Accounting for Job Automation in Advanced Economies:

An Overview of Impact, Contingent Resolution Options, and a Case Study of the UK

By

Paul Hickey

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Supervisor: Dr. Anil Duman

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Abstract

While there is speculation in the academic, corporate, and political worlds about the uniqueness of contemporary automation in advanced economies, including the possibility of robots displacing workers across a range of more cognitively complex and diverse occupations than previously viable, there remains a dearth of literature on the likely extent of this displacement in sectoral or occupational population or percentage terms, indicating actual novelty or otherwise rationalising fears.

Where research has been conducted on the extent of risk there is a lack of questioning of the theoretical premises of the studies, the consequence of which has been fairly equivalent study outcomes throughout the literature which are open to criticism on the basis of qualification of the risk in terms of conceptualisation of the process of automation, of the composition of occupations, engineering bottlenecks, *inter alia.*

The result of general adoption of a particular widely unquestioned theory is that the threat of automation displacing occupations is likely systematically overestimated.

In abeyance, this overestimation is immaterial. However, the nature of studies into this area is that policy implications will likely incorporate feedback from such studies, the academics engaged in writing them, or media which picks up on the studies' conclusions.

The aim of this thesis is to explore the literature on both occupation automation risk and related policy options to develop a clearer understanding actual threat to workforces in advanced economies and the feasibility of various options for policy obviation or remediation of such risk.

The thesis focuses on the UK, one of the G7 nations chosen as representative of advanced economies under scrutiny, as a case study example elucidating substantiated peril for displacement through automation and highlighting what an appropriate policy response might look like in an advanced economy setting.

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1. Introduction

1.1 Background

Automation is affecting all sectors of the economy in novel ways. In the primary sector, progress in technologies such as space-based positioning systems (using GPS); wireless vehicle-to-vehicle and vehicle-to-office communications; and yield monitors have contributed to the reduction of the labour force in advanced economies to the extent that between just 1.7% - 3.5% of all workers in the US; Canada; Northern, Western, and Southern Europe; Japan; or Australia now remain employed in agriculture (ILO 2017; Shearer, Pitla, Luck 2010).

In manufacturing, developments such as fieldbus systems, those with multiple layered automated components monitoring sensors, switches, etc. but supervised centrally from the top by a human operator; asset management systems; wireless networks; big data management systems; and now 3-D printing, alongside increased availability of open source software, are correspondingly facilitating the steady decline seen in advanced economies in this sector, where, in the EU since the 1970s there has been increasing redundancy to the point where the sector now represents just 15% of the region's overall employment (Gupta and Kumar 2013; Jamsa-Jounela 2007; Veugelers 2017); in the US, layoffs have meant nearly 5 million workers in the sector (more than 28%) losing their jobs since the year 2000 (Houseman 2018); in Japan more than 25% of its manufacturing jobs between 1992 – 2012 were lost; and in Australia circa 18% between 2008 – 2016 (Bernard 2009; Georgeson and Harrison 2015; Toth 2016; US Bureau of Labor Statistics 2012; World Bank 2017).

While services is the sector which grew as others stagnated or declined in nearly all advanced economies over the last 25 years (World Bank 2017), there are nonetheless mounting concerns over automation's potential future effects on job retention in this sector as well. New developments in ambient intelligence, sensitive electronic environments which are reactive to people within them, and cloud robotics, which involves collecting information from various computer devices and using the cumulative data for analysis and pervasive improvements to the functionality of the robots which send the data (Chibani et al 2013) may reduce the need for human employment, as ubiquitous robots (ubirobots) overcome the strictures of un-networked / standalone robots through integration with a network, creating a hybrid physical-digital space which in future looks set to satisfy an array of customer and back-office needs and issues remotely and in real-time. Once challenges such as recognising deformable objects like bodies and clothing by machines interacting with humans (Torras 2016) are overcome, robots will technically be able to replace humans in a host of customer-facing service environments. Worries for the long term security of current tertiary sector jobs revolve around the ability to automate previously non-threatened occupations including those with substantial complexity, interactive and non-routine aspects (Frey and Osborne 2013), and the extent to which services are exposed to potential job loss is the subject of considerable concern in academic literature.

1.2 Outline and Relevance of Study

While it is clear that automation is playing its part in altering labour market composition, the purpose of this study is to formulate a broad understanding of the scale of this impact in terms of future occupational displacement. In doing so it will highlight and investigate the two major perspectives on how to discern or distinguish the functionality of automation in terms of its impact on occupations. These perspectives bifurcate the literature on this topic, and the interpretation by authors engaged in research on the topic of correct perspective directs conclusions as regards the nature and degree of threat. In line with this the study will explore the various policies available to government to mitigate or preclude the perceived threat that automation holds to employment. Specifically the thesis will scrutinise the effects that automation will have on the UK's labour market and which policies the UK may adopt to negotiate its position in relation to job loss vis-à-vis automation in coming years.

The relevance of examining this literature is first to emphasise that such a division exists in the conception of the functionality of automative processes when exploring job loss due to automation, a point which is curiously overlooked by the majority of publications on the issue, which follow the original perspective apparently without much deliberation. This division has major implications for policy, as policy ought to be devised substantially differently depending on the drastically disparate conclusions drawn from examinations based on either perspective. As such, the reasons for the division in literature are also relevant for research in academia and future policy and so will also be inspected. Further, comprehensive appraisals of policy options to assuage issues of job loss in relation to automation are sparse in the literature. This study will provide a succinct overview of such options and tailor a solution particular to the context of the UK. The contextualised policy review in tandem with specified job loss figures in relation to automation aims to provide a rigorous analysis of the components of the UK labour force that are likely to be affected. It also aims to outline an early informed, integrated, and implementable solution to minimise potential disruption, as well as indicate aspects of a generalised roadmap for other advanced economies in terms of policy.

1.3 Questions

In light of speculative concerns, two striking questions arise, one regarding the nature of the threat of automation to employment, and the other the manner in which governments ought to respond.

Q.1 What are the overall implications in terms of job loss for advanced economies, to what extent, and at in what way, and how will these implications affect the UK economy generally and sectorally?

Existing studies in this area tend to work off the theoretical and technical modelling of Frey and Osborne (2013). The theory behind this approach is that jobs are strictly automatable or not automatable, and that they can be attributed a "probability of computerisation". The technical process used was called a Gaussian process (jobs were taken from a sample from O*NET, a workplace analysis tool for the US Labour Department). A number of studies were completed on the basis of their theory and method, all of which tended to predict fairly high risks of job losses in their respective economies, i.e. at a 25%+ level of jobs listed as high risk (Bowles 2014; Brzeski and Burk 2015; David 2017; Lee 2017; Pajarinen, Rouvinen and Ekeland 2015), with a predicted 35% risk in the UK (Haldane 2015). Further models such as Aguilera and Barrera (2016) accept the theory but are unable to use the technique due to lack of data, and their research may have less implications for high technology economies in any case as it is based on Latin American countries. However, Arntz, Gregory and Zierahn (2016) reject the theoretical premise that jobs are either completely automatable or not so, and rather begin with the notion that aspects or tasks within occupations may or may not be automatable.

This leads to very different results when implications are analysed, e.g. only 10% of occupations in the UK at high risk of full automation.

As such, the point of departure in the debate over what the implications are for job loss in high technology economies is how to qualify the risk on the basis of which theory makes most *a priori* sense. When this has been established it will be more possible to gauge which spheres will be most heavily affected, to what extent, and perhaps conjecture the rate of change to a degree. Should the theory which makes most sense be Frey and Osborne's then the other studies using their techniques can be directly compared and utilised. Should Arntz, Gregory and Zierahn's, then there potentially needs to be a shift away from the common trend of how to consider automation in the literature and the other research based on Frey and Osborne, along with Frey and Osborne's work itself, and the conclusions of Arntz, Gregory and Zierahn (2016) or related more recent literature based on their approach should instead be more deeply considered either independently or in relation to aspects of the original conceptions which still hold. Thereafter, it will be possible to gauge overall implications for high tech economies broadly, and to delve more deeply into the effect of automation per sector and in context.

Q.2 What are the strategies available in dealing with automation and what is the most viable governmental solution to related threats given the infrastructure available in the context of the high technology economy of the UK?

Existing studies suggest that there are a number of options with regard to managing the threat of automation on job loss, mostly involving restructuring the social welfare system in such a way as to accommodate unemployment. Levin-Waldman (2018) for example predicts that

Universal Basic Income, a politically ambivalent venture (supported by advocates on both left and right) (Battistoni 2017) of giving every citizen enough money to survive, is inevitable to survive technological advances and maintain capitalist markets, while advocating several auxiliary benefits such as abolition of exploitation, the dismissal of the scourge of low-wage work and greater representation of public will (Levin-Waldman 2018).

Negative income tax is essentially the opposite of standard or “positive” income tax where the government takes a portion of earnings in proportion to a greater salary earned. In negative income tax the would-be taxpayer actually receives money if salary is below a certain threshold and the amount received decreases (but not at a one-to-one dollar ratio so as still to incentivise work) up to a certain low bar the more the worker earns (Moffitt 2003). This is a more acute measure of taxation than UBI whereby the target would be those who are suffering most for lack of money rather than the entire economy. This may act as an interim measure, which could hold a basic level of living while other plans are devised, or, depending on rate, may be made satisfactory in itself in the provision for well-being in welfare on a national level. In specifically targeting the lower earners in the economy, it would mean less financial restructuring and perhaps an overall lower financial burden than UBI.

A third option is robot tax. The idea, which is often attributed to Bill Gates, is that some amount of money, potentially the same amount that would be lost in payroll taxes for a human replaced by a machine, is paid by employers who are automating workers out of positions (Paul-Choudhury 2017). This option potentially is easier to implement than UBI in the respect that the tax system can be manipulated as it is to accommodate a different form of tax, whereas with UBI the welfare system would most likely need a substantial overhaul. Nonetheless, a different set of issues arrive when considering this alternative. How are robots legally defined and the capacity of employers to pay tax on the robot (Oberson 2017; 2018)? How the robot tax may be used, e.g. as insurance / support for a worker whose job may be automated / becomes automated, as a reduction in corporation tax relief benefits for automation technology, or for funds to retrain workers whose jobs are lost to automation (Kim 2018)?

A fourth strategy is a government job guarantee. According to Tcherneva (2012) the philosophy of basic income is a misguided one. She argues, against the viewpoint of Guy Standing who is a leading proponent of basic income, that he and advocates of basic income are misled in considering that the nature of jobs in modern society is basically unjust and punishing, and which needs to be escaped from. She believes, in line with those who favour job guarantees that the absence of full employment over time is a catalyst for a race-to-the-bottom situation which will lead to bad jobs. This option, when assessed for viability, certainly seems much less expensive to maintain than universal basic income, an argument made by Harvey (2012) (who also posits that basic income would be less effective) and requires less systematic change than negative income tax.

Finally, education may mitigate potential losses in the job market due to automation. Goldin and Katz (2007) in their analysis of wage differentials as compared to educational attainment in a longitudinal US study note that a nation's economy grows as its technological capacity advances, and that in an progressive technological economy flexible skills and educational infrastructure must be in place should the "race" between education and technology remain balanced (Goldin and Katz 2007, p.26). The notion of lifelong learning is now popular and reflects the aspects of preparation for a future where the knowledge a worker ought to have in professional life will change and adapt over the course of a career (Vamos 2014). Of course, such a new situation requires a new approach to the system of education currently in place in most developed countries whereby “formal” education ends post-high school or post-college.

A number of studies examine these strategies independently generally in theoretical form, or by comparison with one or another alternative policies in theory. Others provide context in relation to certain aspects of inequality or against a removed notion of automation. None work with the most recent figures of automation and attempt to plot a course of navigation in relation to the threat to a specific country as indicated by contemporary academic literature. This study will do so in the case of a chosen advanced economy setting, the UK.

1.4 Expected Outcomes

The expected outcomes (EO) of the first question surrounding the overall implications in terms of job loss for high tech economies and specifically the UK is as follows:

EO.1 Overall there will be a relatively contained impact of automation on job loss in advanced economies as they are more service oriented and highly skilled than other economies. Low-skilled, highly routine areas will be primarily impacted, with less of an impact the more complex and less routine the job being considered for automation is. These premises will hold for the UK.

As for the question about which strategies are available to negotiate automation and the most viable governmental solution per the UK infrastructure, the expected outcome is as following:

EO.2 There are a number of key strategies which are known about already and one can be tailored relative to the specific needs of the UK economy with minor amendments, most preferably the one which finds an equilibrium maximising competitiveness in automation and robotics while providing the best social welfare outcome in tandem.

