THE FOURTH INDUSTRIAL REVOLUTION AND HUMAN CAPITAL DEVELOPMENT

A thesis submitted in fulfilment of the requirements for the degree of

Master of Commerce

KYLE GOLDSCHMIDT

13G0080

November 2017

Supervised By: Professor G. Keeton & Mr D. Fryer

Department of Economics and Economic History
Rhodes University
Grahamstown
South Africa

2017

Declaration

This page serves to declare that I submit this thesis for the degree of Master of Commerce (MCom) in the Department of Economics and Economic History at Rhodes University. I declare that this is my independent work and has not been submitted by me to any other Universities, Technikons or Colleges for degree purposes.

Kyle Goldschmidt

December 2017

Abstract

The focus of the Fourth Industrial Revolution has been on its implications on Human Capital and its need to develop *“21st-Century Skills”* through education to ensure future labour and capital complementarity. Human Capital combined with 21st-Century Skills, it is claimed, can together generate economic growth, jobs and propel an economy into the next Industrial Revolution. However, Schwab’s (2016) concept of the Fourth Industrial Revolution, make no distinction between the Average Worker and the Knowledge Elite and their relationship to each other and successful economic growth. The different nature of these skills is absent in the literature to date. A critical analysis of literature will be used to examine Schwab’s (2016) claim of a Fourth Industrial Revolution and assess how the Average Worker and the Knowledge Elite relate to the Fourth Industrial Revolution and 21st-Century Skills. The evidence is provided on how both the Average Worker and the Knowledge Elite are key contributors to economic growth and will be important in the Fourth Industrial Revolution.

Table of Contents

List of Tables

List of Figures

Introduction

1.1 Context of Research

According to Schwab (2016), the 21st-Century has seen the complete command of technologies that have disrupted the way individuals go about their daily lives. It has given birth to a highly informed and interconnected generation whose lives increasingly revolve around information technology. Schwab (2016) claims that what the world is currently witnessing is more than an evolution of technology, but rather the advent of a whole new Industrial Revolution that is fundamentally changing the way people live, work and relate to one another. Schwab (2016) dubs this era *"The Fourth Industrial Revolution"*. Schwab (2016) describes this revolution as a convergence of rapidly developing technologies that are effectively amalgamating the digital, physical and biological worlds. He states that the emergence of these new technologies is characterised by developments ranging from nanotechnology to artificial intelligence to biotechnologies, which together are having a profound impact on economies, industries and the workplace.

Schwab's (2016) concept of the Fourth Industrial Revolution has been widely adopted by commentators and policymakers such as Infosys (2016), Baweja *et al*. (2016), Deloitte (2015) and the World Economic Forum (2016). The focus has been on the implications for the workplace and required skills. This Fourth Industrial Revolution creates the urgent need to develop what the World Economic Forum (2015) and Schwab (2016) describe as *"21st-Century Skills"* and to adopt policy measures described as *a "Future-Ready Education Ecosystem"* and *"Transition to A New World of Work"*. The *"Future-Ready Education Ecosystem"* is a global blueprint of key action areas that are intended to guide policymakers, the private sector and education specialists, to ensure that they transition education systems into systems that are more responsive and relevant to the Fourth Industrial Revolution. *"Transition to A New World of Work"* is a proposed strategic action plan to ensure that Human Capital is prepared for the transition to a new workplace brought about by the Fourth Industrial Revolution. It outlines a set of strategies that the World Economic Forum (2017a) claims are vital to allow Human Capital to transition seamlessly into a heavy digitised workplace and economy.

However, of importance, and central to this research, is the policy proposed by the (World Economic Forum, 2015), which details the need to develop *"21st-Century Skills"*. These are the claimed set of abilities that all forms of Human Capital will need to succeed in the Fourth Industrial Revolution. Lack of such skills, it is suggested (World Economic Forum, 2015), is producing a growing skills gap, which must be countered through a combination of improved education and technology. Schwab (2016) argues that when they are both effectively deployed, the combination of education and technology, instead of resulting in rising unemployment as machines replace workers, will rather create a new skill set amongst workers. This skill set will allow workers to adapt and *"infuse"* within this ever more prevalent technology-rich marketplace (Schwab, 2016). Schwab (2016) emphasises that in the Fourth Industrial Revolution both technology and society can complement rather than substitute one another as has always been perceived in the past. He claims that technology is not an exogenous force that humankind does not control. Rather, technology is something that can propel society forward and stimulate economic growth. Schwab (2016:4) claims that the Fourth Industrial Revolution has the power to create opportunities that will allow humankind to shape a revolution that *"empowers the state of the world"*.

The key factors that Schwab's (2016) view of the Fourth Industrial Revolution rest on are, firstly, the importance of combining technology and Human Capital; and, secondly, that through appropriate education, technology and Human Capital can together generate economic growth, jobs and propel an economy into the next Industrial Revolution. This thesis seeks to analyse these claims by analysing the historical contribution of Human Capital and technology to economic growth.

When analysing the influence of these key factors on each other, two critical arguments emerge from the literature. Firstly, modern (endogenous) economic growth theory depicts Human Capital as an essential element in economic development (Romer, 1994), that is enhanced through education (Mankiw, 1995). Theoretical findings illustrate that educated Human Capital is more easily able to adopt innovations and technical advancements (Ljungberg, 2004).

A contrary view, based on an analysis of the First Industrial Revolution, demonstrates that Human Capital when measured broadly (the Average Worker), in fact, had a minor influence on growth (Pritchett, 2001; Galor, 2005; Allen, 2009). This finding is reduced to three overarching reasons. Firstly, it is predominately based upon the low education attainment at the time. Secondly, it focuses on the demand for unskilled rather than skilled labour by emerging industries during the First Industrial Revolution (Goldin & Katz, 1998; de Pleijt & Weisdor, 2017). Lastly, it emphasises the deskilling impact that technology over this period had on Human Capital (Marx, 1906; Braverman, 1998).

These two assessments of historical growth provide a perplexing, contradictory set of arguments whose further scrutiny forms the basis of this thesis. The former claim depicts Human Capital to be one of the most critical determinants of modern growth, while the latter perceives Human Capital to have played a minimal role in driving growth historically.

The perceived minimal role of Human Capital during the First Industrial Revolution is based on analysis using average educational attainment, or more specifically, literacy rates, as a measurement of Human Capital. Mokyr & Voth (2010:29) challenge the appropriateness of this measure of Human Capital. They, along with Squicciarini & Voigtländer (2015), argue it is necessary to distinguish between the Human Capital of the Average Worker and that of the upper tail worker, or the Knowledge Elite, to accurately determine their historical importance for growth. They suggest it is the elite group, rather than the Average Worker, which drove the First Industrial Revolution through their ingenuity and technical ability towards important inventions. Moreover, Squicciarini & Voigtländer (2015), Feldman & van der Beek (2016) and Ljungberg (2004) contest the claim that the important inventions and subsequent technological advancement during the period of the First Industrial Revolution, were in fact deskilling. Instead, they argue that there was a need for re-skilling founded on evidence of capital-labour complementarity and skill-demanding capital.

This research considers both views of industrialisation to be valid. It will show that neither view is incorrect, but instead, they are mutually inclusive accounts of historical development that in fact support one another. It shows that it is necessary to distinguish between the Average Worker and the Knowledge Elite. The importance of the latter is veiled in those studies that use average education attainment as the measure of Human Capital (Mokyr & Voth, 2010). This means that it is also necessary to distinguish between the terms *schooling* and *education*.

In accounting for the driving forces behind the past Industrial Revolutions, a more precise distinction between Productive Forces and of Production Relations emerges from the literature (Edgell, 2012; Hodson & Sullivan, 2008 and Marx, 1978). The more explicit distinction between Productive Forces and of Production Relations gives valuable insights into how technological advancement impacted on workers' skills and knowledge.

When analysing the causes of why industrialisation during the First Industrial Revolution occurred in Britain, two notable arguments between Mokyr (2005) and Allen (2009) emerged amongst the various accounts and expositions on growth and development theories. Mokyr (2005) argues that the origin of the First Industrial Revolution is founded in the Enlightenment Movement, which created an enabling intellectual environment in Britain. Central to the Industrial Enlightenment were institutions such as the Baconian programme and the Royal Society, which were underlined by the desire to transfer new knowledge and apply it. Mokyr (2002:3) argues that the Enlightenment movement generated cultural conditions that nurtured *"Useful Knowledge"* for industrialisation that was exploited by the highly-skilled craftsmen, or as Squicciarini & Voigtländer (2015:2) depict it – the Knowledge

Elite[1], and fostered innovation and economic growth. The Knowledge Elite were the highly skilled inventors, mechanical engineers and craftsman, who progressively made improvements to famous inventions such as the steam engine, spinning jennies and iron refinements. In Mokyr's (2002) view, this enlightenment movement improved both institutional quality and technological capabilities that together made the First Industrial Revolution possible.

Allen (2009) provides a different argument as to why the First Industrial Revolution occurred in Britain rather than elsewhere. He suggests its origin lay in Britain's unique wage and price structure which encouraged technological breakthroughs, spurred on by an increasing demand for inventions that substituted capital and energy for relatively expensive labour. Both accounts, Mokyr (2005) and Allen (2009), give weight to the role of the Knowledge Elite, and the importance of the substitution of capital for labour as drivers of industrial growth.

Economic theory and evidence in the literature suggest that the Knowledge Elite are both necessary and able to keep up with advances at the technology frontier, and that capital was, in fact, complementary to labour, rather than substituting. This is accounted for by Romer's (1994) New Growth Model, which states that investment in innovation and knowledge, and in Human Capital are all key contributors to economic growth because of their spillover effects that help advance new technologies. The Average Worker can account for changes in output by moving societies along a given production function, while the Knowledge Elite can shift the production function outwards, leading to increased total output by increasing total factor productivity.

An analysis of the literature, therefore, highlights both the critical role of the Knowledge Elite and that the associated technological advancements were, in fact, skilled-biased and complementary to labour. This finding is not to say that the Knowledge Elite is the only or even central driver of economic growth, nor that deskilling never occurred during the process of industrialisation. Instead, the Knowledge Elite is a critical driver, in combination with other growth determinants, in shifting the production function and aiding the process of industrialisation.

However, Schwab's (2016) concept of the Fourth Industrial Revolution, which depicts the complementarity between labour and capital, make no distinction between the Average Worker and the Knowledge Elite. Instead, reference is made merely to "21st-Century Skills" as if these are uniform

[1] The terms "Knowledge Elite" and "Average Worker" are conceptualised by Squicciarini & Voigtländer (2015:2) and their understanding of each will developed throughout this research.

and universal. The nature of these skills and their relationship to the Average Worker and the Knowledge Elite is absent in the literature to date.

1.2 Goals of the Research

The principal goal of this research is to critically examine Schwab's (2016) claim of a Fourth Industrial Revolution, specifically to its occurrence and its potential effect on workers and their skills.
Sub-goals are:

- Examine and account for the two opposing views regarding the extent that Human Capital affects economic growth
- Identify the distinguishing factors between Mokyr (2005) and Allen's accounts on why industrialisation occurred in Britain, during the First Industrial Revolution.
- Distinguish between the Average Worker and the Knowledge Elite and how their respective skills and knowledge were affected by industrialisation.
- Examine the claims of deskilling in past industrialisation and the extent that reskilling did occur.
- Distinguishing between the Average Worker and the Knowledge Elite, and examining their importance in the ability of an economy to grow in the future.
- Conduct a cross-country comparison between South Africa, other developing countries and Advanced Economies to measure their readiness to meet the challenges of the Fourth Industrial Revolution.

1.3 Methods, Procedures and Techniques

The research will use a mixed method approach that is both qualitative and quantitative. Based on Schwab's (2016) claim, a critical review of the literature will be used to determine the Fourth Industrial Revolution's occurrence and its potential effect on workers and their skills. A review of the literature will continue in assessing both accounts on why industrialisation during the First Industrial Revolution occurred in Britain. The same method will be used to distinguish between the Average Worker and the Knowledge Elite, the impact that industrialisation had on their respective skills and knowledge, and to examine the claims of deskilling/reskilling in past industrialisation. Finally, the ability of an economy to grow in the future will be examined by distinguishing between the Average Worker and the Knowledge Elite. In conclusion, national indicators will be used in a high-level cross-country comparison between South Africa, other developing countries and Advanced Economies, to measure their relative readiness to meet the challenges of the Fourth Industrial Revolution

A critical review of the literature about previous industrialisation and forms of technological change will be used to determine whether a Fourth Industrial Revolution actually exists. Schwab's (2016) account of past and future Industrial Revolutions will then be compared to evolutionary economics, such as those detailed by Perez (2009). This will determine whether the Fourth Industrial Revolution is, as Schwab (2016) argues, an entirely new Industrial Revolution, or if it is just an extension of what the world is already experiencing during the Third Industrial Revolution.

In assessing Schwab's (2016) claim of the potential effect of the Fourth Industrial Revolution on workers and their skills, examination of the literature will reveal the historical interplay between workers skills and industrialisation. This will be used to assess the demand for a creation of an entirely new skill set amongst workers and how skills and technology affect one another.

In examining literature to account for the two opposing views regarding the extent that Human Capital had historically on economic growth, the focus will be on the role that education played in the First Industrial Revolution. This will provide an understanding of why it was claimed that education had a minor role in Human Capital formation, as well as insight into what other forms of education were important. This will lead to a discussion of the importance of expanding measures of education to include informal ways of attaining skills, such as apprenticeships.

The historical role and importance of the Knowledge Elite and the Average Worker will also be assessed from this critical review of the literature. The importance of the Knowledge Elite will be revealed through analysing why the First Industrial Revolution occurred in Britain, as argued between Mokyr (2005) and Allen (2009). Literature will be used to discuss the Average Worker and the effects of industrialisation on knowledge and skills of the Average Worker.

Rather than depicting physical capital as a substitution to Human Capital, evidence from the literature will be examined to assess the historical importance of re-skilling, and for disregarding acquired redundant and irrelevant skills. These findings will be used, firstly, to examine the complementarity of capital and labour and skill-demanding capital. Secondly, they will be used to establish the importance of education and training on Human Capital and its consequent role in economic progression.

This analysis of the historical roles and importance of the Average Worker, the Knowledge Elite and deskilling in previous Industrial Revolutions will form the basis of assessing their likely importance in the Fourth Industrial Revolution. This will lead to the final examination of the role of the inclusion of informal ways of attaining skills, such as apprenticeships, in acquiring the 21st-Century Skills needed to facilitate economic growth and give economies the ability to propel themselves into the Fourth Industrial Revolution successfully.

Therefore, a broader approach needs to be taken in trying to assess a country's readiness for the Fourth Industrial Revolution. Instead of basing a country's likelihood of success on measures of the composition of the Knowledge Elite and Average Worker, the Network Readiness Index (World Economic Forum, 2016) will be used as an imperfect alternative. The Networked Readiness Index outlines the competitiveness landscape of 140 economies to quantify the impact of several key indicators that the World Economic Forum (2016) claims depict how countries are coping with the digital world based on their use of information and communications technologies.

The basis of the Networked Readiness Index is embedded in whether a country possesses the necessary drivers that will allow digital technologies to meet their potential. By extension, it measures whether these digital technologies are impacting on the economy and society. The drivers measured are divided into three sub-indexes namely, the *overall environment*, *readiness* and *usage* (World Economic Forum, 2016). Their *impact* is measured regarding both economic and social impact. *Readiness* further comprises of affordability, infrastructure and skills, while *usage* divided into businesses, individuals and the government.

Indicators from the Network Readiness Index (World Economic Forum, 2016) are used in a high-level cross-country comparison between South Africa, other developing countries and Advanced Economies, to account for their readiness to meet the challenges of the Fourth Industrial Revolution. These indicators are divided into the three sub-indexes namely, the *overall environment*, *readiness* and *usage* (World Economic Forum, 2016). Their *impact* is measured regarding both economic and social impact. Data for this comparison is sourced from the annual Global Information Technology Report 2016 (World Economic Forum, 2016). The Networked Readiness Index therefore to some degree depicts the readiness of countries to make the transition into the Fourth Industrial Revolution.

1.4 Structure of Research

This research consists of 8 chapters as well as an Introduction and Conclusion. Chapter 1 provides an overview of the backdrop, theory and literature regarding the Fourth Industrial Revolution and the Pillars that are central to it. Chapter 2 outlines the implications of Schwab's proposed Fourth Industrial Revolution and various past reiterations. Chapter 3 discusses the consequences of industrialisation on workers' skills and the interplay between Economic Growth, Technological Change & Human Capital. Chapter 4 discusses the relationship between Industrialisation and Education, and how measures of average education can veil the existence (or absence) of the Knowledge Elite. Chapter 5 sheds light on the importance of the Knowledge Elite and their role during the Industrial Revolution. Chapter 6 gives an historical account of industrialisation and importance of the Average Worker, examining how their knowledge and skills were affected by technological advancement in previous

Industrial Revolutions. Chapter 7 discusses the arguments of deskilling and reskilling through technological advances. Chapter 8 discusses the nature of 21st-Century Skills and the Knowledge Elite, and what Human Capital is needed for economies to manage the onset of the Fourth Industrial Revolution successfully. Measures of South Africa relative to other country groupings are included in this Chapter. This is followed by the Conclusion of the thesis.

Chapter 1: The Next Industrial Revolution

Klaus Schwab (2016:8), founder and executive chairman of the World Economic Forum, stated at the 2016 World Economic Forum Conference that *"We must have a comprehensive and globally shared view of how technology is changing our lives and those of future generations, and how it is reshaping the economic, social, cultural and human context in which we live...The changes are so profound that, from the perspective of human history, there has never been a time of greater promise or potential peril"*. Schwab (2016) claims that the coming years will mark the onset of a new revolution that will fundamentally change the way people live, work and relate to one another. Due to the *"scale, scope and complexity"* of this change, Schwab (2016:1) dubs this era *"The Fourth Industrial Revolution"*. This Chapter provides an overview of the backdrop, theory and literature regarding the Fourth Industrial Revolution and the Pillars that are central to it. It is structured as follows: Section 1.1 provides a brief explanation of Schwab's (2016) Fourth Industrial Revolution. Section 1.2 details the interplay between technology, economic growth and Human Capital against the backdrop of Modern Growth Theory. Section **Error! Reference source not found.**sets the stage for those elements of S chwab's Fourth Industrial Revolution this research aims at investigating

1.1 Schwab's Fourth Industrial Revolution

The Fourth Industrial Revolution, for Schwab, is defined by a convergence of rapidly developing technologies that are effectively amalgamating the digital, physical and biological worlds. Physical technologies include 3D printing, autonomous vehicles and advanced robotics. The digital world is embedded in an on-demand economy, utilising the *Internet of Things* (IoT). The biological world is the advancement of synthetic biology, precision medicine and genetic modifications (Schwab, 2016).

Schwab (2016) claims these new technologies will have a profound influence on all economies and industries across the globe. They will connect billions of people to the web, improving business efficiency and improving the management of assets to help regenerate environmental damage. Effectively, the Fourth Industrial Revolution is a culmination of technological advancements and innovations spanning over the past two decades, encompassing the emergence of *Artificial Intelligence* (AI), the *Internet of Things* (IoT), nanotechnology, robotics, autonomous vehicles, 3D printing and biotechnology (Schwab, 2016). These developments, according to Deloitte (2015), are not necessarily new. However, due to the increase in computing power, cost reduction and miniaturisation, they have become more apparent and suitable for industrial use (Deloitte, 2015).

Schwab (2016) believes that the scale, scope, and complexity of such changes justify the claim for the existence of a Fourth Industrial Revolution. Schwab (2016:2) states that the Fourth Industrial Revolution is not merely a prolongation of the Third Industrial Revolution. He provides three reasons for this, namely "*Velocity*, *Scope*, and *Systems Impact*". Furthermore, he claims that the speed of current breakthroughs has no historical precedent.

