious
3	Exploitation and analysis of data increasingly easier due to concentrated data storage	Ethical issues related to data collection and privacy policies

As mentioned earlier, cybersecurity experts notably differ from the other occupational roles as they represent an occupational group that has been created by digitalization. In fact, information security became a relevant worry only after the invention of the computer in the 70s, as reflected in the timeline of cybersecurity and US Government gathered by *the Washington Post*[15]. At present, the increasing role of Internet, cloud storage and Internet-of-Things is having an explosive effect on the demand for cyber security experts, as argued by all the interviewees. This is mostly related to companies giving more emphasis on information security as they realize the importance of it. As more technologies and devices are connected to Internet and networks, the risks become more serious and thus there is immense need for embedding information security comprehensively into all technologies. Interviewee 24 points out that the increasing dangers and threats of cybersecurity is reflected in the product development as today it is very crucial to have a very perfect product which is top-notch so that is truly reliable information security product. The constantly changing nature of the work is summarized by interviewee 24:

> *"This information security is at the moment changing very rapidly [...]. As this world changes to being such that all systems can talk to each other, this information security should be involved in all things comprehensively, not so that it is a glued piece on top of everything. We don't speak of antivirus products anymore, though it is known with this name among consumers. It is an information security product, which is always tailored to fit everyone's individual need."*
>
> (Interviewee 24, Cybersecurity Expert)

Before explaining the changes in task content more in-depth, it is important to understand the task content as it is today. For example, interviewee 25, who works as a security consultant, describes that his tasks include selling cybersecurity solutions for companies who build networks and capacity between their international offices. A big part of the work consists of managing, monitoring and following-up networks' information security as well as analyzing whether or not customer's different information security deviations are real threats or attacks or just common noise. In addition, his tasks include also different information security consulting tasks, for example monitoring and reporting of information security vulnerabilities. Thus, as interviewee 25 states, his work consists of very diverse tasks, which are becoming ever dispersed due to the Internet-of-Things:

> "*On the one hand, new tasks are constantly being developed as technology advances, but on the other hand, also the old technologies will not disappear anywhere. As old technologies are being connected to networks in the industries, there is increasing demand for people who*

[15] The Washington Post, May 16, 2003

understand the protocols of these old technologies that have been developed in the 80s. Electric power plants or diesel motors, are one examples of these."

(Interviewee 25, Cybersecurity Expert)

Therefore, there is increasing need for expertise that relates to old technologies, as well as expertise that relate to the constant development of new technologies. For example, as mentioned by all of the interviewees, at the moment the information security product is strongly shifting from being created into networks to being created directly into the terminal devices, e.g., mobiles and tablets. This is a result of the changing trend that people work increasingly with their phones and tablets, thus creating a big threat for information security. Evidently, this continuous development of technology and the dispersion of the cybersecurity field makes problem solving ever more complex and requires substantially wider skillset from cyber security experts.

The role of automation and *Big Data* is reflected on the work of cybersecurity experts so that problem solving is much faster, thus increasing the efficiency of work tremendously. As interviewee 24 states, whereas previously it took even weeks to manually go through information and define where the problem is, with automatic tools it is easier to rapidly detect the contamination of malwares and thus go straight on focusing on problem solving. This can be done remotely by creating a remote connection with the customer, thus tremendously speeding up the reaction time. The role of *Big Data* further speeds up the analysis, as one can directly ask the software whether there has been any similar detection anywhere and thus it is easier to evaluate the seriousness of the malware. Interviewee 25 adds that this is mainly due to the concentrated data storage and the availability of programming languages that allow to combine systems' interfaces together that gives many possibilities to examine different causal relationships. Furthermore, the increasing automation changes the nature of work towards more proactive operation model, as argued by interviewee 25:

"Work changes more towards these proactive activities than reactive ones. In the future we can automate ever more simple information security alarms. Consequently, the demand rises for skills that relate to analyzing data and constructing analysis based on what the future trends will be and then develop solutions to those trends."

(Interviewee 25, Cybersecurity expert)

All of the interviewees raised the issue that among companies there is lack of true understanding of what information security truly means for them strategically. Hence, there is clear lack of knowledge about information security, which stresses the importance for information security experts to have business related skills. As interviewee 26 stresses: "*We need people who can communicate what information security means for customer's business. The problem with information security is that one only realizes its importance when something bad has happened. This is why we need a bit of this type of selling skills so that you can sell the idea of information security, why exactly is it important for you and your business. If we speak with technical terms, the message doesn't go through.*" Interviewee 25 adds, that if information security is implemented and embedded into the company's strategy in a right way, it can even be an important source of competitive advantage. Consequently, this highlights the increasing importance of understanding customer's business logic and to sell the information security as a solution to the customer, as summarized in Table 14.