1.5 Limitations

The limitations of the thesis are that there are a number of speculative factors influencing the impact of automation for advanced nations which are extremely difficult to account for either pan-nationally or, in some cases, nationally / contextually, such as governmental support and investment, the impact of various lobbying groups and social actors, capital flight and general corporate mobility, fluidity of education sector in accommodating new programmes including the assimilation of technically competent people in IT into teaching positions, youth interest in IT education, Gross National Product and budgetary issues, legal frameworks regarding redundancy, IT and telecommunications infrastructure, synergic environments or lack thereof, and the pace of progress of the Internet of Things.

On a micro level another a substantial limitation relates to engineering bottlenecks in the process of automation (such as perception, creative intelligence, social intelligence etc.) and how quickly they can be overcome, which is essentially a black box insofar as, abstract of the actual problems which need to be solved, it is impossible to accurately gauge the answer to this question.

Another limitation is that the theory and method considered for estimating potential job loss as a consequence of automation shape the results one way or another, and in the instance of the literature currently available the results are skewed fairly significantly on the basis of which approach is used.

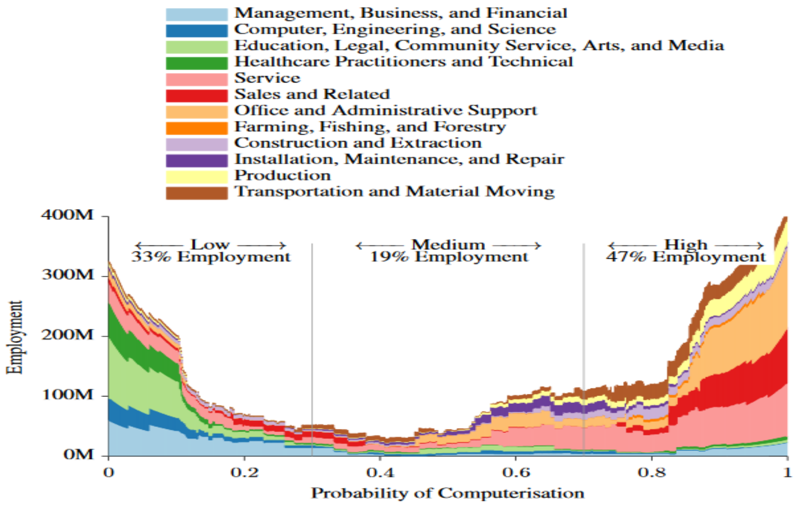
Based on restrictions of research assumptions; socioeconomic, political, commercial, and technological speculative factors; and engineering unknowns related to bottlenecks, the estimates derived from the literature reviewed will be presumptive, generally based on *ceteris paribus* inference, and therefore will be heuristically instructive as opposed to scientifically verifiable.

A final limitation is that the applicability of the policies suggested for the UK in dealing with concerns over automation in displacing jobs will be based on the premises discussed above which are highly contingent, though any potential deviations in severity of automation of occupations can be offset on the policy side by referring to the other options available.

2. Literature Review

2.1 Extent of Automation’s Impact on Labour Markets – Original Methods and Studies Fundamentally Based on Frey and Osborne

The most influential study of the effect of automation on jobs by sector and type is Frey and Osborne (2013), which has shaped the field for this area. The paper argues that susceptibility of jobs to automation is no longer purely related to whether the job is routine or not (while acknowledging routine occupations are still easiest to automate and most at risk) and that jobs requiring social intelligence and creativity will be most resilient to automation. It estimates on overall, and occupation-by-occupation, bases the risk of job loss to automation. The authors plot negative correlations between wages/education and probability of one’s job being automated. They also highlight the effect of engineering bottlenecks, or difficult-to-solve engineering problems related to creative and social intelligence, on the ability to automate in certain areas. Their data is information on all of the jobs and their tasks available on O*NET (a workplace analysis tool for the US Labor Department) which they aggregated to 702 occupations. They deciphered with machine learning specialists which of a sample of such occupations are strictly automatable or not automatable, and assigned a “probability of computerisation”. They then imputed the automatability of the remaining occupations based on the identified bottlenecks and a probabilistic model estimating the power of the bottlenecks to predict an occupation’s automatability. The upshot of their work is that they estimate that 47% of total US employment is at high risk of automation-related displacement, starting with transportation and logistics occupations, alongside the majority of office and administrative support workers, and work in production occupations. This will be followed by a substantial proportion of services, sales and construction occupations, cashiers, counter and rental clerks, and telemarketers jobs.



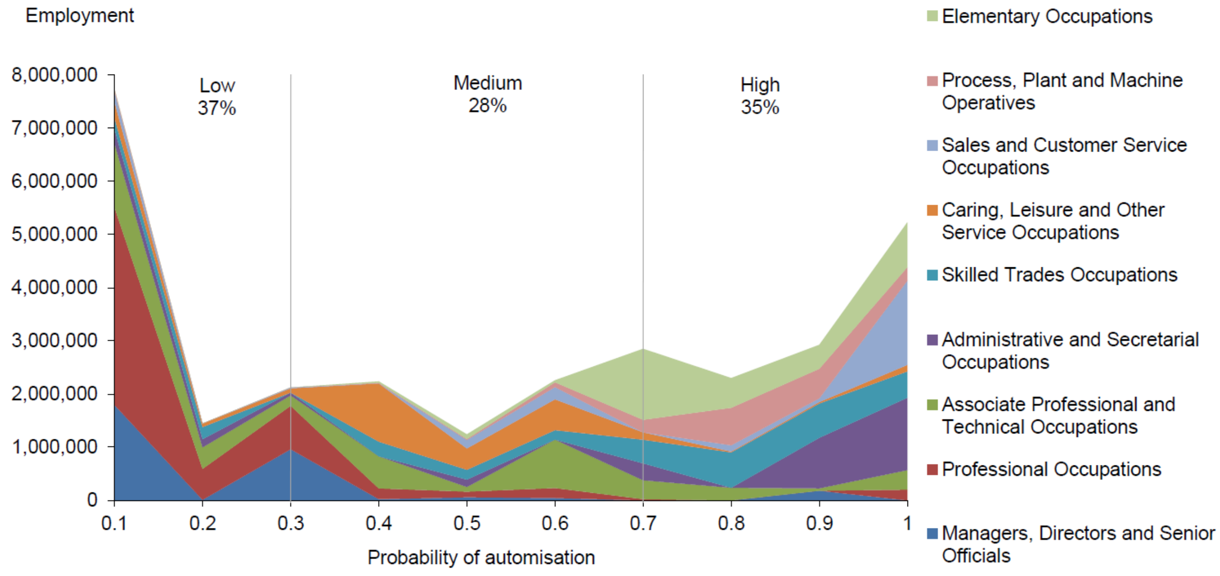
(Frey and Osborne 2013, p.37)

While certainly a catalyst in the area of examining the extent of automation on employment and avant-garde in outlining extensively restrictive engineering blockades formally which are a universal hindrance to automative progression into the labour market, there are a number of criticisms applicable to this paper. One is that the timespan predicted of automatability of occupations and sectors is totally arbitrary. Frey and Osborne predict that all of the displacement they predict will occur in the 10-20 years following year of publication. Given that their study was conducted five years ago in 2013, their predictions are certainly not progressing linearly in terms of job loss, but even if they were, there is no logic explained as to their prediction in relation to timespan. Second, correlations between education/wage and risk of automation bear tenuous conclusions. For example, the authors conclude that the education correlation represents a need for highly skilled people in the market. However, the negative correlations may well be more related to the nature of work that highly educated people or highly paid people do, such as managing others, socially related tasks that are not routine, than due to any skill or other inherent factor of either payment or education *per se*, such that it may just represent a problem of deep class inequality as opposed to skill or talent distribution i.e. to a substantial degree this correlation might not represent causation. Another issue is that the authors' decision to view occupations as strictly automatable or non-automatable is based on very commodious and contentious grounds, whereby if all of the tasks in an occupation can technically be automated it is taken for granted that over the 10-20 year time period that they will be. Other criticisms are those such as that within occupations, task shifting is not considered in terms of the resilience of occupations, nor job creation and its positive effects in responding to automative displacement.

Frey and Osborne's (2013) piece was conducted for the US but appears as a benchmark for other studies which attempt to provide such an estimate on regional or national bases in advanced settings. Exemplifying the speculative nature of this field of enquiry the results of these other studies are mixed. For example Bowles (2014) categorically inflates results relative to Frey and Osborne. He, examining the effect that automation might have on Europe, substituted Frey and Osborne's American Standard Occupational Classification codes with a classification system more commonly used in Europe, the International Standard Classification of Occupations (ISCO) code, which is that used by the International Labor Organization (ILO), and applied the risk to employment data based on a 2012 EU Labour Force survey. His results indicate that the occupations at high risk within the EU-28 countries is anywhere within a range of 46% - 62%, and an average risk of 54%. Brzeski and Burk (2015) on Germany, using employment statistics of the Federal Employment Agency according to its classification of occupations, somewhat mirror Bowles' figures for the German labour market, claiming that 59% of the German labour market is at high risk of automation as opposed to Bowles' figure of 51% for Germany, though it may be argued that this is as a consequence of psychological anchoring as Bowles' article, and Brzeski and Burk's appreciation of it, is mentioned in their analysis. However, other European studies understate the risk relative to Frey and Osborne's conclusions for the US and Bowles for Europe. Pajarinen, Rouvinen and Ekeland (2015) on Finland and Norway, using ISCO codes as per Bowles, find that in Finland and Norway the percent of jobs at high risk of automation stand at 35% and 33% respectively, though they do not surmise why Bowles' prediction of 51% of jobs in Finland at high risk of automation is so far removed from theirs. Haldane (2015), using UK Office of National Statistics figures, predicts that the UK risk is 35%, as opposed to Bowles' 47%. David (2017), using "Career matrix" information from the Japan Institute for Labour Policy and Training and Japanese census material data, predicts that 55% of occupations in Japan are at high risk.

Despite contentions over the extent of risk of automation to employment, there are valuable areas of agreement, such as, by those who investigate, accordance on the areas that will likely be impacted most heavily (Bowles (2013) and Pajarinen, Rouvinen and Ekeland (2015) do not discuss the issue). As per Frey and Osborne (2013), Brzeski and Burk (2015), noted that the following professions which comprised their study had high levels of risk: Office staff and related (86%); Support Staffs (85%); Plant and Machine Operators, Installation Professionals (69%); Service and Sales Professionals (68%); Agriculture, Forestry, and Fisheries Skillsmen (64%;) Craftsmen and Related (63%); Technical and Technical Support (51%); while academic (12%) and executives (11%) have low levels. This corresponds to Frey and Osborne's (2013) predictions for the areas of the economy which will be affected in terms of high risk, though some occupations are slightly under the threshold of high risk as per Frey and Osborne, such as Services and Sales, Plant and Manufacturing, and Technical Support roles. Nonetheless, this implies that the general logic of routine jobs and perhaps level of skill, if not necessarily education, might hold across regions, which has implications for its value. Haldane's (2015) speech and ancillary report highlight similarities to Frey and Osborne (2013) but for the UK, even providing a very similar chart underscoring the distribution of occupational employment in the UK by probability of automation, and a visual form graph which indicates for the UK the probability of automation by occupation. The general outcomes for the UK, though estimated at a less high-risk scale, are similar to the US also. Administrative, sales, manufacturing, elementary occupations, skilled trades, and technical occupations are high risk, while professional, and managers and executives remain relatively secure. The theoretical premises of how to consider the function of automation in relation to employment is the other major tacit agreement from these texts, and this debatable resolution will be discussed at a further point in this literature review.

Chart 27: Distribution of occupational employment in the UK by probability of automation



Source: Frey and Osborne (2013); Bank calculations
Notes: This chart shows the probability of automation based on estimates in Frey and Osborne (2013) matched against UK occupations

(Haldane 2015, p.26)

In David's (2017) research on Japan, in results it is clear to see similarities in the types of occupations most heavily affected with those already reviewed for the Western World where transportation, administration and office support, logistics, manual and process manufacturing jobs are most susceptible to automation. Further, David's results on the least susceptible occupations are also in line with expectations. These occupations are high level professional, executive and managerial areas, as well as other areas that either require exemplary emotional intelligence or creativity.

Outside of these research publications there is a scarcity of literature around the extent that automation will displace workers from their occupations inclusive of overall percentage predictions and potential sectoral effects in advanced economies. In any case, what can be initially determined from the mixed results and moot premises with regard to extent is that any level of risk which is predicted in the literature is heuristic and best, and specious at worst. Insofar as results can be justified heuristically, it is probably best to consider them relatively rather than absolutely or independently, so that it can perhaps be said that the US, Japan, and Germany are more highly exposed to automation in the workplace than the UK, Finland, Norway, but to what extent is fairly unknown. The remaining relevant literature which engages in with the question of extent to which automation may displace workers will be explored in the next two sections.

