Automation and Employment: The Case of South Africa

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Abstract

In the two centuries since the Industrial Revolution technological progress has had a major impact on the types of work humans perform. The invention of increasingly advanced machinery decreases, on one hand, the need for certain forms of manual labour while, on the other, creating new needs and new types of work. Through continuous cycles of this process advanced industries have emerged enabling standards of living to rise across the world. The most recent wave of technological progress is characterised by increasingly intelligent computers and computer-driven machinery. This has coincided with the rise of economic inequality in previously egalitarian countries, prompting debate over the implications of the computer revolution for low and medium-skilled workers. In this study focus falls on the possible implications of these developments for the South African labour market. By using Frey and Osborne (2013)'s computerisation probabilities in combination with Stats SA labour market data, a future outlook is determined and presented. Findings suggest that the occupations performed by almost 35% of South African workers (roughly 4.5 million people) are potentially automatable in the near future.

Keywords: automation, employment, South Africa, labour displacement

1 Introduction

The replacement of human labour with machinery has been a contentious economic, social and political issue since the development and adoption of production technologies during the industrial revolution (1760-1840). It is now well-known that these technologies triggered the permanent acceleration in output per capita growth rates in Western Europe and, consequently, a dramatic rise in the wealth of its citizens (O'Rourke et al., 2013). Despite these gains, not all workers embraced the new technologies. During 1811 and 1816 a group of English textile workers, known as the *Luddites*, recognised the threat of innovative technologies to the value of their labour and, consequently, their financial well-being. They responded through an organised and wide-spread rebellion aimed at the destruction of industrial machinery leading to multiple clashes with the British Army (Archer, 2000).

With the exception of isolated incidents, Luddism lost its momentum as the productivity gains enabled by technological progress created new employment opportunities for displaced workers. This process continued over the course of the 19th and 20th centuries, enabling consistent increases in productivity and rising standards of living (Rifkin, 1995; Brynjolfsson and McAfee, 2012, 2014). Recently, however, Luddite fears have been rekindled by pundits who argue that, unlike the machines built to economise physical labour, modern digital technologies have the ability to replace cognitive labour. This new wave of the technological revolution, it is argued, has the potential to change the relationship between labour and capital in an unprecedented manner (Brynjolfsson and McAfee, 2012, 2014; Rifkin, 1995; Marchant et al., 2014; Naude and Nagler, 2015)

Importantly, modern Luddism appears not to be 'overtly antitechnology or antimachine per se' but reflects, rather, 'an anti-inequality ideology' (Lehman, 2015, 266). Central to this standpoint are two key arguments. The first dictates that technological progress creates a skills bias in the economy which has the potential to trigger long-term *structural unemployment*. Secondly, such a bias exacerbates economic inequality by devaluating low-skilled labour, leading to the *hollowing out of the middle class* Lehman (2015). While debate rages on about the validity of modern Luddite claims, a number of publications on the matter (Sabadash, 2013; Brynjolfsson and McAfee, 2012, 2014; Rifkin, 1995) have started to gain recognition among mainstream economists (Naude and Nagler, 2015).

Research in this area has been dominated, perhaps unsurprisingly, by scholars and statistics from technologically-mature countries in the developed world, with little attention being paid to the fate of developing countries. This study aims to address this gap in the literature by investigating the possible implications of advancing computer technology for the South African labour market. To this end two primary research objectives were addressed:

1. To determine, based on publicly available data, the range of occupations performed by South African workers and an estimation of the number of workers in each of these occupations.

2. To determine, based on the findings of the first objective and Frey and Osborne (2013)'s computerisation probability index, how advancing automation technologies may effect labour demand in South Africa.

Three factors make South Africa an interesting case for the analysis of automation and labour demand. The first is the fact that it is, due to its history of colonisation and racial segregation, already one of the most unequal economies in the world (The World Bank, 2016; Van der Berg, 2011). The second, closely associated with the first, is its high unemployment rate (24,9%) (The World Bank, 2016). The third is that, while South Africa is a developing nation, it has, by global standards, some technologically-advanced industries. The financial sector is a prime example. According to the 2015/2016 World Economic Forum Global Competitiveness Survey South Africa is ranked 8th (out of 140 countries) in Financial Sector Development.

The article commences with an overview of the discourses concerning technology and employment, briefly summarising prominent perspectives in this area of research. This is followed by an overview of the South African economy based on World Bank data. To asses the possible impacts of advancing computing technologies on the South African labour market, the study utilises labour force data collected by Statistics South Africa (StatsSA) in combination with Frey and Osborne (2013)'s predictions about the susceptibility of jobs to computerisation.

It is important to note that the author adopts an amoral stance on the matter under investigation. No agenda, be it pro- or anti-technology, egalitarian or capitalist is favoured. Interest falls, rather, on an unbiased analysis of the various positions adopted by a range of scholars and a balanced presentation of labour dynamics in South Africa. While acknowledging the importance of the moral and ethical dimensions of this discourse, it is posited that these fall beyond the scope of this article.

2 Technology and Employment: The End of Work

It is broadly acknowledged that the dynamic nature of technological innovations negates our ability to accurately predict the future impacts of any specific technology on labour demand (Sabadash, 2013). This is especially applicable in the case of *Information Technology (IT)* which, firstly, impacts labour requirements in diverse ways across industries and sectors (Sabadash, 2013; Brynjolfsson and McAfee, 2012) and, secondly, continues to rapidly accelerate in both capacity and areas of application. There is ongoing discourse with a number of competing perspectives promoting different interpretations of economic indicators such as GDP, median income, unemployment and economic inequality.

One perspective, which has started to gain interest in the US since the mid-1990s, is that we are approaching a new era in which the need for human labour will diminish. Anchored around the work of Rifkin (1995), it provides a convincing rationale for recent economic trends in the *United States of America* (US)(Brynjolfsson and McAfee, 2012, 2014; Rifkin, 1995).

