Automation and the Labour Market

A literature review on the potential threat to human labour posed by automation

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Abstract

The effect of automation on the labour market is a discussion that appears from time to time across history, and it will likely never end unless the machines eventually becomes capable of performing every task a human can do. By conducting a literature review I aim to see whether there are reasons to worry about the future of the labour market, or if the literature suggests that like before, humans will find other work to do. Using selected works the literature review is conducted in three parts. The first part covers literature related to the topic of education and skills, the second part covers labour market trends, and the third part covers how automation might impact the labour market in the future. My findings suggest that there are reasons to worry about the future of the labour market. Both high and low-skilled workers show signs of losing in the battle for the jobs and the money, though the labour fortunes of the low-skilled workers are much worse. The amount of workers that are employed in jobs with a high risk of being automated is high everywhere, including Norway, and the rate of job creation has not shown a positive trend the last few decades, with 2000-2009 being the worst decade since the Great Depression. The progress of labour saving technology show no signs of stopping however, and what some economists deem to be the most dangerous type of technology for human labour, technologies that replaces workers without increasing productivity, might be on the verge of entering the economy in large numbers. The literature also shows that despite all of these trends, the labour market still stands, and it is highly possible that it will remain in the future. The natural forces of economics does not appear to pull in that direction however, so while the labour market may remain as the main distributor of wealth in the future, my interpretation of the literature is that it will not, if the natural forces of economics is the deciding factor.

Preface

I would like to thank my supervisor Marcus Hagedorn for providing valuable guidance, both when I was deciding how to write this thesis, and when I was writing it. I think it would be much more difficult to write a thesis on this subject in any other way than he suggested.

I struggled long with how to approach this thesis, and I am grateful that I was provided the correct guidance at the correct time. I hope that the end result is pleasing, and a valuable contribution.

I would like to thank all my friends and family for supporting me throughout the writing process, and for assisting in proofreading the thesis. My years spent at the University of Oslo have been exiting, both personally and academically, and I am grateful to all who have helped in making them so.

Any inaccuracies in the presentation of the literature are my own.

Fredrik Wium, May 2019

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1 Introduction

The effect of automation in the labour market is not a new concern. It has been a theme since at least the industrial revolution with the machine breakers, and every so often since then the possibility of machines making the human worker redundant has been raised, and equally often it has been shot down by the argument that it did not happen the last time it was predicted, and thus it will not happen now. With the ever-changing possibilities of what can be achieved with technology the fact that automation has not made human labour redundant yet is not in itself a guarantee that it will never be happen.

Predicting to what degree machines can replace humans will always be very difficult, and things that were ones believed to be impossible might one day prove to be very much possible. In a paper from 2003 (Autor, Levy, & Murnane, 2003) it is argued that routine tasks are well suited for automations since the actions can be put in code, whereas non-routine tasks like driving a car through traffic is not well suited for automation. Less than a decade later, Google succeeded in automating a fleet of Toyota Prius cars (Brynjolfsson & McAfee, 2014, Chapter 2), self-driving cars are now being developed and tested by most major automakers[1], and jobs involving driving are put high on the list of jobs at risk of being automated by Frey & Osborne (2013) in their seminal paper. This is likely not the only example of innovations previously believed impossible that turned out to be possible, and thus any categorization of a profession as non-automatable can only be temporary.

Since the seminal paper by Frey & Osborne (2013) was published, the effect of automation on the labour market has gained new interest, with several published works expressing concerns for the future of the labour market (See for example (Brynjolfsson & McAfee, 2014), and (Ford, 2016)). While the literature that deals directly with the possible effects of automation on the labour market is not vast, there is much more literature to choose from related topics like labour market trends. There is thus enough literature available to conduct a literature review.

In this thesis, I will start by presenting an overview over the historical literature on the impact of automation and other technological improvements on the labour market. Since this subject is heavily reliant on what is technologically possible, and since what is technologically

[1]"Driverless investment tops $1.6B so far this month." (Demaitre, 15.02. 2019)

possible is continuously changing, much of the older literature will not be as relevant as the new. However, some of it can still be relevant, and is nonetheless helpful to underscore how the threat of automation has been historically perceived.

The main review will be conducted in Section 4. Selected papers will be more thoroughly reviewed; their methods and frameworks will be presented, as well as their findings. Their findings and methods will be considered together with other works that are not given such a thorough review, and an interpretation will be provided as to what the findings suggest concerning the future of the labour market. The literature review will be broadly separated into 3 different, although somewhat overlapping, subsections with different topics related to the trends and future of the labour market, and the role of automation in it. These subsections will each have one or more papers thoroughly reviewed, while other works of the literature are used for comparison and less thorough reviewed. The subsections will begin with a presentation of what kind of results would point towards a future where there are few reasons to think that the demand for human labour will fall, when such a presentation is fitting (there is no such presentation for section 4.3).

The main goals of the review are to see what the trends of the labour market with regards to skills, wages, net job creation, and automation have been over the last few decades, and if recent trends and developments points towards changes in the labour market that are different from all other changes throughout history. Changes that may result in a labour market where the supply of labour far surpasses the demand, or ultimately no demand at all for human labour. While sections 4.1 and 4.2 highlight more general trends, where the role of automation is not always mentioned directly, section 4.3 deals directly with the possible impact of automation on the labour market.

The continued increase in what tasks can be carried out by machines obviously involves many advanced technologies, and the full understanding of what is technologically possible with concepts such as artificial intelligence (AI) and the internet of things, and how they work exactly, is beyond the scope of this thesis. Full understanding of these and other concepts is, however, not necessary. For the purpose of this thesis it is sufficient to see if there are signs that they are entering, or on the verge of entering, the labour market, and also to what the results can be.

The final section provides a summary of the literature review conducted, as well as my own thoughts on the subject. After that a conclusion is provided that states what will, in my view, determine the future developments in the labour market, as it appears in the literature reviewed.

2 A Historical Overview

While the literature on automation as a potential threat to human labour is fairly recent there are several mentions of the threat of machines in the works of the classical economist like David Ricardo (Ricardo, 1821), John Maynard Keynes (Frey & Osborne, 2013) and the slightly more modern Wassily Leontief (Acemoglu & Restrepo, 2017, p. 1). The threat of technological unemployment through creative destruction was a major theme during the industrial revolution, and the lead up to it (Frey & Osborne, 2013). The new literature (after 2010) will be the main focus of the thesis, as the old ones have largely been proven wrong in their predictions (at least with regards to the timeframe they set for their predicted change), and the newer literature will obviously be the more relevant source of information as it was written with more knowledge of the technological possibilities.

While the possibility of massive technological unemployment appears to have been taken seriously in some older works by economists like Keynes (Frey & Osborne, 2013) it seems to be considered much less like a real possibility in later works, and the preferred models in most of the economic literature assumes employment in the medium and long run. Should jobs disappear, the workers must find work elsewhere, and if they cannot do that immediately, they must lower their wage demands, or acquire new skills. In the real world that is not so easy however. That technological improvements and creative destruction bears with it some undesired consequences was pointed out by economists like Schumpeter in the 1960s (Frey & Osborne, 2013), the general consensus appears to be that even though technological innovation can result in jobs disappearing as the labour tasks are either automated(like switchboard operators) or rendered irrelevant (like ice cutters[2]) new jobs are created to make up for the jobs lost.

Papers like Autor et al. (2003) Autor & Dorne (Autor & Dorn, 2013), Acemoglu & Autor (Acemoglu & Autor, 2010) and Beaudry et al. (Beaudry, Green, & Sand, 2013) emphasises a curious phenomenon that has been observed in the US labour market. This phenomenon is the polarization of workers at the high and the low end of the wage distribution, with the typical middle class industrial (blue collar) jobs of the past vanishing, and higher (though not the highest) educated workers moving downwards in the wage distribution into non-routine

[2] A largely obsolete occupation that involved cutting ice from frozen lakes in the winter that was used to keep stored food cooled during the summer, obviously made irrelevant by refrigerators and freezers.

service occupations, pushing the lower skilled workers further down the distribution, or out of the workforce completely. Especially the paper by Beaudry et al. (2013) focuses on what they observe to be the reversal in demand for skilled labour since the turn of the millennium. This is one of the few instances in the literature where workers being pushed down the occupational ladder and out of the workforce due to their skills (or lack thereof) is seriously considered, and even concluded. It is one of the more recent additions to the literature, and touches upon what I consider to be a central question for this thesis; has the development since about the year 2000 been fundamentally different from all other times in modern human history? It also touches upon another central question, whether or not the most important division in the labour market is between workers with the right skills and the wrong for the labour tasks demanded, and not between high and low-skilled workers.

The addition to the literature that got a lot of people talking about the possible threat posed by automation to the labour market was the seminal paper by Frey & Osborne (2013) Titled *The future of employment: How susceptible are jobs to computerisation?* This paper estimated that almost half of the jobs in the United States (47%) were at risk of being automated. While they make no attempt at predicting how fast these jobs will actually be automated, nor do they themselves believe that their findings points toward half the workforce in the US getting unemployed if the vulnerable jobs are indeed automated (Frey & Osborne, 2018), they have written what may be amongst the most important works on the topic of automation as a threat to human labour with regards to both their findings, and the discussion they started. It was for instance used by Martin Ford in his book *Rise of the Robots: Technology and the Threat of a Jobless Future* (Ford, 2016) whose view on the future of work is on the pessimistic side. On the more optimistic side the book by Andrew McAfee and Erik Brynjolfsson titled *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (Brynjolfsson & McAfee, 2014) acknowledges the possibility that sizable parts of the workforce may find themselves without work in the traditional sense, for a long time or permanently, as their services are now longer demanded, and acquiring the skills that are required will be difficult or impossible (Brynjolfsson & McAfee, 2014, pp. 231–232). They are however generally optimistic with regards to the impact of technological progress on human society, but they do believe that the right types of policies must be put in place for it to work out in the best possible way, and that a future without work is an undesirable one even if today's workers are as wealthy, or more wealthy, in this future (Brynjolfsson & McAfee, 2014, p. 234).

Among the latest additions to the literature is a series of papers by Daron Acemoglu and Pascual Restrepo. These papers appears to take the potential threat of automation to the labour market more seriously than the earlier works of literature, and benefit of having been written after some of the tasks long believed to never be automatable , like navigating a car through traffic, were proven to be very much automatable (Brynjolfsson & McAfee, 2014, Chapter 2). Of the many things they touch upon in these papers the most interesting may be a new way of modelling automation. In their view, the common way of modelling automation as a factor-augmenting technological change (that is, viewing automation as something that enhances workers abilities to perform their tasks) is not always realistic. Instead modelling automation as a process in which automation replace workers in the tasks they used to perform (task-based model) is often more realistic (Acemoglu & Restrepo, 2018b). The tradition of modelling automation as factor-augmenting may be why economists for so long have believed that the earlier warnings about technological unemployment from People like Keynes and Leontief (Acemoglu & Restrepo, 2017, p. 1) are wrong. Acemoglu and Restrepo spend a lot of time in all of these papers discussing the different ways and channels through which automation affects the labour market, showing how it may decrease employment and wages, and how it may increase it. One of their main points is that as long as automation increases productivity it will result in more demand for labour, so the technologies that threatens the labour market the most are not necessarily the most fancy and productive ones, but rather the "so-so" technologies that are good enough to replace human labour, but without resulting in major productivity gains (Acemoglu & Restrepo, 2018b).