2.2 New Thinking on Automation and Differing Conclusions

As mentioned, most who attempted to predict results based their theory and methods substantially on the Frey and Osborne approach. Others however use it as the basis for scepticism and interact with its premises and conclusions accordingly. The most noteworthy work in the sceptical space, which acts as a response to Frey and Osborne in relevant and differentiating ways (though still leans on Frey and Osborne to an extent in their methods) is Arntz, Gregory and Zierahn (2016). Their study focuses on task automatability rather than entire occupations, as they believe that even the high risk occupations that Frey and Osborne identified have hard-to-automate tasks and so the potential of the job loss in Frey and Osborne's work is overstated.

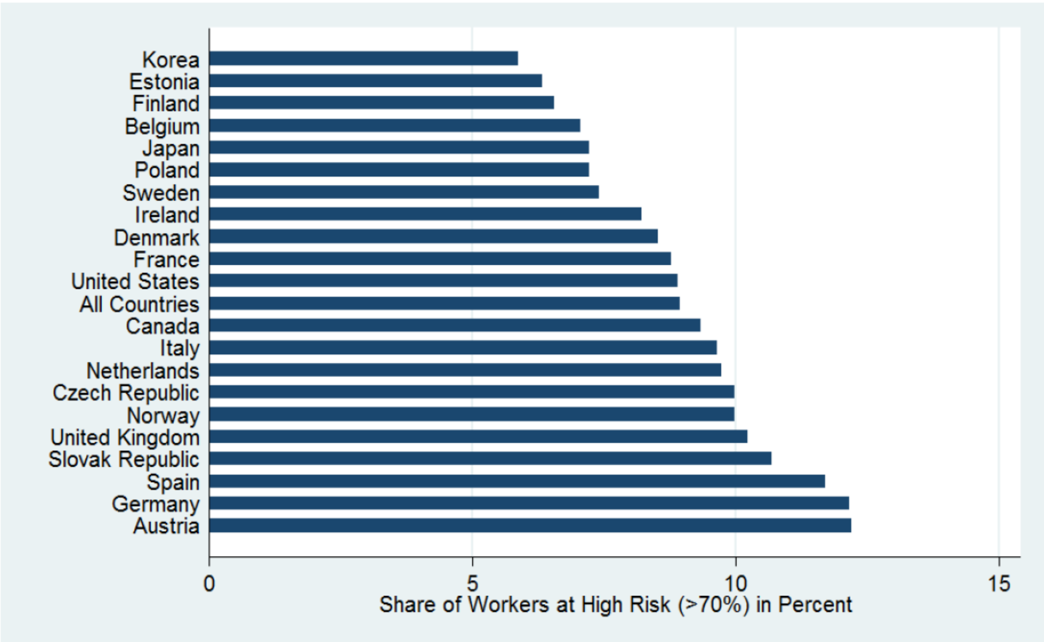
Arntz, Gregory, and Zierahn (2016) dispute Frey and Osborne's (2013) method on the grounds that it was too broad. They believe that as jobs are broken down into series of steps, that a task-based approach is more rigorous and insightful, describing more precisely the threat of job loss due to automation as something that could only be measured based on whether the whole composite array of tasks within an occupation could realistically be automated within a given time period. They considered that the occupation-based approach leads to an overestimation of the automatibility of a job, as occupations which, in that model, would be labelled as high-risk nonetheless often contain a substantial portion of hard-to-automate tasks. Additionally their task-based approach accounts for the heterogeneity of tasks within an employee's occupation. They question the aim and function of automation, remarking that historically the motive has been to automate tasks as opposed to occupations. The cite Spitz-Oener (2006) who finds that most of the hitherto adjustment to automation occurred through changing task structures within a given occupation as opposed to changing employment shares between occupations. They conclude that the threat from progression towards automation is much less than the occupation-based approach suggests.

Indeed Arntz, Gregory, and Zierahn's (2017) revisited their research, reiterating the overestimation of Frey and Osborne's calculations and noting the majority of jobs involve non-automatable tasks including further evidence about non-automatability in that even in nominally equivalent jobs, where workers of the same occupation specialise in different non-automatable tasks. Consequentially, the predictions that they arrive at are less than a quarter of the risk of Frey and Osborne's calculations. As these occupations and many others like it were (admittedly subjectively by Frey and Osborne themselves) selected by Frey and Osborne (2013) as high risk for overall job automation it is questionable if the total figure of high risk of automation per occupation is reliable. Thus, while it may be technically feasible (in the sense of plausible/achievable rather than financially worthwhile) to automate all of the tasks O*NET enumerates for the occupations it qualifies, in a very many instances the cost of doing so is likely to far outweigh the benefit, or otherwise will be impractical. Arntz, Gregory, and Zierahn (2016) note that, coupled with this cost, heterogeneity, difficult-to-automate tasks etc., there are often legal and ethical obstacles which may preclude or impede employee substitution for mechanised process, and that even in the absence of obstacles of the types enumerated here, employees may end up adjusting to a new position and either adopting skills for new tasks or using same general skills for new tasks. They further degrade the assumption of commonality and direct comparability between occupations in different countries, highlighting that equivalent correspondences between occupational classifications and that in the US typically do not exist. In the 'Appendix' section of this thesis is a more detailed account of how the Arntz, Gregory, and Zierahn (2016) approach makes sense in practice.

Specifically, they predict that the highest risk of the 21 OECD countries that they investigate are Germany and Austria (both 12% high risk of automation), while the lowest are Korea and Estonia (both 6%). The US figure falls dramatically from 47% high risk in Frey and Osborne

(2013) to just 9%. The UK falls from estimates of 35% using Frey and Osborne's theory and method (Haldane 2015) to just 10% at high risk. The overall figure that they present for high risk across the 21 countries is 9%.

Figure 3. **Share of Workers with High Automatibility by OECD Countries**



Source: Authors' calculation based on the Survey of Adult Skills (PIAAC) (2012)

(Arntz, Gregory, and Zierahn 2016, p.16)

Most recently Nedelkoska and Quintini (2018), building on Arntz, Gregory, and Zierahn (2016), expanded upon the sample of OECD countries and shored up some gaps such as that of employees currently in non-ICT jobs, found that while Frey and Osborne (2013) grossly overestimated the risk of job loss to automation, Arntz, Gregory, and Zierahn (2016) marginally underestimated it. They indicated some other new lines of thinking additionally, for example that the cross-national variation in the ability of automation is predominantly a function of the disparity in the organisation of work tasks within sectors than by differences in sectoral structures within an economy. They found that the share of workers with the most overall risk with regard to automational displacement, accounting for international differences in occupation descriptions in the 32 OECD countries studied, are Slovakia and Lithuania (with the most high risk of jobs in Slovakia also, at 33%) and lowest in Norway and New Zealand (with Norway having the least high risk of jobs being automated, at 6%). The Nedelkoska and Quintini figure for the US drops dramatically from occupation-based figures nearing 47% in Frey and Osborne (2013) to just 10%, and the interest of this paper, the UK is about 12%, which is significantly lower than the Frey and Osborne theory- and method-based extrapolated figure by the Haldane of 35% (Haldane 2015). The overall figure for high risk as published by Nedelkoska and Quintini across the 32 countries studied is 14%, which marginally higher than the 9% predicted by Arntz, Gregory, and Zierahn (2016), but substantially lower than the figures of 30%+ generally predicted by applying Frey and Osborne's framing.

Whichever theory is accepted in this area of research has significant implications for understanding the actual level of threat of automation on jobs in an economy under investigation, and furthermore on policy if such studies are used to understand the rate of technological job displacement. Accepting the task-based approach as leading to the most reliable outcome of this theoretical exploration has implications in a number of meaningful ways. Firstly, it is the basis of disregarding the results, the overall method (i.e. in its entirety as opposed to partial aspects), and some of the premises of the most widely regarded and seminal work in this field and related concomitant research which makes up the majority of literature in this area. Second, it means baselining future research on the premises and figures derived from the task-based approach method, with the most recent methods and outcomes by Nedelkoska and Quintini (2018) building on the approach, acting as the most reliable basis moving forward. Third it has implications for the conception of practical policy-making, i.e.

the policy or strategy adopted should reflect the less threatening, but still significant, results that task-based results have indicated in Nedelkoska and Quintini (2018) and are likely to indicate in further studies based on this approach, likely a less radical one than would otherwise be adopted working off theory and figures based on occupation-based research.

Of course the theory of Arntz, Gregory, and Zierahn (2016) and built on by Nedelkoska and Quintini (2018) may be better than Frey and Osborne (2013) but still incomplete, and further studies into the improvement of any theoretical bases should be conducted, however, as for the points discussed in this paper, ways to improvement upon Frey and Osborne have clearly been indicated and understood and to that end progress has been made, even if not picked up on by academic literature. Further the method may be developed or new methods devised on the basis of previous studies or on a new basis, which might better capture the relationship between tasks and occupations vis-à-vis automation, however, in the interim this working model acts to indicate levels of potential infliction by machines on occupations.

A final concern related to the automatability of tasks / occupations, and something that is not mentioned in any of the texts on the automation issue as regards employment but may impede progress towards the ends of displacement is that, while tasks are automatable on a case-by-case or task-by-task basis, interrelated tasks that are completed throughout an entire working day and rely on each other may be difficult to automate, especially where different systems need to be used. Further to this, tasks often need to be completed in certain orders, which may be different between jobs of the same occupation. Software allowing sequencing of an unknowable amount of partially-related but often with context-specific tasks, which the average end-user will be able to manipulate for his/her own ends, will be complex to devise.

2.3 Related UK Specific Literature on Extent and Effect of Automation

Aside from the papers already discussed in the literature review, which have indicated a high risk of automation for occupations in the UK anywhere from 10% (Arntz, Gregory, and Zierahn 2016) to 47% (Bowles 2014), there are no major academic articles highlighting the risks of automation on employment in percentage terms for the UK specifically. A 2017 economic outlook paper by PwC UK's Chief Economist John Hawksworth and AI expert Richard Berriman (Berriman and Hawksworth 2017), which explicitly reviewed Frey and Osborne (2013) and Arntz, Gregory, and Zierahn (2016), found that up to 30% of jobs in the UK could be at high risk of automation by the early 2030s, however, less than a year later this figure has been revised downwards to around 20% by the same authors (Berriman and Hawksworth 2018), with an estimation that by the early 2020s only 3% of occupations will be at high risk. Similarly, Deloitte conducted a study in 2015 indicating that 35% of jobs were at high risk in the UK (Deloitte 2015), though they completed this study with the support of Frey and Osborne and as such their results are open to criticism as per the reasoning mentioned in the occupation-based vs. task-based approaches to viewing the threat of automation. Nonetheless, reviews of such papers can support the results of the Bank of England (Haldane 2015) in at least obtaining an indication of which sectors and demographics are most exposed to automation in the UK which will help to project the labour market consequences and the applicability of various policies to the UK, i.e. the trends and tendencies should hold even if figures are suspect.

Haldane (2015) estimates that 15 million jobs could be at risk of automation. As mentioned in the literature review, these jobs tend most heavily to administrative and secretarial occupations, sales and customer services, associate professional and technical, skilled trades, process and manufacturing, and elementary occupations. Berriman and Hawksworth's (2017) trends align closely with these labour market outcomes. As with Haldane's research, Berriman and Hawksworth concur that sales and associated retail services, administrative and support, and manufacturing are among the most high risk, and these industries, alongside transport and storage make up more than 50% of the most at-risk employment populations for automation in the UK, according to their results. The figures below, which should be considered primarily to gauge exposure of industry rather than actual working estimates, are predicated on a 30% high risk of automation. According to the report the highest risk are such that contain the most manual labour and/or routine work, whereas the lowest contains the opposite. Both Haldane (2015) and Berriman and Hawksworth (2017) note that a key differentiating factor is education, and Berriman and Hawksworth's publication moves further than Haldane's in some respects by discussing in more detail about how new jobs unknown to us now will be created in future to mediate some of the automation threat, while advocating that there is a case for government intervention to ensure that potential gains from technological advancement are shared as widely as possible throughout society.