Schwab (2016) sees many benefits flowing from this Fourth Industrial Revolution. He claims it has the potential to increase global income levels and improve peoples' quality of life throughout the world. Focusing on the supply-side benefits of the Fourth Industrial Revolution, based on traditional measures such as GDP, Schwab (2016) argues that the global economy will see a long-term increase in efficiency and productivity because of the resultant cost reductions in trade, communication and transport. This will in turn increase accessibility to world markets, enabling people to consume more at lower prices. Schwab (2016) claims that both human needs and wants are infinite. Therefore, there will be an endless supply of these needs and wants in the long term. Demand-side opportunities for Schwab (2016) will allow greater access to the digital world for consumers, who will benefit from new products and surpluses of production brought on by these revolutionary technologies.

Schwab (2016), however, cautions that businesses might be unable or unwilling to adapt to the onset of these new technologies. Governments, too, may fail to implement regulations enabling the adoption of these new technologies and consequently countries may fail to capture their full benefits.

He further warns that the rise in automation and use of machinery has the potential to replace workers and *"robotise humanity"* and so may exacerbate inequality (Schwab, 2016:105). In this regard, Schwab (2016) shares a common viewpoint with Brynjolfssonn & McAfee (2016) who claim that a new technological revolution could cause greater inequality because of its disruption of labour markets. Schwab (2016), likewise, warns that the rise in labour-substituting machinery, and the net displacement of workers caused by this substitution, will result in a growing gap between the returns to labour and returns to capital.

On a more optimistic note, Schwab (2016) suggests that this displacement will not be entirely negative. He suggests there will be a net increase in safe and rewarding jobs. He claims, also, that in future, human talent will play a far more critical role in the production process, more so than capital. However, this will also give rise to a more segregated job market, with a growing divide between lower-skill/lower-pay jobs and higher-skill/higher-pay jobs, which will increase social tensions. What this reveals for Schwab (2016), is an increase in demand for higher skilled workers, particularly in high-income countries, with a decrease in demand for workers with lower skills and poor education.

This depicts a future job market where there is simultaneously a significant demand for both higher and low-end skills, coupled with a *"hollowing out"* of the middle (Schwab, 2016:47).

In his exposition of the Fourth Industrial Revolution, Schwab (2016) attempts to argue two concepts. Firstly, he tries to prove that such a revolution is happening. Secondly, he warns of the dangerous implications for the world economy if its existence is not recognised and policymakers do not react immediately.

1.2 The Pillars of Industrialisation

Schwab's (2016) Fourth Industrial Revolution rests heavily on the concept of Human Capital and the importance of finding complementarity between technology and Human Capital through education and development of 21st-Century Skills[2]. Together these will, Schwab (2016) claims, generate economic growth and propel economies into the next Industrial Revolution. Entrenched in this vision of the future, however, is the concern that failure to find this complementarity through education will result in job loss and deskilling.

Romer's (1994) New Growth Model, states that investment in innovation and knowledge, and in Human Capital are all key contributors to economic growth because of their spillover effects that help advance new technologies. In this view, if Human Capital is successfully enhanced it will generate both economic growth and jobs that will propel an economy into the next Industrial Revolution. Theoretical findings are that educated Human Capital are more easily able to adopt innovations and technical advancements (Ljungberg, 2004).

An argument that is commonly coupled with any technological advancement, such as the ones said to be brought on by the Fourth Industrial Revolution, is that it is associated with deskilling. The extent of such deskilling is highly contested. Many commentators claim that the experience of previous Industrial Revolutions was re-skilling rather than deskilling. Squicciarini & Voigtländer (2015), Feldman & van der Beek (2016) and Ljungberg (2004) contest the claim that the important inventions and subsequent technological advancement during the period of the First Industrial Revolution, were deskilling. Instead, they argue that there was a need for re-skilling founded on capital-labour complementarity and skill-demanding capital.

---

[2] A concept that is discussed in Section 3.5

In assessing the impact of Schwab's (2016) Fourth Industrial Revolution, the interplay between technology, economic growth and Human Capital needs to be investigated. The effect on the skills and knowledge of Human Capital on technology and their ultimate effect on economic growth needs to be analysed. This analysis will take place in terms of the three concepts of Economic Growth, Technological change and Human Capital.

1.2.1 Economic Growth

Technological change has had a profound and transformative effect on production, industry and economic activity. The implementation and advancement of technology have increased efficiency in production processes and have ultimately lead to higher economic growth and standards of living. Increased efficiency in production processes in manufacturing, as seen in *Industry 4.0*, (Germany Trade and Invest, 2014) is primarily due to the digitisation of traditional industry, the expansion of *Smart Services* and *Green IT* and the implementation of the *Smart Factory*.

However, technological change is multifaceted and is tethered to concepts such as economic growth, production process and Human Capital. It is, therefore, necessary to scrutinise these links and the effects they have on one another.

Ljungberg (2004) states that regardless of the consensus of how everyday life has improved because of technology, there is still constant debate regarding the role that technological change has on economic growth. He highlights that there have been many attempts to incorporate technological change into economics, with mainstream economics depicting it as exogenous. Rosenberg (1974:90) notes that *"Technological change…was regarded as moving along according to certain internal processes or laws of its own, in any case independently of economic forces"*. This depicts technology as a force on its own that directly affects the economy without the economy affecting technology itself. However, Rosenberg (1974) like Romer (1994) perceives technological change as endogenous.

The emergence of endogenous growth theory (Romer, 1994) underlines technological change as an endogenous variable and highlights the processes of learning that are intertwined with new technology and models of innovation. This model is based on endogenous factors and has commonality with the Solow-Swan neoclassical growth model. However, their differences emerge regarding the assumption of diminishing marginal returns to capital investments in the Solow-Swan model. In the Endogenous Growth model diminishing returns to capital investments is absent (Todaro & Smith, 2009).

The following identity depicts the endogenous growth model:

$$Y = f(K, L, H, T)$$

where **Y** depicts the total production in an economy (Total Factor Productivity), **K** represents capital Stock, **L** represents Labour, **H** represents Human Capital acquired through education and **T** represents Technology or Total Factor Productivity.

The endogenous growth model suggests that investment in both human and physical capital induce productivity improvements and external economies that surpass private gains to the extent that they counter any diminishing marginal returns to these capital investments. This results in long-term economic growth. Romer's (1994) New Growth Theory (NGT) is based on the idea of endogeneity through the impact that technological change has on economic performance as well as Human Capital. Romer (1994) states that economic growth is created internally and is a response to economic incentives generated by the market, which is swayed by the private sector or government. Romer (1994) states that investment in innovation and knowledge, and of importance for this research, Human Capital, are significant contributors to sustainable economic growth because of their spillover effects that help advance new technologies. Unlike physical objects, both knowledge and innovation are underscored by increasing returns as they can be shared and reused infinitely. Investment in Human Capital is through both education and training, where innovation and knowledge, a key factor to technological change, are advanced through investment in research and development (R&D).

1.2.2 Technological Change

It is evident thus far that the concept of technology is intertwined with the concepts of economic growth and Human Capital. Various attempts have been made to distinguish between certain aspects of technology. Kaplinsky (1984), for example, separates *techniques* from *technology*. For Kaplinsky (1984), *technology* is the actual process, or physical content, while *technique* is how this technology is employed for an intended purpose. Differentiating technique from technology is of importance to Kaplinsky (1984) who argues that the movement from technology to techniques is due to social constructs rather than mere technical influences. It is these social constructs, such as class relations, that determine the way in which technology translates into techniques and cause instances of deskilling and divisions of labour. Ljungberg (2004) states that technology rests upon the notion of Human Capital. He attempts to distinguish between technology and technical, stating the former is a system or theory that incorporates a more in-depth knowledge, whereas the latter comprises of techniques and practices that involve practical knowledge. The two, however, are often conflated, and the term technology tends to embody both terms.

As already noted, Romer (1994) argues that Human Capital helps advance new technologies, making the concept of Human Capital a significant factor of technological change. This is in marked contrast to Marx, who viewed technological change as a stepping stone for capitalism, believing the endogenous technological change to be part of the class struggle. Whereas Romer's (1994) models of NGT (and notable various other models of growth) regard capital as an input in the production process, for Marx (1978), capital is a far broader concept which is central to class relations. For Marx (1978), the owners of the Means of Production control the Labour Process and purchase Labour Power, while the class that is subjected to the Means of Production are forced to sell their Labour Power. For Marx (1978), capital can only exist within the process of economic exchange. Any form of productivity gain or technological change is through a valorisation process (increasing the value of capital assets) centred on the production of surplus value. This differs from Romer (1994) where increasing output underscores this productivity gain or technological change.

1.2.3 Human Capital

Human Capital is an embodiment of both knowledge and skill, both of which have significant bearings on economic growth. There is much interplay between the concepts of knowledge and skill, but these are often isolated from the notion of Human Capital through their respective expositions. Any attempt to discuss the terms in isolation is complicated, as the definition of either of the terms inevitable refers to the other. For example, Goode (1959:147) defines Human Capital in broad terms as the *"… knowledge, skills, attitudes, aptitudes, and other acquired traits that contribute to production"*. Mankiw (1995:298), on the other hand, distinguishes between knowledge and Human Capital, stating that knowledge is *"society's understanding about how the world works"*, whereas Human Capital is *"the resource expended transmitting this understanding [Knowledge] to the labour force"*.

The concepts of Human Capital, Knowledge and Skill are therefore difficult to isolate. However, since these concepts are significant contributors to economic growth and form the basis of this research, an attempt will be made to analyse them in isolation, to understand their effect on each other, their influence on technology and their ultimate effect on economic growth. This attempt will be made in Chapter 3.

1.3 Conclusions

Understanding these three pillars is imperative to understanding Schwab's (2016) Fourth Industrial Revolution. Establishing them in isolation sets them up for discussion in later Chapters, while still recognising the interplay that they have on one another.

In his exposition of the Fourth Industrial Revolution, Schwab (2016) attempts to do two things. Firstly, he tries to prove that such a revolution is happening. Secondly, he warns of the dangerous implications for the world economy if its existence is not recognised and policymakers do not react immediately. This research will attempt to assess both these elements of Schwab's (2016) thesis. Firstly, the validity of Schwab's (2016) claim that a new (Fourth) Industrial Revolution is occurring will be investigated. This is necessary because some commentators have challenged Schwab's (2016) notion that a new Industrial Revolution is in fact underway. Rifkin (2016), for example, argues that what Schwab (2016) is describing is nothing more than an extension of the Third Industrial Revolution, while Garbee (2016) questions the existence of a new Industrial Revolution altogether. Chapter 2 will, therefore, investigate whether the claims of a Fourth Industrial Revolution are valid.

The second element of Schwab's (2016) exposition concerns the effect that a Fourth Industrial Revolution will have on workers and their skills. Fears of possible job losses because of new technologies have been a feature of all periods of technological change (e.g. the Luddites destroying machines during the First Industrial Revolution). Irrespective of whether what Schwab (2016) is describing should be considered a Fourth Industrial Revolution, it is still beneficial to establish a basis for examining the impact of the technologies Schwab (2016) describes. This basis requires developing a framework in which the effects that technology and Human Capital have on one another can be understood. The primary focus of this framework is on how Human Capital, particularly skills and knowledge, have been affected during previous Industrial Revolutions and their respective technologies. An examination of this element of Schwab's (2016) claim will receive an in-depth analysis in Chapter 3 and onwards.

Chapter 2: A Revolution or Revision?

The first element of Schwab's (2016) exposition is his belief that a Fourth Industrial Revolution is occurring that is different from what happened previously. Rifkin (2016), argues that Schwab's (2016) claim in a distinct new revolution is *"on thin ground"*. Rifkin (2016) argues that current technologies are nothing more than a continuation of the Third Industrial Revolution and many elements of the technology, such as Artificial Intelligence, nanotechnology or robotics, are nothing entirely new. Rifkin (2016) suggests that many of the "revolutionary" technologies that Schwab (2016) uses to advocate the existence of Fourth Industrial Revolution have long existed. Evidence of this can be seen in the fact that these supposedly "new" technologies have already been used as the poster child for Germanys High-Tech Strategy Action Plan: Industry 4.0 which was launched in 2006 (Rifkin, 2016).

The primary aim of this Chapter is to account for the existence of Schwab's Fourth Industrial Revolution. However, there are limitations. Schwab's justification of an entirely new Industrial Revolution is based on just three reasons (Scope, Velocity and Systems Impact). Schwab (2016) leaves little concrete evidence that shows that his Fourth Industrial Revolution is distinctly different from the 'previous' Third Industrial Revolution, other than the three reasons he provides. Even Schwab (2016) realises that his claim is highly contentious as he notes that many academics and professionals will consider his claim and developments to be simply a part of the Third Industrial Revolution. Regardless of this limitation, an attempt will still be made to assess the validity of his claim.

This will be achieved by comparing his claims to another instance they are constantly compared to, namely *Industry 4.0*. Furthermore, Schwab's Fourth Industrial Revolution will be contrasted to that of evolutionary economics, to assess whether what the world currently is experiencing, is in fact what he claims. It is noted that this attempt is imperfect. However, due to the little justification that Schwab provides, it is the best alternative. This Chapter is structured as follows: Section 2.1 establishes Schwab's historical timeline of Industrial Revolutions. Section 2.2 accounts for Schwab's claim that a Fourth Industrial Revolution is occurring. Section 2.3 discusses the accounts that reject Schwab's claim. Section 2.4 contrasts and discusses the incompatibility of Schwab's (2016) depiction of account of Industrial Revolutions with that evolutionary economics as detailed by Perez's (2009) Technological Revolutions. Section 2.5 discusses *Industry 4.0* and its similarities to Schwab's Claim. Section 2.6 concludes the Chapter.

2.1 The Past Industrial Revolutions

Before assessing Schwab's claim, it is necessary to put it in an historical context. The reasons for previous Industrial Revolutions are, however, highly contested. They draw from various historical accounts and theories on growth and development, and on '*coined*' phrases, which often provide for a contradictory and confusing debate.

As depicted in *Table 1*, Schwab (2016) dates the First Industrial Revolution from the 1760s to the 1840s and notes that it saw the rise of the factory and the transition to Industrial Capitalism. This marked the beginning of mechanisation and automation, which served as a critical element of future economic development. Manufacturing saw the increased use of energy-intensive fuels, leading to the use of steam power and locomotives. This resulted in a rise in communication, transport infrastructure, and agricultural development. What followed from the 1870s to 1910s was what was initially regarded as the Technological Revolution, or which has become more commonly known as The Second Industrial Revolution. It comprised of the use of electrical power to create mass production and increase automation. This saw the growth in production efficiency, marked by a division of labour. The standout concept of the Second Industrial Revolution was standardisation, which was a crucial driver in the expansion of supply chains that eventually lead to controlled quality standards and increased production (Baweja *et al.*, 2016). The 1950s marked the beginning of the Information Age through the advent of the Digital Revolution, which had come commonly known as The Third Industrial Revolution. It marked the move away from mechanical and analogue electronic technologies to digital electronics, computing and communication technology.

The start of the 21st-Century is claimed by Schwab (2016) to mark the beginning of the Fourth Industrial Revolution. It is characterised by the convergence of rapidly developing technologies established in the previous, Third, Industrial Revolution, and marks an amalgamation of digital, physical and biological worlds. Schwab (2016:12) states that the Fourth Industrial Revolution is underlined by automation and connectivity and should be interpreted as *"the second machine age"*.

Industrial Revolution	Period	Main Technical Achievement
First Industrial Revolution	1760 - 1840	Steam, mechanical Production
Second Industrial Revolution	1870 - 1914	Mass Production, Electricity
Third Industrial Revolution	1950 - 1970	Electronics, Automated Production
Fourth Industrial Revolution	Present	Cyber-Physical Systems

Table 1: Schwab's (2016:11) Timeline and Account of the Industrial Revolutions

2.2 Schwab's Claim of a Fourth Industrial Revolution

Schwab (2016) is at pains to prove that his notion of the Fourth Industrial Revolution is not merely an updated form of the Third Industrial Revolution. He argues that the Fourth Industrial Revolution *is* an entirely new force on its own. However, he admits that it does build on the Third Industrial Revolution and, that it has already been underway since the middle of the last century. The critical difference, Schwab (2016:1) states, is that *"The speed of current breakthroughs has no historical precedent"*.

He provides three reasons to substantiate his claim that this revolution is distinct from what preceded it. These reasons are the Fourth Industrial Revolution's *Velocity*, *Scope*, and *Systems Impact*. Regarding *Velocity*, Schwab (2016:8) states that due to the "multifaceted, deeply interconnected world we live in and the fact that new technology begets newer and ever more capable technology", the pace of change of this revolution is exponential. The *Scope* of the Fourth Industrial Revolution is such that by combining various technologies and building on the Third Industrial Revolution, it causes paradigm shifts in everything, from the individual sphere to the economy. Third, *Systems Impact* involves the transformation of systems within and across countries, economies and industries. For Schwab (2016), these factors are unique to the Fourth Industrial Revolution and therefore justify its existence as a distinct term, as well as his claim that its impact is unprecedented.

2.3 Rejections of Schwab's Claim

Rifkin (2016) suggests, however, that what Schwab (2016) is describing is nothing more than the Third Industrial Revolution. Rifkin (2016) states that digitisation, which is at the very core of the Third Industrial Revolution, is premised on the ability to turn forms of communication into information that can then be networked. Rifkin (2016:1) argues that the very foundation of digitisation is *"interconnectivity and network building"* which, over time, has become increasingly sophisticated. This, for Rifkin (2016) is no different from Schwab's (2016) notion of the Fourth Industrial Revolution. Rifkin (2016) further suggests that Schwab's (2016) three reasons for *'proving'* the Fourth Industrial Revolution is different from what went before - namely *Velocity*, *Scope*, and *Systems Impact* - are in fact nothing more than highlights of what has already been happening for decades. Rifkin (2016) states that the very nature of computers and technology in the Third Industrial Revolution has caused exponential growth in industries and economies and that this, in turn, completely unsettled entire segments of the economy. Rifkin (2016) therefore, rejects Schwab (2016:1) claim that the *"the speed of current breakthroughs has no historical precedent"* suggesting that the truth is entirely the contrary.

Marr (2016) likewise, suggests that the Fourth Industrial Revolution is nothing new and notes that all Industrial Revolutions were marked at their beginnings with great forms of inequality, workforce polarisation and institutional change. Garbee (2016) states that the exponential growth which Schwab (2016) claims is a defining feature of the Fourth Industrial Revolution is nothing special and is what happens whenever a new system grows. Furthermore, Garbee (2016) notes that the term *'The Fourth Industrial Revolution'* had existed for more than 75 years and was initially used to describe additional indicators of the current (Third) Industrial Revolution when they occurred. Garbee (2016:3) suggests that the term "*Fourth Industrial Revolution"* has repeatedly been used to describe new technical advancements, or more so *"the next best thing"*. Garbee (2016) suggests the ongoing reoccurrence of the term the Fourth Industrial Revolution is best explained by our continuous re-examination of history in the hope of uncovering patterns. Empirical evidence that what the world is currently experiencing is a natural extension of what has come before, and any attempt to re-establish its relevance, is what Garbee (2016:3) describes as *"a yearning for historical familiarity"*.

2.4 Technological Revolutions

This familiar breakdown of past Industrial Revolutions detailed in Section 2.1 conflicts with the evolutionary nature of change postulated by economists such as Perez (2009). Such an evolutionary view of change conflicts with Schwab's (2016) postulation of a new Industrial Revolution.

According to Adams & Mouatt (2010), Kondratiev cycles (Kondratieff, 1925) are a projected long-term fluctuation of the world economy, depicting alternating intervals of high and low economic growth. This evolutionary concept is based on Neo-Schumpeterian economics, which in turn built upon the Kondratiev principle of long cycles of economic development. The basis of the Schumpeterian argument of "creative destruction" rests on the view that economies face transition phases. These are characterised by innovation clusters that promote the upsurge of new technological systems which require institutions to implement both creative and destructive changes (Adams & Mouatt, 2010). These alternating waves range between forty and sixty years. They are portrayed by the commencement of technological innovations, which are sustained over periods of extended economic prosperity, before starting a period of prolonged economic slowdown (Adams & Mouatt, 2010).

However, there is a lack of consensus over when individual waves started and ended. Kondratiev cycles (Kondratieff, 1925) are based on the notion of the world economy being completely distant from the ideas of endogeneity or self-regulation. Instead, the idea rests on the belief that during the downward phase of the cycle, disruptive technologies begin to concentrate. This timeframe is typically half a century and is depictive of an economic recession. The high-level concentration of these technologies and the interaction of these disruptive technologies amongst one another then triggers the upward formation of the Kondratiev cycle, depicted as economic expansion (Adams & Mouatt, 2010).