Table 14: Changes in Cybersecurity Experts' Task Content and the Implications on Skill Demand

	Analytic and Critical Thinking	Creative Intelligence	Social and Emotional Intelligence
Work Efficiency	• Analysis of automatic alarms on information security deviations • Analysis of correlation between different causal relationships	• Automation and *Big Data* enables focusing on problem solving vs. problem definition • Building of automatic alarms to improve efficiency and quality	
Nature of Work	• Human made errors to software still need to be solved by humans • Understanding causal relationships and correlations • Increasing amount of data analysis and conceptualization of the overall view	• Creating new security products due to *Internet of Things* • Continuously modifying the information security product • Creating embedded data protection into all technologies • Integrating information security to fit customer's strategy • Increasing complexity due to the dispersion of information security	• Communicating the importance of information security • Understanding customer's business logic and environment is crucial • Solution driven selling requires understanding the customer
Implications on Skill Demand	• Data analysis skills • Information processing skills • Critical thinking skills are crucial as there is no room for errors	• Explosive increase in various technology specialist skills combined with information security skills • Continuous learning and application of knowledge due to new technologies • Business skills • Legal know-how	• Social skills • Communication skills • Negotiation and selling skills

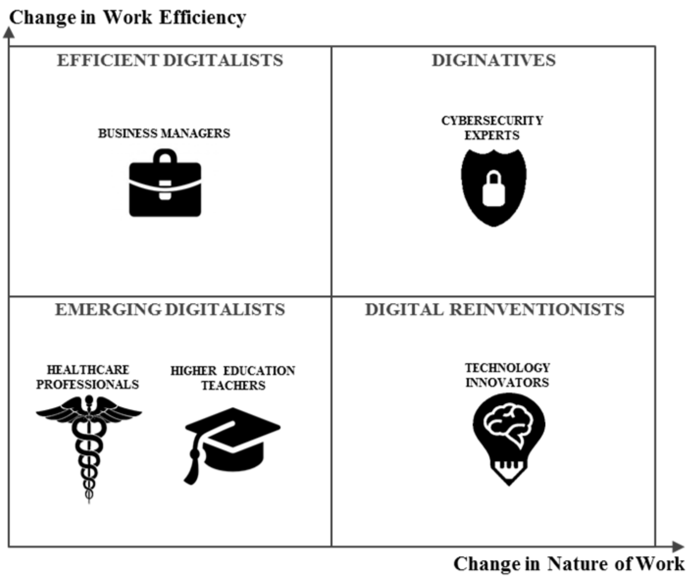
As a last point, the ethical issues related to increasing amount of information and concentrated data storage was brought up by the interviewees. This is related to the point mentioned in the previous paragraph that companies don't comprehensively yet understand the role of information security in their everyday business. Interviewee 25 highlighted that there is clear lack of understanding the privacy protection and legislative issues related to cybersecurity. As he stated, the legislation is at the moment developing strongly to answer to these mentioned gaps. Thus, there is increasing need for people who know how to interpret these upcoming new laws. "*Currently, there is much room for abuse of information as no one really controls the increasing data and information collection*", argued interviewee 25.

In conclusion, the explosive increase in demand for cybersecurity experts relates to the fast technological advancement and connection of all technologies in networks. This induces a strong dispersion of the field of cybersecurity, as there is ever more need for technological expertise knowledge as well as business and legislative knowledge, thus significantly changing the nature of work into a more cross-disciplinary. At the same time the constantly fast changing information security product and development of automatic alarms requires continuous learning and application of new knowledge. All these changes in task content induce a great increase in the skill demand for cybersecurity experts.

4.4 Summary of Results

To conclude this chapter, in this section a summary of the current situation of digitalization in work life is posed based on the analysis in the previous section. The results are presented in Table 15 based on the changes in work efficiency and nature of work of each occupation. Depending on what kind of impact digitalization has had on task content of these occupations, four different categories were created with the corresponding names: diginatives, efficient digitalists, digital reinventionists and emerging digitalists. Consequently, this section summarizes the differences between occupations based on how digitalization has affected their work efficiency and nature of work. The aim is to thus give recommendations on how to better exploit the possibilities brought by digitalization.

Table 15: Change in Work Efficiency and Nature of Work due to Digitalization



Diginatives present occupations which are created by digitalization and new technologies and thus digitalization is the core of the work, on which the tasks are built on. Hence, due to their position as innovative forerunners, the change in work efficiency as well as in nature of work is constantly changing. Cybersecurity experts are placed in this category, as it was somewhat evident that that due to increasing amount of automation and more concentrated data storage, work efficiency has incremented significantly. For example, the work has shifted from time-consuming problem definition to problem solving as automatic alarms and tools can instantly recognize the problem, but need humans for the problem solving tasks. At the same, the nature of work is constantly changing together with technological advancement. For example, the continuously changing information security product and the increase of old technologies in networks induces pressure to have ever wider skillset. Consequently, to keep up with the rapidly changing environment of cybersecurity experts it is important to focus on developing highly skilled cybersecurity experts with ever wider and more specialized skillsets.