Rifkin contends that the notion of continuous *technological change* or *technological progress* has been a key driver of capitalist economies. The Schumpeterian concept of 'creative destruction' describes this feature of capitalism well - continuous cycles of the destruction and renewal of economic structures (Naude and Nagler, 2015; Sabadash, 2013; Frey and Osborne, 2013; Collins, 2010). Technological progress, as used in this context, is not limited to developments in technology industries. While such developments play an important role, the development of machinery or other technological *artefacts* is only one dimension of creative destruction. Cragg (1963)'s knowledge-centred definition of technological progress serves to illustrate this point: 'Technological progress consists of the acquisition of new knowledge which could improve the economy's ability to satisfy economic wants and of facility in using that knowledge' (Cragg, 1963, 312). It is possible, consequently, that technological progress may occur in the absence of new or updated artefacts, when, for example, new knowledge enables production firms to achieve increased quality or efficiency by adopting a new production *process* while using the same production *equipment* and labour inputs.

2.1 Technology and Productivity

A key feature of technological advancement is its impact on *productivity*. Productivity can be broadly defined as the increased output achieved per unit of labour input, generally indicated, on macro level, as an increase in *Gross Domestic Procust (GDP) per capita*. Studies conducted over the past two centuries in a wide variety of industries have consistently found that technological progress leads to increased productivity (Cragg, 1963; Brandtzaeg, 1979; Brynjolfsson and McAfee, 2014, 2012; Collins, 2010; Lehman, 2015; Frey and Osborne, 2013; Haber and Kahn, 1957; Marchant et al., 2014; Rifkin, 1995; Sargent, 2000; Sabadash, 2013).

Rifkin (1995) provides striking historical statistics of the effect of this relationship in the US agriculture sector. In 1850 a single farm worker could produce enough food to feed four people. By 1995, however, a single farmer could produce enough to feed more than 78 people. The first mechanical cotton picker, introduced in the Mississippi delta in 1944, picked 1000 pounds of cotton in one hour, the equivalent of 50 seasoned human pickers. Initial adoption of the technology was rather slow - by 1949 only six percent of the cotton in the US's South was harvested mechanically, but this grew to 78% by 1964. By 1972 the services of human cotton pickers were no longer utilised. In 1995, less than three percent of the American workforce were engaged directly in farming, down from 60% in 1850 (Rifkin, 1995).

These historical trends are not limited to agriculture. In the ten years between 1980 and 1990 United States Steel shrunk its work force from 120 000 to 20 000 while, on the back of increasingly advanced equipment, maintaining roughly the same output (Rifkin, 1995).

Statistics such as these are pervasive across labour-intensive industries where the continuous introduction of new technology enables firms to achieve dramatic productivity gains. In their totality these gains have enabled consistent rise in median income and quality of life observed globally over the past two centuries (Sabadash, 2013).

More recently, advances in IT have begun to enable a similar productivity gains in white-collar occupations. In the office environment the application of computing machinery enhances the efficiency and quality of tasks that require cognitive, as opposed to physical, input from human workers (Frey and Osborne, 2013). This new *wave* of technological progress is systematically making inroads into a domain of work which has, so far, belonged exclusively to human workers (Brynjolfsson and McAfee, 2014, 2012; Rifkin, 1995). On one end of the spectrum are advances in artificial intelligence and machine learning that tend to attract wide media attention - Google's driverless car and IBM's Watson are prime examples. Much less publicised, however, are the incremental advances made by hardware and software producers worldwide which become embedded in firms across industries and influence their operations, structure and labour requirements in various ways.

2.2 Technological Displacement of Work

The *technological displacement of work* refers to instances where, due to technological advances, the need for human labour in certain occupations is lessened or eradicated. This, as stated previously, has been a consistent feature of capitalist development for over 200 years. However, despite such displacement, employment rates have remained relatively consistent. This is possible because, while certain types of work are destroyed, the introduction of technology also creates new labour requirements. If the balance between the destruction and creation of the need for human labour is maintained, employment levels remain undisturbed by technological advances.

Labour market data suggest that, over the past two centuries, the job-creation effect of technological progress has counter-balanced its job-destruction effect (Brynjolfsson and McAfee, 2012), at least if one considers data from 'healthy economies' (Harford, 2012). This is evident in the joint rise of productivity and median household income. However, over the past 15 years these two indicators have begun to break this pattern in the US and Europe. In the US GDP per person 'has continued to grow fairly steadily (except during recessions)', but median household income has not followed suit and, since the turn of the millennium, it has started to drop steadily (Brynjolfsson and McAfee, 2012, 33).

This paradox of achieving continuously growing productivity without generating increased median income, often referred to as *jobless growth*, lies at the heart of contemporary Luddism. The winners in such scenarios are capitalists who own and control productive machinery, while low-skilled (and, more recently, semi-skilled) workers loose out due to the devaluation of their labour. This phenomenon disrupts the traditional 'bargaining principle between capital and labour' as the 'shares of income earned by equipment owners' rise relative to those earned by labourers (Brynjolfsson and McAfee, 2012, 45).

2.3 Skill-Biased Technological Progress

An important feature of technological progress is that it tends to be *skill-biased*. It increases demand for certain skills in the labour market, while decreasing demand for others. The introduction of mechanical cotton pickers, for example, decreased the demand for human cotton picking skills, but increased the demand for skills associated with the development, production, operation and maintenance of mechanical pickers.

In much the same way the computerisation of white-collar work will decrease the demand for skills associated with routine or rule-based tasks in office environments (Frey and Osborne, 2013). Administrative functions like data processing and bookkeeping are typical examples, but as robotics and numerically controlled machinery advance the spectrum of automatable work inevitably widens. The skills that will enjoy increased demand are the more advanced, technically-oriented ones associated with the design, development and maintenance of hardware and software. As demand for these skills rises, so does remuneration for suitably skilled workers, particularly when their skills are scarce. The ensuing pattern implies that high-skilled workers reap the benefits of automation while the demand for and remuneration of low-skilled workers decrease.