There are probably other works of literature that could be relevant to the topic at hand, and the papers and books presented in this overview will not be the only cited works in this thesis, nor will all of the presented literature be given thorough review. However, they cover the main areas of relevant research such as developments and trends in education, wages, productivity, technological progress, the labour market and the economy as whole. While these papers and books are mainly focused on the United States, as a lot of literature tends to be, occasionally, data and results are compared with data from other developed nations, like the countries of the European Union (Acemoglu & Restrepo, 2017). Regardless of that, considering the topic at hand, literature focused on the United States is not likely to be inapplicable to the rest of the developed world. If a labour task is automatable in one country, it is automatable in another country, and there should be no reasons to believe that any two developed countries are so dissimilar from each other concerning labour tasks that the effects of automation on the labour markets will be drastically different in the long run.

3 Methodological Challenges in conducting a literature review

When writing a literature review centred on a theme such as the effect of automation on the labour market one have to make a decision about which papers, books and other works to include, as well as deciding which works gets thoroughly reviewed. Which works one choose will inevitably impact what overall impression the review leaves, and as such two people writing a literature review on the same topic can end up with different conclusions, depending on the choice of literature. Which parts of the literature are chosen will naturally depend on the pre-held views of the writer, and as such the findings presented in this thesis will be somewhat influenced of my own pre-held views on the topic.

Not every work of literature reviewed or mentioned in this thesis has its focused on automation, or even mentions the issue. Thus attributing findings from these works to automation will necessarily be at my own discretion, and it is possible that the findings from these works are weaker when used in a different setting. Even though the role of automation in these findings is difficult to quantify, it is possible that other factors, both observed and unobserved, play a larger role than this thesis gives the impression of. The aim of this thesis is to highlight different trends in the labour market, and what role automation likely play in them, not to provide a definite number of automation effects. The relatively narrow issue may have resulted in a biased reading of the available literature.

As mentioned in the overview section, most of the literature is based on research conducted in the US, so the findings that are presented may not be directly applicable to the rest of the world, but I assume that a task being automatable in one country implies that it is likely to be automatable in all (developed) countries. The findings are on several occasions also compared with similar findings from Europe. The US is an outlier in the developed world when it comes to income inequality, and as Ford (2016) writes it; the US is unique in that it has arguably made political decisions that have accelerated the increasing inequality, rather than combating it or failing to affect/influence it (Ford, 2016, p. 58). Since rising income inequality is a natural effect of a diminishing labour market, having most of the literature focused on the US might have caused an overestimation concerning the potential negative effects of increased automation on the labour market.

4 The Channels of Automation

In this section the main review will be done, where the different channels through which automation might affect the labour market, will be investigated. Section 4.1 will provide the literature review of the selected literature on education and skills. Emphasis will be put on how different education and skill groups are affected by the changes in the labour market, and what role automation and other technological improvements play in it. Section 4.2 will provide the literature review of the selected literature on labour market trends. Emphasis will be put on what the labour market trends suggest with regards to the automation of old jobs, and the creation of new jobs. Section 4.3 will provide the literature review of the selected literature on the effect of automation on the demand for human labour. Emphasis will be put on how automation may affect the demand for human labour, under which circumstances automation reduced the demand for human labour, and how realistic those circumstances are.

4.1 Education and Skills

Whenever the effect of automation on the labour market is discussed, one of the common arguments from those who believe that automation does not threaten the labour market overall, is that even though some labour tasks are clearly fully automated, they are generally low-skilled in nature, and thus the solution is for the replaced workers to acquire new skills. For new students the solution is to get an education that will give them the right skills for future work. If that is the answer, the literature should contain evidence of an increase in college and university enrolment (as well as a higher rate of high school completion), a higher return to education, more workers at the higher end of the wage distribution (assuming jobs that require higher skills have higher wages), and fewer workers in low-skilled occupations, all without increased unemployment.

Education and skills are obviously important economic subjects, covered in many papers over the years, both in those pertaining directly to automation, and in many that do not. In the overview section, four papers are mentioned that all in some form address the wage polarization in the United States. One of the more interesting findings on the topic at hand are the findings from Beaudry et al. (2013) that discuss what they see as a change to demand for different types of skills in the labour market since the turn of the century. The model they use is an extended version of the skill-biased technical change model that views cognitive tasks[3] as a stock rather than a flow. That is, cognitive tasks are not just performed, and then need to be done again. Performing cognitive tasks builds up a stock of capital that they refer to as "organizational capital". The model has three agents; higher educated individuals, lesser educated individuals, and entrepreneurs, all risk neutral. They further assume that the organizational capital is a substitute to routine labour, where technological improvements results in more productive organizational capital, and, for simplicity, assume that technological improvements do not directly impact the productivity of routine tasks (Beaudry et al., 2013, pp. 6–7). Further, they lay out the mathematical construction of the model. Reproducing all of that would be beyond the scope of this review, but the maximization problem they construct for the entrepreneurs, as well as the implications of the model, will be of interest in the further discussion. Explanation of the symbols in the footnote[4]

$$\max_{\{L_t^c\},\{L_t^r\}} \int_0^\infty [F(\Omega_t, L_t^r, N, \theta_t) - w_t^c L_t^c - w_t^r L_t^r] exp^{\rho t}\, dt$$

$$\text{s.t } \dot{\Omega} = L_t^c - \delta\Omega$$

The model implies that, in a steady state, technological improvements will result in a higher rate of employment in the cognitive sector, and that if the rate of depreciation for the organizational capital is sufficiently low, overall employment will fall (Beaudry et al., 2013, p. 10). Furthermore new technological opportunities will lead to a "boom" phase where average employment and wages will rise throughout all employment sectors and education levels, with a higher fraction of both higher and lower educated workers being employed in the cognitive sector (technological changes only has a positive impact on productivity in the cognitive sector). This boom phase eventually develops into a "bust" phase, which results in a lower rate of employment in both the cognitive and routine sector, as the organizational capital stock builds up during the boom. All in all the model implies that new technologies

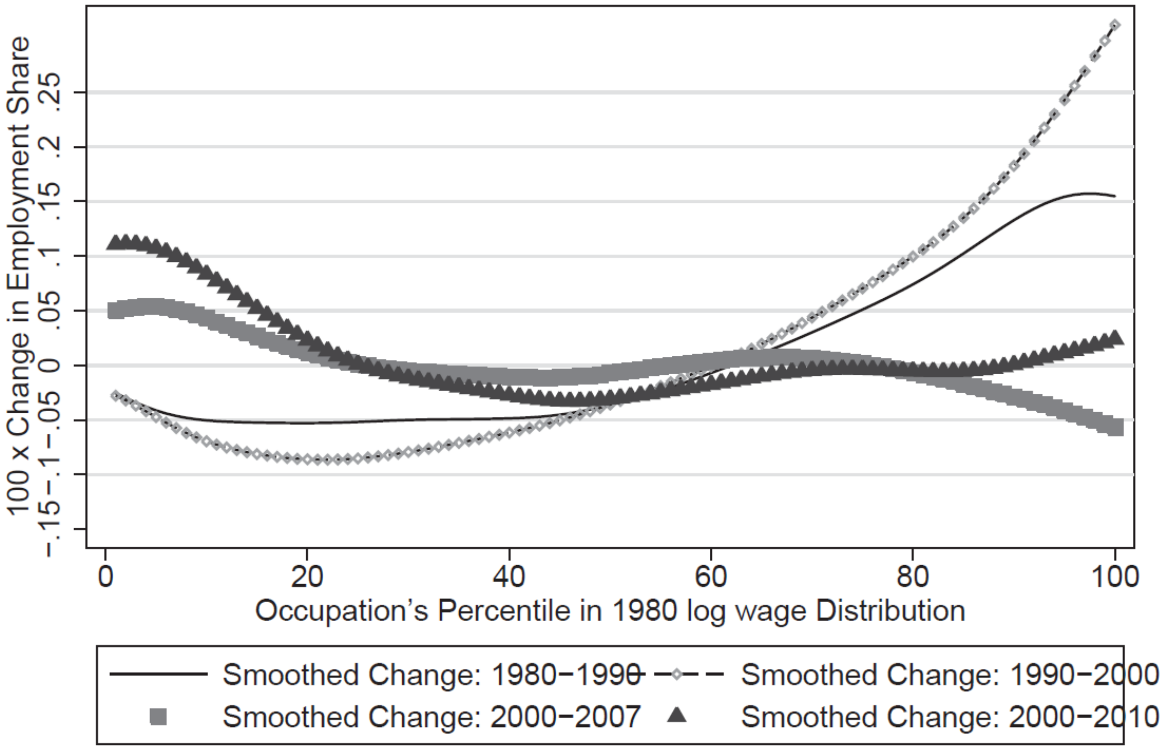
[3] "Cognitive task occupations consist mainly of managers,
professionals and technical workers, and are seen as complementary to Information Technology
capital and the organizational forms that go with it".(Beaudry, Green, & Sand, 2013, p. 1)

[4] L_t^c =effective units of cognitive tasks hired by the representative firm, L_t^r=effective units of routine tasks, F(·) = instantaneous production function, N=entrepreneurs time endowments, θ_t= a technology parameter, δ = depreciation rate of organizational capital, w_t^c/w_t^r=price of the effective units of the skills, Ω= organizational capital, Production function assumed to be increasing in all arguments, concave and exhibiting constant returns to scale with respect to L^r, L^c and N. N is normalized to 1.

will result in a “boom and bust” cycle where the demand for workers in the cognitive sector initially increase as the entrepreneurs need to build their stock of organizational capital, which is a substitute to routine labour. Eventually the demand for labour in the cognitive sector will fall as the stock of organizational capital gets large enough, and since the organizational capital is a substitute for labour in the routine sector, the demand for labour fall in that sector as well (Beaudry et al., 2013, p. 10).

The model presented above thus predicts that technological progress will result in a temporary increase in demand for both high and low-skilled workers, but as the technology gets fully implemented (increasing stock of organizational capital), the demand for both type of workers falls. The decreased demand for both types of labour suggests that they are now both competing for the same low-skilled jobs, implying that high-skilled workers are moving down the occupational ladder, with low-skilled workers moving even further down, or leaving the workforce completely, which is exactly what Beaudry et al. (2013) find to be the case. Using the data of the US Current population survey (CPS) from the Outgoing rotation group (ORG) for the years 1980-2010 they find that in the period 1980-2000 the demand for labour in the cognitive sector was rising, while the demand for labour in routine occupations was falling. Around the turn of the century, the demand for labour in the cognitive sector reversed, while the decline in demand for routine labour accelerated. The overall rate of employment went down (Beaudry et al., 2013, p. 34), while there were increasing rates of employment in low-wage occupations in the period 2000-07 (period chosen to show the changing employment structure before the great recession hit in 2008) as shown in this figure (Beaudry et al., 2013, p. 49):

Figure 1: Smoothed Changes in Employment by Occupation: 1980-2010



Seeing as the fraction of working people who have a college degree has increased since the turn of the century (Beaudry et al., 2013, p. 38), and that the fraction of college educated workers being employed in the routine sector has increased (Beaudry et al., 2013, p. 53) the findings appear to show that high-skilled workers have been pushed down the occupational ladder, with low-skilled workers being pushed even further down, or out of the workforce completely. In other words, the titular "Great Reversal in the Demand for Skill and Cognitive Tasks" appears to have occurred.