Perez (2009) further built on the concept of Kondratiev cycles (Kondratieff, 1925), providing a more nuanced view in which she depicts technological revolutions. According to Perez (2009), two distinct phases can be identified in each technological revolution, namely, the installation phase and the deployment phase. For Perez (2009), the installation phases are the emergence of new technologies that are often driven by a financial bubble. This is followed by a turning point, or a phase of readjustment, in which the financial bubble bursts and marks the critical break between the two phases. The turning point is followed by the deployment period which diffuses the new technological system across the economy and makes the once new technologies the norm. These technological revolutions for Perez (2009) are a collection of interrelated technological innovations. According to Huber (2017:1), what makes these technological revolutions unique is that they are *"interconnected and interdependent in their technologies and markets"* and *"that they have the disruptive potential to transform the rest of the economy and society radically"*.

Perez (2009) classifies five historical, technological revolutions. However, it needs to be noted that there is often a lack of consensus regarding the start and end years of these revolutions. This, therefore, marks difficulty in explaining the exact time frames in which revolutions occurred and leads to debate over what technological revolution the world is currently experiencing. Nevertheless, the long-term historical fluctuations of alternating intervals of high and low economic growth are claimed to demonstrate the existence of previous technological revolutions. Because of the contested length of the previous revolutions, the world can be said currently to be experiencing the expansion of either the fifth technological revolution or the sixth technological revolution.

Technological Revolution/Kondratieff Cycle	Period		
	Initialisation	Turning Point	Deployment
First **The Industrial Revolution**	1771-1790s	1793–1797	1798-1829
Second **Age of Steam and Railways**	1829-1840s	1848–1850	1850-1973
Third **Age of Steel, Electricity and Heavy Engineering**	1875-1893	1890–1895	1895-1918
Fourth **Age of Oil, the Automobile and Mass Production**	1908-1929	Europe 1929 –1933 USA 1929–1943	1943-1974
Fifth **Age of Information and Telecommunications**	1971-2001	2008-20xx	20xx

Table 2: Perez's (2009:9) Technological Revolutions

As portrayed in *Table 2*, Perez (2009) identifies the first revolution as *The Industrial Revolution*, which started in 1771. Mechanised factories, water power and waterways characterised this era with the turning point occurring between 1793 and 1797. Perez (2009:9) dubs the *Second Revolution* as the *“Age of Steam and Railways”* which began in 1829. It was characterised using railways, steam, coal and iron, with the turning point occurring between 1848 and 1850. The *Third Revolution,* dubbed the *“Age of Steel, Electricity and Heavy Engineering”* (Perez, 2009:9), started in 1875. Globalisation and international trade increased due to the increased use of electricity, steel, and heavy engineering. The turning-point of this era was between 1890 and 1895.

Perez (2009) notes that there is overlap between successive revolutions. She states that this is due to the randomness brought about by many other determinants of change and notes that the overlaps are frequent during the early installation phases of new technologies. Perez (2009:9) regards the *Fourth Technological Revolution* as the *“Age of Oil, the Automobile and Mass Production”* which started in 1908. The turning point of this revolution occurred in Europe between 1929 and 1933 and in the USA between 1929 and 1943. Perez (2016:9) states that the *Fifth Technological Revolution* dubbed the *“Age of Information and Telecommunications”* started in 1971. This revolution combined with the prior *Fourth Revolution* were notable for their increase in productivity brought on by the interconnectedness and transformation potential.

Based on Perez’s (2009) theoretical framework, the world economy is still experiencing the *Fifth Technological Revolution*, the turning point of which started only in 2008. The world economy is therefore yet to enter the deployment phase of the current revolution, and, according to Perez (2009), it, therefore, cannot be on the eve of a new Industrial Revolution as Schwab (2016) has argued. This conclusion is supported by Atkinson & Wu (2017) who state that while the *Sixth Technological Revolution* inevitably will emerge, it will not do so until after a period of stagnation lasting 20-30 years. It is this current period of stagnation, they argue (Atkinson & Wu, 2017), that the world is currently experiencing.

2.5 *Industry 4.0*

Schwab (2016) has been criticised for using the term Fourth Industrial Revolution to describe processes already encompassed in terms such as *Industry 4.0*. Therefore, it is useful to compare Schwab’s Fourth Industrial Revolution to a phenomenon that bears prominent similarities, such as those of *Industry 4.0*. Schwab (2016:12) recognises the prior existence of *Industry 4.0* but states that its sole aim is to revolutionise the organisation of global value chains. The Fourth Industrial Revolution, Schwab (2016:14) claims, is something far more significant than this and has a *“scope [which] is much wider”*. However, an investigation of the details of *Industry 4.0* reveals that it is much closer to what Schwab (2016) is stating than Schwab (2016) admits. Significant similarities and few divergences suggest that Schwab (2016) term of a Fourth Industrial Revolution is little different from concepts previously expressed.

Launched in 2006, the *"High-Tech Strategy"* was Germany's approach to bringing key innovation and technology stakeholders together with the purpose of advancing new technologies in the production process. The framework of *High-Tech Strategy 2020* was launched in 2010 with the aim of establishing Germany as the leading provider of science and technology-based solutions in various fields. According to Germany Trade and Invest (2014), in 2011 the German Federal Ministry of Education and Research (Die Forschungsunion Wirtschaft – Wissenschaft) approached Chancellor Merkel, with the proposal to explore various technological trends with the aim of keeping Germany at the cutting edge of technology. In 2012, the German Government implemented the *High-Tech Strategy Action Plan* which identified ten future projects, one of them being *Industrie 4.0* (Industry 4.0) (Germany Trade and Invest, 2014).

Central to *Industry 4.0* initially was what was called *Cyber-Physical Systems.* By 2014 it had evolved into an explicit aim of amalgamating hardware, software, and people to complete work more productively. It involved the digitisation of traditional industries, as well as the expansion of *Smart Services* and *Green IT*. Lasi *et al*. (2014) state that the fundamental concepts of *Industry 4.0* include the "Smart Factory", which is the use of sensors, actors and autonomous systems throughout manufacturing; decentralisation, which is the decomposition of classical production hierarchy towards decentralised self-organisation; and most importantly *Cyber-Physical Systems*, which merge physical and digital systems throughout the manufacturing process.

There is a definite sense of commonality between the terms *Industry 4.0* and the Fourth Industrial Revolution. Many commentators, such as Lasi *et al*. (2014), Baldassari & Roux (2017) and Deloitte (2015) use the terms synonymously.

The term *Industry 4.0* is also not without its critics, who claim it to be nothing more than a buzzword. Christoph (2015) notes that before the popularisation of the term Industry 4.0, there were other similar variations, notably *Digital Manufacturing* in the 1970s and *Computer Integrated Manufacturing* (CIM) in the 1990s. 2000 marked the use of the term *Digital Factory*, 2005 the term *Factory 2.0* and from 2007, *Smart Factory* was popularised.

This suggests that Schwab's (2016) concept of a new (fourth) Industrial Revolution is built mainly upon the term *Industry 4.0*. Moreover, both share a common weakness, notably the use of buzzwords to create awareness and draw attention to the ideas being propagated. This suggests that *'phenomena'* such as the Fourth Industrial Revolution and *Industry 4.0* are in fact part of a strategy to influence economic policy or motivate a grander economic agenda.

2.6 Conclusions

This Chapter provided an overview of the backdrop, theory and literature regarding the Fourth Industrial Revolution. A general conclusion from the literature assessed is that Schwab's (2016) claim of a Fourth Industrial Revolution meets varying amounts of resistance, both regarding its name and its actual existence. At one extreme Schwab's (2016) term is portrayed as nothing different from a concept that stems from *Industry 4.0*, or at best a term that can be used interchangeably with *Industry 4.0*. Rifkin's (2016) argument that the Fourth Industrial Revolution is nothing more than an extension of the Third Industrial Revolution, and Garbee's (2016) belief that Schwab's (2016) attempt at coining the Fourth Industrial Revolution is nothing more than *"a yearning for historical familiarity"*, suggest that claims of a Fourth Industrial Revolution are fallacious. Schwab's (2016) claim is further undermined by Christoph's (2015) arguments about the popularisation of various "buzzwords" in the past century. Perez (2009), likewise, claims that the world is not entering a new Industrial Revolution as Schwab (2016) has argued.

However, while the existence of a Fourth Industrial Revolution is contested, Schwab (2016) has nonetheless raised a set of important concerns. More important than debating the technicalities of when Industrial/Technical Revolutions started or ended is examining these concerns that Schwab (2016) identifies. The phenomena and concerns that he raises, predominantly with regards to the effect of technological change on Human Capital, deserve further consideration. In this regard, the term "Fourth Industrial Revolution" can instead be considered a term that encapsulates the current, and near-future effects that technological change is having and will in future have, on both Human Capital and economic growth. For consistency, the remainder of this research will assume that the Fourth Industrial Revolution does exist. Not in the historical timeline sense suggested by Schwab (2016) and shown in *Table 1*. Instead, it exists in terms of the forces of technological change identified. Moreover, it provides a useful framework for examining the consequent impact and requirements upon Human Capital of future economic growth.

Regardless of the names that institutions and policymakers want to assign to the current era of technological change, there is little doubt that the world is currently facing possibly unprecedented levels of labour-market disruption and insecurity. Therefore, there is a need to analyse more clearly the interplay between technology and Human Capital. By examining historical precedents of these two concepts and their inter-relationships, insights will be provided into how technology and Human Capital currently affect one another and how they will possibly affect each other in the future. The question whether Human Capital was a critical driver in progressing past Industrial Revolutions, and what its possible influence could be in the claimed Fourth Industrial Revolution will be addressed in the next Chapter and the Chapters that follow.

Chapter 3: Industrialisation and Skill

The second element of Schwab's (2016) exposition and the core of this research, is the potential effect on workers and their skills of the Fourth Industrial Revolution, as measured by the increasing implementation and augmentation of labour-using automation technologies. This includes the use of high-level mechanisation, robotics and machine-learning to automate knowledge work. Schwab (2016) claims that the rapid pace of technological advancement, without the development of the necessary skills, will inevitably result in losses of existing jobs amongst low-skilled and middle-skilled workers. This is because these new technologies will change the nature of work across all industries and occupations. The disruptions caused by these new automating technologies will result in the substitution of labour by capital, resulting in increased unemployment unless workers adapt their skills to the demands of the new workplace (Schwab, 2016). It is for this reason that Schwab (2016) claims that workers need to equip themselves with 21st-Century Skills.

Regardless of the empirical validity of Schwab's (2016) Fourth Industrial Revolution, there is a need to address the impact that technology and Human Capital have on one another. The primary aim of this Chapter is, therefore, to assess the effect that industrialisation has on skills and the validity of the claim that it may cause severe labour-market disruption, as Schwab (2016) states. There are conflicting views on the extent of the likely labour-market disruption caused by technological change, and the implications of these changes for required worker skills. However, the concepts of skill and knowledge need to be understood before this impact can be assessed. A key factor underlying Schwab's (2016) view of the Fourth Industrial Revolution is the importance of finding future complementarity between technology and labour. Schwab's claim that there will be substantial job loss of existing jobs amongst low-skilled and middle-skilled workers unless offset by the development of 21st-Century Skills through education and re-educating workers means that the effect that technological change has on required skills and the notion of deskilling needs to be discussed.

The Chapter is structured as follows: Section 3.1 provides a brief outline of the effect that the Fourth Industrial Revolution is claimed to have on workers and their skills. Section 3.2 and Section 3.3 attempt to understand the concepts of skill and knowledge that together make up the term Human Capital, assessing how they are connected and the role they play in economic growth. Section 3.4 discusses the opposing views to Schwab's (2016) notion of severe labour-market disruption due to technological change. Section 3.6 examines the effects that technological change, brought on by Fourth Industrial Revolution, might have on higher-skilled, middle-skilled and lower-skilled workers and investigates the argument of deskilling. Section 3.7 analyses the proposal of developing 21st-

Century Skills, that Human Capital will need to complement technology, while Section 3.8 concludes the Chapter.

3.1 Schwab's Warning

The potential effect of the Fourth Industrial Revolution on workers and their skills is embedded in the increasing implementation and augmentation of labour-saving automation technologies. According to the World Economic Forum (2017b), there will be a critical period of transition over the next five years, depicted by unchanged employment opportunities and decreased job security. However, there will a significant amount of job 'churn' within industries, coupled with skill 'churn' in most occupations. This includes the use of high-level mechanisation, robotics and machine-learning to automate knowledge work. Schwab (2016) claims these forces will inevitably result in an increasingly segregated job market, torn between low-skilled/low-pay and high-skill/high-pay occupations. He further states that the jobs that face the lowest amount of risk regarding automation are ones that require creative and social skills that promote decision making and innovativeness. The opposite is true for middle-income, routine and repetitive jobs which are at greatest risk. The disruptions caused by these new automating technologies will result in the substitution of labour by capital in these areas, resulting in increased unemployment, unless workers adapt their skills to the demands of the new workplace (Schwab, 2016).

Therefore, Schwab (2016) warns that it is becoming increasingly necessary to anticipate future employment needs regarding knowledge and skills. Schwab (2016) states that through both the Fourth Industrial Revolution and non-technological factors, there will be an increase in demand for new goods and services and that this demand will create new professions, positions, occupations and industries. Schwab (2016) claims that it is capital that will most likely impede innovation and economic growth, that talent will play a far more important role in production, and that employment will grow both in low-income manual jobs and in high-income cognitive and creative jobs. In underlining the view of how important a skilled workforce is, both Schwab (2016) and the World Economic Forum (2017b) state that by 2020, complex problem solving, social and systems skills will be in greater demand than their content skill counterparts or physical abilities. Therefore, a key factor underlying Schwab's (2016) view of the Fourth Industrial Revolution is the importance of finding future complementarity between technology and labour. This, he claims, must be achieved through increasing education and re-educating workers through the development of 21st-Century Skills.

The emphasis by Schwab (2016) on skills makes it necessary to gain a better understanding of how the term *Skill* is conceptualised. Difficulty arises when attempting to isolate the concepts of Knowledge and Skill for individual discussion. Since these concepts are significant contributors to economic growth and form the basis of this Chapter, an attempt will be made to analyse them in isolation, to understand their effect on each other and how they are affected by industrialisation. This understanding is important, not just in trying to understand what is meant by 21st-Century Skills, but in understanding the important difference between the Average Worker and the Knowledge Elite that will be developed in later Chapters.

3.2 Skill

Mankiw (1995) states that one of the essential forms of capital accumulation is Human Capital, specifically the acquisition of skills. He suggests that investment in Human Capital can be through education and training, which leads to increased productivity and economic growth. Therefore, for this research, the working definition of Human Capital will be *the knowledge and skill, that labour utilises during the Labour Process and any investment in Human Capital that is achieved through both education and training.* Skill is merely one's ability to do something, while knowledge is the theoretical and practical understanding of something. To understand how the two are connected and the role they play in economic growth, it is necessary to explore both concepts and more clearly define both skill and knowledge.

Brown (1992) and Webster & Leger (1992) agree that the concept of skill is multifaceted and complex. Both Brown (1992) and Webster & Leger (1992) agree that skill comprises of mainly two components, manual skill and knowledge, that are typically attained through education and experience. Both manual ability and knowledge must be considered when conceptualising the notion of skill. The concept of manual skill or dexterity is the capacity to complete a task quickly and efficiently, requiring both perceptual and motor activity (Webster & Leger, 1992). However, Brown (1992) notes that the idea of skill can be conceptualised even further to include not only manual dexterities but also several diverse and unmeasurable elements. It is this concept that hampers any attempt at measuring skills. Webster & Leger (1992) argue that once skills are conceptualised as the sum of both skill and knowledge, then all workers are skilled. Brown (1992) argues that qualifications and educational standards are merely used to enhance the skill status of jobs, and are implemented to limit competitors for jobs in the labour market. They bear little association with the actual skills necessary for the job. Therefore, a reference to a *skilled worker* does not entirely represent a worker that *has* skill. Instead, Webster & Leger (1992:54) suggest that the concept of being skilled is merely a term used for a worker who has *"passed through some barrier to entry into an occupation"* such as formal training or an apprenticeship. Therefore, the terms "semi-skilled" or "unskilled" disguise the fact that such workers, in fact, utilise a diverse set of skills in their work. Brown (1992:217) expands on this by arguing that being considered skilled is only the ability to *"secure material and symbolic resources and advantages about employers and other categories of employees"*.

The barriers that Webster & Leger (1992) refer to are argued to be both a reflection of the required knowledge within the occupation, as well as insight into the organisation power of the said occupation. The barriers are therefore merely artificial, or sociologically deemed, social constructs that do not necessarily even relate to the skills utilised by workers. This argument that skills are socially constructed ties in with Brown's (1992) argument that skills cannot be objectively measured due to the relative organisational power of workers in the labour market, as well as organisation power in its entirety. Webster & Leger (1992) highlight that the introduction of Scientific Management[3] and mechanisation posed a threat to skilled workers through the process of deskilling, which subsequently forced them to form craft unions, to maintain exclusive control over the production process and to control the reproduction of skilled work. Webster & Leger (1992) state that these craft unions were implemented as a highly defensive strategy and conservative approach towards to skills management and to protect their skills.

Tacit skills are an understated concept that draws from craftwork and the notion of protecting their skills. Brown (1992:218) describes *tacit skills* as *"the working knowledge needed by all employees… to be able to participate in the Labour Process"*. These are the routines that are internalised by the worker through on-the-job experiences. Webster & Leger (1992) note that these skills are mainly unnoticed, yet are vital to the production process. This notion of tacit skills overlaps with an essential concept that Brown (1992) outlines, notably the degree of autonomy needed by the worker. This includes the discretion needed by the worker, that links in with the concepts of manual skill and knowledge. A skilled worker needs to exercise both their knowledge and manual skills when completing a task, but must also be allowed a level of discretion or autonomy. Therefore, the notion of skill is a sum of its parts, including both the manual skill and knowledge, as well as the social constructs of skill outlined by Webster & Leger (1992) and Brown (1992). Furthermore, it extends to include tacit skills, the informal knowledge critical to production that opens a degree of autonomy for the worker.

3.3 Knowledge

As is evident above, it is not possible to draw a clear distinction between Knowledge and Skill. The two terms are continuously tethered together as parts of Human Capital. In the discussion of what comprises Skill, the notion of knowledge was mostly left unexplained. An attempt to explain the concept of *Knowledge* will be made in this section. This is done recognising that the two concepts of skill and knowledge are heavily intertwined. Mokyr's (2002) definition of knowledge is fundamental in understanding its relationship with economic performance. Mokyr (2002) notes there are many

[3] Refer to 6.3.1.1 Fordism

difficulties when defining the term knowledge. These are centred against the backdrop of technology and economic change because it is *new* knowledge that has *"helped create modern material culture and the prosperity it has brought about"*. This is embodied in what Mokyr (2002:3) dubs as *"Useful Knowledge"*.

Mokyr (2002:3) further relates the concept of knowledge to the *"natural phenomena that potentially lend themselves to manipulation, such as artefacts, materials, energy, and living beings"*. At the core of Mokyr's (2002) argument is the distinction between different types of knowledge. Knowledge, for Mokyr (2002:4), is either *"Propositional Knowledge"* or *"Prescriptive Knowledge". Propositional Knowledge* is society's depiction of the natural world, while *Prescriptive Knowledge* outlines the techniques used to manipulate the natural world (Mokyr, 2002). Simply put, Propositional Knowledge is the beliefs about the natural world, whereas Prescriptive Knowledge is the translation or application of Propositional Knowledge into instructions or techniques, i.e. the further creation of Knowledge. Mokyr (2002) simplifies this difference further into the *'what'* (Propositional Knowledge) and the *'how'* (Prescriptive Knowledge)[4].