There are two important features of this phenomenon that deserve emphasis. The first is that increasingly smart machinery increases the skill-level human workers need to obtain to remain relevant in the labour market. The natural consequence, which is particularly visible in the current South African context, is an increased demand for higher education. However, the second feature, as shown by Brynjolfsson and McAfee (2012)'s analysis of US labour statistics, is that the demand for high-skilled labour is not growing at the same rate that the demand for low-skilled labour is contracting.

This trend suggests that firms can achieve the same productivity levels while shrinking their overall work forces. Of course, the specialised skills that they require to manage advanced technologies come at a premium. Hence, even though the firm's net profits may not rise, these profits acrue to a smaller group of high-skilled workers, while their low-skilled colleagues loose out. The resulting effect at macro-level is a drop in median income and increased economic inequality (Rifkin, 1995; Brynjolfsson and McAfee, 2012, 2014).

2.4 Competing Perspectives

Opponents of the end-of-work perspective generally adopt one of two positions: *cyclicality* or *stagnation* (Brynjolfsson and McAfee, 2012). Cyclicality holds that median income fails to rise due to high unemployment resulting from an economy which is not growing fast enough. 'In the cyclical explanation, an especially deep drop in demand like the Great Recession is bound to be followed by a long and frustratingly slow recovery' implying that the current situation is no more than a 'business cycle in action' (Brynjolfsson and McAfee, 2012, 4).

Supporters of the cyclical perspective generally adopt a techno-optimistic stance rooted in historical evidence of the long-term positive effects of technological progress. Mokyr et al. (2015) express this view well:

> 'From our perspective, the modern anxieties about long-term, ineradicable technological unemployment, or a widespread lack of meaning because of changes in work patterns seem highly unlikely to come to pass. As has been true now for more than two centuries, technological advance will continue to improve the standard of living in many dramatic and unforeseeable ways. However, fundamental economic principles will continue to operate. Scarcities will still be with us, most notably of time itself. The law of comparative advantage strongly suggests that most workers will still have useful tasks to perform even in an economy where the capacities of robots and automation have increased considerably'.

The stagnation perspective, developed around the work of Cowen (2011), holds that it is not technological progress but, rather, the lack thereof which is to blame for the drop in median income. He posits that the US economy has, since the 1970s, been on a 'technological plateau' characterised by a lack of powerful new ideas to drive economic progress (Cowen, 2011). The antidote is seen to be more and faster technological progress to lift productivity and, in turn, generate the work that will lead to a rise in median income. This view, of course, contradicts the end-of-work perspective and sees technology as the saviour, rather than the culprit.

Brynjolfsson and McAfee (2012) reject this proposition. 'We think it's because the pace [of technological innovation] has sped up so much that it's left a lot of people behind. Many workers, in short, are losing the race against the machine' (Brynjolfsson and McAfee, 2012, 8). They argue, furthermore, that 'technological progress - in particular, improvements in computer hardware, software, and networks - has been so rapid and so surprising that many present-day organisations, institutions, policies, and mindsets are not keeping up' (Brynjolfsson and McAfee, 2012, 8).

2.5 The Social Shaping of Technology

It is important to acknowledge that accurate predictions about the outcomes of technological developments and innovations are hampered by the manner in which these processes are influenced by a range socio-economic factors. This perspective, which Williams and Edge (1996) describes as *the social shaping of technology (SST)*, promotes critical engagement of these factors and frames technological innovation as 'garden of forking paths', the direction or trajectory of which is determined by multiple choices made by multiple actors (Williams and Edge, 1996). SST contrasts ideas about technological innovations as linear, predictable processes as promoted by technological determinism. It acknowledges, rather, the agency of human actors and their choices in determining how the development, diffusion and adoption of technologies occur. This includes the manner in which the worldviews of technology developers become embedded, as 'latent structures' (Strong and Volkoff, 2010), in the artefacts they produce; the processes by which technologies become diffused and adopted by individuals and organisations (Rogers, 2003); and the non-linear ways in which users of technologies make sense of and enact their affordances (Orlikowski and Gash, 1993; Le Roux, 2013).

In the context of this study SST dictates that the design, diffusion and enactment of technologies which economise or replace human labour are complex, unpredictable processes. Treating them as linear and predictable will inevitably lead to false assumptions and conclusions. This raises the question of whether efforts to predict the outcomes of technological advancements on labour demand is of any value. Cilliers (2000) provides a lucid perspective on this matter when he argues that models of complex systems may be of value despite their limitations. 'We have to do all the calculation we possibly can. That is the first part of our responsibility as scientists and managers. Calculation and modelling will provide us with a great deal of vital information. It will just not provide us with all the information' (Cilliers, 2000). This study, accordingly, adopts the view that although technologies are socially shaped and accurate predictions of their impacts on social systems cannot be made, some value can be gained from efforts to determine these impacts based on models and calculations (as is done in this study).

3 A Brief Overview of South African Economic Indicators

Two aspects of the South African economy generally dominate mainstream discourse. These are, firstly, a lack of growth in the recent past and, secondly, a high degree of economic inequality among South Africa's citizens (reflected and exasperated by high unemployment).[1]

The World Bank reports South Africa's GDP for 2015 to be around US$ 313 billion. According to 2015 figures the *Services* sector generates 67.4% of the country's total GDP, with *Industry* generating 30.3% and *Agriculture* 2.4% (Central Intelligence Agency, 2016). While GDP growth rose steadily since the 1970s, and initially recovered well after the Great Recession (2007-2009), it slumped to below 2.5% in 2012/2013 and below 2% in the two years thereafter. This lack of growth has implied that South Africa's GDP has, in US dollar terms, shrunk by around US$ 60 billion between 2010 and 2015.

In the same period the labour force[2] has grown from around 18 million to over 20 million people (the 30th largest in the world) with an unemployment rate consistently hovering around the 25% mark. The combined effect of these trends has been a drop in GDP per capita, in current US$ terms, from US$ 7 392.9

[1] All data reported in this section are drawn from the World Bank Data Bank (The World Bank, 2016), unless indicated differently.