Efficient digitialists, on the other hand, present occupations where digitalization and new technologies have induced a significant increase in work efficiency, but the nature of work still remains to be somewhat the same. Business managers are placed here, as it was clear that due to virtual workplaces, online meetings and omnichannel approach the work efficiency has increased significantly. Nevertheless, the core of the work still remains to be the same, though the methods used in doing that work are completely different. Though this may be a somewhat caricatured statement, it is meant to emphasize the fact that business managers didn’t see that digitalization and new technologies has changed the nature of their work. Instead they saw that it has brought more tools and methods to complete the exact same tasks. For example, digital marketing is still about innovating and creating mental images, although the distribution happens through digital channels. Consequently, to increase the efficiency gains of digitalization it is necessary to develop more digitally oriented business managers with strong people skills. Additionally, there is need to create organization models that support the ever shorter reaction times and trial and error culture with greater employee empowerment and trust building.

On the contrary to efficient digitalists, the impact of digitalization on task content for digital reinventionists is quite the opposite. For digital reinventionists the change in work efficiency has remained somewhat the same, but the nature of the work has changed dramatically. This was reflected in the results of technology innovators, as digitalization and new technologies has changed the very meaning of product development and innovation work, as argued by the interviewees. The increasing amount of information is bringing many new possibilities for technology innovators, but at the same time the work is done increasingly together with co-workers, customers and partners. The new customer and solution orientation is changing product development to be ever more cross-disciplinary, which is inducing great demand in the skillsets of technology innovators. For example, there was clear need for generalists who can combine business knowledge to their in-depth knowledge. At the same time, the global competition is significantly increasing, which again increases the importance of top know-how. Therefore, to better exploit the efficiency gains of digitalization, there is need for highly skilled technology innovators with strong social skills as well as the ability to apply their knowledge in an ever more cross-disciplinary setting.

The fourth remaining category was named as emerging digitalists to represent occupations that are on the verge of having big changes both in work efficiency and in nature of work. Higher education teachers and healthcare professionals were placed in this category, as in both of these occupations the effect of digitalization has been well thought through, however, the realization of the changes had not yet occurred in the extent that could be possible with the already existent technologies. Consequently, there are big possibilities to improve the quality of both education and patient treatment if digitalization is being exploited in the optimal way. To obtain the improved quality, it is important to first, change the nature of work so that it truly offers benefits for patients and students. Secondly, only when the improved quality has been obtained, the increase in the efficiency of work can be realized.

With regards to higher education teachers, digitalization offers great tools to constantly improve the methods and materials used based on the better availability of measures on the quality of learning. Moreover, by increasing teacher-student interaction and finding the optimal level of online material and classroom teaching, learning can become more individualized due to diverse teaching methods. This, however, requires digitally innovative higher education teachers who possess both strong disciplinary knowledge as well as pedagogical skills.

Regarding healthcare professionals, digitalization is creating efficient tools to improve the quality of patient treatments by redesigning time-consuming, costly and pointless patient processes so that the focus is increasingly on patient. While intelligent healthcare systems can provide healthcare professional with important decision-making tools, the emergence of quantified self and digital services capitalize on the fact that patients are the expertise of their own healthcare. Both of these changes, however, change the nature of work so that there is more need for both systems thinking and empathy skills. Additionally, as information systems play such a big role in healthcare professionals, there is increasing need for healthcare professionals that understand and know how to both exploit and develop the intelligent information systems and digital tools they are offered.

Consequently, as Table 15 indicates, digitalization induces both work efficiency and nature of work related changes in the work of all of the occupations under scrutiny in this study. However, for some the nature of work hasn't yet changed enough to fit to the demands of the new digital economy. This has prevented them to achieve the tremendous efficiency gains that digital technologies can at best provide. As the nature of work keeps changing, it is important to react to these changes by focusing on having the right skills and the right organizational models in place. Only then can the true efficiency gains be obtained.