In their conclusion of the paper Beaudry et al (2013) write that they find the reversal in demand for cognitive tasks to be a simple and intuitive explanation for the different labour market trends pre and post-2000, though it is obviously not the only possible explanation, there is a substantial disagreement about the causes behind the poor showing (at the time they wrote the paper) of the US labour market (Beaudry et al., 2013, p. abstract). Assuming that their results are correct there are several possible implications for how technological change affects the different sectors of the labour market. The most relevant for this subsection are the findings that suggest that high-skilled workers are not immune to the effects of technological improvements, seeing as the educational attainment has risen, while the share of workers with higher education in the cognitive sector has fallen. While the high-skilled workers are still better off than the low-skilled workers, a substantial share of them appears to be pushed down the wage distribution, leaving them worse off than they were. There is support for this in other works of the literature as well. In his book Ford (2016) writes early on about workers at McDonald's. While a typical employee at McDonald's used to be a high school student working part time, more than 90% of their current employees are older than 20 years old, with the average age being 35 (Ford, 2016, p. 13). He also mentions that when McDonalds's launched an initiative to hire 50 000 workers, they got over one million applications (this was in 2011, so the Great Recession probably contributed to this). With a lot of these older workers having families to support, and the wage offered at the fast food restaurants being what it is (Ford, 2016, p. 14), there are clear signs that workers are getting pushed down the wage distribution, with the erstwhile high school part-time workers likely having a much harder time finding any jobs.

The other papers from the literature on wage polarization are more focused on an increased number of workers on the edges of wage distribution, with the middle disappearing (hence, why it is called wage polarization). While Acemoglu & Autor (2010) do mention briefly that since the turn of the century most of the growth in employment has been in the low-wage sector (Acemoglu & Autor, 2010, p. 17) they do not emphasize it throughout the paper. Their main point on that matter is that what they call middle-skill occupations[5], a skill category that Beaudry et al. (2013) do not use, have been in decline since the early 1980s. It is important to note that Beaudry et al. (2013) is based in part on the paper by Acemoglu & Autor (2010) (Beaudry et al., 2013, p. 1), so it might be more accurate to view it as a continuation of their work rather than an opposing narrative.

Acemoglu & Autor (2010) uses a framework based on what they call the "canonical model", a central organizing framework to study the returns to skill and the evolution of earnings inequality that is based on the work of economists beginning in the 1970s (Acemoglu & Autor, 2010, p. abstract, 32). They augment this model however, as it is, in their view, not sufficient to fully comprehend the labour market trends. One of the shortcomings of the model, as they see it, is that it assumes that technological improvements are factor-augmenting, that is, they help to increase the productivity of high-skilled or low-skilled labour (the only skill levels in the canonical model), and never replace it. The shortcomings of using

[5] sales, office and administrative workers, production workers, and operatives (Acemoglu & Autor, 2010, p. 19)

a factor-augmenting model is further detailed in a later paper by Acemoglu & Restepo (2018b) and will be discussed further in a later subsection. The full details of the framework they use and the augmenting they do to the canonical model is beyond the scope of this thesis. For this subsection, it is enough to note that they augment the canonical model to include three skill levels. The skill levels are applied to a task to produce output, they do not produce output themselves (a task-based model) (Acemoglu & Autor, 2010, p. 46).

Their general findings show that over the past five decades, employment in middle-skill occupations have decreased, whereas employment in low-skilled and high-skilled occupations has increased. They also find that over the past 3 decades almost all of the increased employment in the low-skilled sector was in service occupations, manual non-routine jobs that are much harder to automate than typical routine jobs (Autor et al., 2003). While they find that employment in high-skilled occupations has increased over the course of the first four decades, that was not the case for the previous one (2000-2009).

Considering the differences in approach and classification it is a bit tricky to determine to which degree the findings of Beaudry et al. (2013) and Acemoglu & Autor (2010) are contradictory or in agreement. They both conclude that over the past decades a number of workers have been pushed down the occupational ladder to jobs that require less skill than they possess. However, they diverge a bit when it comes to the occupational fortune of the high-skilled workers. They both find a higher number of college educated workers in low-skilled occupations in the later decades, but while Beaudry et al. (2013) view this as a result of a reversal in demand for labour in cognitive tasks, Acemoglu & Autor (2010) view this as a result of a reduced demand in the middle sector, typical blue collar jobs, with some of it being due to higher educational attainment (Acemoglu & Autor, 2010, p. 26). These differences are not huge, or necessarily consequential, but differences nonetheless.

Regardless of which phenomenon the papers emphasizes, or which results better captures the true trends in the movement of labour of different skills, the implications are relevant for this subsection because both wage polarization and reversal in demand for cognitive skills suggest that obtaining higher skills does not guarantee a job in the high-skilled, high-wage sector. Both papers found an increasing fraction of college educated workers in low-skilled occupations, and both found (though only one emphasized) that employment in the high-skilled sector fell in the 2000s, despite increased educational attainment, and even before the Great Recession hit. This suggests that getting more skilled does not guarantee a new and better job if the old job is lost to technological innovation. Increasing the educational attainment of the future workforce may not result in them getting jobs that require their full set of skills (and thus the wages that comes with that). To the degree that they are able to find work with their higher skills, they are very likely to move downwards on the wage distribution, and thus getting an academic degree may be more about beating out high school educated workers for a low-skill job than getting a job that requires high skills (Beaudry et al., 2013, p. 3).

What both papers make clear is that it is not primarily the low-skill jobs that are destroyed by automation, but rather jobs in the middle of the wage distribution, and even those at the top. Following Autor et al. (2003) the jobs that are most at risk from automation are routine jobs, that is, jobs whose content is relatively easy to put in code. In Acemoglu & Autor (2010) and other works of literature on wage polarization, the findings in general are that middle-skill jobs such as the classical blue collar jobs are going away, whereas employment in low-skilled, non-routine manual jobs such as service occupations, and high-skilled occupations are increasing. This increased employment in high-wage occupations is not found in the first decade of the 2000s however, and Beaudry et al. (2013) suggests employment in the high-skilled, high-wage cognitive sector fell in this decade, even before the Great Recession. The most relevant implication of these findings for this subsection is that higher-skilled workers are not necessarily more protected from having their jobs destroyed by automation and other technological improvements than low-skilled workers. While all the findings from the literature suggest that high-skilled workers have, on average, better fortunes in the labour market than low-skilled workers, that does not mean that their fortunes are objectively good (Ford, 2016, p. 49). Higher-skill workers are found to be an increasing part of the workforce in the literature, and to have a better chance, on average, of finding a job, but increasingly those jobs are not jobs that require all the skills of the worker, and they are of course paid for the tasks they actually perform, not the tasks they are capable of performing. All in all, the findings from the literature do suggest that higher-skilled workers have every reason to fear the effects of automation, and based on that, there appears to be no reasons to believe that making all replaced workers and future workers more skilled will solve all the issues related to jobs getting destroyed by automation.

This entire thesis can be said to rest on the belief that the absence of something in the past does not mean that it cannot happen, so even though a higher and better education has not necessarily meant more skilled and higher paid jobs since the turn of the century, that does not mean that it will not be the case in the future. Higher educated workers have always, on average, been better off in the labour market than lower educated workers (Ford, 2016, p. 49), and Beaudry et al. (2013), together with the rest of the literature on wage polarization, do find that the highest skilled individuals still do find high paying jobs. There are also several ideas presented in the literature about different ways the education system can get better at preparing students for the labour market of the future (Brynjolfsson & McAfee, 2014, Chapter 12). While education is certainly important, and there is every reason to believe that getting a higher education and more skills will be better than not, the fact that the highest skilled individuals show no signs of being pushed out of the labour market does not mean that the labour market as a whole will remain.

One of the trends that might separate the recent technological advancements from those of the past is that it has become much easier for the most successful in a field to reap the whole benefit, leaving nothing to the second best (Brynjolfsson & McAfee, 2014, Chapter 10). While the principles of comparative advantages may have been a ruling paradigm in the labour market up until now, that is not necessarily the case in the future labour market (Ford, 2016, pp. 73–75). Unless everyone is somehow able to be the best within a sector, or niche within a sector that yields enough return to be a liveable income, there are strong signs in the literature that even the high-skilled individuals might find themselves outcompeted by the best in the field, and thus a more educated population will not automatically result in a larger workforce.

4.2 Labour market trends

One thing that all the contributors to the literature appear to agree on is that occupations come and occupations go. The destruction of old jobs and the creation of new jobs have been going on for as long as the labour market has existed, and for as long as preferences, circumstances and technology have changed. As previously mentioned this has led to a belief that no matter how many jobs get lost to automation or other forces, new jobs will be created, and mass unemployment will not occur because of automation. If this is the case the literature should show that when jobs disappear because the tasks involved were fully automated (or rendered irrelevant), or technological improvements made the workers more productive, equally many, or more new jobs are created within a reasonably timeframe.

Considering that for most people the labour market is their main source of income the new jobs that are created should also pay equal or higher real wages, because if the labour yields lower and lower returns to the point of subsistence, having a job obviously declines in value. Automation need not affect the number of jobs at all, and still have a profound effect on the value of human labour. A job need not disappear to lose its value, and the labour market need not disappear to lose its relevance concerning the distribution of wealth in society.

As the previous subsection laid out, one relevant labour market trend during the past decades has been that jobs in the middle of the wage distribution have been decreasing, with jobs at top and bottom seeing an increase. The types of jobs that have been increasing at the bottom have been low-skilled, non-routine manual service jobs. These jobs are not so easy to automate as they require flexibility and situational adaptiveness that machines do not currently have (Autor et al., 2003). To figure out how threatened, if at all, the labour market is from automation, it is crucial to try and figure out how susceptible the jobs of today are to automation, and the arguably most famous paper to do just that is the seminal paper by Frey & Osborne (2013).

4.2.1 Susceptibility to automation

The paper begins by reviewing how automation has affected workers since the industrial revolution, noting that in the beginning automation was de-skilling; meaning that it was beneficial to low-skill factory workers to the detriment of skilled artisans, turning what was previously a production process involving one artisan into a production process with many unskilled workers. In the 20th century however, that trend reversed, with technological improvements taking the skill-biased form that the literature mentions frequently, increasing the demand for more skilled machine operators while decreasing the demand for unskilled workers. Further they go through certain tasks that were recently believed to be beyond what a machine could do, such as navigating a car through traffic, recognizing handwriting on a piece of paper, and recognizing voices, all of which have been proven possible in recent years.