Mokyr (2002:5) further breaks down Propositional Knowledge into two forms. Firstly, *"the observation, classification, measurement, and cataloguing of natural phenomena"* and, secondly, the *"establishment of regularities, principles, and natural laws that govern these phenomena".* Prescriptive Knowledge, on the other hand, is detailed by Mokyr (2002:10) as the instructions and designs that reside in one's mind or in storage devices (such as books, manuals, hard drives) that depict the ways to *"adapt means to a well-defined end".* It outlines how activities are to be carried out, which Mokyr (2002:10) describes as *"production"* or the production process. Most pertinent is that these instructions and designs can then be further taught, manipulated, transferred and improved upon. An addition to Propositional Knowledge is regarded as a *discovery,* whereas an addition to Prescriptive Knowledge is considered as an *invention*.

Mokyr's (2002) description of Useful Knowledge, notably Propositional Knowledge, is relevant because it describes the provision of the techniques that are implemented during economic production. In other words, to provide the instructions that form a production technique (the *"how"* or Prescriptive Knowledge), an understanding of the fundamentals that underlie these instructions must be known (the *"what"* or Propositional Knowledge). Mokyr's (2002) notion of Useful Knowledge provides the foundations needed to understand industrialisation, or more notably the driving forces of

---

[4] Not to overcomplicate the matter, the 'how' skill and knowledge are interlinked through Mokyr (2002:4) belief that "how" knowledge is, in fact, the "possession of a skill".

Industrial Revolution. Mokyr (2002:29) states *"The key to the Industrial Revolution was technology, and technology is knowledge"*.

Due to the constant reference that Schwab (2016), and much of the literature, make to skills, Sections 3.2 and 3.3 have attempted to isolate the terms knowledge and skills for individual discussion to analyse the effect technology has on Human Capital. The significant focus on skill is due to the concept always being singled out in literature analysing the impacts of Human Capital and technology.

Knowledge, especially Useful Knowledge, plays an essential role in the formation of Human Capital but seems to be mostly ignored in the literature. The emphasis on skills at this point is to provide a 'like-for-like' assessment but does not negate the importance of knowledge. Knowledge and the significant role played by knowledge in past industrialisation will be returned to later in the research, where the important difference between the Average Worker and the Knowledge Elite is enunciated.

3.4 Labour Market Disruption

Schwab (2016), like the World Economic Forum (2017b), states that the Fourth Industrial Revolution will bring about severe labour market disruptions. This will be coupled with significant amounts of job and skill churn. Schwab (2016) argues along with Frey & Osborne (2013) that over the next 20 years, 47% of jobs in the US are at risk of automation. The resultant need for low-skilled and medium-skilled workers to transition to tasks that are not susceptible to such automation will, in this view, create polarisation in the labour market.

However, Atkinson & Wu (2017:1) provide a contrasting view, arguing against the belief that jobs are being lost to automation, or that the world is currently experiencing a high level of labour market *"churn"*. They define churn *as the "the sum of the absolute values of jobs added in growing occupations and jobs lost in declining occupations"*. They, however, argue that the opposite is true, particularly in the United States, where job churn is at an historic low. They state that in the two decades from 1850 to 1870, occupational churn peaked at over 50%, whereas in the last 15 years, it decreased to around 10%. This belief is shared with Yglesias (2015) who also counters the popular belief that the world is experiencing an accelerating pace of automation. Instead, Yglesias (2015) suggests the world is witnessing a productivity growth slowdown, stating that productivity during the last decade has advanced at the slowest rate in 75 years. Yglesias (2015) states that this productivity slowdown is often overshadowed by the growth of the economy, but this growth is due to the addition of workers, rather than the outfitting of workers with new machines to enhance their capabilities.

Likewise, Atkinson & Wu (2017:1) claim politicians and policymakers, directly referencing Klaus Schwab, make grim assessments of labour-market disruption due to technological change, because of *“faulty logic and erroneous empirical analysis”*. They repeat the common misconception that robots can do most jobs, or that once a job or industry is lost that there is no second order job created because of newly created products and industries (Atkinson & Wu, 2017). Rather than automation, the level of job churn that occurs is in fact owed to crashes, or turning points (Perez, 2009), such as the financial crisis of 2007-08. Atkinson & Wu (2017) warn that this misconception over the relation between labour-markets and technological change may cause resentment towards technological progress, causing society to become risk-averse and as a result impeding technological innovation.

These findings by Atkinson & Wu (2017) contradict a central pillar of Schwab’s (2016) thesis. Schwab’s (2016) idea that the world is currently experiencing a significant disruption of labour markets is rejected by Atkinson & Wu’s (2017) claim that occupational churn is at its lowest since the 1850s. They further say that technology is not destroying more jobs than it ever has, arguing that in the period from 2010 to 2015 in the USA, there were six technology-related jobs created for every job lost, which translates to the lowest share of jobs lost to technology in any period since 1950 to 1960. Atkinson & Wu (2017) provide an historical account of the railroad industry between 1850 and 1860. During this time, the number of railroad workers increased by 600%, with sustained growth for the remainder of the century. Through increased productivity on the railroads and the growth of the automobile industry, railroad occupations thereafter decreased every decade. However, as railroad jobs declined, the jobs associated with the automobile industry grew from almost no jobs in 1910 to over 1.8 million in 2000. The point that Atkinson & Wu (2017) make is that technology creates far more jobs than it destroys when it enables the creation of whole new industries and occupations.

Yglesias (2015) provides a different narrative for the common misconception that machines are taking over jobs, that rest on two arguments. Firstly, he instead claims that technology is consuming more of our leisure time, with the average American consuming on average 23% of their waking hours watching television, reading, or playing games (Yglesias, 2015). The point in case is the rapid transformation of the technological landscape in the media and entertainment industries in the last 20 years. With the inclusion of technologies such as Netflix, UberEats and the iPad, it is *believed* that life for most people has been revolutionised by digital technology (Yglesias, 2015).

Secondly, on the point that technology has transformed the media and entertainment industries, Yglesias (2015) underlines how it is commonly misconstrued that the media and entertainment industries make up a large proportion of the workforce in the US economy. In fact, they amount to less than 23% of the workforce of the United States. The argument that technology means there is an increased likelihood that people will now order food through UberEats using their iPad or binge watch a series through Netflix justifies the conclusion that a radical impact has occurred in their respective industries is, Yglesias (2015) argues, a somewhat superficial assessment. Instead, he argues, the implication of those services has had no profound effect on the core work in those industries. UberEats, for example, has not affected how food gets made or served but instead has only affected the way the consumer orders food. Yglesias (2015) notes, too, that high-end occupations still have not been influenced by automation, such as supposed robot doctors or lawyers. He argues that even medical records still cannot be adequately digitised. Yglesias (2015) concludes that current technology that is often depicted as revolutionary has in fact not had as a profound economic impact as, say, commercial airliners or the microprocessor once had. Yglesias (2015) states that the industry benefiting the most from accelerated productivity is, in fact, the information technology industry itself, but this does not have a driving change in the broader economy. Yglesias (2015) aligns with Atkinson & Wu's (2017) view that the economic slowdown that the economy is currently experiencing is coinciding with a period of high unemployment, weak demand and slow wage growth. However, this should not be attributed to the advancement of technology in the job market. Atkinson & Wu (2017:3) claim that labour market disruption is not abnormally high and has been *"vastly overstated, as they always have been"*. Instead, there should, in fact, be a concerted effort to speed up the rate of creative destruction of technological change to bring about productivity growth.

3.5 The Shift in Skills Demand

Baweja *et al*. (2016) analyse the probable economic and investment consequences of the Fourth Industrial Revolution. Baweja *et al*. (2016), focusing on the effect on required labour and skills, note that certain economy types will be better suited to take advantage of the Fourth Industrial Revolution than others. Focusing on the concept of *"flexibility"*[5], they argue that economies with the most flexible labour markets, infrastructure, educational and legal systems are more likely to reap the rewards of the Fourth Industrial Revolution. Baweja *et al*. (2016) note that the Fourth Industrial Revolution is founded mainly on the concepts of extreme automation and communication and warn that these will have different effects on developing and developed economies respectively.

Contrary to Yglesias (2015) and Atkinson and Wu (2017), Baweja *et al*. (2016) suggest that the Fourth Industrial Revolution, coupled with technological change, will possibly decrease total employment in the long run. They argue, however, that while a decline in employment is possible, it is not inevitable. They explain this possibility by examining the effects that the Fourth Industrial Revolution will have on higher-skilled, middle-skilled and lower-skilled workers. Baweja *et al*. (2016) differ from Schwab

[5]The term "Flexibility" is expanded on in Chapter 7

(2016) in that they claim that both middle-skilled *and* lower-skilled workers face a higher chance of unemployment due to technological change unless workers re-skill themselves into tasks that extreme automation is unable to perform. Higher-skilled workers will be more favoured because their existing skills will allow them to understand the new technology.

This outcome is defined by Baweja *et al*. (2016:14) as *"workforce polarisation"*. In the short run, the Fourth Industrial Revolution could increase frictional unemployment amongst lower-skilled and middle-skilled workers, unless workers *"re-skill, relocate or adapt"* (Baweja *et al*., 2016:14). The concept of flexibility is central to their findings. They conclude that the required skills themselves need to be flexible and that middle-skilled and lower-skilled workers need to be skilled in change and adaptability to address the impending skills gap (Baweja *et al*., 2016).

Loi (2015) expands on this, stating that skill-biased technological change increases the demand for both higher-skilled and lower-skilled workers while simultaneously decreasing the demand for middle-skilled workers. If this technological change is met with an insufficient supply of the required skills, job polarisation might leave most workers with worse jobs than they currently have. Loi (2015) agrees that appropriate advancement in education will increase the level of skills of the middle-skilled worker. This will increase human productivity and allow for the acquisition of skills that are complementary to technological innovation, resulting in what Loi (2015:208) dubs the *"resurrection of the middle class"*.

The above accounts provide conflicting views on the extent of the likely labour-market disruption due to technological change, and the implications of these changes for required worker skills. With any advancement of technology, there is job loss, but this technological progression is coupled with the creation of new jobs, industries and demand for new skills. These findings imply that instead of focusing on possible job losses there should be a shift in focus towards analysing the effect of technological change on required Human Capital skills, particularly reskilling and deskilling.

Yglesias (2015) notes that machines have been replacing humans for hundreds of years, but asserts that one must not forget that these marked significant benefits for society. He argues that although these *'disruptions'* did result in job losses and lower wages for some workers, on average the number of jobs increased and living standards rose. He further states that for centuries new technologies have perpetuated the fear that technological advancement will cause significant labour market disruptions and result in significant job loss. At its extreme, this has created the exaggerated belief that machines will one day take all the jobs and we will live in a world without work. Yglesias (2015) concludes that history has proven that these significant technological or Industrial Revolutions did not lead to fewer jobs, but in fact, brought about job growth and improved living standards.

Since the advent of the First Industrial Revolution, there has been a persistent belief that the evolving nature of both technology and machines results in job loss and deskilling of workers. Deskilling is the scenario that both labour-intensive and mental work is requiring less skill to carry out the job.

The above accounts suggest that changing technology will see a shift in demand towards both higher-skilled and lower-skilled workers but a simultaneous decrease in the demand for middle-skilled workers unless these workers re-skill themselves into tasks that extreme automation is unable to perform.

3.6 Technological Change and Skill

Two camps emerge when discussing the concept of deskilling, especially the effect of industrialisation and technological change on workers and their skills. Firstly, that technological change brought on by industrialisation had a deskilling effect, resulting in a loss of skill and increasing the demand for unskilled labour. Secondly, there was instead a more positive effect on workers' skills. Technological change, in this view, created a need for workers to reskill themselves and ultimately increased the demand for skilled labour.

Assessing the notions of deskilling and reskilling, notably whether skill levels rose or fell, during industrialisation is contested. Mitch (1999) notes that both Marx (1906) and Thompson (1989) claim that skill levels fell overall and that this was evident by the substitution of machinery for skilled labour. Conversely, Harris (1976:167) argues that a whole new skill set was required. He states that the First Industrial Revolution created a demand for a *"whole range of new trades, [The Industrial Revolution] subdivided old ones, and created new types of skilled worker, some of which became a permanent feature of the industrial scene"*.

Mitch (1999) attempts to resolve the controversy on deskilling by suggesting that the First Industrial Revolution did not have either a uniform propensity towards skills-demanding or skills-saving. Both were present and detailed quantitative evidence on the impact on overall worker composition is impossible because of inadequate information.

These expositions provide insight into how technological change has impacted workers skill during past industrialisation and therefore may provide relevance when these effects are analysed against the backdrop of the Fourth Industrial Revolution. Understanding the notion of deskilling and reskilling draws from various historical accounts, and these accounts will be discussed in detail in Chapter 7. It is necessary first to investigate Schwab's (2016) view that capital and labour will be complementary in the Fourth Industrial Revolution

3.6.1 Reskilling and Skill-Demanding

Hodgson (2016) argues that during previous Industrial Revolutions the actual impact of deskilling is difficult to measure. Hodgson (2016), like Marshall (1920), notes that machines always first replace the most repetitive and muscular labour. Nevertheless, work that involves judgement or adaptive skill on the part of workers is much less readily replaceable by machines. Hodgson (2016) states that the destructive nature of capitalism, in fact, limits the extent to which machines can replace jobs.

Both Hodgson (2016) and Marshall (1920) agree that there is a limit to what machines can do and that due to the very tentative and ever-changing world, there is, in fact, a need for adaptability, oversight, and skilled human judgement. It is at this point that Hodgson (2016) parts from the notion of *true* deskilling having ever actually occurred, and states that Marx & Engels's (1988) widespread prediction of deskilling has failed to materialise. Hodgson (2016) suggests that historical evidence demonstrates that machines, in fact, enhance skills, rather than reducing them. Although substantive deskilling has occurred, it is because existing skills have been replaced by a shift towards a more significant and more complex skill set.

Hodgson (2016) further elaborates on this, stating that capitalism has evolved along a trend towards a more knowledge-intensive set of skills. Hodgson (2016) further counters the argument of extensive deskilling by noting that the implementation of automation and reduction of unskilled jobs creates the need for sophisticated and educated human judgement, that is both flexible and capable of displaying empathy, creativity, and intuition. Unskilled workers displaced by Taylorized[6] work systems, could either end up unemployed or move towards these newly created needs for complex jobs requiring human judgement. Hodgson (2016) indicates that the increased diversity of goods and services produced, coupled with the growing complexity of economic systems, means that there is a vast increase in the need for knowledge-based and judgemental tasks that only humans can perform. It is this growing need for greater knowledge intensity and judgemental skills that Hodgson (2016:203) states will add a *"premium"* towards education and knowledge-intensive skill training.

3.6.2 Deskilling and Disenhancement

Contrary to Hodgson's (2016) claim that the world has shifted towards knowledge-based and judgemental skills, Loi (2015:202) argues that technology in fact *"disenhances"* individuals rather than

---

[6] Refer to 6.2.1.1 Fordism

enhancing them. Loi (2015) argues that machines and technology will lead to the substitution of those human skills characteristic of middle-skilled jobs and will eventually lead to their elimination entirely. Loi (2015) compares his claim of human disenhancement to Marx & Engels' (1988) notion of deskilling. Loi (2015) agrees that contemporary economic theory is compatible with technological change and that this change is beneficial to workers. Technological innovation substitutes capital for lower-skilled workers, but at the same time is often skill-based and increases the relative demand for sophisticated skills that act as a complement to capital. This, Loi (2015) suggests, *hollows out* middle-income jobs, creating a more segregated job market and an increasing divide between lower-income jobs and higher-income jobs.

3.6.3 The Worker and The Machine

Up to this point, Loi (2015), like Hodgson (2016), argues that technological innovation has resulted in an increased demand for more sophisticated, yet human, sets of skills. This belief echoes that of Harris (1976:264) that the First Industrial Revolution created a need for *"a precarious combination of manipulative skill embodying a physical training and a judgment requiring both experience and intelligence."*

However, the distinction between the two viewpoints is that Loi (2015) states that technological change creates technological unemployment and that Hodgson's (2016) argument neglects the extent to which new technology affects demand for human skills, as well as how the supply of human skills responds. Loi (2015) elaborates on this principle, maintaining that technological innovation that is complementary of human skill, and in turn higher skills, is only economically beneficial if the supply of higher skills keeps pace with the skills demanded. Loi (2015) is, therefore, directly referring to the education of workers, and how the inability of society to produce a suitable supply of educated workers otherwise results in increasing wages only for the skill set in short supply. It is this lack of higher skills and the subsequent wage growth that increases inequality and the gap between lower-skilled and higher-skilled workers. It determines whether technological change is beneficial for society, or just the skilled few.

Therefore, Loi (2015) concludes that education affects the supply of complementary human skills and that lack of such skills only adds more to the *premium* placed on education. So, while Loi (2015) to some extent agrees with both Hodgson (2016) and Marshall (1920) that machines always first replace the most repetitive labour, increasing the need for adaptive skills, he takes this further by stating that societies' adaption to technological change rewards humans with jobs where mechanisation is unable to substitute them.

3.7 21st-Century Skills

Both Loi (2015) and Hodgson (2016) argue that there is, therefore, a growing need to develop a skill set that is less susceptible to automation, which involves creativity, intuition and human judgement. Their view aligns with Schwab (2016) who too argues that Human Capital will need to reskill to keep pace with changing technology. Therefore, Schwab (2016) notes that the Fourth Industrial Revolution Industrial is coupled with an urgent need to develop what the World Economic Forum (2015) refers to as *"21st-Century Skills"*. These are the set of abilities that all forms of Human Capital will need to succeed in the Fourth Industrial Revolution. These skills are a set of abilities that are broadly characterised into three categories, namely: Foundation literacies, competencies, and character qualities (World Economic Forum, 2015). The World Economic Forum (2015) states that there has been a radical shift in the global marketplace toward a skill set that needs to be able to deal with unstructured problems, analyse information and collaborate with new technologies. This skill set is in desperate need due the increasing automation and digitisation of previously manual and routine labour.

Schwab (2016) argues that when deployed efficiently, the combination of education and technology, instead of resulting in rising unemployment as machines replace workers, will instead create a new skill set that will allow workers to *adapt* and *infuse* within this ever more technology-rich marketplace (Schwab, 2016). Schwab (2016) emphasises that in the Fourth Industrial Revolution both technology and society can complement rather than substitute one another as has been perceived to have been the case in the past. The World Economic Forum (2015) suggests that to counter this skill gap, education technology needs are deployed efficiently to develop skills such as creativity, communication, and collaboration. Of a range of possible solutions, they claim that education technology, when efficiently integrated, holds the most potential.

O'Connor (2016) argues that in the past school education focused mostly on developing the core cognitive competencies of reading, writing and arithmetic. However, he suggests machines have long since exceeded humans in their ability to perform these competencies. O'Connor (2016), therefore, asks what are the other skills humans can develop, that will have a more significant comparative advantage over machines. O'Connor (2016:1) suggests that due to artificial intelligence's methodical approach to problem-solving, there needs to be a shift towards more creative education investment, because humans still have superior ability over machines when it comes to exercising intuition, creativity and persuasion, encompassed by the concept *"emotional quotient"* or *"EQ"*. This suggestion aligns with Hodgson's (2016) notion of shifting towards the much-needed skill set that displays professional human judgement, and that is both flexible and capable of displaying empathy, creativity, and intuition. However, O'Connor (2016) maintains that humans also need to continue to develop the cognitive skills, as they are essential for the successful functioning of a democratic society and form a solid foundation for higher order problem-solving.

Infosys (2016) suggests that current education is failing to prepare young people for their future jobs and that to adapt to the emerging economy, young people need to develop creative, mathematical and technical skills. Infosys (2016) further claims that future work will consist of a shift towards less linear, more erratic career paths. To address this, young people will need to reskill themselves in a *"fluid manner"* in what Infosys (2016:23) describes as *"liquid skills"*. This concept of liquid skills is merely a skill set founded on flexibility that will allow young workers to respond to the demands of changing careers. These liquid skills resonate with Baweja *et al*. (2016) concept of flexibility, which stated that workers would need to be skilled in change and adaptability to address the impending skills gap.