Industry	PwC Estimate of Jobs at high risk of automation (millions)
Wholesale and retail trade	2.25
Manufacturing	1.22
Administrative and support services	1.09
Transportation and storage	0.95
Professional, scientific and technical	0.78
Human health and social work	0.73
Accommodation and food services	0.59
Construction	0.52
Public administration and defence	0.47
Information and communication	0.39
Financial and insurance	0.35
Education	0.26
Arts and entertainment	0.22
Other services	0.17
Real estate	0.16
Water, sewage and waste management	0.13
Agriculture, forestry and fishing	0.07
Electricity and gas supply	0.05
Mining and quarrying	0.01
Domestic personnel and self-subsistence	0.01

(Berriman and Hawksworth 2017)

What is not present in Haldane (2015) but is noteworthy in Berriman and Hawksworth (2017) is the breakdown of threat in the UK as it relates to sex and the degree of educational advancement. For example, males are relatively more at risk than females, and those with mid-level high school attainment, and pre-graduate have a severe disadvantage when it comes to displacement than highly educated individuals.

Worker characteristics	Employment share (%)	Job automation (% at potential high risk)	Jobs at potential high risk of automation (millions)
Gender:			
Female	46%	26%	4.1
Male	54%	35%	6.3
Education:			
Low education (GCSE level or lower)	19%	46%	3.0
Medium education	51%	36%	6.2
High education (graduates)	30%	12%	1.2

Sources: PwC estimates using PIAAC data

(Berriman and Hawksworth 2017, p.36)

Also showing some discrepancy are whether an employer is public or private sector, which unsurprisingly favours job resilience in the public sector where it is more difficult to fire, and whether an employer is large, medium, or small, which is marginal but nonetheless predictable, in that corporates have the resources to buffer and reallocate.

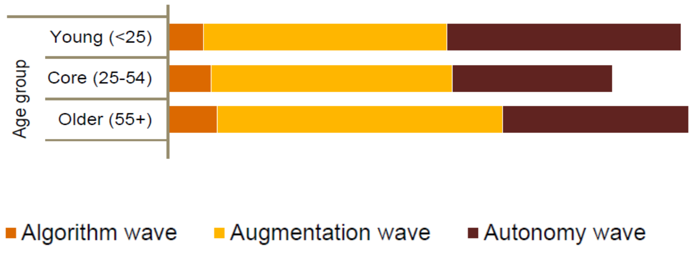
Employer characteristics	Job automation (% at potential high risk)
Public sector	22%
Private sector	34%
Employees:	
<11	30%
11-1000	32%
1000+	24%

Sources: PwC estimates using PIAAC data

(Berriman and Hawksworth 2017, p.36)

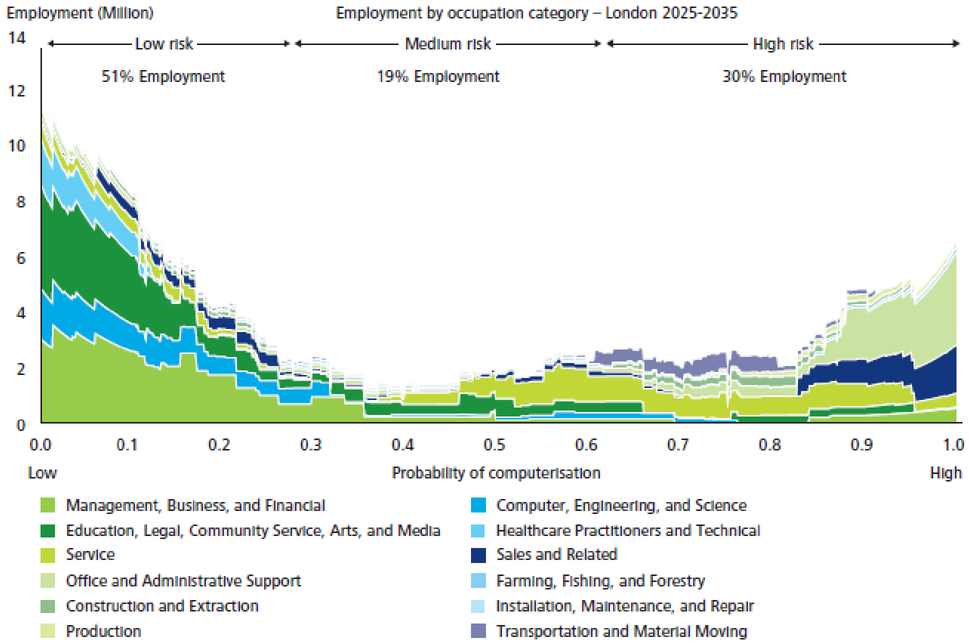
While Berriman and Hawksworth's more recent publication (2018) bore very similar results to the year before (though construction was now qualified as a more pressing high risk), a notable addition to their work, especially in relation to policy formation is the 'wave' conception they produced. From their research they expounded that there would likely be three waves, an algorithmic wave, which we are currently in the middle of, where simple tasks and analyses of structured data are automated, into an augmentation wave, where machines support decision-making and work in tandem with humans in semi-controlled environments, into the third autonomous wave, where there is full automation of physical labour along with manual dexterity and problem-solving in uncontrolled environments. While a timeline is provided over the next 20 in any case, if it is possible to work on the basis of these advances, policy will need to be adaptive and flexible from the beginning so that any long-term plans can be tailored towards the new waves effects.

In their later publication they also predict the impact of automation on age group per wave, where, as may be common, younger and older people will be at greatest risk overall and in relation to high-risk of automation occupations. Education and sex differences were similar to their previous results, and education remained the greatest predictor of risk.



(Berriman and Hawksworth 2018, p.4)

Deloitte's (2015) investigation with Frey and Osborne inspected different angles of the problem from the perspective of the UK, by comparing the UK broadly to its largest employment area, London. Specifically examining the capital, Frey and Osborne found that Londoners have less high risk than the UK overall, and, conversely, that London has a higher low-risk/no-risk than the UK overall. They also found that jobs paying more than £100K are five times less likely to be lost to automation than jobs paying under £30K. For London, this is eight times less likely. The reason proffered for the relatively low number of high risk to automation jobs in London is as a substantial portion of the workforce already occupies high-skill roles not easily replaceable by technology. With regard to London the following graph indicates risk:



(Deloitte UK 2015, p.8)

Once more this broadly complies with other investigations in terms of where the high risk lies, however the employment composition is such in London that it is coincidently not likely to be as heavily affected as UK more generally.

A more curious aspect of this report is how Frey and Osborne and Deloitte's analysts considered the problem in terms of any potential deleterious impact on employment by occupation and rate. Though no clear figures were presented in net gain or loss terms, the tables below which were provided indicated that jobs which had been lost in London and the UK more diffusely over a recent 12 year period were likely at least partially offset by extremely rapidly growing new occupations which were non-existent five years before.

Figure 4. Jobs lost from London, 2001 – 2013

	London		Rest of the UK	
ONS job description	Numbers lost		Numbers lost	
	000s	%	000s	%
Library assistants and clerks	4.7	65	22.0	48
Sales-related occupations	9.1	65	42.2	40
Filing, record assistants and clerks	14.1	58	49.1	30
Travel agents	7.3	56	20.9	44
Counter clerks	15.9	48	91.7	46
PAs and other secretaries	32.9	44	162.6	47
Collectors, sales persons, credit agents	0.8	43	2.1	8
Pensions and insurance clerks	2.9	38	5.3	7
Credit controllers	1.9	33	19.2	37
Accounts wages clerks, bookkeepers	**30.1**	**32**	**109.4**	**23**
Total and weighted average reductions	**119.7**	**43**	**524.5**	**34**

Source: ONS Annual Population Survey, 2014

Figure 5. Fastest-growing job titles – global view

LinkedIn job title	New jobs globally, 2008-13	Growth multiple
IOS developer	12,545	× 142
Android developer	10,501	× 199
Zumba instructor	6,315	× 396
Social media intern	4,325	× 174
Data scientist	4,184	× 30
User interface/user experience designer	3,350	× 22
Big data architect	3,440	× 0
Beach body coach	3,360	× 0
Cloud services specialist	3,119	× 17
Digital marketing specialist	2,720	× 17

Source: LinkedIn Talent Blog, Top 10 Job Titles That Didn't Exist 5 Years ago, Sohan Murthy, Jan 6 2014

(Deloitte UK 2015, p.10, both tables)

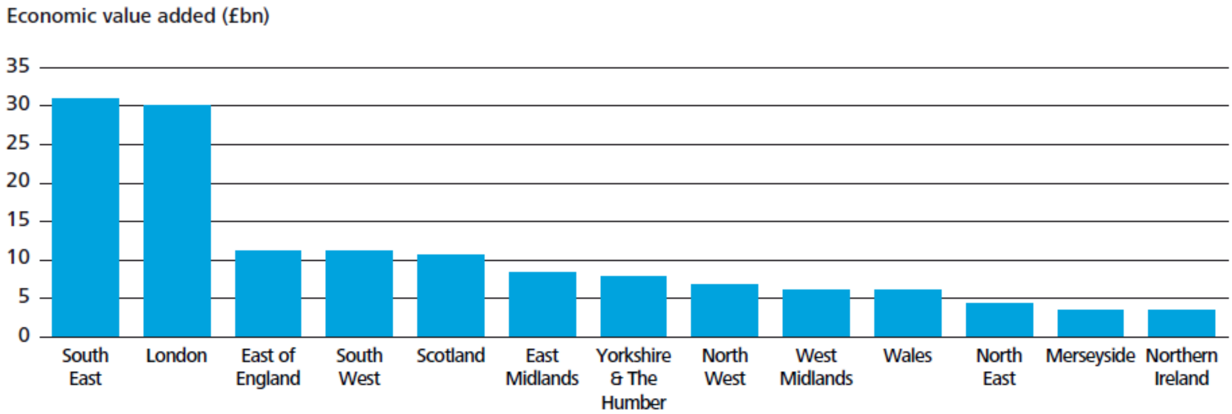
As such conclusions tended towards promotion of greater education, focusing on skills and abilities needed a tech-driven economy, as well as finding ways to retain agility and healthy movement within the employment market.

While Berriman and Hawksworth (2017) likely overestimate the high risk of automation to employment in the UK the areas of exposure are still likely to retain relevance. Their overall estimates claim that 30% of all occupations, or 10.4 million occupations are at high risk. If this figure is extrapolated to the most recent task-based estimates of percentage risk in the UK, of Nedelkoska and Quintini (2018), which estimate 12% overall high risk, then only 4.17 million jobs are at high. Specifically, the areas of Wholesale and retail trade (2.25 million); Manufacturing (1.22 million); Administrative and Support Services (1.09 million); and Transportation and Storage (0.95 million); which, cumulatively comprise more than 50% of the high risk of automation under Berriman and Hawksworth's (2017) estimates, only present a high risk to a total of 2.2 million jobs if applied to the Nedelkoska and Quintini (2018) percentage estimates. This is thus likely circa the population figure for total high risk of automation in the UK, *ceteris paribus.*

Industry	PwC Estimate (2017) of Jobs at High Risk of Automation (millions)	Revised Estimate using Nedelkoska and Quintini (2018) Percentage Estimates as Guidance
Wholesale and Retail Trade	2.25	0.90
Manufacturing	1.22	0.49
Administrative and Support Services	1.09	0.44
Transportation and Storage	0.95	0.38
Professional, Scientific, and Technical	0.78	0.31
Human Health and Social Work	0.73	0.29
Accommodation and Food Services	0.59	0.24
Construction	0.52	0.21
Public Administration and Defence	0.47	0.19
Information and Communications	0.39	0.16
Financial and Insurance	0.35	0.14
Education	0.26	0.10
Arts and Entertainment	0.22	0.09
Other Services	0.17	0.07
Real Estate	0.16	0.06
Water, Sewege, and Waste Management	0.13	0.05
Agriculture, Forestry, and Fishing	0.07	0.03
Electricity and Gas Supply	0.05	0.02
Mining and Quarrying	0.01	0.00
Domestic Personnel and Self-Subsitence	0.01	0.00
Total High Risk of Occupations from Automation in UK Population	10.42	4.17

(Berriman and Hawksworth 2017; Author's Analysis)

Analysis of the specific extent of automation on the UK's economy primarily points to its resistance in face of automation, especially in London but also generally. This can be indicated by low figures such as the 10% risk of high automation for the UK presented by Arntz, Gregory, and Zierahn (2016) or 12% high risk indicated by Nedelkoska and Quintini (2018), or in the representation of the UK in studies of the risks in Europe relative to other states, such as Bowles (2014), where the UK is positioned as one of the workforces least threatened by automation. Deloitte's work with Frey and Osborne (Deloitte 2015) pointed to resistances seen in education and its further work has since highlighted that every region in the UK from the period of 2001 – 2015 actually benefitted economically from the application of technology to work, clarifying that while some regions have noticed a decline in high-risk of automation, highly routine jobs, that this has been offset by creation of higher skill, non-routine occupations which have added, in sum, 140 billion to the economy in new wages.