As a basis for their continued investigation into the automation susceptibility of labour tasks they begin with the task model of Autor et al. (2003) which use the following aggregate, constant-returns-to-scale, Cobb-Douglas production function (Autor et al., 2003, p. 7):

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

Where L_R and L_N are routine and non-routine labour inputs, while C is computer capital, all measured in efficiency units, and C and L_R are perfect substitutes. The version used by Frey & Osborne is slightly different however, in that they use susceptible and non-susceptible labour inputs (L_S and L_{NS}) rather than routine and non-routine[6]. The more relevant difference however is that in Frey & Osborne's model C is not confined to routine tasks, but can also substitute for several types of non-routine tasks[7]. There is however certain "engineering bottlenecks" to computerization that they identify, and in further developing their methodology for determining how susceptible different jobs are to automation they use three different task characteristics that represents these bottlenecks, and thus how fast these bottlenecks can be resolved will be the boundaries for the automation of non-routine tasks. Labour inputs with these task characteristics sums up to make the L_{NS} of the model:

$$L_{NS} = \sum_{i=1}^{n} (L_{PM.i} + L_{C,i} + L_{S,i})$$

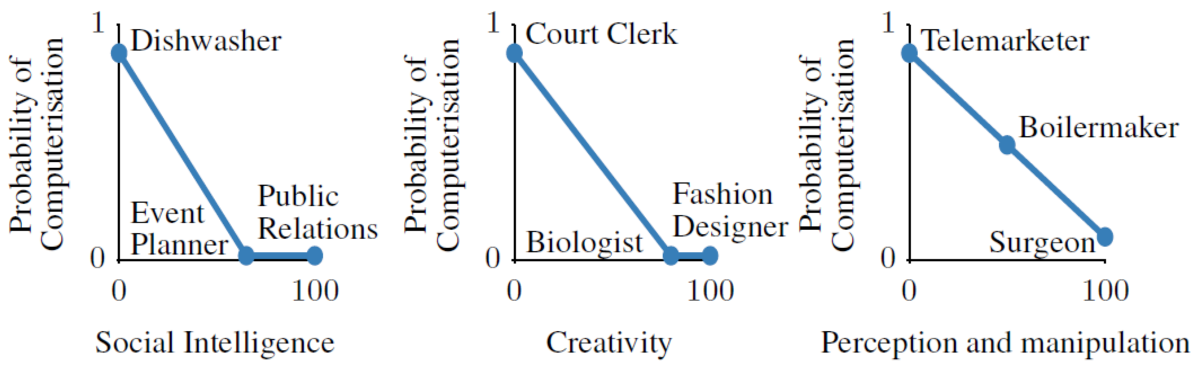
L_{PM} is labour input to tasks that require perception and manipulation (being able to perceive what needs to be done, and being able to do it), L_C is labour input into tasks that require creative intelligence (such as coming up with ideas that are novel and valuable), and L_S likewise for tasks that require intelligence (such as the ability to negotiate, persuade, and provide care) (Frey & Osborne, 2013, pp. 24–26). These characteristics are crucial in their further work to determine the susceptibility of labour tasks to automation, as they examine the

[6] $Q = (L_S + C)^{1-\beta} L_{NS}^{\beta} \ , \ \beta \in [0,1]$ (Frey & Osborne, 2013, p. 23)

[7] In the paper they write: "The above described simple model differs from the task model of Autor, et al. (2003), in that L_{NS} is not confined to routine labour inputs" (Frey & Osborne, 2013, p. 23). This makes little sense considering that L_{NS} is non-routine labour input. I will assume that they meant that C is not confined to routine labour inputs, since the entire context of the model description is that computer capital can perform an increasing number of non-routine labour tasks due to technological improvements.

susceptibility as a function of them, neatly summed up in this figure (Frey & Osborne, 2013, p. 27):

Figure 2: Probability of computerization



To implement the methodology they use data from O*NET, an online service developed for the US Department of Labour. The 2010 version of O*NET contains information on 903 detailed occupations, largely corresponding to the Standard Occupational Classification (SOC) of the Labour Department (Frey & Osborne, 2013, p. 28). For the sake of having a complete set of occupations with both SOC and O*NET data they exclude occupations that lack O*NET data, leaving them with a dataset consisting of 702 occupations (Frey & Osborne, 2013, p. 28). After determining some drawbacks of methods used by other researchers concerning using the O*NET, data they apply a method of hand-labelling occupations. More precisely, they, together with researchers within the field of machine learning, look at the data, and give 70 occupations a label of 1 if they consider it fully automatable, and 0 if not. They caution that they only applied 1 if they were really confident, though it will of course be somewhat subjective (Frey & Osborne, 2013, p. 30). They go on to examine whether or not their subjective labelling is accurate, and, after developing an algorithm to determine if their subjective labelling was systematically and consistently related to the O*NET variables, they conclude that they were, and that their approach is validated (Frey & Osborne, 2013, p. 34).

With a validated approach in hand, they go on to predict how many of the 702 occupations are in the different probability intervals of being automated. They acknowledge that they speculate on the impact of technology that is in the early stages of development, and that historical data on their impact obviously does not exist, which is the reason why they focus on a mix of occupations that existed in 2010. They also note that they do not attempt to try to predict the future composition of the US labour market. Their ultimate findings are that 47% of current US workers are employed in occupations that are in the high-risk category (≥ 0.7) of being automated, 19% are in the medium risk category (≥ 0.3 , < 0.7) and 35% are in the low risk category (< 0.3). They view the high risk category as occupations that are fully automatable relatively soon, maybe within a decade or two (Frey & Osborne, 2013, p. 38).

Within their different risk categories one of their more interesting findings with regards to the literature on wage polarization is that many service occupations, the low-skill, non-routine occupations where most of the job growth in the US has occurred over the past decade, fall within the high risk category (Frey & Osborne, 2013, pp. 44–45). Related to that, they find that a substantial part of the high risk classified occupations fall within the low-skill category. Continuing on that path they find that the probability of an occupation getting automated is decreasing with the share of highly educated workers (bachelor's degree or better) employed, and with the average median wage (Frey & Osborne, 2013, p. 41). The prediction of their model is thus that in the next two decades, it is the low-skill, low-wage occupations that will be most susceptible to automation, rather than the middle-skill occupations that the wage polarization literature has found in the past decades (Frey & Osborne, 2013, p. 42).

At first glance it might seem like their findings are contradictory to Beaudry et al. (2013), and thus contradictory to most of the points made in the subsection on education and skills in this thesis, but that need not be the case. Beaudry et al. (2013) never claim that their observed reversal in demand for cognitive tasks stems from high-skill jobs being more susceptible to automation. Their main point is that high-skilled workers get pushed down the occupational ladder, not that high-skilled jobs are falling to automation. Furthermore the findings of Frey & Osborne (2013) do not suggest that high-skilled individuals will automatically have great fortunes in the labour market, only that the occupations with high-skilled characteristics are less susceptible to automation. They do however predict that the wage polarization trend of recent decades will face a truncation, and that low-skill, low wage occupations will face automation in the near future, whereas high-skill, high wage occupations are much less exposed (Frey & Osborne, 2013, p. 42).

An important point to make is that Frey & Osborne (2013) makes no attempt to predict the future composition of the US labour market, nor do they predict that 47% of US jobs will get automated within the next two decades. Several possible legislative, regulatory, and popular opinion hindrances must be cleared for something like that to happen. What they do predict however is that just with the technology available today (a few years ago now), and assuming that the applicability of this technology follows the predicted path, nearly half of the US workforce could be replaced within a relatively short timeframe. Even if only half of those workers end up being replaced by machines within the next two decades, it is hard to argue that it would not be a massive upheaval of the labour market, requiring that a whole lot of people find new work in the sectors not susceptible to automation. The concluding remarks of Frey & Osborne (2013) are that affected workers will have to reallocate to tasks that require some of the characteristic skills that make up the aforementioned bottlenecks, such as creative and social intelligence, but in order to win the race against the machines, they need to acquire these skills (Frey & Osborne, 2013, p. 45).

If one assumes that both Frey & Osborne (2013) and Beaudry et al. (2013) are correct in their results and interpretation of them, a decent portion of the workers in low-skilled occupations may already be capable of entering the occupations in the non-susceptible sectors, since many of them are high-skilled workers doing low-skilled work. A more pessimistic view of it however, is that high-skilled workers are not necessarily endowed with the right kind of skills, such as creative and social intelligence, and that acquiring these kinds of skills is not straightforward. How realistic it is that those kinds of skills are something that can be acquired or not, is not brought up a lot in the literature, if at all. However, the findings of these two papers, though they do not mention it themselves, point toward this question being among the most important ones when it comes to the impact of automation on the labour market.

4.2.2 Creation of new jobs

While the questions surrounding the ability of workers to attain every kind of skill, depending on demand, are not easily answered, the literature is better equipped when it comes to the creation of new jobs. While it is theoretically possible for the 47% of workers in high-susceptible jobs, as identified by Frey & Osborne (2013), to move into the existing occupations in the currently non-susceptible sectors, they are unlikely to all find jobs there. Considering that the less susceptible occupations are generally the high-wage occupations, it is reasonable to assume that they would already work there if they could. Therefore, if the labour market is to remain as the main distributor of wealth in society, new jobs need to be created, and considering the findings of Frey & Osborne (2013), many new jobs, and fairly quickly.

In January of 2010, the Washington Post reported that in the first decade of the twenty-first century the net amount of new jobs added to the US economy was zero, something that has not happened since the Great Depression (Ford, 2016, p. introduction). Clearly, that result is affected by the Great Recession that began in 2007, but even before the Great Recession hit, the 2000s were on track to become the worst decade for job growth since World War II (Ford, 2016, p. 43). In the past half century only the 1990s manage to keep up with the job creation of the preceding decade (Ford, 2016, p. 43), clearly suggesting that the rate of job creation has been declining for a while. The US labour market needs roughly 1 million new jobs each year just to keep up with the population growth (Ford, 2016, p. introduction), so a decade ending with the same number of jobs that it started with is a major setback, not maintaining the status quo.

The rate at which new jobs are created is viewed pessimistically by several authors contributing to the literature, and the declining growth described in the previous paragraph can be illustrated with the following comparisons that are often used to illustrate the differences in employment between old industries and new. At its employment peak General Motors (GM) employed approximately 840 000 workers, and earned about 11 billion dollars (inflation adjusted). The other auto giants like Ford and Chrysler also employed hundreds of thousands of workers, and the automotive industry supported workers in other peripheral industries, directly and indirectly creating and supporting millions of jobs. Google on the other hand made 14 billion dollars in profit in 2012, employing only 38 000 people (Ford, 2016, pp. 75–76). To compare the employment at one erstwhile industry leader with what arguably replaced them more directly one can look at Kodak and Instagram. At its employment peak, Kodak employed more than 145 000 people, whereas a team of 15 people developed Instagram, a picture sharing service and app now owned by Facebook. By the time Instagram was sold, Facebook employed about 4600 people, and Kodak filed for bankruptcy

(Brynjolfsson & McAfee, 2014, pp. 126–127). One of the defining characteristics of technological improvements and innovation is clearly that more and more wealth can be created with fewer and fewer workers. As noted by Brynjolfsson & McAfee (2014, p. 127) the founder of Kodak became a rich man. However, Kodak also supported many middle-class jobs, while Facebook, with their small workforce, is worth many times more than Kodak ever was, and made at least seven people billionaires. New jobs are still created while others disappear, but as these examples make clear, often many fewer jobs are created in new sectors versus the old ones that go away.