3.8 Conclusions

This Chapter aimed to assess how Human Capital with specific regard to skills is affected by the technological change brought on by industrialisation. Schwab's (2016) warning plays on the deep-seated emotions and fears about job displacement, work polarisation and the potential of growing job loss because of these radically new technologies. Such fears lead to an urgent search for policies to counter their potentially damaging effects on society and the nature of work. It was shown that there are conflicting views on the extent of the likely labour-market disruption due to technological change, and the implications of these changes for required worker skills. Atkinson & Wu (2017), for example, argue that there should be a concerted effort to increase technological advancement rather than oppose it.

A key factor underlying Schwab's (2016) view of the Fourth Industrial Revolution is the importance of finding future complementarity between technology and labour. It is evident by the above accounts that technological advancement increases the demand for both higher-skilled and lower-skilled workers, while simultaneously decreasing the demand for middle-skilled workers. However, as suggested, by allowing the development of 21st-Century Skills, could, in fact, lead to Loi's (2015:208) *"resurrection of the middle class"*, allowing middle-class workers also to be complementary to technology. Schwab (2016) claims that this must be achieved through the development of 21st-Century Skills through education and re-educating workers.

Loi (2015), Hodgson (2016) and Schwab (2016) all suggest there is a need to develop this 21st-Century Skill set that is less susceptible to automation, involving creativity, intuition and human judgement. Mokyr's (2002) description of Useful Knowledge, notably Propositional Knowledge, is relevant when analysing these 21st-Century Skills. Mokyr's (2002) notion of Useful Knowledge provides the foundations needed to understand the impact of industrialisation. This understanding suggests that the creation of 21st- Century Skills would effectively allow Human Capital to complement Capital and become the driving force of industrialisation. This will allow Human Capital to possess both the skills, such as intuition and creativity and the techniques that are implemented during economic production. This will allow Human Capital to gain an understanding of the fundamentals that underlie these techniques and will grant Human Capital the true flexibility that will allow for labour market mobility and the ability to take on a varying number of roles within an occupation. Rather than instilling fear and panic about the effects of technology, the analysis suggests that policymakers should instead encourage technological change that would, in turn, create new jobs and industries. They should focus on the establishment of a workforce that is capable of complementing technology with a skill set that does not make them fall by the wayside or make them easily replaceable by machines.

Schwab (2016) argues that the development of 21st-Century Skills must be achieved through education and re-education of existing workers. When referring to the working definition of Human Capital, it is stated that *any investment in Human Capital is achieved through both education and training.* Therefore, it is necessary to scrutinise the relationship between education and Human Capital. Romer (1994) states that investment in Human Capital is a significant contributor to economic growth because of its spillover effects that help advance new technologies. Considering the importance attached to education in developing a new skill set for Human Capital, thereby contributing to economic growth, it is necessary to examine further the link between industrialisation and education in Chapter 4.

Chapter 4: Industrialisation and Education

The key factors on which Schwab's (2016) view of the Fourth Industrial Revolution rests are the importance of combining technology and Human Capital, which together can generate economic growth, jobs and propel an economy into the next Industrial Revolution. Loi (2015), Hodgson (2016) and Schwab (2016) agree that there is a need to develop a skill set that is less susceptible to automation, and which therefore involves creativity, intuition and human judgement - which the World Economic Forum (2015) calls 21st-Century Skills. The common view amongst these authors is their belief in the importance of developing a new skill set, rooted in the form of education that will grant Human Capital a sense of flexibility, intuition and creativity.

A working definition of Human Capital in this thesis is that *any investment in Human Capital is achieved through both education and training.* The links between technology, economic growth and Human Capital are highlighted by Ljungberg (2004) who argues that technology rests upon the notion of Human Capital. This is further supported by Endogenous Growth Theory's depiction of technological change as an endogenous variable in which the processes of learning are intertwined with new technology and models of innovation.

When analysing the influence that technology, Human Capital and education have on each other, two conflicting arguments emerge from the literature. These are claims that, on the one hand, depict Human Capital to be one of the most critical determinants of growth, while, on the other hand, are those who perceive Human Capital to have played a minimal role in driving growth historically. These two assessments of historical growth provide a perplexing, contradictory set of arguments whose further scrutiny forms the basis of this Chapter. Considering the bearing that education is supposed to have on developing a new skill set contributing to economic growth; it is necessary first to scrutinise the empirical link between economic growth and education further. This will be assessed specifically concerning the First Industrial Revolution.

This Chapter will focus primarily on the effect that Human Capital and industrialisation have on one another. The Chapter is structured as follows: Section 4.1 discusses the two opposing views regarding the importance of Human Capital for economic growth. Section 4.2 further examines the link between education and schooling and their influence on Human Capital during the First Industrial Revolution, to understand better the cause of the controversy regarding their historical role in promoting economic development. Based on these findings, Section 4.3 will then consider a more nuanced perception of education and will revisit and discuss the extent that Human Capital appropriately defined affects economic growth. Section 4.4 concludes it is necessary to differentiate between two forms of Human

Capital to accurately determine the importance of Human Capital for economic growth. Section 4.5 concludes the Chapter.

4.1 The Two Camps

Romer (1994) states that investment in Human Capital is a significant contributor to economic growth because of its spillover effects that help advance new technologies. The interplay between economic growth, education and Human Capital draws from various expositions of economic development. Squicciarini & Voigtländer (2015) note that there are varying views about Human Capital's importance. One camp argues that Human Capital played a very significant role historically in economic development. Todaro & Smith (2009), for example, state that any investment in either human or physical capital induces productivity improvements and external economies. Mankiw (1995) states that the acquisition of skills and investment in Human Capital is an essential form of capital accumulation. This Human Capital investment is achieved through education and training, which leads to increased productivity and economic growth. Squicciarini & Voigtländer (2015) find from an analysis of the role that education had on Human Capital and industrial development in 18th-Century France, that Human Capital was indeed important during the period of historical industrialisation. Squicciarini & Voigtländer (2015). Squicciarini & Voigtländer's (2015) study is based on Mokyr & Voth's (2010) claim that the existence of both an *Average Worker* and an *upper-tail skilled minority* were important contributors to historical industrial success. This importance is revealed only when utilising a nuanced view of education which subsequently reveals the importance of the roles of both the Average Worker and an upper-tail skilled minority (Mokyr & Voth, 2010).

Other commentators have perceived the historical role of Human Capital to have been minor. Mokyr (2013) acknowledges these claims by noting, for example, that the European countries Moldova and Belarus, which are today economically backwards compared to their European counterparts, have respectable educational statistics. This education has not translated into meaningful economic development. This argument is substantiated further by Pritchett (2001) who found the role of education to be of little importance. These findings, Mokyr (2013:2) notes, highlight that Human Capital alone is not a *"magic formula for rapid economic growth"*.

The argument that education is of little importance applies not only to the contemporary world but also historically. Education's role in the First Industrial Revolution is also controversial. Galor (2005) for instance, argues that during the first phase of the First Industrial Revolution, there was no correlation between industrialisation and education. He claims that education at that time focused on religion social, and national endeavours, and therefore had limited relevance for the production process. Mitch (1999) argues that educational attainment was low and inconsequential for economic growth in Britain during the First Industrial Revolution. Allen (2009) reaches the same conclusion, arguing that the low education attainment at that time of the First Industrial Revolution demonstrate the low importance of literacy for growth during this period.

In trying to understand why *education* is perceived to have a minor role in industrialisation it is important to understand the different conceptualisation of the term between the First Industrial Revolution and a contemporary setting. The synonymous use of the terms *schooling* and *education* in a modern setting, combined with the contemporary use of measures such as numeracy and literacy rates, in conducting historical analysis, have confused this debate. Therefore, it is necessary to reconceptualise the terms, to understand the way in which they were perceived as being different during the First Industrial Revolution.

Understanding the importance of Human Capital during industrialisation is central to this research's examination of the importance of skills in meeting the challenges of the Fourth Industrial Revolution. It is, therefore, necessary to further scrutinise at length the historical link between education and training and their influence on Human Capital to better understand the cause of the controversy regarding their past role in promoting economic development.

4.2 Education and Schooling

One reason for the conflicting findings on the role of education in economic growth is that the terms schooling and education are often incorrectly conflated. Dewey (1944) describes education as the actual process of facilitating learning, which sees to the acquisition of both skills and knowledge, where a school is merely an institution that provides the environment to facilitate education. However, even this attempt at separating the terms is inadequate to understand the perception of education and schooling during the First Industrial Revolution. Mokyr (2013), however, provides a more nuanced view that provides insight into how the two terms were considered at the time of the First Industrial Revolution to be more separate activities than they are today. Mokyr (2013) notes that this impacts on how their contribution to Human Capital and, therefore, to growth is measured.

Mokyr (2005) argues that when *education* is appropriately measured it was indeed a significant factor in the First Industrial Revolution. He argues that at the onset of the Industrial Revolution, knowledge and skills were, for the most part, acquired through apprenticeships rather than formal schooling. These apprenticeships were paid for services, partly in cash and partly through services towards their Masters. The education attained through these apprenticeships were mostly skills that were explicitly needed for the occupation. The interpretation of education in this way resonates with Webster & Leger, (1992:54), who claim that the concept of being skilled is merely a term used for a worker who has *“passed through some barrier to entry into an occupation”* such as formal training or an *apprenticeship*. This broader understanding of education, Mokyr (2005) suggests is important, because the advanced skills and the extensive Useful Knowledge of highly-skilled craftsmen and mechanical engineers which were needed for the First Industrial Revolution - and were responsible for the important inventions which revolutionised production - were in fact founded upon this mode of education, such as apprenticeships, rather than learnt in the classroom. This is not to deny that these highly-skilled craftsmen and mechanical engineers did not have access to foundational skills such as mathematics or science, or were in any way illiterate. Mokyr (2005) is merely suggesting that, for the majority, apprenticeships were the most dominant form of education, and its pertinence was owed to the overall effect that these highly-skilled craftsmen and mechanical engineers had on the First Industrial Revolution. Mathematics, science and literacy would have been accessed via the apprenticeship system.

Schooling, on the other hand, at that time was far more multifaceted and different from schooling today (Mokyr, 2013). It was directed towards the middle-class, who attended fee-paying grammar schools and included charity and religious institutions. Mokyr (2013) notes that one would hardly regard the schooling that was received at that time as *‘Human Capital’*. However, this does not negate the importance of schooling, as it saw the teaching of some dialectical reasoning, was open to modern ideas, taught social conditioning, such as respect, obedience, religion and loyalty to the state, which was all instrumental in creating a civil society. However, what was learnt in the classroom was hardly the skills and knowledge *critical* for economic growth.

4.2.1 Schooling and its Indirect Measurement

This difference between schooling and education, made by Mokyr (2013), is important in explaining the different findings in the literature regarding the importance (or lack thereof) of education during the First Industrial Revolution. It has already been established that the contemporary synonymous interpretation of *schooling* and *education* means that a standard tool of measurement is literacy and numeracy rates. However, when the same approach is used in an historical analysis of *education* during the First Industrial Revolution (considering the differentiation, made by Mokyr (2013) between education and schooling), it is it is unsurprising that *education’s* contribution to the rate of innovation during the First Industrial Revolution is found to have been minor. The use of these measures to those who were educated through apprenticeships, for instance, leads to results that argue that Britain’s literacy rates were weak at the time of the Industrial Revolution. Mokyr (2013) highlights that the application of literacy and numeracy measures to apprenticeships and other informal modes of education leads to arguments that only 60% of British males and 40% of British females were considered literate. When literacy and numeracy rates are used as a proxy for Human Capital, without considering how schooling and education were *separate phenomena* at the time of the First Industrial Revolution, it is unsurprising that 'education's' contribution to the rate of innovation during the Industrial Revolution is believed to be limited.

Ljungberg (2004) highlights that changes in literacy rates in Britain before 1850 were insignificant and therefore concludes that literacy had minimal importance *during* the First Industrial Revolution. However, he warns that this does not mean that literacy was unimportant overall. Ljungberg (2004:6) claims that literacy is an efficient *"transaction technology"* and the more literate, or *enlightened* a population is, the smoother a country can adopt innovations and technological advancements. Ljungberg (2004) claims that while literacy and numeracy rates were low during the First Industrial Revolution, their importance only emerged later, closer to the Second Industrial Revolution. This was mostly due to the need to allow for the smoother adoption of innovations and technological advancements into the workplace, rather than their initial invention. Thus Ljungberg (2004) concludes that even though literacy played little role in the early creation of new technologies, it was important for their later widespread and efficient adoption. This is not to say that based on Ljungberg (2004) assessment that literacy had minimal importance *during* the First Industrial Revolution, that he believes that the highly-skilled craftsmen and mechanical engineers (that Mokyr (2005) mentions) were illiterate. Rather Ljungberg (2004) regards literacy to have had less importance amongst the *general population* during the early phases of the Industrial Revolution.

de Pleijt & Weisdor extend the argument of the debate specifically on *literacy*. de Pleijt & Weisdor (2017) argue that both literacy and numeracy rates are indirect measures of education and do not make any clear distinction between the abilities required for different occupations. de Pleijt & Weisdor (2017:2) state that *"the literacy rate assigns the same skills to a literate farm worker and a literate university professor, with no distinction being made between the enormous variation in ability required of these two very different roles"*.

What is revealed from these arguments is that the use of literacy and numeracy rates, to measure education at the time of the First Industrial Revolution, is therefore inadequate in assessing how Human Capital impacted technological progress and economic growth. It does not show how the highly skilled craftsmen, responsible for the success of Britain during the First Industrial Revolution, obtained their technical abilities and skills. Such an explanation is possible only by departing from the view that *schooling* was the only way only to attain skills at the time (and measuring it by literacy and numeracy), towards a more nuanced view of education which includes more informal modes of education, such as through apprenticeships and personal contracts.

4.2.2 Education and the Informal Institution

Mokyr (2013) reminds that by the mid-1800s, there was an increase in mathematics and science attainment, but concludes that this did not bring about a sharp transition to science-based invention. This is particularly true for the highly skilled craftsmen and important innovators, who did not *specifically* study formal mathematics and science. The lack of formal *schooling* amongst the general population in Britain during the early phases of the First Industrial Revolution lead many industrialists to downplay its importance (Mokyr, 2013). Indeed, schooling was regarded as a hindrance, or irrelevant, by most of the notable inventors of the Industrial Revolution. Beyond his attendance at a grammar school, James Watt, who was responsible for introducing the improvements to the steam machine in 1769, lacked any formal schooling that was useful in arriving at these improvements (Mokyr, 2013). Richard Arkwright, who invented the throstle, which was a device that could produce stronger threads for yarns, which in turn lead to the development of the water frame in 1769, had no previous experience in the spinning process. According to Howes (2016), Richard Arkwright was a barber and wig maker by trade, which provided none of the knowledge needed for the improvements he ultimately provided towards the water frame.

Mokyr (2013) argues that while formal schooling was unimportant in the application towards the most notable inventions during the first Industrial Revolution, the informal education provided by apprenticeships and informal contracts was fundamental to the First Industrial Revolution and Human Capital development. He argues that it is impossible to overlook their role in creating the skills and Useful Knowledge needed during this era. He says that it was through apprenticeships that the skilled craftsmen obtained *tacit* knowledge[7] that was key to their success.

The informal institution of apprenticeships was extremely popular at the time. Mitch (2004, in Mokyr, 2013) calculates that over a quarter of British youth at that time went through some form of an apprentice programme. During an apprenticeship, training was conducted through observation and imitation over a period of years. Significant variance marked the flexibility of the informal institution in quality, length to complete the apprenticeship, as well as the level of technological complexity involved in specific industries. It was this institution, Mokyr (2013) argues, that nonetheless produced highly-skilled craftsmen, mechanical engineers and a competent labour force. The importance of these apprenticeships and informal contracts, in developing these highly-skilled craftsmen and mechanical

[7] Tacit knowledge in this event share commonality with the concept of tacit skill discussed in Chapter 3. Tacit Knowledge being the informal knowledge that is critical to production and is obtained through on-the-job experiences.

engineers, highlights the importance that these modes of skills attainment could play in future industrialisation such as the Fourth Industrial Revolution.

4.3 The Importance of Education-Reinstated

What is evident from the arguments mentioned above is the shortcoming of utilising the contemporary definition of schooling and education in producing the Human Capital necessary for economic success. A nuanced view of attaining skills is called for, i.e. through the inclusion of apprenticeships and informal personal contracts. The conclusion from these findings is that the total *stock* of Human Capital is an insufficient indicator for accounting for economic growth. Instead, Mokyr (2013) argues, the *composition* of Human Capital should be analysed. This is supported by Howes (2016) who argues that there should be a greater focus on the *content* of education rather than its *level*. Mokyr & Voth (2010) show that the perceived minimal role of Human Capital during the First Industrial Revolution in some of the literature is because education is incorrectly measured in terms of literacy and numeracy rates (a measurement that would have been more applicable in measuring schooling in that period). This measure of educational attainment as a measurement of Human Capital veils the necessary skills and Useful Knowledge that was needed by the highly skilled craftsmen during the Industrial Revolution. This is due to the inability of these measurements to account for informal education, such as apprenticeships.

Mokyr (2013) further denies that formal schooling was unimportant. Firstly, Mokyr (2013) states that it was in the combined interest of the state and industrialists to teach more people rather than better teach a limited number of workers. This is because industrialists cannot educate only their own workers, as their investment will be bid away by other employers. The inability of property rights to protect investment in Human Capital leads to market failure (Mokyr, 2013). Therefore, to avoid this market failure, investment in Human Capital needs to be by the state. Of critical importance is the point of educating more people, rather than educating a limited number of workers better. Secondly, Mokyr (2013) argues that there was, in fact, a deep complementarity between physical and Human Capital. This is supported by Ljungberg (2004), Svensson (2004) and Reis (2004), Mokyr & Voth (2010), Squicciarini & Voigtländer (2015) and Feldman & van der Beek (2016) who argue that the Industrial Revolution created a need for reskilling and a disregard for irrelevant skills. This is rooted in the belief of capital-labour complementarity and skill-demanding capital. Mokyr (2013) argues it was in the interests of industrialists to invest in Human Capital and (Friedman, 1977) advantageous to upgrade (re-skill) rather than downgrade (deskill) jobs. This is a topic that requires further discussion and will be discussed in detail in Chapter 7.

4.4 The Knowledge Elite and The Average Worker

This Chapter has highlighted the danger of conflating the terms schooling and education. Interpreting the terms as they existed at the time of the First Industrial Revolution, reinstates the importance of *'education'*. Instead of utilising measures of average education, such as literacy and numeracy rates, the inclusion of informal modes of education, such as apprenticeships, reinforces the role that education and training had on Human Capital, and most importantly economic growth. What emerges from the inclusion of informal modes of education into the analysis, is the importance during the First Industrial Revolution of the highly-skilled craftsmen - the Knowledge Elite. Mokyr & Voth (2010) and Squicciarini & Voigtländer (2015) argue that it is necessary to distinguish this Knowledge Elite from measures of average Human Capital or the Average Worker, to accurately determine their importance for economic growth. Squicciarini & Voigtländer (2015:2) state that "the Knowledge Elite" is a broadened definition of Mokyr's (2005) "upper-tail knowledge" which "reflects an interest in scientific advances…(that) comprises not only innovative and entrepreneurial capabilities in adopting and improving new technology but also lower access costs to modern techniques…The local presence of people embodying such (Useful) knowledge". They argue that it was this elite group, rather than the Average Worker[8], who drove the First Industrial Revolution. They did this through their ingenuity and technical ability that lead to critical inventions, and they acquired these abilities through their informal education in institutions such as apprenticeships.

Distinguishing between these two forms of Human Capital further reinstates the importance of Human Capital, and by extension, education during the Industrial Revolution. This resonates with Romer's (1994) perception of Human Capital as an essential element in economic development, which is enhanced through education. Mokyr & Voth's (2010) differentiation between the Average Worker and the Knowledge Elite provides an expanded understanding of how these two concepts influence and are themselves influenced, by both economic growth and technological change. Therefore, understanding the emergence of these two conceptualisations of Human Capital is necessary to comprehend the effect that they both had on industrialisation, as well as the effect that industrialisation, specifically technological change, had on their respective skills and knowledge. A deeper investigation of the importance of these two forms of Human Capital may reveal not only the role they played in previous industrialisations but possibly also the role they might play in a Fourth Industrial Revolution.