Source: Frey and Osborne, ONS, Deloitte analysis 2015

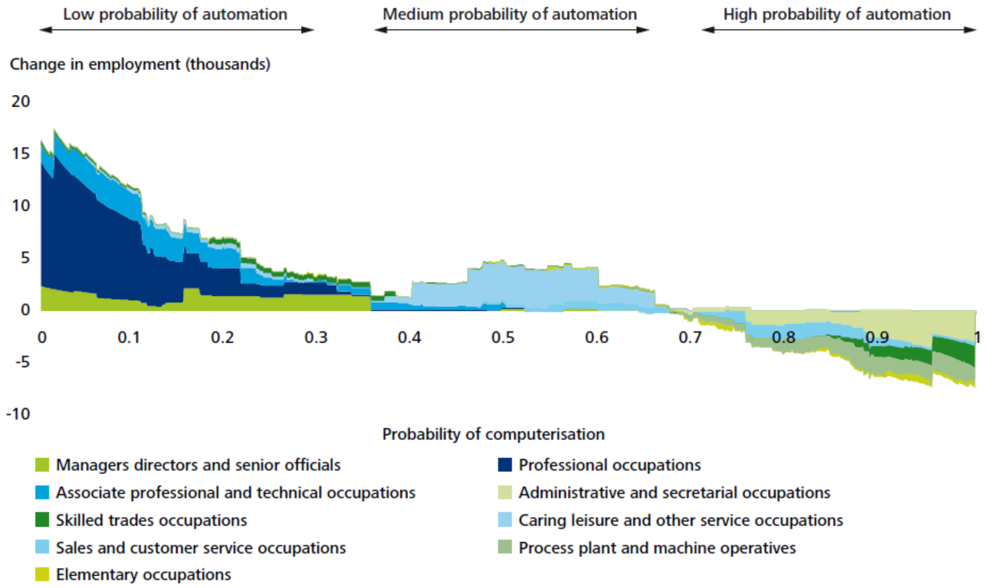
(Deloitte 2015, p.4)

In this same period a shift has occurred from low skilled to high skilled work, where growth has been seen in professional and management occupations and others associated with low risk of automation whereas jobs have been lost in elementary occupations and factory work, but with an overall ratio of four jobs created to one lost in this period.

Region	Increase in high skill jobs	Increase in medium skill jobs	Increase in low skill jobs	Net job creation	Economic value added (£bn)
South East	47%	28%	-3%	845,000	31
London	41%	42%	1%	870,000	30
East of England	29%	22%	-9%	306,000	11
South West	19%	8%	-21%	256,000	11
Scotland	31%	21%	-4%	317,000	11
East Midlands	35%	22%	-11%	221,000	8
Yorkshire and Humber	30%	22%	-11%	214,000	8
North West	24%	16%	-12%	152,000	7
West Midlands	24%	23%	-14%	152,000	6
Wales	31%	29%	0.1%	221,000	6
North East	27%	26%	-6%	131,000	4
Merseyside	48%	32%	6%	127,000	3
Northern Ireland	8%	5%	-9%	135,000	3

Source: Frey and Osborne, ONS, Deloitte analysis 2016

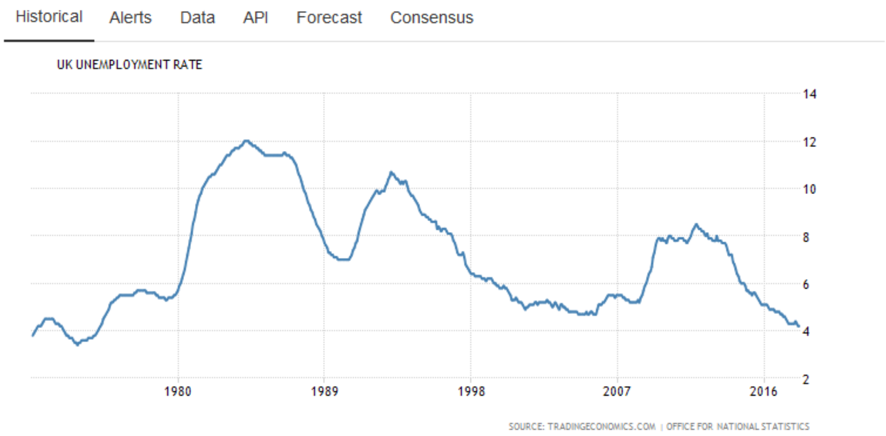
(Deloitte 2016a, p.17)



Note: The area under all curves (sum of employment in each probability bin) is equal to the total change in employment.
Source: Frey and Osborne, ONS, Deloitte analysis 2015

(Deloitte 2016b, p.3)

Overall, employment figures in the UK highlight that this has led to an unemployment rate which is lower than the early 2000s, standing at a rate of 4.2% by March 2018, which is also lower than its 42 year average of 7.05%.



(Trading Economics and UK Office for National Statistics 2018)

2.4 Assessing Policy Responses to Automation

Insofar as any conclusion tending towards the task-based approach implicates policy strategy, the relatively low risk of automation across countries explored suggests that radical alternatives to social welfare, at least to the extent that the options would be considered in direct relation to automation, are not required in the short-term. Specifically in relation to policy options originally mentioned in this paper, UBI and large scale government job guarantee programmes, which would require almost overhauling the tax or public employment systems, respectively, would therefore be considered an immediately unnecessary solution. For separate reasons, a robot tax would be insufficient in light of theoretical concerns. As robots will not replace humans universally and the progression will be gradual, on a task-by-task basis with humans potentially relocating to other parts of the company, it would be difficult to identify when it has become appropriate to tax the related task automations which makes up an occupation and ensure that taxes are introduced at such a point. The most reasonable alternatives in this case therefore are educational reskilling and acquisition programmes and, to a lesser degree, a negative income tax. However, while these will be perused in this paper, especially in relation to the UK in some detail, the others will not be disregarded as part of the research.

The reason for this is threefold. One is that the 'jury is still out' on which approach is more pertinent to objectivity between the occupation-based and task-based approach, and as such, it is in line with the current *status quo* to present at least a single most-viable solution in either case. Two it that, while in the short-term automation might be difficult to establish for certain tasks and there may be issues of heterogeneity which ensures employee retention, that it is still the case that difficult tasks will be automated over time and heterogeneity might be accounted for in applications or packages which replace certain occupations over time, and in such a scenario, these other more radical measures may become final-hope solutions and necessary. A third is that, should technological progression outpace the ability to create new occupations then education might not readily provide the correct or fitting knowledge immediately to address the new technology due to asymmetrical understandings between avant-garde technology AI experts and educational professors and lecturers. In such a case other means than education would be needed as temporary solutions while technology providers and government figure out the skills needed, how to fund, and how to deliver the requisite programmes.

As can be observed from the literature review, there is negative correlation between education and job loss from automation on a national level (Bowles 2014; Frey and Osborne 2013; Lee

2017; Pajarinen, Rouvinen and Ekeland 2015). It is in this vein that proposals over lifelong learning gained popularity, as, since greater education generally leads to less risk of unemployment in relation to automation, then continued access to education ought to provide reasonable opportunities to people not to slip through the net, even if their basic education is no longer valuable in the job market. Lifelong learning reflects a future where the knowledge a worker should have in professional life will change and adapt over the course of a career (Vamos 2014). Yet, the question remains of how to integrate such a needed development on a policy level. An exciting opportunity for governments is to work with Massive Online Open Courses (MOOCs) providers to develop and deliver courses needed to mitigate potential employment threats in future and even to develop their own platforms (Belleflamme and Jacqmin 2016), and provide opportunity so that lifelong learning objectives may be met. MOOCs are a relatively new phenomenon, since 2008 (Zawacki-Richter et al. 2018), and, while in this short time they have been endorsed by political leaders such as Obama (2013) who commended Carnegie Mellon, Arizona State, and Georgia Tech for their efforts in this area, more needs to be done on the side of governments in high tech economies to ensure that access and recognisability of these courses are realised, and to ensure that enough courses which are directed towards ends that the government need to be addressed are provided.

The formal recognition of Massive Online Open Courses (MOOCs), at least in public sector employment competitions, and working with universities and providers to accredit appropriate courses currently available, especially in relation to IT, which reach an appropriate academic level, might be a fairly non-invasive way to stimulate interest and begin precluding the worst potential effects of automation in high tech economies where there is a high penetration of internet access. Belleflamme and Jacqmin (2016) here note the need for quality assurance agencies to work on both governmental and MOOC providers sides to encourage teaching innovations by way of accreditation. Further investment in funding specifically new IT related programmes in the university system, and ensuring skilled teachers are available in a secondary school system which actually provides computer science courses in every school, are further steps in the right direction. An example of a successfully heavily subsidised education system in terms of promoting directed economic outcomes by way of fully funded IT courses is Ireland. Since 2011 Ireland's government and the European Social Fund have jointly sponsored full scholarships to a range of IT programmes (and others with targeted economic benefit) aimed at conversion students and the unemployed, using its Higher Education Authority government body to work directly with various colleges and providers to ensure skills appropriate to its heavily tech-oriented economy are produced nationally (Department of Education and Skills Ireland 2018). Moreover, there is accordance across types of theory that creativity and emotional intelligence are human factors resistant to automation (Arntz, Gregory, and Zierahn 2016; Frey and Osborne 2013). To address this point Altass and Wiebe (2017) in their article about re-imagining education policy and practice in the tech era posit that the focus for educational policy should therefore be to move away from "individual content knowledge" (p.55) and environments where students are discouraged to fail, alongside standardised testing, to a digital learning portfolio model, where a holistic, manifold, and pragmatic approach is taken to assessing learning both on cognitive and emotional levels in an environment which encourages innovation, collaboration, and critical thinking. While alternative modes of providing clearly needed educational courses are incumbent on the government on one side, future considerations about the nature of skillsets which are, and will be, increasingly useful more broadly need to also be integrated. However, the latter may be a longer term plan, as it involves a greater review and overhaul of the pedagogical system on every level.

Complementary to such educational reform to satiate high-risk or would-be high-risk employment occupants with means to manage might be a negative income tax. Benefits of such a tax are that it lowers levels of inequality (Amine and Dos Santos 2013) as well as both relative and absolute poverty (Angyridis and Thompson 2016). Further, it redeems a central economic liberal desire for markets enabling cooperation without coercion in a system which would be somewhat addressing economic dependence (Preiss 2015). However, such benefits are counterbalanced by a significant reduction in output (Angyridis and Thompson 2016), and more precisely in relation to automation-related effects, negative income tax neither fully compensates for heavy job losses, in the worst case scenarios, nor in by its own nature ameliorates the position of high-risk or would-be high-risk employment occupants in relation to the fact or constituent components of automation in terms of employment retention or obtention. As such the negative income proposition would need to be considered as a concomitant measure to educational reforms or to more sweeping social welfare reforms, as per eventual necessity for change, rather than the main politico-economic resort. Otherwise, it may act as an interim solution, retaining a basic level of living while other programmes are developed.

Of the measures more aptly suited to heavier job loss, as predicted by the occupation-based theories of automation, where educational approaches or the limited effects of negative income tax will not suffice as the situation would be virtually systematic with regard to progressively lost employment affecting large swathes of the economy, such that could not be readily or likely even in the medium term be remedied by the education system or negative income taxes alone, there are three main options generally forwarded, namely: Universal Basic Income, Robot Tax, and Government Job Guarantees.

In Martin van Raay's (2015) article "Robots are all tax avoiders" he poses the question of, when tax-paying taxi drivers are replaced by autonomous taxi services vehicles, who will pay the unemployment benefit of the original human driver, since robots don't pay taxes? While a valuable question of where money comes from for unemployment benefits, and how it should be drawn, it is not self-evident that robot tax is the answer. Similarly, though robot tax is a catchy political soundbite phrase, this taxation has some debilitating restrictions. Questions which would need to be asked in this regard is at what point ought automative processes to be taxed, to what extent, and how to define such taxation. For example, if a programmer finds out how to automation one task of an employee's day, should this be taxed, and how, i.e. how to impute income based on robot activities (Oberson 2017)? How can this be qualified in terms of amount of tax? This is related to how robots are legally defined for the purposes of potential taxation is still inconclusive, whereby a clear definition may eventually be based on AI and degree of autonomy measures (Oberson 2017). Other aspects of taxing robots are also difficult, such as, in order to tax appropriately, should robots be granted a "legal personality", which generally refers to "an entity that can own property in its own name, that can sue or be sued and that may also enter into contractual relationships" (Oberson 2017, p. 251) which opens up a welter of potential secondary legal issues. Additionally there are remaining questions over how the robot tax may be used, e.g. as insurance / support for an employee whose job may be automated / at risk of automation, as a reduction in corporation tax relief benefits for automation machinery, or for funds to public coffers to reskill workers whose occupations are lost to automation (Kim 2018)? While there are a number of legal and practical obstacles to robot tax which are not as readily apparent in other options perhaps the most convincing in the longer term for why robot tax may not be an appropriate solution to automation's effect on employment is that the successful implementation of robot tax is requires simultaneous implementation in numerous countries or regions as otherwise capital flight may occur, where organisations impacted just move from one jurisdiction to another in which there is no robot tax otherwise (Gasteiger and Prettner 2017). This means international cooperation is implied for any specific single economy considering this option in the case of heavy automation, such that could likely not be obtained in the face of current market practices.