[2] The labour force includes all people aged 15 and over including both the employed and those actively seeking employment.

in 2010 to US$ 5 691,7 in 2015. In global terms (208 countries) South Africa is ranked 31st based on GDP size, 162nd based on GDP growth, 118th based GDP per capita and 180th based on employment rate.

While South Africa's is not the only economy struggling to grow post-recession, it's high level of inequality sets it apart from comparable cases. Inequality is a sensitive theme in the country's public discourse, incontrovertibly tied to it's history of racial segregation. 'In South Africa with its high levels of racial inequality, inequality in income distribution is especially large and persistent. For an upper middle income country (in terms of GDP per capita and economic structure), South African social indicators (e.g., life expectancy, infant mortality or quality of education) are closer to lower middle income or even low income countries' (Van der Berg, 2011, 120).

Van der Berg (2011) warns, however, that one should be careful to adopt an oversimplified perspective of the sources of inequality. 'It is common to ascribe South African inequality and even poverty to racial discrimination and in particular to apartheid. This of course offers only a part of the explanation. In a poor pre-colonial society, colonial settlement and then the mineral discoveries laid the basis for a highly dualistic economy that was from the outset highly inegalitarian. Racial discrimination under first British colonial rule and then apartheid distributed the spoils of economic growth along racial lines, which laid the foundation for patterns of further development and privilege in a society stratified by race' (Van der Berg, 2011, 120).

As argued in the preceding section, it is not possible to accurately determine the extent to which the automation of work has contributed to South Africa's income inequality over the past century. What is well-known, however, is that racial discrimination had a negative impact on the availability and quality of education for disadvantaged population groups (Van der Berg, 2011, 134). One may argue, on this basis, that workers from these groups would have been more exposed to technological displacement than high-skilled workers from privileged groups. Such a proposition recognises technology's agency in maintaining economic inequality through its impact on labour demand, opposing ideas about technology as flattener or leveller of the economic playing field as proposed by Friedman (2007).

South Africa's indicators provide little evidence of economic growth and, as such, disqualifies the hypothesis that the pattern of jobless growth observed in the US is currently occurring there too. Moreover, any comparison between the two economies should be done with sensitivity to the greatly differing levels of technological (and, by implication, knowledge) maturity in their industries. However, this does not imply that South African workers are protected from the wave of automation currently infiltrating US firms. As the these technologies mature and decrease in cost, they will become increasingly attractive to firms in developing economies. From the perspective of SST one should be mindful of the effect that the availability of cheap labour has on the adoption of automation technologies. Capital owners will compare the costs of technologies to those of human labour when considering adoption and it may not be cost-effective to automate (yet). However, labour-related factors like wage increase demands, strikes and unionisation may make automation an attractive strategy despite higher costs.

4 Research Design

This study set out to determine the possible future impacts of the adoption of increasingly advanced computing technologies for labour demand in South Africa.

To address this question two data sources are analysed. The first is data which describe the current structure, in terms of the types of work people perform, of the South African work force. Statistics South Africa (Stats SA) performs a *Quarterly Labour Force Survey (QLFS)* which is a house-hold sample survey collecting 'data on the labour market activities of individuals aged 15 years and above' residing within the country. The survey covers a large set of variables which include the respondent's current occupation and industry. In the analysis the researcher utilised the *Labour Market Dynamics in South Africa (LMDSA)* datasets (2008-2014) which are constructed using data from each of the four QLFS datasets in of every year.

The second source is the occupation computerisation probability index developed by Frey and Osborne (2013) at the *Oxford Martin Institute for the Impacts of Future Technology*. In their oft-cited study the authors analyse the 702 occupations defined by the US Labour Department with the aim of determining the probability that the work performed in each occupation can be computerised. The authors base their analysis on a model which considers the presence of three types of tasks in the occupation: perception an manipulation tasks, creative intelligence tasks and, finally, social intelligence tasks. Using these factors as basis, they follow a multi-step process to produce probability (0-1) for each occupation.

In their subsequent analysis of the US labour market they conclude that 'around 47 percent of total US employment' have a high probability of being computerised 'relatively soon, perhaps over the next decade or two' (Frey and Osborne, 2013, 44). 'Most workers in transportation and logistics occupations, together with the bulk of office and administrative support workers, and labour in production occupations are at risk' of automation (Frey and Osborne, 2013, 44).

The list of occupations analysed in the automation index is based on US Labour Department's Standard Occupation Classification (SOC). Stats SA, however, utilises its own classification system in the QLFS - the South African Standard Classification of Occupations (SASCO). To achieve compatibility between the datasets the researcher manually matched the SASCO occupations to their SOC correspondents. In most cases occupations could be matched with a high degree of confidence based on the names used in the different systems. However, when this was not the case the researcher consulted the SOC and SASCO descriptions to find correspondents.

Based on the LMDSA dataset South Africans, in 2014, worked in a total of 377 different occupation types. The researcher was able to match 285 of these to corresponding SOC occupations and, consequently, probabilities of computerisation. SASCO occupations that could not be associated with SOC counterparts typically had low numbers of workers. These included, for example, *Traditional chiefs and heads of villages; Subsistence farmers; Mining and quarrying labourers; and Faith healers*. Combined, these occupations accounted for less that seven percent of the employed workforce in 2014.

Having established compatibility between the datasets, the researcher analysed the data in two primary phases. The first phase involved a high-level analysis of trends in the period between 2008 and 2014. This afforded the researcher an overview of the labour market structure and the identification of growing and declining occupations during this period. Of course, the Great Recession falls within the period analysed and its implications for the labour market are reflected in the data.

The second phase of the analysis considered the future implications of the computerisation of work by relating Frey and Osborne (2013)'s probabilities to the labour market structure as represented by 2014 LMDSA data. This included the stratification of the labour market data based on population groups (African/Black; Coloured; Indian/Asian; White).

5 Findings

Before considering labour market trends between 2008 and 2014, it is worth noting some general figures which describe the South African labour force. Based on World Bank data South Africa's working-age population (all people aged 15-65) represents around 65% of the total population (roughly 35 million people). The labour force, which excludes those persons who are not employed nor seeking employment, consists of roughly 20 million people. Of this 20 million around 12 million people had *work for which they were being paid* in 2014.