Despite all of these rather massive changes in the labour market over the recent decades that have been reviewed so far, mass unemployment has not occurred yet. However, as has been stated several times in this thesis, the fact that it has not occurred yet does not mean it never will. Nevertheless, automation has been going on at a high pace for a while, and there are no signs in the literature that the current situation is one of unusually high unemployment. The often-cited David Autor wrote a paper aptly titled *Why Are There Still So Many Jobs? The History and Future of Workplace Automation* (Autor, 2015) that delves into why that might be the case.

The main factor that Autor (2015) points to for this phenomenon is that while automation and other technological improvements do substitute certain tasks, those tasks that are not susceptible to automation are often complementary to it. Most work processes require the input of many types of labour and capital, and if one or more of the labour inputs gets replaced by a more productive automated input, the demand for the remaining types of labour inputs will generally rise (Autor, 2015, p. 6). Furthermore, with increased productivity comes increased supply and lower prices, so the amount of work required to maintain the material standards of living has gone down. However, the share of the population that engages in paid work has generally risen over the past century. The amount of working hours needed per week for the average American to obtain the material standards of 1915 is about 17 hours. But there are no signs that the population sees this as a desirable standard of living, suggesting that aggregate demand rises with the increased productivity, increasing the need for labour input (Autor, 2015, p. 8). Autor (2015) also writes about the trends that other papers reviewed in this thesis focus on (He was a co-author on several of them), such as wage (or job) polarization, and also the non-susceptibility of labour tasks with certain characteristics. When writing about the reversal in high-skilled demand that Beaudry et al.(2013) focus on, Autor

(2015) offers a partial explanation for the phenomenon that does not involve increased susceptibility in the high-skilled sectors. Using data from FRED[8] he finds that around the turn of the century, when the observed reversal in demand for high-skill tasks began, the investments in information processing equipment and software fell from nearly 5% of GDP to about 3.5% of GDP. This is likely linked to the famous "dot-com" bubble of the early 2000s. Falling investments in these technologies fit poorly with increased automation, so Autor (2015) believes that the slowdown in the high-skill sectors might stem from this slowdown in investments, rather than substitution of high-skilled workers (Autor, 2015, pp. 21–22).

It is important to note that Autor (2015) does not state that Beaudry et al. (Beaudry et al., 2013) are wrong in their assessments with regards to the reversal in demand for high-skilled labour tasks. He explicitly writes that increased automation is a possible reason for it (Autor, 2015, p. 21) (though that is not exactly what Beaudry et al. (2013) builds their framework on, as was reviewed earlier). Autors (2015) take on it is nonetheless valuable to underline the fact that different experts within a field can look at the same data, and come to different conclusions, as well as underlining that there are more than one possible cause for observed trends.

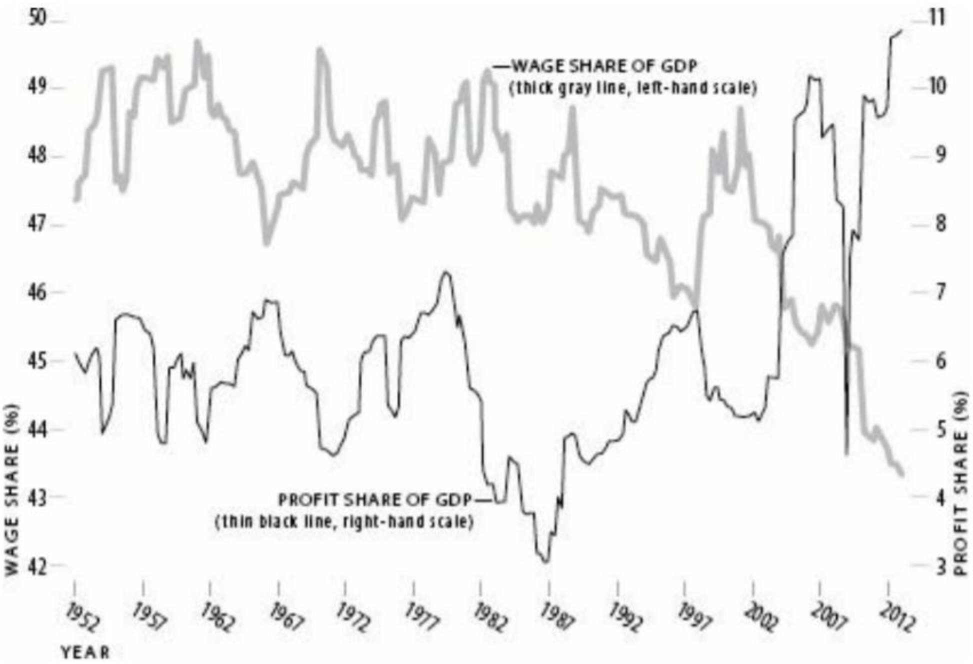
4.2.3 Wages

A job disappearing is not the only bad economic outcome workers can endure, the reduction or stagnation in real wages has the potential to be equally devastating. In the 1970s the relationship between productivity and wages began to dissolve (Ford, 2016, p. introduction). The wage of a "typical"[9] American worker peaked in 1973 (Ford, 2016, p. 34), while the income of the median American household feared moderately better over the next 3 decades (Ford, 2016, p. 34), until their income peaked in 1999, (Brynjolfsson & McAfee, 2014, p. 129).

The decoupling of wages and productivity is very visible when comparing the share of GDP that is made up of wages, with how much is made up by corporate profits. The US results are shown in this figure (Brynjolfsson & McAfee, 2014, p. 144):

[8] Federal Reserve Bank of St. Louis
[9] "production and nonsupervisory workers in the private sector" (Ford, 2016, p. 34)

Figure 3: Wage share of GDP vs. Corporate profit share of GDP



While the fact that corporate profits have increased their share of GDP does not alone indicate that workers are facing a decline or stagnation in their income, it does show that more and more of the productivity increase benefits capital owners rather than workers, and the aforementioned income development of the median household does show that the "typical" American worker is not much better off now than in the 1970s in terms of income. The figure also shows that a sharp decline in the wage share of GDP began around the turn of the century, the same time that several other trends relevant for this thesis began, such as the reversal in demand for cognitive tasks identified by Beaudry et al. (2013), and the aforementioned beginning of a decade without job growth. The literature clearly suggests that many things have been different since the turn of century, and generally not to the benefit of workers concerning income.

Automation is by no means the only possible explanation for these trends. Many factors have likely contributed to the declining fortunes of wage earners, and to the benefit of capital owners. The policies of taxation, education, and other areas, will naturally affect the fortunes of workers, regardless of technological changes, and as Ford (2016) writes it; The US especially has made political decisions in the last few decades that have likely contributed to the increasing inequalities in income (Ford, 2016, pp. 57–58). There are similar trends in many other developed countries too however, and although a failure to enact policies to combat the rising inequalities might have occurred in all of these countries (Ford, 2016, p. 57), it seems very likely that they have all faced forces beyond their control. As previously mentioned, one of the defining characteristics of increased automation is that fewer and fewer people are capable of creating more wealth with fewer workers, which has likely contributed to the increased number of workers fighting over a stagnant, or even reduced, number of jobs. The most basic economic models will predict that this will result in a downwards pressure on wages, which appears to be what has happened.

4.2.4 Applicability outside the US

Automation and other technological improvements will likely not affect different countries very differently in the long run. If machines can perform a task in one country, it can in generally do it in another country too, and machines obviously do not receive wages. This is why automation and offshoring are usually considered as different possible causes for jobs disappearing in the literature (see for example (Frey & Osborne, 2013) and (Acemoglu & Autor, 2010)). Nevertheless, the literature also mentions that the US is significantly different from other developed nations when it comes to income inequality (they have higher inequality) (Ford, 2016, p. 46), which is very relevant with regards to the labour market since that is where most people get their income. The literature also mentions Scandinavia as the developed region with the lowest income inequality (Ford, 2016, p. 46), so to put the predictions of Frey & Osborne (2013) to the test it seems logical to see how they fare in the less economically unequal areas of the developed world.

This is what Pajarinen et al. (Pajarinen, Rouvinen, & Ekeland, 2015) do when they write about how susceptible jobs are to automation in Norway and Finland[10]. Using the same methodology as Frey & Osborne (2013), they use data from *Statistics Finland* and *Statistics*

[10] As is well known Finland is not considered part of Scandinavia despite being on the Scandinavian Peninsula, but it is not to different from its Nordic neighbours in terms of development and inequality, and when writing a paper about only Finland, the same authors (only Pajarinen and Rouvinen for that paper) found the same general results as when they wrote about Finland and Norway (Pajarinen & Rouvinen, 2014).

Norway (SSB), as well as converting the original O*NET data from Frey & Osborne (2013) to the *International Standard Classification of Occupations* (ISCO) to ensure that cross country comparisons could be made (Pajarinen et al., 2015, p. 4). Their final data set contains 374 occupations for Norway, and 410 occupations for Finland. Their end results are that 33% of Norwegian workers are in the high-risk category (same thresholds as in Frey & Osborne (2013)) of getting automated, whereas the same number for Finland is 35%. Their updated result for the United States, based on Frey & Osborne (2013), but using data based on 2012 rather than 2010, is that 49% of US workers are in the high-risk category, whereas their updated result using the aforementioned conversion to ISCO classification, is 45% (Pajarinen et al., 2015, pp. 4–5). The estimated susceptibility to automation is clearly significantly lower in Norway and Finland compared to the United States. However, having approximately one-third of workers in occupations with a high risk of being automated within the next two decades is still a lot, and the effect on the labour market if they are all automated will be dramatic. The skill content of the tasks that are in the high-risk category of getting automated is fairly equal in all three countries (Pajarinen et al., 2015, p. 5).

At the end of their paper Pajarinen et al. (2015) writes that they are optimistic about the ability of the economy to adjust to the changes brought on by technology in the longer run, but more pessimistic in the short run as they see more jobs getting destroyed than created (Pajarinen et al., 2015, p. 6). Another concern they have for Norway and Finland, that is not applicable to the United States, is that many of the most lucrative business positions in the digital space are held by foreign entities such as Google and Apple (Pajarinen et al., 2015, p. 6).

The applicability of research on phenomena such as wage polarization outside of the US is largely upheld in the already cited papers, which focus on the US. It is usually mentioned, though they rarely delves much into it, that similar trend are found in other developed regions such as the European Union, though not necessarily to the same extent as in the US (see for example (Autor & Dorn, 2013, p. 8), (Autor, 2015, p. 15), and (Acemoglu & Autor, 2010)).