The remaining options in the face of heavy job loss therefore are Universal Basic Income (UBI) and government job guarantees. While Tcherneva (2012) argues against the viewpoint of UBI proponents who claim that basic income is adjusting for a society in which employment is basically unjust and punishing, and which needs to be escaped from, she notes that UBI will lead to a race-to-the-bottom situation for the workforce in which those who do not want to are not obliged to work. Most convincingly, she notes that there is a fundamental tension between the way income is generated and how basic income wishes to distribute it, which will negative impact the income generation process and thus the destabilising implications of implementing basic income practices are not worth it. She contends that job guarantees conversely have a stabilising effect by ensuring work towards public ends for all who desire it as part of a fully employed economy. Harvey (2012) also argues that UBI would be more costly and less effective than a job guarantee. UBI would involve funding everyone, even the wealthy, whereas job guarantee only those who need the work. However, job guarantees nonetheless still have the propensity to run up high budgets in times of substantial unemployment, which will only come down when unemployment reaches normal levels (Tymoigne 2014). While such guarantee policy of employment represents a commitment by those governments undertaking it to guarantee that anyone desirous and capable of working will be given a job at least at minimum wage (Hopkins 2015), in practice this may mean a bloated public sector, which can lead to corruption by state officials in terms of getting such jobs (such as that which led to significant problems in the Greek economy, see Kovras and Loizides 2014 for details). There are also concerns over innovation when considering this approach. The expression "necessity is the mother of invention" emanates from the notion that certain needs lead to creative and innovative production, the type of which is most needed in the technologically advanced world of today; however, if this need is taken from people by facilitating jobs for everyone, many of which jobs might otherwise be redundant, it might hinder this innovation and in its place useless output might be the outcome.

Job creation by government as a method of job guarantee, which is the most verifiable and strict method of ensuring the jobs actually are created from the government's point of view (as opposed to working with private sector on initiatives), runs counterproductively as regards free market principles and indeed contrary to its basic philosophical premises of freedom of state authority (Humboldt 1993), as this method of job creation concentrates general daily control and therefore power over the activities of people's lives in the hands of the state. Indeed, it is such notions which inspire prominent figures in the area of UBI such as Van Parijs (2006) and Ackerman and Alstott (2006), which are proponents of the simple principle that the emancipation of the ability to achieve social justice can be obtained most effectively by means of financial deposits but in disagreement with regard to the approach with which to best structure these deposits. Van Parijs' (2006) thesis is essentially that meaningless work is degrading and the necessity to work should not be mandatory to survival, not least as forcing people to take unwanted jobs is sub-optimal in terms of productivity and has negative consequences both for employer and employee. His main idea is that redistribution towards the public could occur by way of monthly payments irrespective of salary by redistribution of current governmental spending.

Ackerman and Alstott (2006) believe that the most socially just and unbound manner to provide universal income, which encompasses both liberty and equality, is through one-time stakeholder payments. They argue that through an initial 2% income tax on those earning over $230,000 in the US that a one-off payment of $80,000 would be feasible to each individual at the suggested age of 21, and that only 20% of the population would bear any cost of the first provision. Thereafter they discuss another means of provision based on successes of the initial cohorts of the scheme and how they would be obliged to contribute their financial rewards to future generations. Ackerman and Alstott's general thesis is that this stakeholder method is the most unrestrictive and fair way of providing a truly liberal (as it allows people to make their own choices) yet equal (as it would be applicable to the entire nation and not means tested for recipient nor favour already rich or poor) starting point in life.

Others predict UBI as an inevitability Levin-Waldman (2018) in the face of technological advances and to maintain capitalist markets, and UBI's politically ambivalent nature is praised (i.e. supported by both left and right) in relation to its possibility for mobilisation (Battistoni 2017; Levin-Waldman 2018). Still, the simple argument of Tcherneva (2012) is difficult to remove from this argument, that there of an inherent tension between how income is generated and basic income wishes to distribute it, or, as Flassbeck (2017) puts it, it is impossible to divorce income from production and retain a system reflecting anything similar to the current capitalist model. He also mentions inflationary effects. An example of this is where everyone in the economy has a predictable amount of extra money universally, there is nothing to stop shopkeepers by increasing their prices 1% or whatever the amount may be to match the additional income. Other points of difficulty in establishing UBI involve disregard for unpleasant but necessary work, it is difficult to see why anyone would ever choose to take up menial labour, and elements of moral hazard associated with unearned money. Finally, it is questionable how to finance UBI. In some instances financing basic income would require doubling tax rates which would lead to a distributive struggle such as one which might have never before been seen (Flassbeck 2017). Calls for using funding that would alternatively be used for quantitative easing, such as Guy Standing's proposal (World Economic Forum 2017), are similarly misguided due to adverse economic effects.

As such, government job guarantees, while not ideal from an economic or social liberal perspective, nonetheless perhaps constitute the most prudent means of addressing worker displacement in face of automation that is available as an alternative in the case of significant progressive encroachment due to technological advances, while educational policy reforms act as the best recommendation as a preclusive measure in the instance of less severe job loss. Indeed, educational reforms can be instigated in the short run as government job guarantees begin to be developed, financing allowed, or the two programmes could run simultaneously to different degrees, as per the extent of need for one or the other in practice.

3. Research Methodology

According to Gerring (2008) a case study is a form of analysis in which one or more cases are examined which are expected to provide insight into a larger population. He notes that there are a number of techniques for case selection: Typical Case; Diverse Case; Extreme Case; Deviant Case; Influential Case; Crucial Case; Pathway Case; Most-Similar Case; and Most-Different Case selection. To contextualise the literature review in a way in which in-depth information is determined on the effects, consequences, and potential solutions of the impact of automation on employment in a practical setting yet retain broadly relatable and generalizable findings a "Typical Case" case study approach will be chosen for this paper. Reasons for the suitability of this approach relative to the others mentioned is that there are a cohort of advanced economies undergoing new types of automation, and, while deeper exploration of one indicates more precisely specific issues occurring and measures which may be taken, nonetheless globalisation leads to interconnected technology which ought to progress at fairly similar rates across nations with advanced technological infrastructures and as such there are arguably no strikingly diverse, extreme, crucial, or wildly deviant cases at a national level. Similarly, as automation functions the same way universally, the same industries should be affected to a somewhat tantamount degree.

Evidence for such positions can be partially inferred by studies specifically studying advanced economy outcomes, such as Bowles (2014) looking at Europe and predicting high risk of automation between all countries at a relatively low deviation between 46% - 62% of high risk, or even from Nedelkoska and Quintini's (2018) where the advanced economy component of their OECD study similarly was somewhat constrained in terms of range of high-risk, and by comparing the industries and types of jobs affected most heavily which again have overlapping results (e.g. Frey and Osborne's general results mirror Brzeski and Burk's, Haldane's, and Lee's). Most-similar or most-different cases were considered among the options as it would be interesting to discover why for example the US might have different outcomes to the UK despite similar economic orientations and infrastructural capacities, or why there might be similar outcomes for Ireland and Sweden, despite different economic and social backgrounds. However, once again the differences in terms of extent and effect of automation do not justify such studies and furthermore approaches may say more about the countries in question than the overall *status quo* of advanced economies under consideration. Influential cases, ones which attempt to show that deviant cases are not really deviant, or do not challenge the core of the theory might be more valuable in this field as it stands, however, the level of speculation and contingency is such that any number of external factors could be influencing the rates of change and the premises even hugely skew the results so this method may not be reliable. Finally, the pathway case selection where the causal effect of X_1 on Y can be isolated from other confounding factors (X_2) is unviable for the same reason.

To elect which case to choose as typical then this study will select a single nation which will be as representative as possible of advanced economies. To ensure that the economy is both advanced and has a large enough population for the propensity of as rich as possible a research industry, a G7 country will be selected. G7 countries represent the largest advanced economies in the world (IMF 2018). The seven countries in this group are Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States (IMF 2018). Of these economies, a number have had independent studies assessing the extent of potential risk due to automation on the labour force, the results of which have been indicated in the literature review, namely, the US, the UK, Germany, and Japan. Of these areas where more research has been conducted into the area of interest to this paper, i.e. the extent of automation, the UK stands out as the most representative option for case study in relation to the task-based approach's results, the approach which seems the most rigorous. This is as the UK best represents the overall figure for high risk on the basis of combining the results from Arntz, Gregory, and Zierahn (2016) and Nedelkoska and Quintini (2018). Arntz, Gregory, and Zierahn (2016) attribute a 10% of high risk of job automation to the UK, with an overall high risk for all countries examined at 9%. Nedelkoska and Quintini (2018) attribute a 12% of high risk of job automation to the UK, with an overall high risk for all countries examined at 14%. In these estimates the US and German figures tends to be too far above the overall high risk figures, and Japan's results mixed / too different from each other. Concomitantly, the UK is representative of areas of risk, as based on drawings from the literature review – transportation and logistics, office and administrative, and production / manufacturing, alongside services, sales, and construction (Berriman and Hawksworth 2017). Conversely it is a typical case in the sense that its management, professional, education, creative, and jobs requiring excellent social skills or creativity are at fairly low risk (Berriman and Hawksworth 2017).

In Gerring (2006) he reviews the term "case study" per se, noting that it is notoriously difficult to define. He explains that definition as a "case study" might mean (verbatim from text, p.17; references also from original text indicating where definitions came from):

"that its method is qualitative, small-N (according to Eckstein 1975; George and Bennett 2005; Lijphart 1975; Orum, Feagin, and Sjoberg 1991; Van Evera 1997; Yin 1994; that the research is holistic, thick (a more or less comprehensive examination of a phenomenon) (Goode and Hart 1952; Queen 1928; Ragin 1987, 1997; Stoecker 1991; Verschuren 2001); that it utilizes a particular type of evidence (e.g., ethnographic, clinical, nonexperimental, non-survey-based, participant-observation, process-tracing, historical, textual, or field research) (George and Bennett 2005; Hamel 1993; Hammersley and Gomm 2000; Yin 1994); that its method of evidence gathering is naturalistic (a "real-life context") (Yin 2003; that the topic is diffuse (case and context are difficult to distinguish) (Yin 1994, p.123); that it employs triangulation ("multiple sources of evidence") (Yin 1994, p.123); that the research investigates the properties of a single observation, (Campbell and Stanley 1963; Eckstein 1975); that the research investigates the properties of a single phenomenon, instance, or example. (This is probably the most common understanding of the term. George and Bennett (2005, p.17), for example, define a case as “an instance of a class of events.” (Note that elsewhere in the same chapter they infer that the analysis of that instance will be small-N, i.e. qualitative. See also Odell (2001, p.162) and Thies (2002 p.353)”.

In this research the case study will be taken to mean the most common understanding of the term, i.e. that the research examines properties of a single example, however the case study fits other definitions, in that it will also be holistic / thick, qualitative / small-N, and will employ some measure of triangulation. The case study will use the UK as the single example for which to investigate relevant properties of the effects of automation by sector and demographic, potential labour market consequences, and applicability of various policies. It will holistically review such material in a qualitative fashion using multiple sources to corroborate evidence.