Among these income earners the top 10% hold a share of just over 50% of all income while the top 20% hold a share of almost 70%. Due to this skewed distribution it is estimated that only around 3.3 million workers contribute 99% of all income tax collected by the South African Revenue Service (SARS) (Joubert, 2013).

5.1 General Trends (2008 to 2014)

In each of the six LMDSA datasets covering the period between 2008 and 2014, an average of around 40% of people aged 15-65 are associated with specific occupations. Consequently, the analysed section of the sample for each year ranges between just over 13 million people (2008) to just over 14 million people (2014).[3]

According to 2014 figures over half of all South African workers (7.08 million people) perform just 20 different occupations. These occupations are presented in Table 1. The table shows the occupations, the numbers of workers for 2008 and 2014 and changes in those numbers for the relevant period. It should be noted that comparison of the LMDSA data across years suggests that certain changes in data coding practices were implemented. For example, as indicated in the table, the data show a sharp drop in the number of *Street food vendors* but also a notable increase in the number of *Cooks*.

[3]This number is higher than the number of workers which claim to have *paid work*, suggesting that many workers are classified into occupations without necessarily receiving remuneration. For example, based on 2014 data, just over 7% of people claiming not to have paid work own businesses.

Occupation	2008	2014	Change	% Change
Domestic helpers and cleaners	1 075 993	1 030 588	-45 405	-4%
Farmhands and labourers	834 886	905 965	71 079	9%
Other office clerks and clerks not elsewhere classified ...	373 351	521 360	148 009	40%
Helpers and cleaners in offices, hotels and other ...	475 298	511 056	35 758	8%
Shop salespersons and demonstrators, Salespersons ...	393 841	455 255	61 413	16%
Protective services workers not elsewhere classified ...	346 118	438 888	92 770	27%
Hand-packers and other manufacturing labourers	396 023	396 684	661	0%
Street food vendors and related workers	437 589	317 885	-119 704	-27%
Cashiers and ticket clerks	260 218	285 530	25 312	10%
Primary education teaching associate professionals	282 719	268 257	-14 463	-5%
Cooks	172 314	264 491	92 177	53%
Bricklayers and stonemasons (including apprentices/trainees)	275 735	225 366	-50 369	-18%
Heavy truck and lorry drivers	210 677	215 692	5 015	2%
Sweepers and related labourers	45 688	205 293	159 605	349%
Teaching associate professionals not elsewhere classified	233 046	190 313	-42 732	-18%
Construction and maintenance labourers: roads, dams ...	207 132	176 711	-30 420	-15%
Police officers, traffic officers, Police officers ...	127 190	173 709	46 519	37%
Motor vehicle mechanics and fitters	193 122	173 350	-19 772	-10%
Finance and administration managers/department managers	137 795	172 019	34 225	25%
Street vendors, non-food products	143 638	160 110	16 472	11%
	6 622 371	7 088 521		

Table 1: The 20 largest occupations and their growth/decline between 2008 and 2014.

An outlier in the table is *Sweepers and related labourers* which grew by 349% in the relevant period. Bhorat et al. (2016) argue that this can be contributed to the government's Expanded Public Works Programme (EPWP). 'The EPWP creates jobs through government funded infrastructure projects, through its non-profit organization and community work programme, as well as through its public environment and culture programmes. As such, much of the public sector job growth ... relates to the construction industry, the protection and safety sector, public sanitation, and personal care industries' (Bhorat et al., 2016, 20).

A brief analysis of IT-oriented occupations reveals some interesting trends (see Table **??**). Perhaps most interesting is that there were an estimated 3 689 fewer *Computer Programmers* in 2014 than in 2008 (a drop from 21 211 to 17 522). However, *Computer systems designers and analysts* grew from 22 796 in 2008 to 31 783 in 2014, an increase of 8 987 workers. Similarly, *Computing services managers/department managers* grew from 1 334 to 9 221 over the relevant period.[4] *Computer assistants* increased by 4 905 while *Electronics and telecommunications engineers* dropped from 3 473 in 2008 to 2 691 in 2014.

Of course, these figures are not necessarily reflective of changes in demand for IT skills. The outsourcing or offshouring of work and the immigration of highly skilled IT workers are examples of factors which may cause the number of South Africa-based IT professionals to change.

Analysis of administrative white-collar occupations also reveals some interesting trends. One occupation which has grown quite substantially (40%) is *Office clerks and clerks not elsewhere classified.* Closer inspection of the data suggests that this growth can largely be attributed to government and government-owned organisations, with little change observed for private sector organisations. Overall, public sector employment has grown from 14.5% of total employment in 2008 to 17.5% in 2014, creating more than half a million jobs during a period of 'extreme labour market distress' (Bhorat et al., 2016).

While high and medium-skilled occupations like *Accountants* and *Bookkeepers* have increased somewhat, it is clear that most of the lower skilled administrative occupations shrunk. *Accounting and bookkeeping clerks* dropped by 12 469 while *Library and filing clerks* dropped by 41 303. So too has *Receptionists and information clerks* (-19%), *Secretaries* (-9%) and *Stock clerks* (-9%).

Of course, these figures provide no specific evidence of the role of the influence of technology on labour demand. Growth and decline in occupations may result from a wide range of factors and isolating the impact of technological advancement across sectors and industries would require consideration of evidence about technological capital investment at firm/industry level (which, to the researcher's best knowledge, is not publicly available at this time) in relation to occupation growth and decline.

[4]The increased size of this occupation (591%) may, again, result from changes in coding practices related to the QLFS. It may also be that, due to the lack of texture in terms of IT occupation types in the SASCO list, this occupation has come to represent an increasingly wide range of professional roles.)