4.3 Automation and work

For this part of the literature review, the most recent literature that focuses directly on the impact of automation on the labour market will be investigated. Frey & Osborne (2013) highlighted how large the fraction of workers that have jobs susceptible to automation potentially is, and the papers highlighted in this subsection will be the papers that delves more into what the effects are of automation entering the labour market.

The most relevant papers for this subsection are a series of working papers written by Daron Acemoglu and Pascual Restrepo. The first one to be reviewed here is the last one they wrote titled “Modeling Automation” (Acemoglu & Restrepo, 2018b).

4.3.1 Modeling Automation

In this paper, they discuss the different ways automation can be modelled. The primary focus is on whether the factor-augmenting approach, were technological progress is modelled as improving the productivity of existing factors, or the task-based approach, where automation is modelled as substituting for labour in certain tasks, is the better approach to describing the real world. If one uses the factor-augmenting approach automation will generally not appear as a threat to the labour market, as increased productivity will always result in a higher demand for goods, and thus a higher demand for labour. If one uses the task-based approach however, automation is viewed as substituting tasks previously performed by human labour, and will result in fewer jobs unless it increases productivity sufficiently (Acemoglu & Restrepo, 2018b, p. 2).

They show how the different factor-augmenting approaches work, by showing the implications of capital-augmenting technological changes, and the implications of labour-augmenting technological changes. Their presentation of these approaches is based on the following Cobb-Douglas production function, and corollary equilibrium wage and labour share expressions (explanation of the variables in footnote[11]) (Acemoglu & Restrepo, 2018b, p. 3) :

$$Y = F(A_K K, A_L L)$$

$$W = A_L F_L(A_K K, A_L L)$$

$$S_L = \frac{WL}{Y}$$

[11] Y= aggregate output, W=equilibrium wage, S_L=labour share in the economy, L=labour, K=capital, A_K=capital augmenting technology, A_L=labour augmenting technology

If automation is modelled as a being capital-augmenting technological change, it will always increase the labour demand and the equilibrium wage. This is the case because with constant returns to scale, as the production function is, increasing the productivity of capital, or making capital effectively more abundant, will increase the marginal product of labour (Acemoglu & Restrepo, 2018b, p. 4). The idea that automation will always increase the demand for labour, and increase the equilibrium wage, does not sound very intuitive, and is at odds with most of the findings reviewed so far in this thesis. It also contradicts what Acemoglu and Restrepo find in their own paper on the effect of industrial robots in the US labour market (Acemoglu & Restrepo, 2017). If automation is modelled as a labour-augmenting technological change they conclude similarly that increasing automation will always increase labour demand and the equilibrium wage (Acemoglu & Restrepo, 2018b, p. 5). One point of difference between the two approaches is that the labour share of total income will increase with capital-augmenting technological change if the elasticity of substitution is less than 1, as the literature broadly agrees that it is (Acemoglu & Restrepo, 2018b, p. 4) while the reverse is true for labour-augmenting technological change. Regardless, neither factor-augmenting approach yield results that fit well with the empirical evidence, as the empirical evidence shows that automation does substitute for human labour, and can result in lower demand for labour and lower wages (Acemoglu & Restrepo, 2018b, pp. 4–5).

The central point of Acemoglu & Restrepo (2018b) is that a task-based approach is better suited to model automation in the labour market. Automation can substitute for human labour, and thus a model that allows for that does sound like a natural choice. The task-based model presented in the paper is one where aggregate output is determined by a continuum of tasks as shown in this equation (details in the footnote[12]) (Acemoglu & Restrepo, 2018b, p. 6):

$$Y = \left(\int_{N-1}^{N} y(i)^{\frac{\sigma-1}{\sigma}} \, di \right)^{\frac{\sigma}{\sigma-1}}$$

The production function of task i $y(i)$ is given by: (details in footnote[13]) (Acemoglu & Restrepo, 2018b, p. 6):

$$y(i) = \eta(i)k(i) + \gamma(i)l(i)$$

[12] σ= elasticity of substitution between tasks, i=task, N=number of tasks (Acemoglu & Restrepo, 2018b, p. 6)
[13] $\eta(i)$=productivity of capital in task i, $\gamma(i)$=productivity of labour in task i

If the task $i > \mathbf{I}$ the task is not technologically automated, and has to be produced with labour. If the task $i \leq \mathbf{I}$, it is technologically automated, and can be produced with either labour or capital. They further assume that if the task is technologically automated, it is strictly cheaper to produce with capital. This underlines the key aspect of the approach; that if a task is technologically automated, labour and capital are perfect substitutes (Acemoglu & Restrepo, 2018b, p. 6). Automation is thus modelled as increasing **I** (Acemoglu & Restrepo, 2018b, p. 6), increasing the number of tasks that can be performed with capital, and since production with capital is assumed to be cheaper when it is possible, the number of tasks that will be performed by capital will increase. With a task-based approach, the direct effect of automation will be fewer jobs, which is, as previously mentioned, more in line with the empirical evidence, including the authors own previous work (Acemoglu & Restrepo, 2017), than the implications of the factor-augmenting approach.

After showing more of the mathematics of the task-based approach that will not be replicated here (Acemoglu & Restrepo, 2018b, p. 7), they end their paper by mentioning some of the implications that are highlighted by the task-based approach. These implications include the productivity effect; automation will result in fewer tasks performed by labour, but if productivity is sufficiently increased, labour demand will increase in the remaining tasks. This suggests that the technology that poses the greatest threat to the labour market is not the highly productive type, but rather the "so-so" type of technology that is good enough to be adopted, but without increasing productivity much. The productivity effect also highlights that more productive technology in tasks that have already been automated will increase labour demand. This approach also highlights what most of the literature on automation highlights; that the creation of new tasks will be crucial for the future of the labour market, as automation reduces the amount of tasks that labour is competitive in. The other implications are largely based on the ones mentioned (Acemoglu & Restrepo, 2018b, pp. 8–9). As mentioned earlier, the empirical evidence largely supports the fact that increased automation can result in fewer jobs and lower wages, so there are few reasons to doubt that they are right about the usefulness of a modelling approach that allows for these effects.

In a more thorough paper Acemoglu & Restrepo (2018a) write about the aforementioned task-based approach, and some of the historic and future implications of automation in the labour market. They begin by stating that much of the debate around automation centers on what they call a false dichotomy, with alarmists who argue that automation spells the end of the labour market on one side, and optimists who argue that automation is just like other technological improvements in history, and just like they did not put an end to human labour, there are no reasons to be concerned that it will be different this time (Acemoglu & Restrepo, 2018a, p. 1). As mentioned in their other paper (Acemoglu & Restrepo, 2018b) they believe that automation can have both positive and negative effects on employment and wages, depending on how it directly impacts employment and how it impacts productivity. They want to develop a framework for thinking about automation and its impact on the labour market (Acemoglu & Restrepo, 2018a, p. 1), and that framework is based on the task-based approach they describe in "Modeling Automation" (Acemoglu & Restrepo, 2018b).

They further highlight some of the countervailing effects automation can have on the demand for labour. The first and foremost of these, the productivity effect, has been mentioned a lot in the literature, and both capital accumulation and deepening of automation, where the increase in quantity or productivity of capital in tasks human labour has already been replaced in, are mentioned in Acemoglu & Restrepo (2018b). Additional countervailing effects include that increased automation may endogenously give firms incentives to introduce labour-intensive tasks by reducing the labour share and wages, making further automation less profitable (Acemoglu & Restrepo, 2018a, p. 10). They also mention that certain new automation technologies, especially AI (artificial intelligence) can be utilized to improve the educational system by allowing more optimized individualized education platforms, giving more students the ability to increase their skill level (Acemoglu & Restrepo, 2018a, p. 10). This is in addition to the countervailing effect of the new tasks that can be created by the new technology that allows for increased automation.

Outside the realm of models Acemoglu & Restrepo (2018a) point out some important points that are difficult to capture in a model. The new tasks that technological improvements create, and the existing tasks that experience increased demand due to the productivity effect, may require very different skills than the tasks that are automated, making the adaption to the new labour market potentially difficult for many of the replaced workers (Acemoglu & Restrepo, 2018a, p. 12). Additionally, they write that as the speed of automation increases, the number of tasks that are replaced will increase. The need for new skills to perform the new tasks that technological progress creates will likely increase. The future workforce will need to obtain these skills, and they are worried that the current (US) education system is not capable of identifying the necessary skills of the future, and thus not capable of providing those skills.

This will likely cause trouble for both the workers and the economy as a whole (Acemoglu & Restrepo, 2018a, p. 13). This touches upon several of the important points of this thesis mentioned in the overview and previous sections, including the ability of workers to obtain the necessary skills to participate in the labour market, the possibility that important effects are not visible in existing models, and the well-known problem that having all economic actors maximizing their own utility will often result on lower overall utility. It also highlights another important issue, whether the observed negative effects of automation on the labour market are persistent effects, or if they are temporary effects caused by frictions in the labour market due to a mismatch between technology and skills, that will be solved eventually.

4.3.2 Empirical results

The paper mentioned in the previous subsection that showed that automation can result in lower labour demand and wages was Acemoglu & Restrepo (2017). In this paper, they investigate the effect of introducing industrial robots[14] in the US labour market. More specifically, by using a model where robots compete against humans in the execution of different tasks, just like they advocate in Acemoglu & Restrepo (2018b), and analysing the labour market at the commuting zone[15] level, they analyse the effect of industrial robots on labour demand and wages (Acemoglu & Restrepo, 2017, p. abstract).

Between 1993 and 2007 the stock of industrial robots in the US and Western Europe increased fourfold, equivalent to increasing it to 1 new industrial robot per one thousand workers in the US, and 1.6 per thousand in Western Europe (Acemoglu & Restrepo, 2017, p. 2). Using IFC (International Federation of Robotics) data from 19 industries where data on the increase in robots usage exist, as well as using data from the census on these industries' baseline share of the employment before the aforementioned increase in industrial robots occurred; they construct their measure of *exposure to robots.* This measure is used to leverage the fact that different commuting zones will differ in their distribution of industrial employment, and will thus be affected differently by increased use of industrial robots (Acemoglu & Restrepo, 2017, p. 3). Since the increased use of robotics in certain industries

[14] "An automatically controlled, reprogrammable, and multipurpose [machine]", as defined by the International Federation of Robotics(IFC) (Acemoglu & Restrepo, 2017, p. 2)
[15] A limited geographical area, typically a city

may be related to other factors, and those factors can again be affecting the employment and wages in said industries, the authors use similar data from developed countries in Europe to reduce the possibility of omitted variable bias (Acemoglu & Restrepo, 2017, p. 3). This approach is more helpful still, because there are industry level data from the European countries going back to 1993, while the US data begins in 2004 (Acemoglu & Restrepo, 2017, p. 3).