5 Conclusion

The objective of this study is to understand how digitalization and new technologies are changing task content and skill demand for five selected occupations: business managers, technology innovators, higher education teachers, healthcare professionals and cybersecurity experts. Based on the study by Frey and Osborne (2013) these occupations have a low probability of being replaced by computers despite of the exponential speed of technological progress and advances in machine learning and mobile robotics. This is because these jobs include tasks that require manipulation and reception, creative intelligence and social intelligence skills, all in which humans still have a comparative advantage over computers. Nonetheless, little is known about how these technological advancements are changing task content of these occupations and what the corresponding indications are on the required skills. Therefore, this study aims to fill in this gap in the literature and provide recommendations on the skills that will be increasingly in demand in the near future. Furthermore, the aim is also to study the role of digitalization in the work life of the selected occupations under study and provide recommendations on how to increase the productivity of the work by exploiting the benefits of digitalization.

Vast amount of scholars have studied how technological change has increased skill demand (e.g., Katz and Murphy, 1992; Autor, Katz and Krueger, 1998) and shifted work from routine to nonroutine work (e.g., Autor, Levy and Murnane, 2003; Acemoglu and Autor, 2011). Furthermore, the novel study by Frey and Osborne (2013) indicates that in the near future advances in machine learning and mobile robotics are shifting the division of work between humans and computers according to their comparative advantage. This new division of labor between humans and computers is becoming ever more evident as computers and robots are becoming not only better but also cheaper than human labor (Levy and Murnane, 2004). As a result, there is great need for understanding how the nature of work is changing in the new digital economy, which is the aim of this research. Granted that predicting the future of technological development is extremely difficult, the results of this study should be interpreted with caution. Nevertheless, this does not mean that we should not be prepared for the changing skill demand implied by the changes in task content in order to provide a smoother transit into the new digital economy.

5.1 Main Findings

Based on the results of this study, it was clear that the task content and the corresponding skill demand for the occupations under study has increased towards tasks that require increasingly skills related to analytical and critical thinking, creative intelligence and social and emotional intelligence. In addition, there were some common effects of digitalization on the work life for all occupations. Those were divided into information efficiency, technology efficiency and people efficiency related opportunities and challenges, indicating that in each of the categories there are clear benefits but also obstacles that currently prevent the realization of these benefits.

Regarding the occupation-specific main findings, it was clear that digitalization affects the task content of the selected occupations under study in two ways: by increasing the efficiency of work and by changing the nature of work. Across the different occupations, the extent of these effects varied depending on the role that digitalization has had in their work. Accordingly, in order to increase the efficiency of work it is necessary to reorganize the work so that the obstacles in obtaining improved levels of information, technology and people efficiency can be realized. It is important to focus on changing the nature of work to fit the needs of the new digital economy and ensure that the workers have the right skills in order to gain the increased level of productivity offered by digitalization.

Based on the findings, the underlying theoretical propositions developed by Frey and Osborne (2013) can be verified to be accurate for the occupations under study with small modifications. According to them the bottlenecks to computerization are manipulation and perception, creative intelligence and social intelligence tasks. However, while manipulation and perception related tasks were relevant only for healthcare professionals, they were not described as skills that will be increasingly in need in the near future. It seems that it is only due to the intuitiveness of these skills why humans still have a comparative advantage over computers in manipulation and perception tasks. Additionally, as digitalization offers tools for more effective self-development and information sharing, it is not only social intelligence, but also emotional intelligence that is an increasingly important skill to possess. Digitalization causes also an explosive increase in the availability of information and data and thus there are increasingly difficulties with information overload. Information overload increases the tasks that relate to processing information and evaluating what is the most important information. As a result, in all of the occupations the skills for analytical and critical thinking emerged as being in high demand in the near future as knowledge management and the use of information in decision-making increases.

Digitalization has three ways how it can improve the efficiency of work for all occupations. These were divided into three topics: information efficiency, technology efficiency and people efficiency. There were clear opportunities and challenges in each of these areas. In order to gain the benefits of digitalization, these challenges should be dissolved as described below.

Information efficiency: It was clear that the increasing availability of information and data enables analysis of completely new causal relationships and improves predictability, shifting the nature of work from reactive towards proactive. Nonetheless, currently the challenges in improved exploitation of information relate to putting more effort in information security, critically interpreting the available performance measurements and creating long-term digital visions which build coherence in actions and decision-making.

Technology efficiency: Due to technological advancements the work is becoming more challenging as the amount of routine tasks has decreased. Additionally, with digital technologies work can be done increasingly online irrelevant of time and place, significantly increasing the efficiency of work. Nevertheless, many used technologies and information systems lack user experience thinking, and hence to some extent it has even increased routine type of work, especially “secretary work”. Therefore, the next wave in the development of technologies will be the accentuation of humanity in technologies so that technology is designed for humans, not the other way around.