Occupation	2008	2014	Change	% Change
Other office clerks and clerks not elsewhere classified...	373 351	521 360	148 009	40%
Accountants and related accounting occupations	68 271	72 509	4 238	6%
Administrative secretaries and related associate professionals	10 342	11 466	1 124	11%
Bookkeepers	34 043	34 684	641	2%
Statistical finance clerks	57 541	56 714	-827	-1%
Secretaries	80 650	73 646	-7 004	-9%
Accounting and bookkeeping clerks	65 594	53 098	-12 496	-19%
Stock clerks	142 799	130 024	-12 774	-9%
Receptionists and information clerks	108 768	93 303	-15 465	-14%
Library and filing clerks	68 261	26 958	-41 303	-61%
Data entry operators	31 691	31 765	74	0%
Word-processor and related operators	3 426	2 646	-780	-23%

Table 2: Workers in administrative office occupations from 2008 to 2014

Risk level	Probability range	Number of workers
1	0-0.099	1 975 149
2	0.1-0.199	717 199
3	0.2-0.299	311 022
4	0.3-0.399	621 955
5	0.4-0.499	65 028
6	0.5-0.599	316 779
7	0.6-0.699	1 909 588
8	0.7-0.799	1 093 360
9	0.8-0.899	2 605 365
10	0.9-0.999	3 613 811
Total		13 229 255

Table 3: Estimated number of occupants at risk levels 1 to 10.

5.2 Risk of Computerisation

By combining Frey and Osborne (2013)'s probabilities with the 2014 LMDSA data, it is possible to produce an estimation of the implications of advancements in computing technologies for South Africa's labour market. Of course, readers should interpret such an estimation with the understanding that the probabilities reflect Frey and Osborne (2013)'s predictions of which occupations could, through advances in machine learning and robotics, be computerised rather than actual changes in labour demand. There are significant differences between the availability of a technology, its commercialisation, its uptake and, finally, its impact on labour demand. Nonetheless, historical examples (e.g., the mechanical cotton picker) provide strong evidence that labour-saving technologies can infiltrate industries rapidly once their benefits outweigh their costs.

The 285 occupations analysed in this section (i.e., those associated with computerisation probabilities) represent around 13.2 million South African workers based on 2014 data. For the purpose of the analysis the researcher categorised occupations according to 10 risk levels based on Frey and Osborne (2013)'s probabilities. The highest risk level (10) represents occupations with probabilities of 0.9 or greater, while the lowest risk category (1) represents occupations with probabilities of less than 0.1. Table 3 presents the 10 risk levels with the total number of workers in each based on 2014 data. The distribution is visualised as an area graph in Figure 1.

Level 10, suggesting a very high likelihood of computerisation, included 64 occupations. These 64 occupations represent an estimated total of just over 3.6 million workers (27.3% of workers). Just over 520 000 workers at this level are employed as general *Office clerks* and another 450 000 as *Shop salespersons and demonstrators, Salespersons, Petrol pump attendants*. Between 2008 and 2014 the combined number of workers employed in these occupations grew by about 340 000.

Level 9, which includes 39 occupations, represents almost 2.6 million (19.7% of workers). *Farmhands and labourers* represent just over 900 000 workers at this level and the level grew by around 77 000 workers between 2008 and 2014. Level 8 (29 occupations, 1.1 million workers) grew by 112 000 workers in the analysed period, while level 7 (17 occupations, 1.9 million workers) grew by roughly 43 000 workers.

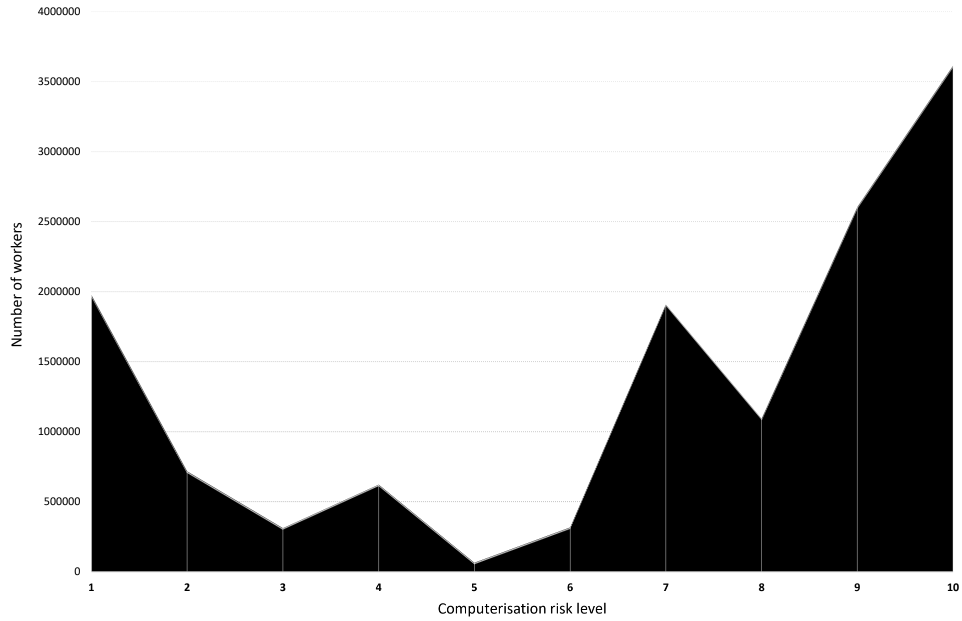

Figure 1: An area graphs representing worker numbers (vertical axes) in relation to computerisation risk level (horizontal axes).

Domestic helpers and cleaners represent just over a million of the workers at level 7. Combined, levels 7 to 10 include over 9 million (almost 70%) of South African workers.

Levels 4, 5 and 6 represent a combined total of 34 occupations and just over a million workers, declining by around 30 000 workers in the seven year period analysed. Almost 400 000 of these workers are employed as *Hand-packers and other manufacturing labourers*, which has a computerisation probability of 0.38.

Levels 3 and 2 include a combined total of 37 occupations and just over a million workers. *General managers of business services* (122 667), *Building and related electricians* (122 413) and *Hairdressers, barbers and beauticians* (106 204) represent the most popular occupations in these levels. Occupants in these two levels increased by just over 160 000 between 2008 and 2014.