Using a model approach similar to the one they recommend in Acemoglu & Restrepo (2018b), they estimate the effect of industrial robots on labour demand and wages both in a hypothetical setting where the commuting zones exist in autarky, and the more realistic setting where there is trade between them. The estimated effect of increased use of industrial robots in a commuting zone with average exposure to robotics is a 0.37 percentage point's reduction in the employment to population ratio, and 0.73% reduction in average wages, compared to commuting zones with no exposure. This is equivalent to one new industrial robot reducing employment by 6.2 workers (Acemoglu & Restrepo, 2017, p. 4). When they adjust for the trade between commuting zones, the estimated negative impact is reduced to 0.34 percentage points for employment, and 0.5% for wages.

To ensure that their results are not driven by the industry with the most industrial robots (automotive industry), or other factors such as general economic trends, increase in other types of physical capital or foreign competition they run several robustness checks. The full mathematical presentation of their methods will not be replicated here. They find that even when they omit the automotive industry, most of the geographical variations in their results are still found. They also find that the increase in industrial robot usage largely occurred within the same industries in Europe and the US, and that the industries that face foreign competition in the form of imports (Chinese and Mexican imports specifically) are not the same ones that are most impacted by industrial robots, nor are the industries that have experienced huge increases in other types of capital equal to the ones exposed to industrial robots (Acemoglu & Restrepo, 2017, pp. 16–19).

Their overall findings thus show that the introduction and increased use of industrial robots in the US labour market resulted in lower aggregate employment, and lower wages (Acemoglu & Restrepo, 2017, pp. 27–28). The introduction of industrial robots also resulted in a modest GDP growth concurrent with reduced employment (Acemoglu & Restrepo, 2017, p. 28), and the trends that they find to have occurred since approximately 1990 are not correlated with the trends they spot before, further strengthening the case that the industrial robots are the cause of the fall in employment and wages (Acemoglu & Restrepo, 2017, p. 29). All in all their result points towards industrial robots having an impact on the US labour market that is different from all other impact of modern times, such as offshoring, imports and accumulation of other types of capital. This is a crucial piece of empirical evidence concerning the thesis, since the possibility of automation impacting the labour market differently in the past few decades is the most concrete type of evidence that points towards the labour market being threatened.

4.3.3 The technologies to fear

As virtually all of the literature makes clear, the direct effects of technological improvements can be both positive and negative, while there are more divided opinions when it comes to the indirect and long-term effects, with some believing that the replacement of human labour will accelerate while the creation of new jobs stagnate, and others believing that enough new jobs will always be created (Acemoglu & Restrepo, 2018a, p. 1). The findings from Acemoglu & Restrepo (2017) do suggests that the long term causal effect of one type of technological improvement (the industrial robot) can in fact be negative, and as such this subsection will focus on what kinds of technologies are likely to negatively impact the labour market, and what evidence exist that these kinds of technologies are entering the labour market.

In Acemoglu & Restrepo (2018a) and Acemoglu & Restrepo (2018b), the task-based approach they use to develop their framework, and the mathematical model that follows from it, models automation as a technological improvement that increases the number of tasks that can be performed by machines, thereby reducing the demand for labour. The channel through which it can increase the demand for labour is by increasing the productivity, thereby increasing the demand for all the remaining tasks in the production, including those still performed by labour. The most destructive kind of technological improvements with regards to the labour market in this model is thus the kind that is good enough to replace the human workers in a given task, but not good enough to increase productivity measurably, what Acemoglu & Restrepo calls “so-so” technologies (Acemoglu & Restrepo, 2018a, p. 7). One implication from this is that the technologies that threaten labour demand the most are the ones that are, concerning production, most human-like.

In the field of robotics and AI, one of the major hindrances with regards to automating certain tasks has been what is known as Moravec's paradox, the realization that creating a robot or a computer program to perform tasks that require high-level reasoning is relatively easy, whereas creating a robot or computer program to perform tasks that require spatial awareness, situational awareness, and mobility is very difficult (Brynjolfsson & McAfee, 2014, pp. 28–29). Developing "so-so" technologies have thus not necessarily been easier than developing very productive technologies. That may be changing. In 2008, the company Rethink Robotics was founded, and a few years later they developed the robot Baxter (Brynjolfsson & McAfee, 2014, p. 30). Baxter is a humanoid robot with arms that can work independently of each other, an LCD screen for a face, and sensors capable of primitive spatial awareness and vision. It can be trained to do tasks by guiding its arms through the steps the first time, and is mounted on wheels to sidestep the mobility issue, requiring humans to move it around (Brynjolfsson & McAfee, 2014, pp. 30–31). Baxter is also a fairly reasonably priced robot. At about $20 000 it is much cheaper than the industrial robots that were the subject of Acemolgu & Restrepo (2017) (Brynjolfsson & McAfee, 2014, p. 30), and should thus be a viable option for a larger number of businesses and sectors than these "traditional" industrial robots. Baxter is not capable of working as fast as a trained human worker, but with an estimated hourly operating cost of $4 (Brynjolfsson & McAfee, 2014, p. 142), it does not need to be as fast to be cost effective, and given that humans cannot work at maximum speed over an extended period of time due to fatigue, something robots do not suffer from on a day-to-day basis, it should be a viable contender for several tasks (Brynjolfsson & McAfee, 2014, p. 31).

The types of automation made viable with machines like Baxter might be the "so-so" kind that Acemoglu & Restrepo (2018a) warns is the greatest threat to labour demand. It is cheap to operate on an hourly basis, but not much more effective per unit of time than an average skilled worker is, and will likely not increase productivity much. If a machine and a human are equally productive per unit of time, and the machine not prohibitively expensive, the machine will likely be the preferred choice by a profit maximizing business. A machine does not get tired, get sick, are paid, need lunch, need vacation, go on strike, and is overall a more reliable asset than a human[16]. Baxter is also almost certainly not the apex of what a humanoid robot can accomplish, with Moore's Law continuing to ensure that computational power increases exponentially (Brynjolfsson & McAfee, 2014, p. 143). The entrance of "so-so"

[16] Every person that has ever been involved with technology in any way is almost guaranteed to have experienced several instances of machines that malfunctioned, broke down, or in other ways suffered technical issues that needed fixing by trained personnel. In the long run however they must be said to be more reliable than humans.

technologies in the labour market may be about to take off. What none of the papers and books reviewed in this thesis could have known is that Rethink Robotics, the company behind Baxter and the successor robot Sawyer (Rethink Robotics, n.d.-b), went bankrupt in October 2018, suggesting that things may move a bit slower in the market for humanoid industrial robots than they anticipated. Their assets were bought by the HAHN Group the same month however, so they are still in business (Rethink Robotics, n.d.-a).

The introduction of these “so-so” technologies is what Acemoglu & Restrepo (2018a) view as the greatest threat to labour demand due to them not increasing productivity, but considering how humanoid these “so-so” technologies can be, there may be reasons to fear them even if they should move beyond the “so-so” levels of productivity to a higher level of productivity as the technology improves. If one imagines an android that can do anything a human can do, but does not come with any of the aforementioned limitations such as fatigue, and does not receive a wage, it will be preferable to a human worker every time, and its increased work capacity will likely result in a massive increase in productivity. This android will also be cheap to buy, and is capable of producing other versions of itself. As per the model presented in Acemoglu & Restrepo (2018b) the increase in productivity will increase the demand of every other tasks involved in the production. However, with a fully functional android available to complete all these tasks without getting paid, there are no reasons to hire humans to complete these tasks, and thus the increased productivity will not result in higher labour demand (Brynjolfsson & McAfee, 2014, pp. 180–181).

Obviously, a fully functional android does not exist yet, and there are no signs that there will be one anytime soon. But the theoretical example is important to show that despite what the different models in the literature show, there are no law of economics that states that better technology will always result in more and better jobs for humans (Brynjolfsson & McAfee, 2014, p. 181). A profit-maximizing firm will have no natural incentives to choose a human worker if a machine is equally good, and may even have natural incentives to choose a machine that is a bit slower, if it is cheap enough and reliable enough to operate. For many centuries and even millennia before the industrial revolution horses were an important part of human society and economy. When the industrial revolution began much of the work previously performed by horses was gradually taken over by machines, and this continued for centuries into the machine age. However, horses remained an important part of human society, as even with virtually all the industrial production and agricultural jobs being done by machines and humans, horses were still in many instances the best method of land transportation. That ended with the introduction and mass adaptation of the automobile, transforming the horse from an integral part of human society, into a fun sideshow.

The fate of the horse is what Wassily Leontief uses to illustrate that job creation is far from guaranteed (Acemoglu & Restrepo, 2016, p. 1). Acemoglu & Restrepo (2016) expresses the same belief as in their other papers, that humans have a comparative advantage in new tasks, something horses did not at their time of replacement. Considering the history of the horse however, it appears that it did have a comparative advantage in new and existing tasks, until it did not. Humans are naturally and empirically more difficult to replace in the production of goods and services than horses, but with the current advancements in humanoid robots discussed above, replacing humans in many kinds of tasks, without increasing productivity much, might be the next step of automation in the labour market. The thought experiment with the fully functional android also highlights that even if productivity increases with this automation, the increased demand for complimentary tasks need not result in an increased demand for human labour.

One of the most central questions concerning the impact of automation on the labour market is whether technological improvements that increase productivity can also result in lower labour demand. As mentioned earlier, there are scenarios were this can happen, but it largely rests on technology that does not currently exists. The more interesting question is whether the increased productivity from technological improvements can result in a saturated market, where labour demand falls because the demand for goods reaches its peak, and increasing automation only leads to reduced employment. Considering a representative consumer that does not wish to consume more if given the opportunity is unorthodox in economics, and the literature reviewed in this thesis generally does not touch upon the idea of a saturated market. It is however mentioned quickly in a few places. In Acemoglu & Restrepo (2018a), after writing about how increasing use of machines like tractors and combined harvesters in agriculture did not substitute for human workers, as the tasks they performed were already fairly automated, the authors write in a footnote that these technological improvements did result in lower demand for agricultural workers because of inelastic demand for agricultural goods (Acemoglu & Restrepo, 2018a, p. 8). In other words, the production level achievable with the machines and labour force in the agricultural sector after the introduction of these innovations was higher than what was demanded, resulting in lower levels of employment. In

Autor (2015), after writing about how the citizens in the developed world are devoting an increasing amount of time to leisure, the author asks whether these trends indicates that the demand for consumption is approaching saturation. He concludes that he does not think that is the case (Autor, 2015, p. 8).

It is difficult to determine whether there is a limit to how much consumption the population can demand if given the purchasing power. As mentioned, the general assumption in economics is that there is no such limit, and its absence from the literature except for a few places where it is mentioned quickly, or put in a footnote, suggests that economists do not generally consider it as a possibility. One exception is agricultural goods, where the inelastic demand attributed to necessary goods is used to explain the fall in employment following the introduction of highly productive and labour saving technology. The demand for normal goods is certainly not inelastic from the first unit. As pointed out by Autor (2015) the total demand of households has increased as productivity has increased over the past century, suggesting a clear elastic demand (Autor, 2015, p. 8). The question is if the demand for normal goods will be continuously elastic, or if there exist a point where the supply is so high that the demand turns inelastic due to saturation. The literature is very sparse on this, but from a logical standpoint, there should be a scenario where the supply of goods is so great that the consumer simply does not have the time to consume any additional production of goods. It is very difficult to predict what will happen in the future, but what will definitely remain are the limitations of having 24 hours a day, 7 days a week, and 365\366 days a year. If it is possible to reach this theoretical production level using mostly machines, there are few reasons to believe that there will be enough demand for human labour to support a functional labour market. Autor (2015) makes the point that if this scenario should occur, there will be no economic problem. Having access to more goods than one can consume is fundamentally good for the consumer, and the problem will be how to distribute the wealth, not the scarcity of jobs (Autor, 2015, p. 28). As mentioned in the subsection on education and skills, the distribution of wealth has tilted massively in the favour of the best within an industry, so redistributing this theoretical excess amount of wealth will likely not be an easy problem to solve.