4. Analysis

4.1 Effects of Automation in the UK and its Labour Market Consequences

As previously noted any attempt to produce exact results enumerating the impact of automation on occupational populations on a grand scale is subject to the whim of the theory and techniques used and contingent on speculative factors in producing results. In the instance of the UK estimates range from 10% (Arntz, Gregory, and Zierahn 2016) to 47% (Bowles 2014). However, studies based on the UK provide some interesting insights which have further theoretical implications about what is the best way to determine the risk of automation generally. For example, Deloitte (2015) discuss the mitigating effects of the industrial and highly concentrated capitalist nature of cities, where London is more sheltered from automative processes in terms of employment than the rest of the UK. This approach raises the question of whether it is more worthwhile to explore the risk of automation between say, the UK and Germany, or to explore the risk profiles between Manchester and Berlin. Furthermore the Deloitte / Frey and Osborne (2016b) study highlights quite starkly the alleviative properties of job creation in the face of job loss historically, as related to all factors including technological progression, noting that in no region in the UK over the 2001-2015 area was job loss greater than job creation, with losses in low skill jobs generally occurring simultaneously with gains in medium and high skill. This raises another question of, even if there can be concluded predicted value of assessing job loss related to automation, is there worth, or what is the worth, in studying it independently of job creation likelihood in relation to technology or otherwise? In this case of the UK it is also found that over the same period of 2001-2015 while automation displaced workers, over £140 billion was added to the economy in new wages (Deloitte 2016a) and unemployment from the period of the early 1970s to the present day is roughly the same (circa 4.2%) (TradingEconomics 2018). Wage gains were not distributed equally, as London and the South East bore the greatest gains, each more than six times that of Northern Ireland and around five times that of Wales. While this inherently indicates international components as well as regional, such results provide reasonable bases for considering the risk and outcomes of automation on area-specific grounds, perhaps comparing areas on the basis population size, or a composite of population plus educational attainment and wages, for example. Other ways to segment research might include the extent of public sector vs private sector work in the region, which was also indicated in a UK study (Berriman and Hawksworth 2018) to hold for the UK, however, it must be carefully reviewed internationally as different public sectors have labour laws more protective of employment than others.

As per literature review, it is likely that while Berriman and Hawksworth's study (2017) overestimate the risk of automation to employment in the UK and figures are not well triangulated, the areas of exposure nonetheless are in fact agreed upon in UK-focused literature and applying the task-based results to employment figures can derive workable results for the purposes of analysis. For example, Berriman and Hawksworth claim that 30% of all occupations, or 10.4 million occupations, are at high risk. Using task-based estimates of percentage risk in the UK (Nedelkoska and Quintini 2018), which estimate 12% overall high risk, then only 4.17 million jobs are under heavy exposure. Specifically, the areas of Wholesale and retail trade (2.25 million); Manufacturing (1.22 million); Administrative and Support Services (1.09 million); and Transportation and Storage (0.95 million); comprising more than half of the high risk areas of automation under Berriman and Hawksworth's (2017) estimates, only present a high risk to a total of 2.2 million jobs in the whole of the UK if applied to the Nedelkoska and Quintini (2018) percentage estimates.

Principally, what this research indicates for the UK and more broadly generalised for other advanced nations is that the risk of automation is reasonably low, and that in addition to threats in industries listed in the literature review which primarily contain routine and non-social tasks, that a severe indicator of risk is region and concentration of industry.

The most frequently cited variables which are posited to influence outcomes primarily hold internationally when considering why the UK is different or comparable to other nations. For example, the figures for Frey and Osborne (2013), Brzeski and Burk (2015), Pajarinen, Rouvinen and Ekeland (2015), and Haldane (2015) which all discuss the key correlations between wage/education and risk of job automation as per Frey and Osborne (2013) generally hold in international terms for education given the figures predicted. According to the OECD, the United States has around the same number of graduates from third level (45.6% of 25-64 year olds) as Finland (44.3%), Norway (43%), and UK (46%), while Germany (28.3%) has substantially less ($OECD_1$ 2018). Given the basic equation of education vs automation which is perhaps the most dominant one in the literature, the outcome might be suspected to be, *ceteris paribus*, that the risk of automation among all countries inspected apart from Germany is reasonably similar, as per educational attainment. This is mostly the case, where in Germany Brzeski and Burk (2015) have predicted that over 50% of occupations are at high risk of automation, whereas in the other European countries the average figure is in 34% for the other studies. The US is an outlier where education seemingly did not play a particular role in reducing job risk relative to international counterparts, though its geographical and cultural removal from the other countries might play a part in explaining this.

Wage figures correlated to automation provides a less predictable story, *ceteris paribus*. The US has an average wage of circa $60K per capita, while the Norway has around $54K, and Finland, Germany, and the UK are all between $42-47K ($OECD_2$ 2018). This would suggest that, if the logic of wages negative correlation to risk of job automation is conceived internationally and has a truly eminent role to play in this outcome, that the US and to a slightly lesser extent Norway ought to be less at risk from the effects of automation than their European counterparts, while Finland, Germany, and the UK should have similar risk profiles. However, while Norway has a low risk profile, this is in line with Finland and the UK. Furthermore, Germany has a high risk profile, as does the US, which, given the wage model ought to be the most protected. However, Germany's profile might be more influenced by the composition of its labour force, which will be discussed in the next paragraph, than its wages, and the US, as per the previous paragraph might expect differing outcomes due to its geographical and cultural removal from the other countries.

Other factors considered to mitigate against automation in terms of employment appear more universally correct, *ceteris paribus*: for example working in the public sector vs the private, and in private services vs manufacturing. Relative to the question of private services vs manufacturing, this premise seems to indicate in line with the theory to a strong degree. Germany has the highest level of manufacturing and lowest level of services compared with the UK, US, Norway, and Finland (Germany has 27% working population in manufacturing; 72% in services) and this is reflected in its corroborated reports of highest risk in the literature (ILO 2017). The others have fairly similar levels of manufacturing and services compositions to one another, but as such, the US remains an outsider in terms of risk, which is substantially higher than the others as per the literature reviewed (ILO 2017). This risk profile generally makes sense in light of the agreement across the literature that routine tasks are at highest risk of automation and manufacturing historically has involved more routine tasks than service occupations.

In terms of public sector vs private, the effects are also mostly correct. Norway has a higher level of public sector employment (circa 35%) than the UK (24%) and Finland (25%), which have more in turn than the US (15%) and Germany (12%), which have more again than Japan (8%) (Brock 2001; OECD 2016; 2017). Norway, the UK, and Finland‘s risk figures of automation displacing workers are virtually the same in the literature, and the US figures are comparable to Germany and Japan in terms of risk, with the latter three, with lower levels of public sector employment, at higher risk. Thus, while the literature was correct in this area also, *ceteris paribus.*

Taken in sum, education; wages; services sector ratio relative to manufacturing; and public sector labour force percent; have mostly expected effects when viewed internationally, as per the literature‘s predicted overall outcomes, and thus generally account for differences in outcomes between advanced nations including the UK (which has other drivers such as region and population density looked at which also account for risk).

However, as the risk of automation is based on very liberal or commodious definitions, inclusive of everything that is technically automatable (as emanating from the occupation-based approach) rather than able to be automated in spite of significant engineering problems, it is nonetheless likely that while such variables indicate the UK’s relative security regarding the risk of automation, due to a highly educated and fairly well paid, services-oriented economy, with a public sector comprising nearly a quarter of the overall workforce, as the variables apply to full occupations rather than specific tasks the level of risk is still substantially overestimated in the occupation-based literature.

4.2 Applicability of Policies to the UK

Given the historical preponderance of job creation relative to job loss from automation in the UK, additional mitigating factors such as high level of education and historically rising wages in tandem with technological progression, and the likelihood of overstatement of risk of automation in the UK in displacing workers based on theory, certainly policy need not tend towards radical, redistribution notions as per the *status quo* of the employment environment in the UK. Thus, proposals such as UBI and robot tax, both of which are difficult to implement and devise, certainly need not be enshrined in policy. Further, government job guarantees, which implicates government in the economic process to a far larger degree than is currently the case in the UK, are also unnecessary, especially in light of job creation elucidated in the Deloitte (2016a) report. Negative income tax, to the extent that it might be considered, need not be in relation to automation, again in light of Deloitte's conclusions. The most viable and worthwhile solution, in the current moment, is therefore education, ensuring that skills needed in the fast-paced technology environment are affordable and readily learnable, by institutions and means set up for the purposes of ensuring agility and employability in a progressively technologically advanced environment.

Some major chronic concerns have since been initially addressed by the UK annual budget in November 2017 (HM Treasury 2017) where £75 million was allotted to AI, including the sponsorship of 450 new PhD fellowships in AI programmes initially, and of the number of trained computer science teachers to be increased to upskill 8000 by the end of Parliament including ensuring at least one teacher for every school at GCSE (mid-second level exams) level. Shortly afterwards the government published a report called “Industrial Strategy: Building a Britain fit for the future” (Clark 2017). In it, some of the concerns over potential job loss were addressed, such as helping adults to reskill and upskill with a focus on digital skills. Further to this £30 million was set aside for the purposes of testing the use of AI and novel education technology (edtech) in online digital skills courses in an inchoate plan called the National Retraining Scheme (NRS).

Further to this, a high level group, the National Retraining Partnership will be established which will comprise government, businesses, and workers (by way of the Trade Union Congress), to set the strategic direction and oversee implementation of the scheme. The National Retraining Scheme has yet to be codified in documentation of details. Some this year, such as the Campaign for Learning, an independent charity which works for socio-economic inclusion via education, and NCFE, an educational charity which develops nationally recognised qualifications and awards have made early attempts to influence the agenda and content of the scheme. The paper the aforementioned groups devised (Pember 2018) raises an interesting question – whether the NRS will be employer led or adult led – which is currently unclear. It suggests that the only appropriate manner to formulate the NRS is in an adult led way, as this is the only way to account for people outside of the workforce, on contract, agency staff, self-employed etc. However, it would seem that there are issues with adult led also, namely, how to transfer the information about what skills are needed in rapidly more tech-savvy and automated economy to them, and moreover, how to predict industries which are least likely for automation. Further this question does not address the employer led aspect fully – employers may not actually mind losing employees should automation do the job more efficiency and rapidly – economically it would make sense in such an environment not to retrain employees but to let them go.

The prescriptions advocated are to bring educational institutes into the decision-making process for the NRS; to review lessons from the past in advance; to clearly define roles of each stakeholder; to provide credited and commercial credits or units in addition to full qualifications to meet market needs; to ensure service for those not in employment under an employer or otherwise unemployed; for the Department of Education to publish a lifelong learning strategy; and for new avenues of funding and maintenance to be allocated. As with any proposal of this sort there will be debate over particular allocations and lobbying for different groups. However, taking a step back, there may be an alternative way of thinking about how to best solve this policy issue.

An alternative approach to shaping the retraining scheme is, rather than simply reviewing lessons, integrated partners, adding credited non-degree awards, etc. in a fairly haphazard and inductive way, to instead use the reports that have been received on job automation and the likely significant losses based on technological progression to shape the scheme in a way which accounts for these already identified specific high risk areas. Specifically, this could involve looking at wholesale and retail trade, manufacturing, transport, and administrative and support services to begin with, and analysing where losses in these industries are most likely to occur and where, should these losses occur, are the most fruitful avenues to turn to either based on the potential for new jobs in the area or based on the overall transferability of some of the worker's skills into another realm with marginal upskilling.

Following the same logic, those involved in the process should be specific actors who are aware of trends in the area and are technically equipped to provide clairvoyant progressive solutions – this may involve a mix of technologists in the areas of automation and IoT, business leaders in consulting and in specifically threatened industries, labour economists, and educators specifically working in areas with the chances of being most affected.

The question of whether the scheme should be employer or adult led is a false dichotomy in the sense that, as mentioned, employers are primarily concerned with profit seeking, and given this purpose, will seek what is best to maximise profit *per se* which is a different mandate than what this scheme proposes. Granted, employers should be included in the process and help to guide the education to be provided that is useful for industry, but this should not lead the whole process. Similarly, an adult led scheme is unlikely to be an optimum output, as adults may naturally gravitate towards that which is easy or interesting for them, and this might lead to more educational availability in areas not under threat or useful for industry and the money would be relatively functionless. The best option appears to rather be a government led scheme, where the government uses its relevant departments to understand the overall nature of the problem given the information it has received so far and further information it may receive from the various actors that ought to be involved, and thereafter work in tandem with educational facilities and organisations to provide options which are tailored to minimising the impact of technological progress on the professional lives of citizens.

Analysing further the results of literature proposed in this paper, focusing on areas outside London, and especially the areas where economic progress has least occurred as a consequence of technological progression, such as in Northern Ireland, Merseyside, Northeast, and Wales, would help to support the most vulnerable, while assessing the need for intervention due to risk in areas with middling economic progression in line with technological progression, such as West Midlands, Northwest, Yorkshire and the Humber, and East Midlands. Further to those in the sectors mentioned, those in lowest wage, lowest education, and most routine work should be weighted and triaged for re-skilling targeting through advertisements and material highlighting risks. The edtech in online digital skills proposal from the budget needs to be organised in such a way that the courses are accessible to all, and that they lead to qualifications that will at least be recognised for interviewing and employment purposes in the public sector, and work to have them integrated into the accreditation system of higher education, delivered by way of MOOCs or otherwise.