Occupations at level 1 (65 in total), those most resistant to computerisation, represent almost two million people. Large occupations at this level include *Primary education teaching professionals* (268 257), *Police and traffic officers* (173 709) and *Nurses* (143 014). On average level 1 occupations represent just over 30 000 workers per occupation, much lower than the roughly 70 000 average observed at level 10. Between 2008 and 2014 occupations at this level grew by 270 000 workers.

5.3 Risk of Computerisation and Population Groups

Stats SA distinguishes between four population groups: Black/African (80.2% of the total population), Coloured (8.8%), Indian (2.5%) and White (8.4%). Based on 2014 LMDSA data around 31% of blacks between 16 and 65 have paid work. The ratio is somewhat higher among coloured (45%) and Indian (42%) people, but similar for whites (34%). In the case of whites, however, only 4.5% of people are considered unemployed (not employed but seeking employment) while 23.7% of blacks are unemployed. 17% of coloured people and 9% of Indian people are unemployed.

Around 71% of workers in the ten risk levels that were analysed are black (9.38 million), 14% are coloured (1.86 million), 12% are white (1.58 million) and 3% are Indian (400 000). Table 4 presents a breakdown of workers in the four population groups based on the 10 risk levels. Table 5 presents the same data but with percentages based on the population group totals.

Risk level	Black	Coloured	Indian	White	Total
1	1 166 658	241 847	88 251	478 393	1 975 149
2	333 165	87 039	48 292	248 704	717 199
3	150 611	45 234	23 806	91 371	311 022
4	442 731	124 761	10 713	43 750	621 955
5	35 418	12 247	2 891	14 471	65 028
6	221 117	40 172	12 413	43 077	316 779
7	1 599 458	259 156	14 964	36 010	1 909 588
8	750 573	182 079	33 158	127 549	1 093 360
9	2 086 379	380 978	34 858	103 150	2 605 365
10	2 595 975	489 409	134 843	393 585	3 613 811
Total	9 382 085	1 862 921	404 187	1 580 061	13 229 255

Table 4: Estimated number of occupants by risk levels and population group.

Risk level	Black	Coloured	Indian	White	Total
1	12,4	13,0	21,8	30,3	14,9
2	3,6	4,7	11,9	15,7	5,4
3	1,6	2,4	5,9	5,8	2,4
4	4,7	6,7	2,7	2,8	4,7
5	0,4	0,7	0,7	0,9	0,5
6	2,4	2,2	3,1	2,7	2,4
7	17,0	13,9	3,7	2,3	14,4
8	8,0	9,8	8,2	8,1	8,3
9	22,2	20,5	8,6	6,5	19,7
10	27,7	26,3	33,4	24,9	27,3
	100,0	100,0	100,0	100,0	100,0

Table 5: Estimated percentage of occupants by risk levels and population group.

It is evident from the data that the previously disadvantaged population groups are more exposed to job losses due to the computerisation of work than their white counterparts. 75% of black workers are situated at levels 7 to 10, so are 70% of coloured workers. For all groups other than whites the largest portion of workers are situated at level 10. For whites, however, the largest portion is situated at level 1 (over 30%). These differences are illustrated by area graphs in Figure 2. Each graph represents the number of workers from the population group (vertical axis) in relation to their risk level (horizontal axis).

The relativity small portion of white workers in high risk occupations may seem to suggest that, in comparison to other groups, whites will not experience a significant decrease in labour demand due to computerisation. While this deduction is valid, it should be noted that there are high numbers of white workers in administrative service sector occupations. Of the seven most largest occupations among whites, four are at level 10 (*Office clerks, Salespersons, Secretaries and Accountants*) and one is at level 8 (*Finance and administration managers*). Combined, these five occupations employ over 300 000 of the 1.58 million white workers.

As illustrated on the area graph for black workers, the high number of *Domestic helpers and cleaners* (over 900 000 black workers perform this occupation) create a spike at level 7. The same pattern is observable for coloured workers. Both groups also have high numbers of workers that are employed as *Farmhands and labourers* with a computerisation probability of 0.97. The excess unemployed, low-skilled workers has kept wages for farmworkers low, a situation which culminated in protests and strike action during 2012 and 2013.

6 Discussion

The findings of this study suggest that the occupations held by 3.6 million South African workers, just over 27.3% of all workers in the country, are highly susceptible to computerisation through advances in artificial intelligence and robotics. It was found, furthermore, that over 3.2 million of these workers are from previously disadvantaged population groups (Black/Coloured/Indian). While almost 400 000 white South