---

[8] Although referred to by Squicciarini & Voigtländer (2015), the Average Worker is merely depicted as Human Capital that was accounted through measurements of schooling and literacy. This research broadens the term to encapsulate Human Capital that possess the skills and knowledge necessary for the adoption and diffusion of new technology in the workplace. By elimination, it is Human Capital that does not formulate as part of the Knowledge Elite.

4.5 Conclusions

This Chapter’s primary aim was to account for the two opposing views regarding the extent that Human Capital affects economic growth. This was followed by the further examination of the link between education and training and their influence on Human Capital, to understand better the causes of the controversy regarding their role in promoting economic development. It was revealed that a more nuanced perception of education reinstated the importance that Human Capital had on economic growth. It was shown that there is a need to further differentiate between the Knowledge Elite and the Average Worker to accurately determine the importance of Human Capital for economic growth. The role of the Knowledge Elite (commonly referred to as the upper tail knowledge or highly skilled craftsman), will be explored in more detail in Chapter 5. A more detailed examination of Mokyr’s (2005) and Allen’s (2009) explanations of why the First Industrial Revolution took place in the time and location that it did, will provide greater insight into how industrialisation occurs. Furthermore, it will provide a sense of historical precedence for understanding more clearly how the Fourth Industrial Revolution may impact on society.

Thereafter the importance of the Average Worker will be analysed, detailing how their knowledge and skills were affected by the technological changes brought on by prior Industrial Revolutions. This is an aspect that is often absent in the literature, as the constant focus is geared towards the role of the Knowledge Elite. The Average Worker and its role will be analysed in Chapter 6.

Chapter 5: The Importance of The Knowledge Elite

The importance of the Knowledge Elite, also commonly referred to as the upper tail knowledge or highly skilled craftsman, is identified by Mokyr's (2005) explanation of the First Industrial Revolution. Both Allen (2009) and Mokyr (2005) set out to explain why the First Industrial Revolution occurred in Britain and reach contending explanations. Mokyr (2005) argues that it was due to the *Enlightenment Movement* which created an enabling, intellectual environment. Central to the Enlightenment Movement were institutions such as the Baconian programme and the Royal Society, which were propelled by the desire to transfer new knowledge and apply it. Mokyr (2002:3) claims the Enlightenment Movement generated cultural conditions that nurtured *"Useful Knowledge"*[9] for industrialisation, which was exploited by the Knowledge Elite and fostered innovation and economic growth. Allen (2009) provides a different argument as to why the First Industrial Revolution occurred in Britain rather than elsewhere. He suggests its origin lay in Britain's unique wage and price structure, which encouraged technological breakthrough, spurred on by the increasing demand for inventions that substituted capital and energy for relatively expensive labour. Both accounts (Mokyr, 2005 and Allen, 2009) give weight to the role of the Knowledge Elite, and the importance of the substitution of capital for labour as drivers of industrial growth and the First Industrial Revolution.

The primary aim of this Chapter is to account for the importance of the Knowledge Elite. This is done through both Allen's (2009) and Mokyr's (2005) accounts of why profound innovations originated in Britain and, furthermore, why Britain adopted these innovations first and faster than other areas of Europe. In the process, four key aspects that are pertinent to this research are revealed. The first is that both these accounts detail the reason they believe that the First Industrial Revolution occurred where it did, and why innovations occurred there first. This explanation provides insight into the possible causal factors that might also influence future industrialisation. The second aspect is centred around Mokyr's notion of Useful Knowledge and the fact that it is central to the development of the Knowledge Elite, through apprenticeships and informal contracts. Accounting for Mokyr's (2002) historical interpretation of the First Industrial Revolution is necessary in two ways. Firstly, it will help understand the notion of Useful Knowledge, and this involves investigating his depictions of the Enlightenment Movement and Scientific Revolution separately. Secondly, it will detail how the Knowledge Elite emerged because of social depth and cultural conditions. The Third aspect is centred on accounting for Allen's (2009) historical interpretation for the First Industrial Revolution, as this is necessary to understand why he believes innovation at the time was induced by the low prices of

[9] Mokyr's (2002) concept of Useful Knowledge is described as the embodiment of both Propositional and Prescriptive knowledge. Propositional Knowledge is the beliefs about the natural world, where Prescriptive Knowledge is the translation or application of Propositional Knowledge into instructions or techniques, i.e. The further creation of Knowledge – See Chapter 3.

energy and the high cost of labour in Britain. This account reveals another important aspect that is relevant to this research, namely the concept of deskilling and Schwab's (2016) warning regarding possible future substitution of capital for labour. The last aspect is that both accounts will provide their respective interpretations of Micro-inventions and Macro-inventions and how these were central to industrialisation in Britain.

The structure of this Chapter is as follows: Section 5.1 will account for Mokyr's (2005) notion of the Industrial Enlightenment and the Knowledge Elite. Section 5.2 will account for Allen's (2009) exposition of a unique wage and price structure and capital substitution. Section 5.3 critiques their arguments together. Section 5.4 discusses Mokyr's (2005) and Allen's (2009) respective interpretations of Micro-inventions and Macro-inventions. Section 5.5 discusses how these two authors' respective theories are, in fact, not contradictory and concludes the Chapter.

5.1 Mokyr's Notion of Culture and Ideology

In attempting to explain why the First Industrial Revolution occurred in Britain Mokyr (2005) argues that the *Enlightenment Movement* in Britain created a critical intellectual, enabling environment. The Enlightenment Movement generated cultural conditions that nurtured both innovation and the supply of the highly-skilled craftsmen who were responsible for key innovations. This Enlightenment Movement improved both institutional quality and technological capabilities that made the First Industrial Revolution possible. Mokyr's (2002) account of the Enlightenment Movement and *Scientific Revolution* as precursors to the First Industrial Revolution leads to his notion of *Useful Knowledge*. The First Industrial Revolution was fundamentally a technological revolution, and Mokyr (2002) states that the sustained acceleration of technological progress and timing of the First Industrial Revolution were due to intellectual developments. Mokyr (2002:29) states *"The key to the Industrial Revolution was technology, and technology is knowledge".* Mokyr's (2002:29) attempts to *"re-examine the epistemic roots"* of industrialisation, lead to the explanation that the timing of the First Industrial Revolution was owed to the Scientific Revolution of the 17th-Century and the Enlightenment Movement of the 18th-Century. Mokyr (2002) claims that there is a neglected link between the Industrial and Scientific Revolutions.

To better explain the concept of Useful Knowledge, Mokyr's (2002) depiction of the Enlightenment Movement and Scientific Revolution are developed separately. This will, in turn, depict how both eras contributed to the enhancement of Useful Knowledge, which subsequently accelerated technological change within the Industrial Revolution.

5.1.1 The Industrial Enlightenment

Mokyr (2005) argues that attempts to explain the First Industrial Revolution are often over-encumbered using economic factors, such as relative prices, endowments, fiscal and monetary institutions and demand factors. The problem with using these economic factors in describing the Industrial Revolution, he argues, is that they fall victim to the conclusion that growth is endogenous, and they are all heavily reliant on technological change as the driver of growth. Mokyr (2005) states that since technology was key to the Industrial Revolution, it is necessary to account for the rapidity and widespread nature of its change during this period and why did it accelerate rather than *"fizzle out"*? Mokyr's (2002) account of the Enlightenment Movement and its features are aimed at explaining the timing of the Industrial Revolution. As noted previously, Mokyr (2005:288) states that *"The Industrial Revolution was a Western phenomenon. It was more than just a British affair if less than a 'European' affair"*. Due to the expansiveness of the enlightenment movement, Mokyr (2002:35) examines only a small portion of it, which he dubs *"Industrial Enlightenment"*. The Industrial Enlightenment creates a linkage between the Scientific Revolution and the First Industrial Revolution and subsequently explains *"why the Industrial Revolution took place in western Europe (although not why it took place in Britain and not in France or the Netherlands.)"* (Mokyr, 2002:29).

The period of enlightenment that spanned from the 17th-Century to the 18th-Century is regarded as an intellectual revolution and is widely believed to have brought about the onset of modern economic growth, through the application of both scientific and experimental techniques towards technology (Squicciarini & Voigtländer, 2015). For Mokyr (2005:291), Industrial Enlightenment was underlined by *"a belief in the possibility and desirability of economic progress and growth through knowledge"*. Mokyr (2005:291) states that the prominent feature of this era was *"the idea of improvement"*. Mokyr (2002:35) further states that *"the Industrial Enlightenment transformed the two sets of Useful Knowledge [Propositional Knowledge and Prescriptive Knowledge] and the relationship between them"*. This, he suggests, was achieved in three ways: by determining superior techniques through the measuring and classification of work practices; by understanding how techniques worked and linking them to Propositional Knowledge; and by enabling the interaction between those who held the Propositional Knowledge and by those who carried out the techniques set out in the Prescriptive Knowledge. Squicciarini & Voigtländer (2015) further note that Industrial Enlightenment promoted economic growth and industrial development by expanding Propositional Knowledge, by reducing the costs of accessing existing knowledge and the practical application of this knowledge.

In sum, Mokyr (2005) claims the Industrial Enlightenment to be a period characterised by a determination to change, complemented by the desire to transfer new knowledge and apply it. Central to this was the *Baconian Programme* (founded by Francis Bacon), which was based on the premise of science and technology to ensure social progress. The Baconian Programme aimed at solving practical problems and making the results widely accessible, through scientific method and experimentation (Mokyr, 2005, p. 40). The Baconian way of thinking had a significant influence on British scientific activity and gave rise to professional scientific societies such as the *Royal Society*. Its impact was further evident in 18th-Century France, through Diderot and d'Alembert's *Encyclopédie* (Allen, 2009). Mokyr (2002:42) describes the Encyclopédie as a document that *"embodies the conviction that the mapping from propositional to prescriptive knowledge and their continued interaction held the key to economic progress"*. Simply put, the Encyclopédie was an embodiment of both information and knowledge that increased the accessibility of *Useful Knowledge*.

5.1.2 The Highly-Skilled Craftsman

The importance of the changes mentioned above is evident when analysing the most prominent inventions of the Industrial Revolution. The Industrial Revolution's most notable invention was steam power, but Mokyr (2005) states that the impact of steam power on industry and productivity was limited in the early years of the Industrial Revolution. Mokyr (2005:146) argues that the power of steam is continuously misconstrued as a radical innovation that was universal in its application. The reality, he suggests, is that during the early part of the Industrial Revolution, steam power did not reach consumers homes and left most of the economy and manufacturing industries untouched. Instead, Mokyr (2005) argues that the prominent inventions of the First Industrial Revolution were a combination of *micro-inventions* that together made up *macro-inventions.*

It was these *micro-inventions* that provided the many useful additions to the steam engine, such as the Spinning Jenny and the Puddling Process, which allowed them to be regarded as fundamental inventions of the Industrial Revolution. In 1712 Thomas Newcomen created the first practical steam engine, and by 1770 the primary use of Newcomen machines was pumping water out of coal mines. However, James Watt introduced improvements to the machine in 1769 that gave it industrial purpose. These improvements increased the steam engine's reliability, adaptability and efficiency, and made it easier to install, repair and maintain. The point that Mokyr (2005) is demonstrating is that the industrial application of steam power could not have materialised without the very elementary scientific discoveries upon which it was founded.

Another industry whose emergence is strongly associated with the First Industrial Revolution was the cotton industry. This industry which was also constructed on constant improvements, experimentation and the desire to allow for social progress. Mokyr (2005) notes that the spinning wheel, or more specifically the act of spinning, was an old skill that, despite subtle advancements during the middle ages, remained a manual task. However, the spinning wheel was displaced by improvements introduced by three notable inventors during the Industrial Revolution. James Hargreaves invented the Spinning Jenny which twisted the yarn by rotating spindles. However, the yarn that was produced was not very strong. Richard Arkwright then invented the throstle, which was a device that could produce stronger threads for yarns. This ultimately lead to the development of the water frame. In 1769, Arkwright patented the water frame, which brought about the advent of the very first mixed Factory System, namely Cromford Mill, in Derbyshire, England. This factory system brought about the use of machinery, extended working hours, timed labour and, most notably, the division of labour. Finally, in 1779, Samuel Crompton combined all these inventions into one that produced high-quality yarn using Richard Arkwright's throstle and the speed of James Hargreaves Spinning Jenny (Mokyr, 2005).

Iron was another industry that became the poster child of the Industrial Revolution. For centuries, producers were unable to refine pig iron into a more malleable wrought iron that could be used in more extensive applications. Henry Cort discovered how to refine pig iron into wrought iron utilising well-known techniques and simultaneously avoid their respective pitfalls. This saw Cort develop what became known as the Puddling Process (Mokyr, 2005). The point that (Mokyr, 2005) makes is that Cort's discovery only materialised through the utilisation and transfer of Useful Knowledge.

These highly skilled inventors, mechanical engineers and craftsmen are but a few of the notable figures that made the First Industrial Revolution possible. They epitomised the very core of the Baconian programme: the desire to ensure economic and social progress through the utilisation and transfer of Useful Knowledge. This, in turn, Mokyr (2005) argues, saw the rapid development of the British manufacturing sector, founded on Useful Knowledge and human ingenuity. It encompassed small innovations that had a significant impact in various industries, as well as solutions to age-old problems. Mokyr (2005) concludes that it was the advanced skills and the extensive Useful Knowledge of Britain's mechanical engineers, founded upon highly informal training such as apprenticeships, that explains why Britain experienced these innovations first and faster than other areas of Europe.

In sum, it was these highly skilled inventors, mechanical engineers and craftsmen that made progressive improvements to the steam engine, spinning jennies and the iron refinements that made Britain the pioneers of the Industrial Revolution. What Mokyr (2005) reveals are that highly-skilled craftsmen were responsible for the culmination of micro improvements made to the notable inventions of the Industrial Revolution. Furthermore, their knowledge and skill set were developed through a combination of informal institutions such as apprenticeship programmes, as well as the influence of The Baconian programmes, and professional scientific societies such as the Royal Society.

However, several authors have argued that Mokyr's (2005) exposition of the origin of the first Industrial Revolution, revealed by the existence of the Knowledge Elite, still does not explain why the First Industrial Revolution occurred in Britain rather than elsewhere in Europe. Allen (2009) does not refute the existence or importance of Mokyr's (2005) Knowledge Elite but contests the reasons that drove these notable inventors to make their inventions.

5.2 Allen's Notion of Induced Innovation

Allen (2009) provides an alternative argument as to why the First Industrial Revolution occurred in Britain. He argues that Britain's unique wage and price structure spurred demand for inventions that substituted capital and energy for labour. Britain, in Allen's (2009) view, had high labour wages, but inexpensive coal. The opposite was true in other countries, where labour costs were much lower, and the cost of energy higher. Allen (2009), therefore, argues that the First Industrial Revolution happened first in Britain because the high cost of labour forced firms to adopt labour-saving practices to stay competitive. The key to achieving this was utilising the abundance of cheap British coal. The innovations that utilised this coal allowed firms to stay competitive by increasing efficiency. It was because it was cost-effective that Britain industrialised first. Allen (2009) further argues while the Industrial Enlightenment was important, this was a Europe-wide phenomenon and did not set Britain apart from the rest of Europe.

5.2.1 The Substitution of Capital for Labour

Allen (2009) claims that Britain's unique wage and price structure was the result of its success in the global economy and its geographical location. High wages were the result of an increase in international trade, marked by Britain's export of new draperies. This resulted in growth in the population of London in response to the trade-induced increase in labour demand. Britain's higher trade per capita provides a possible explanation as to why wages were high. Allen (2009) also states that coal was not only abundant in Britain, it was also cheap. This made Britain the only region in the world that had a combination of high wages and cheap energy. As the price of labour rose, relative to the price of capital, it became increasingly necessary to substitute capital for labour.

Allen argues that high wages and cheap energy determined the speed and nature of the technological change ("induced innovation") that occurred in Britain. Distinguishing between *product* and *process* innovation, Allen (2009) notes that Britain's high wage economy created a mass market that could afford tradables from Asia. This was unique at the time in comparison to the rest of Europe. To meet the high local demand, British manufacturers imitated the goods (i.e. Product innovation) that were imported from Asia. Linked to this product innovation was *process innovation* because of the need to redesign production techniques to suit local production costs. These process revisions focused on reducing the high cost of labour by implementing labour-saving techniques. In this respect, Allen (2009) sides with Hicks (1932) who argued that the creation of labour saving capital was a response to high labour costs.

Allen (2009), therefore, claims that the adoption of new technologies was more cost-effective in Britain than the rest of Europe precisely because Britain's factor costs (labour) were higher. He argues that Europe lagged Britain in adopting the new technologies, not because they were unaffordable elsewhere, but because they were not cost-effective in countries where labour costs were lower. Allen (2009) argues that as a result, the British inventions were predominately labour-saving and capital-using. He illustrates his argument with the example of the high level of mechanisation in English pin factories, notably the Warmley mill. Here, Newcomen machines were used to pump water back into the production process, as the natural flow of water was not reliable, and the result was job losses.

Allen (2009) further, suggests that the famous inventions that occurred during the First Industrial Revolution were British because Research and Development (R&D) was more profitable there than anywhere else. He notes that R&D is costly, and other European countries lacked the benefits to justify putting aside resources towards such research. Lastly, Allen (2009) states that improvements in technology allowed it to become more cost-effective and therefore increased its viability in other countries later in the century. Through the expansion and improvement of technology, both capital and energy intensities declined. This was evident, for example, in the Newcomen machine which became more fuel efficient because of improvements introduced by James Watt. John Smeaton further reduced the amount of coal needed for its operation, and this eventually allowed the steam engine to be profitably used in France, where coal was much costlier.

5.2.2 The Highly-Skilled Craftsman Revisited

To better understand Allen's argument, it is useful to revisit the notable inventors of the Industrial Revolution. In 1709, long before Henry Cort, Abraham Darby developed a new process for smelting iron where pig iron was made using coke rather than charcoal. This was based on an idea by Dud Dudley, who was the first to smelt iron ore using coke. Using this example, Allen (2009:17) states that coke smelting was a *"little idea"*. Two main problems still encumbered the high cost of coke iron. Firstly, the lack of market for the new product and, secondly, high production costs. R&D overcame the first problem, and the second was solved inadvertently by resolving problems of irregular water supply.

Allen (2009) argues that coke smelting was, in fact, a biased technical improvement that would not have been profitable to use in the rest of Europe, nor would it have been profitable to invent outside of Britain. Allen (2009) argues that coke smelting rested on no significant scientific discovery or higher degree of knowledge. Due to coal's inexpensiveness in Britain, there were countless attempts to substitute coal in most applications during the 17th-Century. The difference was that these other attempts were not economical. Abraham Darby's 1st contribution to the invention of coke smelting succeeded because it was commercially viable. This was achieved through R&D, technological borrowing, apprenticeships and other recent development in copper and iron industries. The initially high cost of coke smelting, which limited its expansion into the economy, was overcome through accidental discoveries made while solving other problems. The installation of the Newcomen machines, which were used to pump water and increase water supply, unintentionally cut fuel consumption, making it an energy-saving technological improvement that then made coke more competitive than charcoal. The use of coke over charcoal cut costs in Britain, where coal was abundant, giving it an advantage over countries where coal was expensive.

When accounting for cotton spinning, specifically Hargreaves' spinning jenny and Arkwright's water frame, Allen (2009) argues that neither was based on new scientific discoveries. Both the spinning jenny and the water frame involved the successful overcoming of engineering challenges. There was no scientific breakthrough or original idea, and therefore no macro-invention. Both the spinning jenny and the water frame required significant expenditure in R&D to overcome developmental challenges, and they borrowed technology and recent developments in other industries.

Allen's (2009) argument is that 'inventions' in the iron and cotton industries were not *big ideas* based on new scientific discoveries. However, he admits the steam engine was a departure from his argument. Allen (2009:25) agrees that the steam engine was a *"big idea"* and one with a scientific spin-off. He argues that the discovery of atmospheric weight underpinned the development of the steam engine. Nonetheless, he insists his argument that economic incentives played a vital role, is still relevant. Without such incentives, the steam engine would not have been invented. While the Newcomen engine had a scientific basis, he maintains that similar engineering challenges were encountered to that of cotton and iron. These difficulties were overcome through R&D, which required economic commitment.