There should be a priority of attention dedicated to younger than 25 and older than 55 year old workers, who will be most affected in the coming years by automation. Further, there needs to be more attention from the government in working with private industry, as this will be more heavily impacted than public. To address the younger than 25 there needs to be funding not just to ensure that there is a computer science teacher for every school up to GCSE level (mid-high school exam levels), but all the way to the end of high school. This is imperative to equip teenagers and young adults with the skillset they need to adapt to the future of technology. For those older than 55, they need to be targeted in a compassionate, communal way, so that engagement in the process of learning new technologies is not daunting or overwhelming, including the setting up of community learning centres for tech in less tech-savvy areas of the UK, such as smaller cities and possibly towns. While there are more men at risk than women further investigation needs to be undertaken by the government to understand if this is a consequence of an inflexibility of men or whether men are involved in less emotionally intelligent and/or more highly routine tasks. If men are noted to be more inflexible, then psychological measures in terms of promoting more occupational psychologists in the marketplace and promoting the value of their work alongside supporting education in this area might help to stimulate interest by the private sector, while they could be more easily integrated into the public sector. Similar approaches could be taken for building emotional intelligence. As for men possibly engaging in more routine tasks, the previous measures may address this.

Small private businesses should also be prioritised for such a programme of support, as they are more at risks than corporates. While it would be difficult to work with each small company one-by-one, tax incentives might be a way to encourage enrolment of staff in programmes for their own development which fight against potential for overall market displacement should automation take their current job. The level of incentive could be based on an actuarial decision trading off the risk of unemployment (including the burden incurred by society for such a loss) and the likelihood of employment in knowing certain skills.

On a more granular level, focusing on occupations actually listed as highest risk (as per Frey and Osborne's seminal 2013 publication for example) and working on them one by one for finding specific ways to counteract the likelihood of automation or otherwise use the skills required for such a job to best match potential related skills to help a displaced worker most easily move into a new position in a new industry is also an option, though the administrative side of this approach might end up oppressively onerous.

Finally, in relation to schooling, and in line somewhat with occupational psychologists, is a longer term focus by the government on reorienting the school system towards the ends of real social development and emotional development and intelligence. These skills are not only beneficial for employment purposes in which they will be highly valued in a high tech economy, but also for managing life. Initiatives to teach children to hold mutually incompatible theories in their heads such as one might find in philosophy or psychology would help towards this end, as would socialisation practices and roleplays. On the subject/curriculum side, the government can more easily mandate programmes, but on the socialisation they may incorporate schooling institutions into the National Retraining Partnership to work closely with educational providers as well as businesses and workers to build a more economically sustainable, but also more rounded society.

Deloitte (2016a) has indicated that technological progression has created more jobs than it has destroyed in the UK in recent years, and contributed significantly to economic growth in the meantime. Haldane (2015) surmises three longer-term solutions to any upcoming problems: relax, retrain and redistribute. Relax, as far as Haldane is concerned, means to let working hours be reduced and more free time due to automation, with a controversial claim that maybe the term "zero hour contract" will become an aspirational one to be using about oneself. Retrain, means to upskill in both cognitive and non-cognitive tasks, and redistribute means reallocation of resources through government intervention. In the situation currently, the algorithmic phase, there is no need to move past "relax" and "retrain" principles, the former of which has been to let the free market work uninterrupted, and prepare with "retrain" measures, steps which the government is undertaking. As for the upcoming augmentation and autonomous stages, there is no indication, as with any empirical basis, that massive redistribution will be needed to remedy problems, at least any more than there are calls that remedies are needed to fix the current inequality situation, which is a separate issue. As such, the government should continue broadly with its current approach, with guidance such as provided in this policy section of how to structure any retraining plan, until such a time as it seems as though there is either an imminent spike in automation such that is unprecedented, or it becomes apparent through the course of the augmentation phase of automation that job creation / substitution is or will no longer match job loss. If either such time looms, then redistributive options should be deeply deliberated.

5. Conclusion

In conclusion, the overall implications for advanced economies are not foreseeably revolutionary in terms of impact on job loss *per se* and especially in light of job creation. There is systematic overestimation of risk of automation borne by theoretical approach, with the implications for irreplaceable job loss exaggerated in light of recent historical figures of employment alongside indications of job creation. The overall level of high risk of automation to occupations in advanced economies, while always speculative, likely stands at somewhere between 9% and 14% general, based on the overall figure for high risk as published by Nedelkoska and Quintini across the 32 OECD countries of 14%, and the overall figure over 21 OECD countries of 9% predicted by Arntz, Gregory, and Zierahn (2016), though, considering these countries include less advanced economies with less highly-skilled, technically-advanced labour forces, combined with more advanced, the figure for advanced countries of high risk should be on the lower end of this scale, tending towards 10% or 11%. The high risk sectors of the economy are those with more routine, lower skilled and/or non-creative/ non-socially adept areas of occupation, particularly including manufacturing; services and sales; transportation and logistics; construction; office, administrative, and technical support, while professional, managerial, executive, creative, and jobs requiring high levels of emotional intelligence are resistant. This will affect the UK to some extent in the short-to-medium term (covering the next ten to twenty years) in the same areas as generally under high risk of threat but the UK is sheltered from heavy effects due to a highly skilled and tech savvy labour force, particularly in cities such as London, and, if the current educational system is modified in such ways as suggested, then technological changes are set to add economically to a more diverse and dynamic workforce. To that end, Expected Outcome 1 is a valid one in light of this thesis's research:

EO.1 Overall there will be a relatively contained impact of automation on job loss in advanced economies as they are more service oriented and highly skilled than other economies. Low-skilled, highly routine areas will be primarily impacted, with less of an impact the more complex and less routine the job being considered for automation is. These premises will hold for the UK.

Moreover, there are a number of strategy policies which are viable for managing automation issues in relation to workforce displacement. Well-known and widely debated solutions are those such as Universal Basic Income (UBI), robot tax, government job guarantees, negative income tax, and education system intervention and modification. Given the orientation of the UK's political sphere, in terms of its focus on development and technological progression, its historical economic and social advancement as a consequence of technological innovation and use, the historic and recent malleability of its workforce to adapt to changing labour dynamics, and its high class and multifaceted education system it is set up to manage automation in an efficient, economically fruitful, and socially-considerate way. As the risks initially presented in academic and related literature might also be overestimated, the least radical of the options available, and the most integrative in terms of continuing incentive for progression and creativity within a capitalist marketplace, is that of manipulating the education system to the ends of re-baselining at the early stages towards new economic needs and upskilling for those in line for displacement due to automation. As discussed in this paper, the Chief Economist of the Bank of England, Andy Haldane (2015) suggested that there are three ways to deal with the policy aspect of automation in terms of governmental application to it: relax, retrain, redistribute. At present, all signs promote the notions of relaxing (in terms of a *laissez-faire* approach to the marketplace) and retraining, at least in terms of setting up schemes in which retraining or better training is possible, while heavy redistribution is not indicated as necessary insofar as figures of losses vs gains from automation in the labour force show for the immediate or indeed medium term. The government is underway in its modifications in the educational system though the suggestions provided in this paper by way of how to best approach the process given the literature available might well be heeded. One caveat as regards the relax and retrain approaches is that technological advancement by way of automation might well be progressive in the sense that if coding becomes more intuitive due to the creative of more easy-to-use programming languages or simply more coders involved in the economy then automation might occur at rates which eventually outpace the creation of jobs which are difficult to automate or require creative skills. Further, machines might be programmed in such a way as machine learning reduces the need for heavy human interaction post-initial programming and as such might reduce human need to substantial extents. In case of such scenarios looming more apparently, real investigation in future will need to be conducted into redistributive measures for automative consequences, which might begin with introducing more dynamic social protection options. An example of this may be to introduce piecemeal or partial options for temporary unemployment, or easily accessible partial subsidies. Thus, in the same way as additional credits or units could be added outside of the education system to support a rapidly changing and flexible new work system, social security could reflect this by compartmentalising social security to reflect the growing number of contract and temporary jobs. Progressively, the more comprehensive options for redistribution mentioned in the policy component of this paper would need to be considered as permanent/long-term solution options. Nonetheless, accounting for this caveat, as things stand, Expected Outcome 2 is also valid in light of this thesis's research, with education as the present solution:

EO.2 There are a number of key strategies which are known about already and one can be tailored relative to the specific needs of the UK economy with minor amendments, most preferably the one which finds an equilibrium maximising competitiveness in automation and robotics while providing the best social welfare outcome in tandem.

Appendix

To explain the issue with occupation-based approach in more detail in relation to superficially oversimplifying the ease of automation, and provide reasons to consider the results from Arntz, Gregory, and Zierahn (2016) it is possible to review examples from Frey and Osborne (2013) of a number of jobs labelled as highly automatable: “Computer Operator”, “Administrative Services Manager”, “Budget Analysts”, and “Aircraft Mechanics and Service Technicians”. According to O*NET descriptions of these professions which Frey and Osborne used for their study (see following link to explore professions: https://www.onetonline.org/find/), the Aircraft Mechanics and Service Technicians job (arguably two jobs) comprises 38 tasks; the other professions listed contain between 13 – 15 which of course are somewhat broad given the spectrum they need to cover. Immediately it is possible to understand the concern raised by Arntz, Gregory, and Zierahn (2016). These professions have multiple meanings and levels, and are very context-specific. For example, an Administrative Services Manager for a bank would have a different role with very different tasks than an Administrative Services Manager for a children’s theme park or a community-based arthouse. A Budget Analyst working for a mom-and-pop shop may have very different responsibilities to one working for a multinational organisation. The tasks that Aircraft Mechanics do would not always reflect the intricate interrelation between different parts of a plane’s engineering and construction, which are not automatable strictly. A Computer Operator may need to work with different systems and bespoke set-ups which may not be easily automated in the strictly binary sense in which Frey and Osborne (2013) propose their results.

Additionally, even within the tasks themselves some are likely difficult to automate. Take, for example, the tasks which O*NET lists for an Administrative Services Manager (Administrative Services Manager summary report on O*NET: https://www.onetonline.org/link/summary/11-3011.00). Such things as "Monitor the facility to ensure that it remains safe, secure, and well-maintained"; "Set goals and deadlines for the department"; "Hire and terminate clerical and administrative personnel"; and "Participate in architectural and engineering planning and design, including space and installation management" are difficult features to automate as ensuring facility safety and security may involve integrating several staff functions and monitoring the external environment. Setting goals and deadlines might similarly relate to external factors and haphazard circumstantial occurrences which throw operations off course. Architectural and engineering planning includes issues of aesthetics and function as well as monitoring follow-through to adequate standards.

The other occupations have similar automational difficulties. For example, a Budget Analyst (Budget Analyst summary report on O*NET: https://www.onetonline.org/link/summary/13-2031.00) is expected to "Interpret budget directives and establish policies for carrying out directives"; "Consult with managers to ensure that budget adjustments are made in accordance with program changes"; "Review operating budgets to analyze trends affecting budget needs"; and "Provide advice and technical assistance with cost analysis, fiscal allocation, and budget preparation". However, interpreting budget directives involves more than simply taking step-by-step direction and might require amalgamation of up-to-date knowledge of external business circumstances gleaned from partially contemporary circumstantial sources. Establishing policies often involves contingencies and re-write based on what works or does not. Budget adjustments in one area might affect another – all such contingencies could not likely be programmed in advance. Analysing trends may involve non-pre-programmable news and information sources. Providing worthy assistance with cost analysis, fiscal allocation, and budget preparation involves an overview of the company or an area of work including insight and ongoing contingencies which would be very difficult to pre-programme. For Aircraft Mechanics and Service Technicians (Aircraft Mechanics and Service Technicians summary report https://www.onetonline.org/link/summary/49-3011.00), some of the tasks in the list were "Read and interpret maintenance manuals, service bulletins, and other specifications to determine the feasibility and method of repairing or replacing malfunctioning or damaged components"; "Read and interpret pilots' descriptions of problems to diagnose causes"; and "Listen to operating engines to detect and diagnose malfunctions such as sticking or burned valves". The interpretation of manuals and service bulletins as per the problem to be fixed is a task which surely requires extrapolation of general principles which have been inscribed to relatively new and sometimes unpredictable problems, which is something automation would struggle with. Interpreting pilots' problems may involve situational and likely integrated / interrelated knowledge of systems, including interfacing technologies and specifically devised workarounds etc. Listening to operating engines to detect issues is certainly not something that will be automated very soon as current technology even has problems picking up voices for sending text messages, making calls etc.

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