People efficiency: The increasing amount of information enables better measurement of worker’s work performance and provides important feedback for continous development of workers’ skills. This also requires to be able to continously learn and develop one’s own skills based on the feedback. However, at the same time it will be harder to hide poor performance in a more information-driven and efficiency focused work environment. This highlights the importance of individuals capability to take care of their own well-being and control their stress levels. Moreover, the increasing role of information sharing and team work will require completely new ways of organizing work. Be it product development, solution selling, teaching or treating patients, in all of these areas the best possible outcome can be achieved by working together and sharing information with each other regardless of the position of the employee.

Regarding the occupation-specific results, the effect of digitalization can be divided into efficiency of work and nature of work related changes. Across the occupations under study, the role of these two effects varied based on the role digitalization has in their work.

Cybersecurity experts differ from the other occupations as they are in fact created by digitalization and thus they were named as being diginatives. The work efficiency of cybersecurity experts has incremented significantly due to the increasing amount of automation and more concentrated data storage. Additionally, due to the continuously changing information security product, the nature of work is currently changing rapidly. As more technologies, e.g., electrical power plants, are connected to the network, the needed skillset from cybersecurity experts increase significantly and even disperses to different specialized areas. At the same time there is no room for mistakes, which increases the need for highly skilled cybersecurity experts. Accordingly, to ensure that the efficiency of work will continue to increase in the future, it is important to develop the skills of cybersecurity experts to match with the explosive increase in demand induced by technological advancements.

Business managers were identified as efficient digitalists since the efficiency of work has increased significantly due to virtual workplaces, online meetings and the use of omnichannel approach in communication, marketing and sales. The nature of work, on the other hand, has remained somewhat the same. The core of the work still consists of customer meetings and creation of mental images, although these are increasingly carried out through digital channels. Nonetheless, there was clear lack of deep understanding of digitalization, which is required in creating persistent long-term digital vision and proper organizational models that support the required culture of trial and error.

Technology innovators were identified as digital reinventionists for whom the nature of work has changed dramatically due to technological advancements. The work is done increasingly together with co-workers, customers and partners requiring more social and teamwork skills. Furthermore, as product development is becoming more customer and solution oriented, the nature of work is ever more cross-disciplinary. However, the current organization models based on silos, do not support the new cross-disciplinary product development work. These changes induce demand for technology innovators who have both specialist and generalist knowledge so that they can apply their in-depth knowledge in this new cross-disciplinary setting combining technological knowledge to business knowledge. Accordingly, to increase the efficiency of technology innovators' work, there is need to ensure that the right organization models and skills are in place.

Higher education teachers were identified as being emerging digitalists since the work efficiency and nature of work have not yet changed according to the demands of digitalization. However, currently they are on the verge of big digital transformation. The role of higher education teachers is changing from being information distributor to information facilitator. This means that there is increasing need for good pedagogical skills combined with strong disciplinary knowledge. The work will be increasingly about continuous development of teaching methods by finding the optimal level of online material and classroom teaching. Additionally, as teaching becomes more individualized due to the diverse teaching methods offered by digitalization, there is need for digitally innovative higher education teachers who effectively exploit the opportunities offered by digitalization.

Healthcare professionals, like higher education teachers, are categorized as emerging digitalists for whome digitalization is about to significantly change the nature of work. For healthcare professionals the emergence of quantified self and digital services will change the nature of work so that the focus is increasingly on improving the quality of patient treatment. This induces need for a good combination of systems thinking and empathy skills. Additionally, since information systems play such a large role in healthcare professionals' work, there is an increasing need for healthcare professionals who possess the understanding and know-how to both exploit and develop the intelligent information systems and digital tools they are offered.

In all of these occupations the changes in the nature of work and the implied results in skill demand should be carefully investigated in order to ensure that the quality of service will increase. The biggest benefit of digitalization is that it enables better quality in service, which can then significantly increase the cost-effectiveness of work for these chosen occupations.

5.2 Practical Implications

The results of this study imply that the obstacles preventing the increase in the productivity of work in the occupations under study are related to the changes in the nature of work and the corresponding changes in skill demand. As argued by Brynjolfsson and Hitt (1998), it is important to realize that computerization does not automatically increase productivity, but it is an essential component of a broader system of organizational changes which do increase productivity. Considering the current alarming trends of decreasing productivity growth in Finland (Pohjola, 2007), it is ever more important to focus on unleashing the increased productivity benefits offered by digitalization.

This is important for many occupations who are currently experiencing big changes in the way their work is done; for business mangers, technology innovators and cybersecurity experts, who are faced against with ever stiffer global competition and increasing demand for high-skilled workers, and for the more traditional occupations, such as higher education teachers and healthcare professionals. As this study implies, these more traditional occupations are currently on the verge of big transformation induced by digitalization. To successfully implement this transformation, it is important to ensure that workers' have the right skills to be able to effectively share and exploit the increasing amount of information. Surviving in the new digital economy means that work should be organized so that the focus is increasingly on the customer, patient or student, as well as on the employee doing the work. Moreover, it is crucial that the required support systems in organizations are in place so that workers will not be left alone with the new digital tools and technologies and there will be no polarization of workforce. The work that was designed for mass production and assembly lines simply does not suit to the new needs of the new digital economy based on knowledge and information sharing.