The literature on a saturation of the market for normal goods is sparse, so any implications it could have on the labour market will be speculative on my part. Assuming that there is a possibility that technologies that increase productivity can result in lower labour demand, there are several kinds of technologies that might already exist that can be a threat. When electricity was first introduced in factories to replace the steam engine, it did not lead to any immediate growth in productivity. This was because electrical power was utilized in the same way as steam power, with a giant engine in the middle of the factory. It took several decades before the layouts of the factories were changed to fully utilize the potential of electricity, leading to higher productivity (Brynjolfsson & McAfee, 2014, p. 102). Whether a new technology is handled with an old mindset or a new mindset can thus make a lot of difference, so it is possible that a potentially labour saving technology is currently being used, but not utilized to its full potential.

All in all the technologies to fear that are visible in the task-based model of Acemoglu & Restrepo (2018a) are not the ones that increase productivity, but rather the "so-so" technologies that are good enough to get implemented, but are not much more productive than the human labour it substitutes for. There is also evidence that suggests that these kinds of technologies might be on the verge of entering the labour market in a more impactful way than before. Technologies that increase productivity are generally not considered a threat to labour demand, but there are cases in history where that has happened, and by conducting a thought experiment involving an android, a scenario where higher productivity does not increase labour demand becomes visible. Though the case for "so-so" technologies as the most "threatening" kind of automation to human labour has more backing in the literature, workers may have reason to fear both it and the kind that increases productivity.

5 Summary and concluding remarks

The effects of automation on the labour market is a theme that has been discussed for decades, but it is just recently that the possibility of a future where humans are largely not needed in the production of goods and services began to be seriously considered, after some earlier predictions missed their timelines (Brynjolfsson & McAfee, 2014, p. 141). The literature on the theme of automation is thus a developing field, and just like some the assumptions from older papers like Autor et al. (2003) were proven to be incorrect within a decade, there may be assumptions and conclusions in the works reviewed in this thesis that are proven incorrect in the near future, both in regard to the direction of automation being a threat to the labour market, and not. While working on this thesis, two new working papers on the subject by Acemoglu and Restrepo have been made available to the public ((Acemoglu & Restrepo, 2019a); (Acemoglu & Restrepo, 2019b)). The overall narrative in these papers are not different from their other working papers, but they show that the effects of automation on the labour market is a developing field, and thus underlines that anything that involves technology can develop quickly.

This thesis discuss several papers that point in the same direction with regards to jobs disappearing, job creation, the labour market polarizing, and technological innovation continuing at an ever increasing speed, a discussion that argues major changes in the labour market across the developed world are happening. Where new technology will have a major impact on the demands for human labour; qualitatively and quantitatively.

The goal has been to see how automation and other technological advances have affected the labour market in the past few decades, and how it might affect it in the future.

The papers reviewed in section 4.1 on education and skills pointed towards a shift in the trends on labour demand, where the increase in demand for high-skilled workers appears to have stalled, and even reversed since the turn of the century, resulting in higher-skilled workers doing low-skilled jobs. While automation is not directly mentioned as the probable cause of this observed trend, the building of stock occurring from the completion of cognitive tasks that Beaudry et al. (2013) use in their model can be viewed as a form of automation. Other papers reviewed in section 4.1 focus on the wage polarization that has occurred in the US labour market over the last decades, where jobs in the middle of the wage distribution have disappeared, while jobs at the high and low end of the wage distribution have increased. Considering that jobs in the middle traditionally have been blue-collar jobs, their disappearance fits well with the findings of Autor et al. (2003) that routine jobs are more susceptible to automation. Furthermore, the findings from Acemoglu & Autor (2010) suggest that these trends have occurred simultaneously with an increase in educational attainment. In sum the literature from section 4.1 points towards changes in the labour market where higher education or high-skilled competence does not make one immune against the forces that destroy jobs. While all of the literature finds educated and high-skilled workers more resistance to changes in the labour market than uneducated and low-skilled workers, they too have reason to fear the results if the destruction of jobs accelerate, and the creation of jobs does not keep pace.

Section 4.2 on labour market trends reviewed literature that pertains to the themes of susceptibility of labour tasks to automation, job creation, and wages. More precisely, to see if there were signs in the literature that suggested the labour market show signs of quantitatively or qualitatively reduction in its capacity of being the main distributor of wealth in society, or of being in danger of being reduced. In the section, the seminal paper by Frey & Osborne (2013) was reviewed, and it showed that nearly half of the US workforce was employed in occupations that were at high risk of being automated, according to their framework. That a task can be automated does not mean that it will get automated, but the findings suggest that a huge part of the workforce are in danger of getting replaced by automation, and that many new jobs will need to be created to ensure a functioning labour market. The literature does not find very encouraging signs concerning the creation of new tasks or wages, with the trend clearly showing that modern firms employ far fewer workers than more “classical” firms, and the successor industries employing far fewer workers than the industries they replace, while earning more money, without benefiting the median worker. As pointed out by Autor (2015) however, there are still many jobs, after decades of automation, so there are forces that so far have ensured that the labour market has not disappeared.

Section 4.3 on automation and work sought to highlight through which channels automation can reduce the demand for labour, and how it may increase it. Using a series of working papers Acemoglu and Restrepo outlined a modelling framework based on a task-based model that, in their view, is better suited to represent the real world impact of automation than frameworks that use factor-augmenting models (Acemoglu & Restrepo, 2018b). According to this framework, automation increases the number of tasks machines can perform, and thus result in lower labour demand. If automation increases productivity in the tasks that it performs, demand for the other tasks, including those still performed by human labour, also increases, and thus resulting in higher labour demand. Consequently, the task-based model thus predicts that the effect of automation on labour demand is determined by how many new tasks it allows machines to perform, and how much it increases productivity. The implication being that the technologies that threaten humans labour the most are not the highly productive kind, but rather the “so-so” kind, good enough to get implemented, but not good enough to increase productivity much.

Section 4.3 also provided findings indicating that the “so-so” technologies might be on the verge of entering the labour market on a larger scale than earlier, and providing findings that suggested that productivity increasing automation can result in lower demand for human labour in certain instances where the demand is inelastic, and the market saturated. A thought experiment was presented, where any additional increase in demand for production tasks could be met with machines and thus resulting in no additional labour demand at all. While it is difficult to predict how technologies might interact with the labour market in the future, the literature reviewed has shown the different channels through which it can both increase and decrease the demand for human labour.

The literature cannot predict the future, and different people will likely view the results differently, but the findings may indicate that increased automation will result in a downscaling of job demand, which will affect workers across all skill levels. The literature on education and skills shows that increased educational attainment does not automatically yield better jobs, and that the demand for human labour in high-skilled tasks has not kept on increasing since the turn of the century, even before the Great Recession. Jobs in the middle of the wage distribution have been hit especially hard, with the bulk of the displaced workers moving down the distribution. The number of workers highly susceptible to automation is found to be high; in all countries surveyed, including the US and Nordic countries. The jobs predicted to be most susceptible to automation are those that have provided much of the job growth over the recent decades, suggesting that the major route for the displaced workers is in danger of disappearing. The speed at which new jobs are created has not been great since the turn of the century, and the jobs that have been created have generally not been high-wage jobs. Technological improvements will likely continue at an ever-increasing speed with the help of Moore’s law, making the number of tasks only humans can perform lower and lower. There are signs that reasonably priced “so-so” technologies are on the verge of entering the economy on a larger scale, enabling automation without increased productivity, removing the one component that most economic models predict will increase labour demand.

While all of this sound like pessimistic predictions that need not at all be the case. As pointed out by Autor (2015, p. 28), if human labour is indeed outcompeted by technology that means that more wealth is available than ever before, and that having an abundance of wealth is fundamentally a good outcome, with the problem being that of distribution. Brynjolfsson & McAfee (2014) view a future without work as less desirable due to the belief that the value of work is not just monetary, but that it also gives workers a sense of purpose and self-worth, and that solving the problem of distribution in a wealth abundant society will not help people achieve that (Brynjolfsson & McAfee, 2014, p. 234). Regardless of those concerns a future where everything people need, and more, can be produced without human input need not be a future where people do not work. All economic actors will still be endowed with time that can be spent working with something, that may or may not contribute to GDP. There should be ways that a working population can be maintained through governmental policies should that be deemed desirable, and removing the necessity of human labour for survival can be a positive development in many ways.

The possible implications of a future without a need for human labour, what policies might be enacted to reach the best possible outcome, and what the best possible outcome is, are discussions that need their own papers. Equally, if not more interesting is the scenario where a majority of the population can participate in the labour market, but a substantial minority cannot. The unavoidable conflict over redistribution from those who contribute to GDP to those who are effectively prevented from contributing, is arguably more worrisome than how to distribute a machine produced overflow of wealth. All of these topics are likely good subjects for future research.

What the future will bring with regards to the labour market cannot be determined with certainty, but what might be the most important findings from the literature reviewed in this thesis is that there are no law of economics that dictate that there will be enough jobs for everyone when old jobs gets lost to technological improvements, nor can anyone guarantee themselves a job by being highly skilled. Technology will only get better, and job creation shows few signs of accelerating, if anything it appears to slow down. While it is fully possible that the future is not a jobless one, there appears to be no natural economical mechanisms that prevent it, should the technology become good enough. The trend of fewer and fewer people being capable of producing more and more with an ever decreasing amount of employees is unlikely to be helpful with regards to job creation. These trends have been going on for a long time, and the labour market has not been substantially diminished yet, which makes it easy to assume that it can never happen. Technology does not generally improve linearly however; it improves exponentially, as Moore's Law states (Brynjolfsson & McAfee, 2014, pp. 41–42). Therefore the quote by Hemmingway that a man goes broke "Gradually and then suddenly" might be a predictive one (Brynjolfsson & McAfee, 2014, p. 20). The future may be one where most people participate in the labour market, such as today, but the literature strongly indicates that the natural forces of economics now pulls in the direction of less demand for human labour. Those forces may be counteracted, but it will not happen on its own. A jobless future has been predicted many times, and those predictions have missed so far, but that does not prove that it can never happen. The prospect of replacing the horse in all important aspects of the economy was unthinkable, until it was not. The prospect of humans landing on the moon was unthinkable, until it was not. Likewise, in the future, someone might write a paper or book, were they remark that the belief that there would always be a need for humans in the production of goods and services was the only prevailing one, until it was not.

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