Allen's (2009) account of First Industrial Revolution inventions, therefore argues that the underpinning of these inventions was economic factors as opposed to Mokyr's (2005) belief in the importance of culture, ideology and Useful Knowledge. By analysing the source of the idea embodied in the invention, he distinguishes between the roles of scientific discovery and technological borrowing. Apart from the steam engine, which was based on scientific discovery, he argues that technological borrowing formed the basis of invention. This depicts the First Industrial Revolution as the product of lots of *small ideas*, rather than *big ideas*. Furthermore, he argues that R&D was utilised in all inventions to overcome developmental challenges and perfect the inventions. This R&D was profitable only in Britain, where it was fuelled by economic and financial incentives. More so, all the inventions mentioned above rest comfortably in his argument of a unique wage and price structure. The inventions were biased in the sense that they aimed at reducing costs in Britain rather than in foreign markets. Therefore, these inventions were uniquely suited to Britain. This means that they were unable to be profitably adopted abroad due to those countries having the opposite combination of costs, namely low wages and expensive energy. Allen (2009) therefore concludes that inventions during the First Industrial Revolution were responses to Britain's unique wage and price structure, which is why the inventions were British and why technical innovation was biased in favour of labour-saving inventions.

5.3 Mokyr and Allen

Allen (2009) explains the First Industrial Revolution in terms of natural resource endowment, trade and profit opportunities, which impacted on both the demand and supply of technology. This account, however, goes head-on with Mokyr's (2005) claim that *Industrial Enlightenment* and *Useful Knowledge* were critical drivers of the Industrial Revolution, in which inventions were the result of culture and ideas. Allen (2009) claims that economic evolution was a far more significant and stronger contributor towards the First Industrial Revolution than culture and ideas. Allen (2009) reduces Mokyr's (2005) arguments down to three 'idealistic' explanations of the Industrial Revolution. Firstly, he claims that Mokyr's (2005) idea of technological breakthroughs during the First Industrial Revolution rested on the backbone of macro-inventions. Secondly, that according to Mokyr (2005) these technological breakthroughs were the result of the implementation and use of scientific discoveries that were driven by science rather than economics. Lastly, that the First Industrial Revolution was a result of, what Mokyr (2005) argues, was the spread of a scientific culture that affected people's study of technology.

Allen's (2009) account of the First Industrial Revolution is based on wages and prices that created the incentive to innovate and invent technology. This differs with Mokyr (2002) concepts of culture and Useful Knowledge. Mokyr (2012) treats all inventions during the First Industrial Revolution as micro-inventions whereas Allen (2009) subjects any inventions to two tests. Firstly, whether an ‘invention’ is either created from nothing, or is the further development of an existing idea; and, secondly, whether this invention involved R&D that was sensible relative to available economic benefits. Based on these two tests, Allen (2009) agrees with Mokyr (2012) that most inventions during the First Industrial Revolution were micro-inventions. However, Allen (2009) differs from Mokyr (2002) regarding the role of Useful Knowledge and the spread of a scientific culture that affected people's study of technology, claiming that Mokyr’s (2012) explanation is mostly amorphous.

5.4 Macro-inventions and Micro-inventions

The concepts of micro-inventions and macro-inventions differ when analysing both Mokyr’s (2012) and Allen’s (2009) interpretations of the terms. These differences are key to understanding their contrasting theories. Mokyr (2012:23) states that the First Industrial Revolution was *“a clustering of macro-inventions leading to an acceleration in micro-inventions. The macro-inventions not only increased productivity at the time but opened enough new technological vistas to assure that further change was forthcoming”*. As noted, Mokyr’s (2005) idea of the First Industrial Revolution is embedded in the Industrial Enlightenment, which helped produce macro-inventions that were radically new ideas, without precedent, that created a major disruption. This *cluster of macro-inventions* was, for Mokyr (2012), the bedrock of the Industrial Revolution. It set the stage for continued micro-inventions that turned the original inventions into ones that reached consumers’ homes and completely transformed the economy and manufacturing industries. Mokyr (1993:23) states that these micro-inventions lead to the *“gradual diffusion, adaptation, improvement, and extension of the techniques developed during the Industrial Revolution”*.

Allen’s (2009) view of macro-inventions is comparable to Mokyr (2012), in that he regards them as significant advancements that lead to increased productivity. However, a key area of focus for him was its effect on the composition of the factors of production (Marx’s Means of Production). Macro-inventions in Britain increased the capital intensity of production. The implementation of labour saving techniques was brought about, Allen (2009) suggests, because of Britain’s unique high wage-cheap coal/energy combination. Macro-Inventions would ultimately lead to the *“the small incremental steps that improve, adapt, and streamline existing techniques already in use, reducing costs, improving form and function, increasing durability, and reducing energy and raw material requirements”* (Allen, 2009:12).

5.5 Conclusions

At the beginning of the Chapter, it was stated that the focus would be on answering the questions why profound innovations took place in Britain and, secondly, why Britain adopted these innovations first and faster than other areas of Europe. Mokyr's (2002) argument is that the Industrial Enlightenment created the cultural conditions that both nurtured innovation and created a supply of highly-skilled craftsmen who carried out this innovation. It was the adoption of science and the role of Useful Knowledge that saw to economic progress. It is these highly skilled inventors, mechanical engineers and craftsmen, all of whom were British, that progressively made improvements to the steam engine, Spinning Jennies and iron refinements. This explains why these profound innovations took place in Britain and, therefore, answers why they were adopted by Britain first and faster than other areas of Europe.

Allen (2009), however, argues that Britain's unique wage and price structure explains why Britain adopted these innovations first and faster than other areas of Europe. The inventions were, Allen argues, initially not profitable elsewhere, where labour was cheaper and energy more expensive. Allen claims the unique wage and price structure also induced innovation, which is why the inventions occurred in Britain. However, Howes (2015) argues that there is no mechanism by which Britain's unique wage and price structure could inherently induce innovation as Allen (2009) postulates. Howes (2015) agrees with Allen (2009) that the First Industrial Revolution did comprise of labour-saving machinery, but argues this cannot explain the rapid pace of inventiveness of this time. Howes (2015) expands on this notion of a bias towards labour-saving inventions, claiming that inventors of the time had no predetermined ideas as to whether their invention would be labour or capital-saving. Regardless of which one it was, they had every incentive to save on input costs. Howes (2015) argues that many of the notable inventions would still have occurred irrespective of the unique wage and price structure. Discoveries, he suggests, were due to the curiosity of the inventors. There was no way to ensure their economic viability at the point of inception, nor whether they would be labour-saving or labour-using. Howes (2015) concludes that, at most, the unique wage and price structure could determine which inventions were initially likely to be successful.

In analysing the two accounts of the origins of the First Industrial Revolution, it should be recognised that the two theories are not so much contradictory, but instead are concerned with explaining somewhat different phenomena. What does emerge strikingly, however, is Allen's (2009) constant referral to capital-labour substitution. He suggests that there was a pre-existing contest between labour and technology, that existed as far back as the First Industrial Revolution. The issue of labour substitution and deskilling of workers is shared by Schwab (2016) who is concerned that, if inadequately prepared, workers will be unable to complement with technology, and risk being replaced by automation.

The issue of supposed deskilling and worker substitution seems to affect most workers, or the Average Worker as Mokyr & Voth (2010) would describe it. Already, as Mokyr (2005) has proven, the First Industrial Revolution saw the separation of two forms of Human Capital, with the Knowledge Elite playing a widely influential role in the technological advancement and economic growth in Britain. However, the Average Worker is never discussed in detail, particularly the impact that industrialisation and technological change had on their skills and knowledge. The Average Worker will be analysed in the next Chapter against the backdrop of various systems of economic production, consumption and associated socio-economic phenomena that constituted past Industrial Revolutions.

Chapter 6: The Importance of The Average Worker

Both Mokyr & Voth (2010) and Squicciarini & Voigtländer (2015) have argued that it is necessary to distinguish this Knowledge Elite from measures of average Human Capital or the Average Worker, to accurately determine their importance for economic growth. Although referred to by Squicciarini & Voigtländer (2015) they never go beyond depicting the Average Worker as Human Capital that was accounted for through measurements of schooling and literacy. This Chapter broadens the term to encapsulate Human Capital that possesses the skills and knowledge necessary for the adoption and diffusion of new technology in the workplace. Therefore, by process of elimination, it is Human Capital that is not part of the Knowledge Elite. This Chapter discusses the importance of the Average Worker and the effects that industrialisation has had on their skills and knowledge. To discuss the effects of industrialisation, Marx's concept of Historical Materialism needs to be established. This outline provides depth into his view of society and his understanding of the link between society and the individual. This allows the development of a framework through which the effects of industrialisation on the skills and knowledge of the Average Worker can be accounted for.

The purpose of this Chapter is not to recount the various Industrial Revolutions, but rather to allow the role of the Average Worker to be analysed against the backdrop of various systems of economic production, consumption and associated socio-economic phenomena that constituted the respective Industrial Revolutions. First, it is necessary to detail Marx's concept of Historical Materialism and his understanding of the distinction between Productive Forces and of Production Relations. Thereafter, the Industrial Revolutions and their effects on the skills and knowledge of the Average Worker will be discussed. It is shown that the First Industrial Revolution was most notable for the rise of the factory brought on by modern capitalism. The Technological Revolution, or Second Industrial Revolution, saw the implementation of systems of mass production and mass consumption of goods that became known as Fordism. The Digital Revolution, or Third Industrial Revolution, saw the expansion of the Service sector, an updated form of Fordism, as a mode of production.

The importance of how these various systems of economic production and socio-economic phenomena affected the worker and their knowledge and skills is noted. As much as there is a focus on the importance of the Average Worker and how they are affected by technological change, it does not negate the fact that these effects were more widely encompassing, and that it did affect other Human Capital such as the Knowledge Elite. However, in this discussion, the Knowledge Elite are regarded as a minority that arose out of the Average Worker group, all of whom were initially affected by the changing systems of economic production and socio-economic phenomena. Detail of how the Average Worker was affected sets the stage for a discussion regarding the notion of whether deskilling or reskilling took place in the respective Industrial Revolutions. The Average Worker is not explicitly defined by Mokyr & Voth (2010) or Squicciarini & Voigtländer (2015), but can be regarded as low and middle-skilled workers, whose knowledge and skills are necessary to operate and maintain technologies, and account for changes in output by movement along a given production function.

This Chapter will account for the changes in the capitalist modes of production and how this has affected workers and their sense of flexibility and specialisation. The Chapter is structured as follows: Section 6.1 discusses Marx's concept of Historical Materialism. Section 6.2 discusses how the Average Worker emerged and was affected by the factory during the First Industrial Revolution. It carries on this approach by analysing the effects that standardisation and mass production had on the Average Worker during the Second Industrial Revolution. Section 6.3 considers the two opposing views of Neo Fordism and Post Fordism, analysing how the Average Worker was affected. Section 6.4 summarises how work and labour have changed and subsequently affected the Average Worker throughout industrialisation, and concludes the Chapter.

6.1 Historical Materialism

"It is not the consciousness of men that determines their existence but, on the contrary, their social existence that determines their consciousness" (Marx, 1978:66). The concept of *historical materialism*, for Marx, is depicted as the recitation of conflict between groups who have wealth and those who do not. Therefore, history has seen the creation of an extensive division of labour, where people have become accustomed to working for money and buying commodities. Each historical phase saw a clearer distinction between Productive Forces and Production Relations. Marx (1978:66) further emphasises this, stating: *"It is always the direct relationship of the owners of the conditions of production to the direct producers - a relation always naturally corresponding to a definite stage in the development of the methods of labour"*. Mouffe (1979:117) states, *"The nature of man, his historical making, is a practical process…the history of man is the history of labour"*.

This concept of labour is fundamental to Marx's conception of history. This conflict between groups depicts Marx's view of society, where he aims to understand the link between society and the individual. Society, for Marx, is made up of the base and the superstructure. Society has evolved; the Feudalist society is vastly different to contemporary capitalism. Of relevance, contemporary capitalism portrays a superstructure that imposes a set of ideologies such as those of religious, cultural and political instances, that is perpetuated in everyday life. The economic base, which comprises of the production process, harnesses a significant bearing on the class structure and superstructure of society (Stewart & Zaaiman, 2015). Capitalist Production Relations comprises a minority class at the top, the bourgeoisie, who are oppressive of the majority class, the proletariat at the bottom. The superstructure is then utilised to control this separation and maintain a clear line between the two important classes.

Based on Marx's theory of class, rests the ideas of Productive Forces and Production Relations which form part of the base. *Class*, naturally, is a set of people who share the same relationship towards the same Means of Production. The development of Productive Forces sees the existence of Production Relations and different forms of class society. Firstly, *Production Relations* provide the conditions of social existence that determine human consciousness and thus are the framework of every society. The *Productive Forces*, for Marx (1978), consist of both the Means of Production and Labour Power. The *Means of Production* include both the Instruments of Labour and the Objects of Labour. The *Instruments of Labour* are, in the broadest sense, what workers would work with, be it tools, infrastructure or machinery. These facilitate the production of both goods and services. The *Objects of Labour*, are what workers work on, typically known as the raw materials, such as land. Stewart & Zaaiman (2015), referring to the notion of class society, state that the class that own the Means of Production are the *Ruling Class* (Bourgeoisie), whereas the working class (Proletariat) are forced to produce a *surplus value* which the ruling class live off.

Labour Power, on the other hand, is a worker's capacity to work, comprising of skill, knowledge and ingenuity. This Labour Power enables workers to make use of the Means of Production. Marx (1978) distinguishes between labour and Labour Power. *Labour* is the physical act of the worker working, whereas Labour Power is a worker's capacity to work. Burawoy (1985:21) states that workers *"sell neither themselves nor labour services but their Labour Power - their capacity to labour"*. Therefore, workers earn a wage to perform or exercise the capacity to undertake an activity, not in exchange for the activity itself. Labour Power must be organised through management, and only then does the Labour Power become useful. This regulation and organisation allow workers to exercise their capacity in the production of goods and services, or more specifically, Use-Values. *Use-Values are* a product of the Labour Process. Marx highlights that worker productivity is increased by increasing *absolute surplus extraction* i.e. increased control of the worker.

Marx's (1978) notion of the *Labour Process* is the purposeful activity aimed at the production of Use-Values. Brown (1992:175) describes the capitalist Labour Process as one where *"the purpose of the activity is laid down by the capitalist, and the Means of Production, both the objects on which work is to be carried out and the instruments to be used in performing the work, are the property of the capitalist"*. Therefore, the Labour Process comprises of work itself, the Object of labour and the Instruments of Labour. Therefore, Labour Power of the working class (Proletariat) is used in the Labour Process to produce *Use-Values* (goods and services) that generate profits for the Ruling class

(Bourgeoisie). This leads to Marx's notion of exploitation. A clear understanding is imperative to understanding the conflict between groups that depicts Marx's view of society and understanding the link between society and the individual. The onset of the First Industrial Revolution saw a more definite distinction between the Productive Forces and Production Relations and growing importance of the Average Worker.

6.2 The First Industrial Revolution

During the First Industrial Revolution, the rise of the factory saw a transition to capitalism, marking the end of the merchant class, and the putting-out system and ushered in the next stage – Industrial capitalism. This era also saw the growing roles of the Average Worker and the highly skilled craftsman – the Knowledge Elite. Ultimately, the meaning of work has changed under industrial capitalism, where the purpose of work became profit driven (Edgell, 2012). The fundamental goal was economic expansion and renewed profits, or otherwise, the risk of economic failure.

Pre-industrial societies depicted an embedded economy coupled with social power. This is marked by individual autonomy and a democratic sense of life that still governs the economy as an institution. Mokyr (2002) notes that within pre-modern societies, the Average Workers consisted of independent farmers or craftsmen, with no distinction between the concepts of factories, households, plants and firms. The putting out system required labour to be paid a piece wage due to the inability to monitor production. These independent farmers or craftsmen worked in the household assisted by their families and, in some cases, apprentices. Within pre-modern societies, the noticeable transition from cooperative, with little differentiation, to competitive, with gender and class specialisation, eventually saw the emergence of industrial capitalism. This industrial capitalist society is characterised by the rise of the factory, marked with the use of machinery and the specialisation of work roles, all embedded in a profit-oriented market system.

Mokyr (2002) states that the First Industrial Revolution saw the separation of the consumption unit, the household, and the unit of production, the factory. Hodson & Sullivan (2008) states that England was significantly involved in the woollen trade at the time. This set the stage for the enclosure movement which saw the forceful removal of peasants from land and replacing them with grazing sheep. These now displaced peasants provided the necessary labour needed for the factory system. The woollen trade made the capital investment necessary for the factories and machinery (Hodson & Sullivan, 2008). The Labour Process under Industrial capitalism is not inherently new, but rather one adopted from already existing divisions of labour. The highly-skilled inventors, mechanical engineers and craftsmen all owned their Means of Production and had complete control over their Labour Process. Through informal personal contacts and apprenticeships, their acquired skills and knowledge took years to obtain and to be considered mastered. These highly-skilled inventors, mechanical engineers and craftsmen transcended into Industrial capitalism through the separation of the conception of work and the execution of work. Average Workers, however, were separated from their Means of Production and turned into wage labourers to survive.

6.2.1 The Factory

The notion of factories conflates two forms of economic phenomena. Firstly, the collection of Average Workers under one roof, conducting the same work as before, merely away from home, is in fact called *"manufactories"* (Mokyr, 2002:120). However, the actual change in production techniques, constituting the use of machinery, longer working hours, timed labour and a division of labour are termed *"Mills"* (Mokyr, 2002:120). Over time, the division of these two terms no longer held, and so both have been subsumed under the term *'factories'*. Mokyr (2002) claims that both knowledge and technology drove the emergence of factories. The knowledge that is required to carry out production draws from Prescriptive Knowledge, the "which is what" that is necessary to invent and develop new techniques. The very nature of these instructions, designs and techniques means they can be further taught, manipulated, transferred, improved upon and made simpler. Advancing technology means making what was once a complicated process, easier to carry out and execute. This eludes to the notion of deskilling.

Mokyr (2002) notes that the concept that the First Industrial Revolution brought about factories is not entirely accurate. Instead, the First Industrial Revolution saw factories implemented in areas of work where there were none before. The advancement of technology and mechanisation made it worthwhile to bring workers together under one roof. Evidence of the early existence of factories is shown by Thomas Lombe's Derby silk mills in 1718, which employed over 300 workers. When his patent expired more of these mills emerged in other locations (Mokyr, 2002). Another depiction of these early factories was Ambrose Crowley's Stourbridge Ironworks factory in 1682, which employed over 800 workers (Mokyr, 2002). The best illustration of a mixed factory system, however, was in 1769, when Richard Arkwright patented the water frame giving rise to the Cromford Mill, in Derbyshire, England, which employed over 300 workers (Mokyr, 2002). However, the implementation of steam power, saw the substitution of small mills with medium-sized mills, employing more than 400 workers (Mokyr, 2002).

With the onset of the industrial Capitalism and the factory, the Labour Process was transformed such that all workers were housed under one workplace roof. That saw to more control over the Labour Process, comprising more extended hours and timed labour. The division of labour amongst workers separated workers by both education and skill. The removal of the worker from the household meant that Human Capital formation changed, where, before the factory, any investment in Human Capital was in the interest of the parent. The putting-out system tended to require low levels of skill. Any forms of highly-skilled labour or craftsmen remained independent. The advent of large-scale factories saw an increasing interest by employers towards education and training of labour to utilise during the Labour Process[10]. Mokyr (2002) states that the education and training that was provided was not that of a technical nature, but rather that of social conditioning and inculcation, where workers were taught the concept of punctuality, how to be docile and ultimately to follow orders. An important distinction that Mokyr (2002:129) notes is the gap that arose between *"Firm-Specific"* Human Capital and that of *"General"* Human Capital. The former refers to a skill set needed to perform the core competencies of a firm, while the latter refers to a mobile skill-set, which includes the conditioned training (i.e. punctuality, docility), that the worker can employ anywhere.