To be able to effectively exploit the benefits of digitalization, more effort should be put on developing workers' skills towards those in which humans still have a comparative advantage over computers in the near future. These are analytical and critical thinking, creative intelligence and social and emotional intelligence. The development of these skills can happen already in universities but also as continuous training of employees by focusing on creating human interaction and cross-disciplinary settings that develop creative intelligence and social and emotional intelligence skills. Due to the rapid changes induced by technological advancements, it is ever more important for workers to possess the ability to absorb new methods and ways of learning that enable them to develop their skills also after their studies. Only with this effective symbiosis between the skills of humans and computers we can obtain increases in productivity of work, which will be reflected in the nationwide productivity growth rates.

5.3 Limitations of the Study

This research offers a deep understanding of the role of digitalization in the work life of business managers, technology innovators, higher education teachers, healthcare professionals and cybersecurity experts. With the chosen focus the study is able to shed light on how digitalization and new technologies change the task content and skill demand for these selected occupations. This is an area which has been weakly studied within economics lacking evidence especially from Finland. Additionally, it expands our knowledge of the relationship between digitalization and work life as a phenomenon. Nevertheless, it is important to acknowledge the limitations of the study when interpreting the findings.

Firstly, as with all case studies, the results of this study do not represent a generalization of the population, but are only generalizable to theoretical propositions. This study only focuses on five occupations, and thus what applies to them does not necessary apply to all occupations even within the low-risk category. Hence, this multiple case study aims to expand the theory developed by Frey and Osborne (2013) analytically, not statistically. Moreover, due to the qualitative approach of this study, which is also a unique approach in the field of economics, there is much room for biasness due to the subjectivity of the researcher's own interpretations as well as the interviewees' assumptions on technological development. As with all qualitative studies based on in-depth interviews, the selection bias of the interviewees should be carefully examined. Lastly, the true causal relationship between digitalization and changes in task content and skill demand should be carefully interpreted, as it can be at times hard to determine whether the consequent changes are actually a result of digitalization and not, e.g., globalization. Nonetheless, taking all these limitation into considerations, this study offers unique results to be further studied and taken into consideration when planning, e.g., nationwide education policies and work organization related policies.

6 Appendices

Appendix 1: Full-Time Equivalent Employment Shares by Education Level (in percent) and Log College+/High School Wage Premium in the US 1940-1996. Source: Autor, Katz and Krueger (1998).

	High School Dropouts	High School Graduates	Some College	College Graduates	College Equivalents	Log College+/ HS Wage
1940 Census	67.9	19.2	6.5	6.4	9.6	.498
1950 Census	58.6	24.4	9.2	7.8	12.4	.313
1960 Census	49.5	27.7	12.2	10.6	16.7	.396
1970 Census	35.9	34.7	15.6	13.8	21.6	.465
1980 Census	20.7	36.1	22.8	20.4	31.8	.391
1980 CPS	19.1	38.0	22.0	20.9	31.9	.356
1990 CPS	12.7	36.2	25.1	26.1	38.6	.508
1990 Census	11.4	33.0	30.2	25.4	40.6	.549
Feb. 90 CPS	11.5	36.8	25.2	26.5	39.1	.533
1996 CPS	9.4	33.4	28.9	28.3	42.7	.557

Full-time Equivalent (FTE) shares are calculated for samples which include all workers ages 18 - 65 in paid employment (both wage and salary and self-employed workers) during the survey reference week for each Census and CPS sample. Usual weekly hours for CPS samples are imputed for the self-employed using average usual weekly hours for wage and salary workers in the same industry-education-year cell. FTE shares are defined as the share of total weekly hours supplied by each education group. Samples are drawn from the 1940, 1950, 1960, 1970, 1980, and 1990 Census PUMS; the 1980, 1990, and 1996 Merged Outgoing Rotation Groups (MORG) of the Current Population Survey; and the February 1990 Current Population Survey. College equivalents are defined as those with a college education plus half of those with some college. Non-college (or high school) equivalents are those with 12 or fewer years of schooling (or high school diploma or less) plus half of those with some college.

Appendix 2: Focal Cases of CES Production Function of the SBTC model.