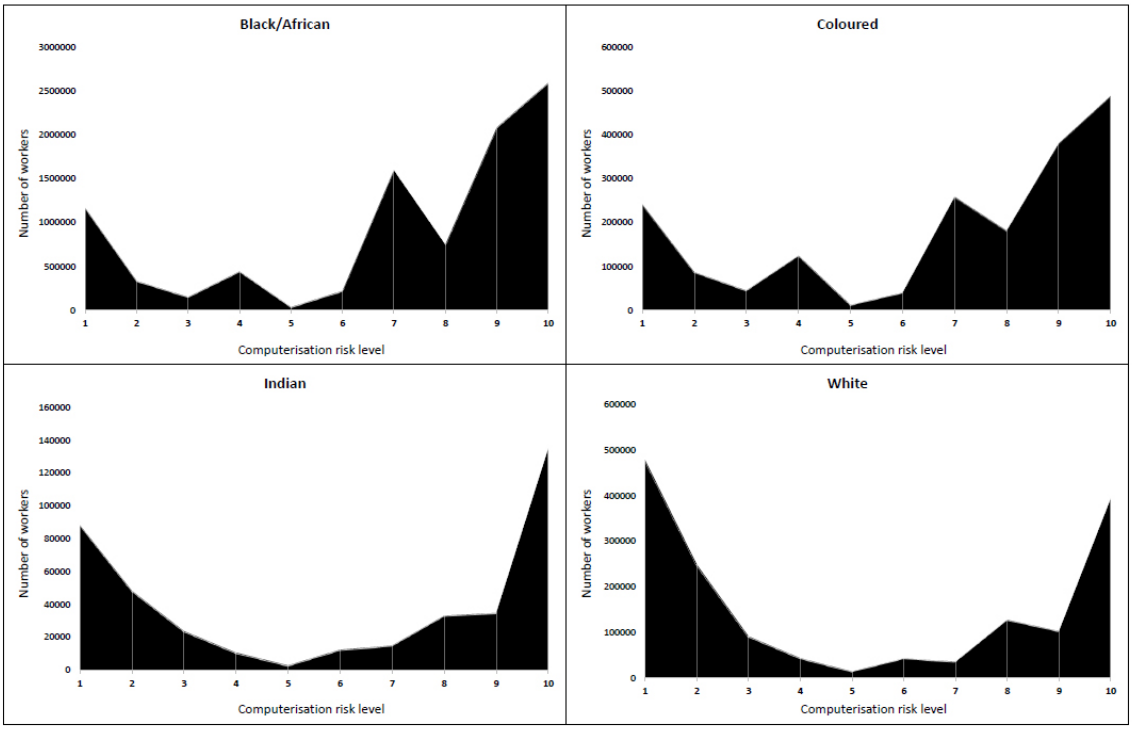

Figure 2: Area graphs representing worker numbers (vertical axes) for the four population groups in relation to risk level (horizontal axes).

Africans also fall in the high-risk category, there is clear evidence that the proportion of white workers in low-risk occupations is greater. A number of questions emerge regarding the interpretation of these findings.

The most important relates, firstly, to the accuracy of Frey and Osborne (2013)'s computerisation probabilities and, secondly, how these should be interpreted for a developing country like South Africa. For example, one needs to consider whether there is indeed a 0.87 probability that the work of *Farmhands and labourers* can be computerised and, if that is the case, whether South African farmers will replace their workers with the associated technologies.

To address the first question it is instructive to consider the increasing number of emerging technologies that defy commonly-held beliefs about what computers are capable of. In 2005 Levy and Murnane (2005) notoriously stated that 'executing a left turn against oncoming traffic involves so many factors that it is hard to imagine discovering the set of rules that can replicate a driver's behaviour'. Of course, Google's fully autonomous Toyota Prius was announced a mere six years later (Frey and Osborne, 2013). Frey and Osborne (2013)'s probabilities for certain occupations may, in a similar way, be perceived as far-fetched or overly techno-optimistic. Ultimately, only time will tell how far the potential of artificial intelligence and robotics can be stretched, and whether the resulting technologies can be produced at a large enough scale. In the absence of certainty in this regard, it may be insightful to consider the opinions of high-tech entrepreneurs like Mark Zuckerburg, Ray Kurzweil and Elon Musk which suggest that we tend to underestimate, rather than overestimate, the speed at which progress is being made.

To address the question regarding the diffusion of new technologies, the historical examples cited by Rifkin (1995) provide some guidance. To maintain the financial viability of their operations capital owners must continuously weigh the potential benefits of new technologies against their costs and compare this to the performance of manual labour. If they fail to harness the productivity benefits offered by automation they risk their position in the market. This is accentuated in the global market where competition is not regulated by national borders and, consequently, access to technology. Of course, governments can adopt measures to limit technology adoption. For example, promoting, through subsidies, the use of manual labour as opposed to machine labour would influence the investment decisions and technology strategies of capital owners. However, as Van der Berg (2011) warns, 'in the absence of improved education, direct interventions to artificially change labour market outcomes also have few prospects for improving poverty and distribution and may reduce the efficient functioning of the labour market, with various possible side-effects'.

A third question worth addressing concerns the balance between labour destruction and creation. Based on the LMDSA data analysed in this study there is evidence that low and medium-skilled white-collar occupations are in decline in the South African private sector. The growth in government employment partly counteracts this, particularly for low-skilled workers, but there is limited growth and even decline in the number of persons working in high-skilled, white-collar occupations. What should be considered in this regard is that South Africa is experiencing a skills-shortage, particularly in IT-oriented occupations. Hence, the number of persons working as computer programmers do not necessarily reflect the demand for such skills. What is evident, however, is that the skills-bias of technological progress favours the high-skilled elite rather than large number of low-skilled workers.

There is broad agreement, even among modern Luddites, that the vilification or even retarding of technological progress is not a feasible strategy for economic growth. One solution which has received some attention is the implementation of negative taxation for manual labour Brynjolfsson and McAfee (2012). Another is the notion of a *Universal Basic Income (UBI)* for all. Rifkin, citing the work of Robert Theobald, argue that 'with machines doing more and more of the work, human beings would need to be guaranteed an income, independent of employment in the formal economy, if they were to survive and the economy were to generate adequate purchasing power to buy the goods and services being produced'. This, he further writes, would put into effect 'the fundamental philosophical belief which has recurred consistently in human history, that each individual has a right to a minimal share in the production of society' (Rifkin, 1995).

For South Africa, with its large number of low-skilled workers, a dramatically improved education system is an obvious and critical concern. The growth in teaching and associated occupations is evidence that the government is trying to make improvements in this regard. However, Van der Berg (2011) expresses scepticism about the realisation of this ideal and concludes that failure in this regard obstructs any effort to address poverty and inequality. Furthermore, based on the findings of this study, it is argued that technology adoption is likely to decrease demand for low and medium-skilled labour in private sector industries, putting further pressure on government to expand its already bloated public sector employment programmes.

While the findings discussed here paint a rather gloomy picture, it is important to also highlight the opportunities created by smart computing technology. Brynjolfsson and McAfee (2012) call for entrepreneurs to consider the possibilities of a *Race with machines* as opposed to *against* machines. Such a view, they argue, can lead to 'new business models that combine the swelling number of mid-skilled workers with ever-cheaper technology to create value'. This approach subverts the dominant notion of the modern tech start-up in which value is created (and owned) by small number of highly skilled workers. Perhaps the glaring inequality of its citizens serves to motivate South Africa's emerging tech entrepreneurs to take up this challenge.

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