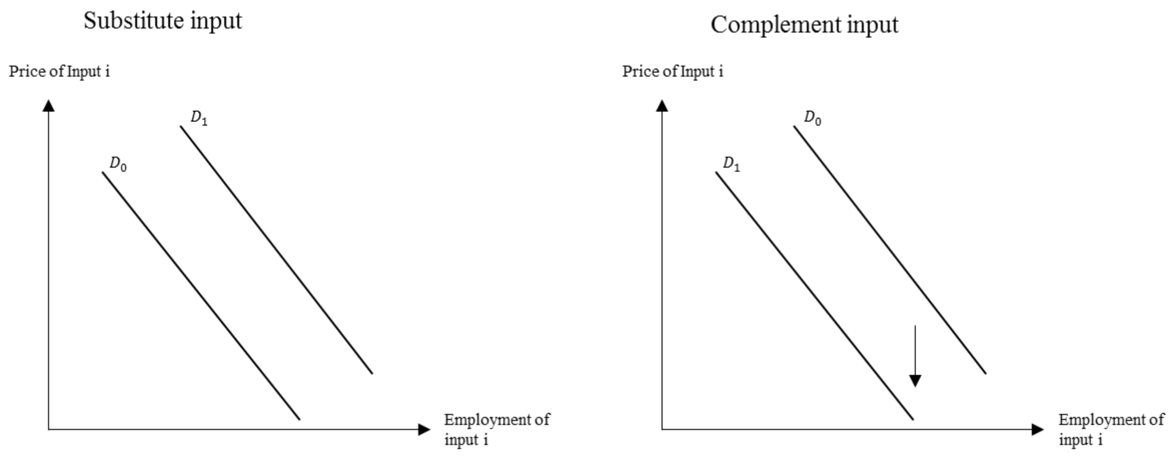
The three focal cases in the CES production function with elasticity of substitution between high and low skill workers are the following:

I. When $\sigma \to 0$, skilled and unskilled are perfect complements. This is also called the Leontief production function which requires fixed proportions of skilled and unskilled workers.

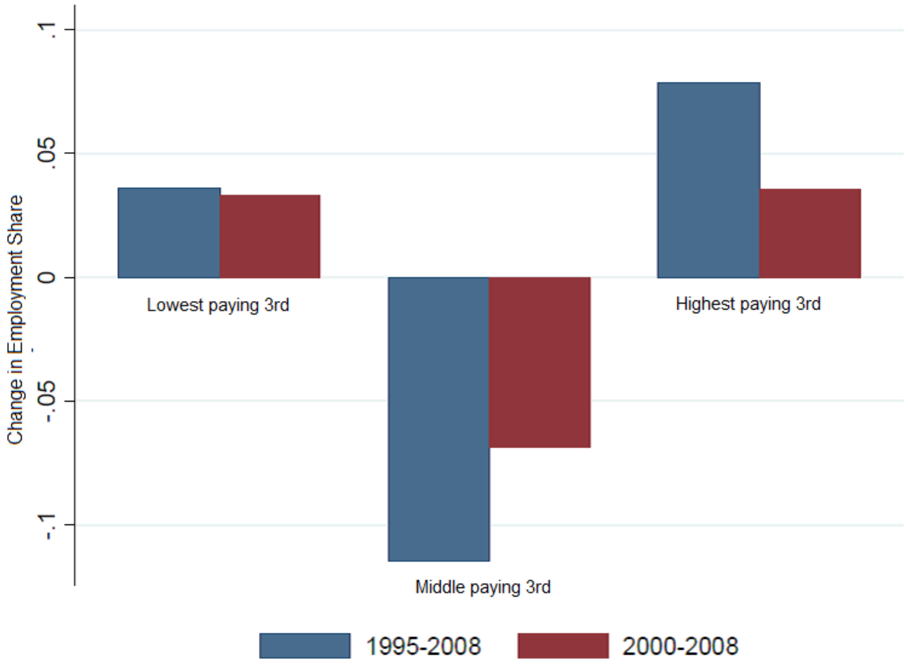
II. When $\sigma \to \infty$, skilled and unskilled workers are perfect substitutes and thus, changes in relative supply will not affect relative wages. In other words, there is only one skill, which H and L workers have in different quantities

III. When $\sigma \to 1$, each factor is paid a fixed share of overall income. This is also called the Cobb Douglas production function.

Appendix 3: The Demand Curve for Substitute and Complement Input in Terms of Employment



Appendix 4: Change in Employment Shares in Finland. Occupations grouped by wage terciles (Mitrunen, 2013).



Appendix 5: Wage Setting Equations Derived from the CES Technology Aggregate Production Function.

Given competitive labor markets, wages are set according to marginal products so that unskilled and skilled wages are:

$$w_L = \frac{\delta Y}{\delta L} = A_l^{\rho}\left[A_l^{\rho} + A_h^{\rho}\left({}^{H}/_{L}\right)^{\rho}\right]^{(1-\rho)/\rho}$$

$$w_H = \frac{\delta Y}{\delta H} = A_h^{\rho}\left[A_h^{\rho} + A_l^{\rho}\left({}^{H}/_{L}\right)^{-\rho}\right]^{(1-\rho)/\rho}$$

By combing the two wage equations above, the skill premium can be derived:

$$w_t = \frac{w_H}{w_L} = \left(\frac{A_h}{A_l}\right)^{\rho}\left(\frac{H}{L}\right)^{\rho-1} = \left(\frac{A_h}{A_l}\right)^{(\sigma-1)/\sigma}\left(\frac{H}{L}\right)^{-1/\sigma}$$

Appendix 6: Interview Guide

I. History and present

- What is your background?
  - What kind of different job functions have you had over the course of the years?
- What does your current job function include?
- How has digitalization affected your work for the last 10 to 5 years?
  - What are the biggest changes that have occurred?
  - How has the change and the speed of change developed during these years?
- How does digitalization appear in your current job functions?
  - How do you exploit information technology in your work?
  - How has this exploitation developed during the recent years?
  - What kind of tasks in your work have been automated and/or replaced by computer?
  - How do you see this has changed your task content?

II. Future

- How do you see that digitalization will change your job functions?
  - What things will change in your work due to digitalization?
  - What things will not change in your work due to digitalization?
  - What are the biggest opportunities of digitalization in your work?
  - What are the biggest threats and risks of digitalization in your work?
- How do you see that automation and robotics will change your job functions and task content in the near future?
  - What tasks in your work will most likely be automated and/or replaced by computer?
  - What tasks will you still continue to do and in what tasks will the computer be better at?
  - What kind of tasks in your work will increase due to increasing automation and robotics?
- How will work, including work environment and community, change in your occupation due to digitalization?
- What kind of skills are needed in your occupation in the future?
  - What kind of skills will be more demanded?
  - What kind of skills will be in short supply?
  - What should be the skills of recent graduates and what skills can you develop while working?
- Will there be new and/or old roles and tasks within your occupational role?
- Are there any roles or/and tasks within your occupational role that will arise in the near future?
- Are there any roles or/and tasks within your occupational role that will fall out in the near future?
- What is the biggest challenge within your occupation in order to fully exploit digitalization?

Appendix 7: List of Interviews

Occupational Role	Inter-viewee	Industry of the Organization	Title of the Interviewee	Date	Lenght of the interview
Business Managers	1	Communication	Head of Customer Relationship Management	29.6.2015	43 min
	2	Management Consulting	Head of Nordic Sales	6.8.2015	65 min
	3	Pulp and Paper Manufacturer	Marketing and Communications Manager	14.8.2015	36 min
	4	Banking	Vice President Human Resources	19.8.2015	49 min
	5	Telecommunication	Director of Operations	19.8.2015	36 min
Technology Innovators	6	Electrical Equipment	Sales Director, Data Center Industry Finland	8.9.2015	54 min
	7	Electrical Equipment	Vice President, Technology and Product Management	29.7.2015	58 min
	8	Telecommunciations	Innovation Manager	16.7.2015	54 min
	9	Telecommunciations	Innovation Leader	8.7.2015	61min
	10	Engineering and Service	Head of Categories	19.8.2015	30 min
Higher Education Teachers	11	University	Researcher, Department of Computer Science	18.6.2015	55 min
	12	University	Postdoctoral Researcher, Communications and Networking	9.6.2015	53 min
	13	University	Professor, Electrical Engineering and Automation	17.6.2015	70 min
	14	University	Professor, Computer Science	13.8.2015	51 min
	15	University	Professor, Mathematics and Systems Analysis	26.6.2015	53 min
	16	University	Professor, Media	18.8.2015	54 min
	17	University	Professor, Multimedia	3.8.2015	38 min
	18	University	University Lecturer, Information and Service Economy	22.6.2015	52 min
Healthcare Professionals	19	Healthcare	Docent of Medicine, Director of Development	10.9.2015	51 min
	20	Healthcare	Docent of Medicine, Psychotherapy and Psychology	7.9.2015	42 min
	21	Healthcare	Specially Trained Nurse, Director of Development	18.9.2015	52 min
	22	Retail	Senior Physician, Occupational Health Care	20.8.2015	58 min
	23	Electrical Equipment	Physician, Occupational Health Care	1.10.2015	38 min
Cybersecurity Experts	24	Computing	Cyber Security Expert	7.9.2015	58 min
	25	Telecommunication	Principal Security Consultant	15.9.2015	41 min
	26	Telecommunication	Head of Security	16.9.2015	48 min

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