The rise of Industrial Capitalism was a gradual process over the course of the Industrial Revolution. Mokyr (2002) notes that pre-industrialisation and the First Industrial Revolution were not a clean break, stating that its discontinuity has been vastly overrated. The idea that capitalist production only started during the First Industrial Revolution is undermined by the fact that the putting-out production system shared similar characteristics to how capitalist production is often described, that being high levels of control and hierarchy. The idea that the factory brought about the use of machinery is contradicted by the reality that mechanical approaches to production were utilised as early as the middle ages. The belief that the division of labour was a product of the factory is challenged by the evidence of separation of tasks during pre-industrial production systems.

Organisation forms that are associated with the emergence of 'capitalism' were motivated more by managerial control, that drove a broader social goal rather than being technically determined. This managerial control had direct implications for Labour Power, i.e. the worker's capacity to work. The increase in skill of a worker increases the capacity to work and produce more output. Marx, however, believed that the increase in managerial control and control of the worker increased absolute surplus extraction and subsequently increased worker productivity. This control is further accentuated through the implementation of capital, where forms of *automation and machinery* control the pace of work. What Marx notes, however, is that the distinctive capitalist relations of production are what compels capitalism to increase relative surplus (i.e. productivity), by innovating and reinvesting surplus in both physical and Human Capital.

[10] This relates to the working definition of Human Capital where any investment in Human Capital is achieved through both education and training

6.3 The Technological Revolution

The most prominent feature of the Technological Revolution, or as it is commonly referred to, the Second Industrial Revolution, was the implementation of economies of scale brought on by standardisation and mass production, which came to be known as Fordism (Grint, 1998). The Second Industrial Revolution saw a significant transformation of work, combined with modern-day capitalism, resulted in a very layered class structure. In trying to unpack Fordism as a mode of accumulation, a clear class analysis is beneficial in revealing exactly what is occurring in the class structure. However, Marx did not unequivocally link a theoretical model of the class structure to the capitalist Labour Process. *Fordism* was a distinctive phase, based on mass consumption and mass production and is a regime of accumulation, or more specifically, a system of production and consumption. Moreover, the notion of class structure during this distinctive phase is highly contested and in doing so is open to all levels of critiques. However, for developing the discussion on Fordism, a brief, simplified outline will be provided.

Fordism stratifies society into various levels with capitalists at the top, who govern and own the Means of Production. This level comprises the state, investors and executives and is considered the ruling class. Beneath the strata of the ruling class is what is known as the upper class, comprising professionals, managers and medium-sized business owners. The strata below the upper class are known as the middle class. These are the labour aristocracy and white-collar workers and are commonly referred to as the bourgeoisie and the petite bourgeoisie. What distinguishes the middle class from the working class is higher income derived from labour, but essentially, they are all wage labourers (Average Human Capital) (Standing, 2011). The middle class possesses skills that the working classes do not. The Average Worker would be the working class, which comprises *low-skilled* menial labour. This also referred to as the *"Precariat"* (Standing, 2011:1). Finally, there is what is considered as the underclass, or the *"reserve army of labour",* which includes the unemployed and part-time workers. It is regarded as the breeding ground for replacement staff of those in the working class (Engels *et al*., 2009:98)

6.3.1 Standardization and Mass Production

6.3.1.1 *Fordism*

The Founder of standardisation was Henry Ford, whose standardisation of the work process came to be known as *Fordism* (Grint, 1998). Fordism was characterised by a system of mass production and mass consumption of goods and was shaped by a class struggle between labour and capital. Fordism involved the use of semi-skilled workers in the production of standardised, unspecialized products for a mass-market. This was achieved using conveyor assembly lines, controlled by management through the technology itself, and built on the processes of *Taylorism* (Grint, 1998).

Taylorism, or what is also known as Scientific Management, gave rise in the early twentieth century to work processes that simultaneously allowed for wage increases and a reduction in employers' labour costs, through the elimination of jobs and the saving of labour time (Braverman *et al*., 1998:78). Braverman *et al*. (1998:78) describe Taylorism as the *"dissociation of the Labour Process from the skills of the workers"*, *"separation of conception from execution"*, and *"use of this monopoly over knowledge to control each step of the Labour Process and its mode of execution"*[11]. These primary principles form the very basis of what Taylor was trying to achieve and evidently was carried over, and evolved, into the Fordist mode of production. Fordism was intended as mass production and a capitalistic form of direct control. However, it is said to have had a destructive effect on the mental and physical life of workers. The subjection of workers to ever-increasing pace of work, combined with decreased resting time, vastly increased fatigue, nervous exhaustion, and stress-related disorders (Grint, 1998:284). The primary aim of Fordism is the use of machinery to prolong the working day as well as by introducing the shift system. This lead to the *"degradation"* (Braverman *et al*. (1998:317) of work through deskilling and work intensification. In Marxist terms, this would be coupled with the concept of *"the real subordination of labour"* and production of absolute surplus value which entailed the loss of the traditional artisan, strict worker discipline, and the *"tethering"* of workers to the machine (Brown, 1992:212). Fordism is thus noted as key to the transition from absolute surplus value production to the *"real subordination of labour"* (Marx & Engels, 1988:33).

6.4 The Digital Revolution

The 1950s marked the beginning of the Information Age through the advent of the Digital Revolution, which has become commonly known as the Third Industrial Revolution. It marked the move away from mechanical and analogue electronic technologies to digital electronics, computing and communication technology. There are claims that there has been a global shift to Post-Industrialism or more specifically *Post-Fordism* economies since the 1970s, which have been countered with the belief that there has been a shift towards Neo-Fordism. An account of each of these concepts is necessary to understand how the concepts of work, labour and skill have been affected, as well as the extent that deskilling has taken place. Various changes in manufacturing accounted for the rapidly changing nature of global capitalism. The implementation of multi-skilling, team working, and worker involvement initiatives, as well as the advancement of technology, have encouraged the notion that the world has made a paradigm shift from classic capitalist production methods to Post-Industrialism

---

[11]Braverman's deskilling thesis will be discussed extensively in Chapter 7

and more specifically Post-Fordism (Kraak, 1996). Conversely, however, it is also argued that classical capitalism still exists and that the Fordist work process has merely been updated to *Neo-Fordism*, or as Belussi & Garibaldi, (1996:86) refer to it, as a *“continuation of the Fordist model”* which includes only minor or *“incremental differences”*.

6.4.1 Post-Fordism

Wood (1989) claims that the 1970’s marked the era of Post-Industrialism, which depicts a buyer-driven commodity chain, controlled by both global and locally dominant retailers. This has been interpreted as *Post-Fordism*, where the work process has become deindustrialised, with the manufacturing aspect of work having been overcome by the service sector, information and distribution. This is mostly due to the success of Taylorism and Fordism. Wood (1989) argues that there has been a rise in more flexible forms of production favouring innovation aimed at meeting market demands. Firms have since increased the degree of work fragmentation and have adopted new technologies that allow for flexible specialisation and eventually flexible workforces (Wood, 1989). Firms that have taken a consumer-centred form of production now allow the customer to choose and individualise the product they wish to purchase. There is a resultant *“product mix”*, with few finished products sharing the same specifications (Wood, 1989:52). Firms that use this flexible approach have shifted from the classical capitalist work process to one that allows the consumer to decide and allows forms to serve *niche* markets. This work process sees the worker becoming more skilled, needing a multitude of skills and abilities to handle various job types relating to consumer demands.

This exposition shares various instances of commonality to that of Schwab’s (2016) Fourth Industrial Revolution, with a skill set that is reminiscent of Infosys’ (2016:23) belief that Human Capital need to reskill themselves in a *“fluid manner”* in what is described as *“liquid skills”*.

Flexibility, which shares the same premise as *liquid skills,* is fundamental to Post-Fordism. Grint (1998) states that Post-Fordism, or flexible specialisation, saw that decentralisation was crucial for both increased flexibility and specialisation. It is centred on *“Functional Flexibility”* and *“Numerical Flexibility”* (Grint, 1998:285). *Functional Flexibility* is based on removing rigid job descriptions so that workers can perform different tasks, while *Numerical Flexibility*, refers to the extent in which a group of workers has no job security (Grint, 1998). Grint (1998:285) states that these workers are employed as temporary, contract, casual, or part-time workers, to make the labour market more *“flexible”*. Grint (1998) claims that it is this concept of flexibility that is a critical component of the new workplace technology.

Grint's (1998) exposition chimes with that of Baweja *et al.*'s (2016) concept of flexibility, which stated that workers would need to be skilled in change and adaptability to address the impending skills gap. The commonality amongst these authors, including Hodgson (2016), Schwab (2016) and Loi (2015) is the belief that there is a timeless need to develop a new skill set, and that this is entrenched in the form of education that would grant Human Capital a sense of flexibility, intuition and creativity.

It is interesting to note that the notion of an urgent need to create a flexible skill set for the onset of the Fourth Industrial Revolution, preceded it as far back as the 1970s. Grint (1998) suggests that with this flexibility, the worker has shifted away from being an unskilled worker on the assembly line to a worker who has a multitude of skills and flexibility, known as functional flexibility. The implementation of *"just-in-time"* (JIT) production and consumer-focused firms, predominantly in Japanese firms, have allowed workers to gain varying ranges of skills (Thompson, 1989:222). Workers are now considered to be more flexible and a form of Human Capital more rather than a *replaceable cog* on the assembly line (Marx, 1906). This reveals the return of the skilled worker, who is now more in control of the production process. This is further emphasised by Braverman *et al*. (1998:39) who state that workers who have been *"forced to sell their Labour Power"* to another also surrender their interest in the Labour Process, which has now been *"alienated"*.

Thompson (1989:221) suggests that management now sees eye-to-eye with the worker, and includes them in decision-making and product improvement, through practices such as *"Quality Circles"* and employee participation groups. For Kraak (1996:49) this includes strategies for identifying workers as *"associates"*, which can have the effect of making them feel at one with the company. Thompson (1989:222) argues that this allows management to implement forms of *"Total-Quality-Management"* (TQM) by using the workers for constant product improvement. These practices, which have been successfully applied in corporations such as Jaguar, Rover and Lucas, have seen increased satisfaction and worker cooperation (Thompson, 1989).

6.4.2 Neo-Fordism

A counter view to Post-Fordism, it that classical capitalism still exists and that the Fordist work process has merely been updated to Neo-Fordism (Thompson, 1989). Pillay & van der Walt (2012: 4) argue that regardless of the changes implemented in the workplace since the 1970s, the Post-Industrialism view fails to see that these advancements are *"upgrades"* to the classical capitalist work process. Pillay & van der Walt (2012:4) state that *"contemporary capitalism"* retains essential features from the past, including authoritarian, Fordist-style labour relations. Turl (2007) furthers this argument by maintaining that a decrease in manufacturing jobs contends with an overall increase in total manufacturing output. This decline in manufacturing jobs is not resultant of a reduction in importance of mass production, but rather a product of the "*historical logic of capital accumulation and an inevitable result of production mechanisation"* (Turl, 2007:2). Turl (2007) claims that since the 1970s, the USA has seen manufacturing output double, while countries such as South Africa, Brazil, China and Korea have experienced massive growth in the last 60 years. Furthermore, Turl (2007) states that, since the 1950s, the number of industrial workers has increased by 25 million in the USA, growing to an estimated 112 million in 1998.

Turl (2007:2) maintains that the current prominence of the service sector is not an indication of deindustrialisation, as defined in the concept of Post-Industrialism. He suggests there is still manufacturing taking place in the service industry, which aids the *"soft"* intangible services which serve as the basis on which the service sector functions. The service sector cannot work, nor survive, without this manufacturing aspect. Turl (2007:12) states that what are considered "services" are *"closely linked to industrial production",* with services, such as distribution, call centres or education showing a clear relationship in the chain of industrial production. This ranges from the telecommunication cables used by the call centre, roads used for delivery, or buildings used by schools, which all facilitate industrial production. Actual service sector employment is, in fact, dominated by manufacturing and is not quantitatively different. Service sector employees are menial, semi-skilled based, such as receptionists or delivery drivers, still conducting repetitive and intense work (Wood, 1989).

It is suggested that while Neo-Fordism was the solution to all the shortfalls of classic Fordism, it should be considered merely as a brief phase that forms part of a more significant evolution of the Fordist production system. Grint (1998) claims that this increased form of specialisation is not, in fact, the solution to the shortfalls of Fordism. Instead, problems remain within the bureaucratic control structures and over-centralised decision-making. Grint (1998:287) states that the claim that Neo-Fordism is merely an evolution of the fundamentals of Fordism is contended. Grint (1998:287) argues that the belief that a *"shift"* or redesign of the Fordist work process that Post-Fordism implies, undermines the very concept of Post-Fordism.

Thompson (1989:228), for example, states there has been no qualitative breakthrough in organisation structures, with flexibility being only *"partial breaks"* in Taylorism and Fordism. According to Thompson (1989), Fordism has therefore simply evolved. Practices such as Quality Circles and employee participation groups are a way of internalising the Taylorist techniques and have always coexisted with other work systems. The ability for consumer specialisation and flexibility is merely a result of technological improvements on the assembly line, without any apparent increase in worker control. This makes the worker easily replaceable, and the concept of *flexibility* is rather an expansion of formerly established skills (Thompson, 1989). The multitude of skills gained by the worker is offset by the extent to which those jobs have become routinised, making the worker easily replaceable. Edgell (2012:60) states that in large offices, work has become so routinised and standardised, it *“almost resembles a factory production line”*.

Thompson (1989), however, states that there has been an increase in the number of skills a worker has, but that this is a far cry from a renewed form of craft labour. In this view, the notion of workers simultaneously becoming multi-skilled and more flexible is further undermined by the fact that workers face increased responsibilities and effort intensification from top-down management. The worker is, therefore, faced with multitasking more rather than multi-skilling. Practices, such as JIT, force the worker to face continual and controlled pressure. This aspect is a core feature of classical capitalism (Thompson, 1989). This form of worker flexibility is merely a way of gaining maximum surplus value from the worker.

The growing international network of firms and globalisation of companies has strengthened the argument against Post-Fordism. Huge multi-national firms are increasingly faced with the need to outsource their business-related tasks, with companies starting to compete in the hope of being used by these global firms. These smaller outsourcing firms offer cheaper forms of labour and production causing a global competition in *“the race to the bottom”* (Kraak, 1996:51). This, in turn, emulates Global-Fordism. Turl (2007:1) reiterates this by describing that production has spread *“horizontally”* across regions and that this spatial dispersion of production is more accurately described as global or regional Fordism.

Furthermore, an updated form of classic capitalism can be noted in modern-day workplaces. These workplaces illustrate the importance of control management in the workplace, notably in South Africa. These workplace regimes showed strong characteristics of the racially oppressive order that was evident in South Africa’s settler-colonial history (von Holdt & Webster, 2005:7). This workplace regime is hegemonic combined with Neo-Fordism but falls short in the sense that agreements reached can be considered *forced* by either party. It is characterised by authoritarian managerial practices that preclude the ability to negotiate change and maintains Fordist features, such as work intensification (von Holdt & Webster, 2005:7). This labour intensification is pure exploitation of the worker through continuous repetition of simple routine based tasks.

The global character of Post-Fordism and Neo-Fordism allows the world to function on low wages and structurally high unemployment. Therefore, it is evident to this school of thinking that classic capitalism still dominates the world. While the services sector has increased in importance, this does not indicate there has been a shift to Post-Fordism. Instead, the world depicts characteristics of Neo-Fordism, while maintaining some Fordist concepts.

6.5 Conclusions

The evolution of various systems of economic production, consumption and associated socio-economic phenomena that spanned the respective Industrial Revolutions, saw the formation of the Average Worker, whose skills and knowledge were affected by the increase in automation and use of machinery. The factory saw the transformation of the Labour Process that the Average Worker was subjected to, where all workers were housed under one workplace roof, coupled with extended hours, timed labour and the division of labour. The Average Worker experienced education and training that was applicable only to the Labour Process and necessary for the job at hand. Mokyr (2002) states this was inclusive of social conditioning geared towards the teaching of the concept of punctuality, docility and following orders.

Armed with "*Firm-Specific*" skills, Mokyr (2002:129) argues that the Average Worker possessed the core competencies that that firm needed during production. The prominence of deskilling and supposed loss in workers skill became more apparent with the onset of Fordism during the Second Industrial Revolution. Fordism saw the Average Worker possess only the skill necessary to produce standardised, unspecialized products for a mass-market. The Average Worker experienced an intensification of the pace of work, decreased resting time and increased fatigue. Leading, Braverman *et al*. (1998:317) argue, to work being degraded due to the combination of deskilling and work intensification.

At this point, the Average Worker is said to have possessed the least amount of skill necessary to carry out the task on the assembly line. This, it is claimed, was transformed during the Third Industrial Revolution, where the Average Worker gained a multitude of skills and abilities to handle the various job types required for flexible specialisation. This notion of flexibility is similar to that identified by Loi (2015), Baweja *et al*. (2016), Hodgson (2016) and Schwab (2016).

However, this notion of flexibility is refuted by those who believe the world is experiencing Neo-Fordism, and that the concept of *flexibility* is merely an expansion of formerly established skills that allow the worker to be easily replaceable (Thompson, 1989). It is argued that the focus on the multitude of skills acquired by the worker fail to recognise the extent that jobs have become routinised. Therefore, the Average Worker has transformed from having an encompassing skill set that allowed the completion of tasks, to a skill set that allows for a degree of flexibility that allows the Average Worker to be skilled in change, adaptability and performing different tasks in production.

This highly contested debate over whether the world is experiencing either Post-Fordism or Neo-Fordism is an important example of the danger of fads, buzzwords and over-playing certain characteristics in labour markets. Authors such as Wood (1989) and Thompson (1989) epitomise those who seize on the notion of either Post-Fordism or Neo-Fordism being a new form of workplace or social order. The same argument extends to the likes of Schwab (2016), who have seized on certain aspects of current labour markets or workplaces to project into the future and deemed it to be the Fourth Industrial Revolution.

The extent to which the role of the Average Worker has evolved over the different periods of industrialisation is embedded in how both work and labour have transformed. The connotation of work has changed under industrial capitalism, with the purpose of work having become profit-driven (Edgell, 2012). Marx and Engels saw work as central to human existence. They argued that the coming together through work saw the development of societies, which also then lead to private property, class separation and a social division of labour. Braverman (1998:278) argued that with the rise of capitalism, the *"Universal Market"* had developed. He argued that the increase in goods and services in modern-day society were, in fact, becoming commodities to be bought and sold. Due to the expansion of capital accumulation, the home production of *Use-Values* began to be replaced by cheaper, manufactured goods. People were, thus, unable to sustain their personal needs and wants and were therefore required to seek paid employment. This employment would be the only way to provide for oneself and their families. It was this phenomenon ensured the supply of labour needed for capitalist businesses.

This Chapter makes constant reference to the argument that deskilling occurred during the process of industrialisation. The Average Worker is believed to have lost a considerable portion of their skill set during successive changes in the systems of economic production and consumption. This is a concept that has spanned throughout this research, having briefly been discussed in a contemporary setting in Chapter 3. The conventional school of thought is that deskilling did occur and that the Average Worker lost its expansive skill set, becoming a low-skilled worker on the production line. However, there is also evidence that, even though deskilling did occur, the literature often ignores the extent to which there was simultaneously an increase in capital-labour complementarity and skill-demanding capital.

These claims have obvious resonance with the warnings that the Fourth Industrial Revolution will lead to job losses unless accompanied by the development of 21st-Century Skills and will, therefore, be developed and explored further in the Chapter that follows.

Chapter 7: Human Capital and Deskilling

The extent to which previous Industrial Revolutions lead to deskilling or reskilling is highly contested. Squicciarini & Voigtländer (2015), Feldman & van der Beek (2016) and Ljungberg (2004), for example, contest the claim that the important inventions and subsequent technological advancement during the First Industrial Revolution, were deskilling. Instead, they argue that there was a need for re-skilling founded on evidence of capital-labour complementarity and skill-demanding capital.

The discussion in the previous Chapter of how the Average Worker was affected by industrialisation, sets the stage for a deeper analysis of the notion of deskilling. Both Hodgson (2016) and Loi (2015) provided contemporary viewpoints regarding the concept of deskilling that allows an investigation of Schwab's (2016) idealistic view of capital and labour complementary in the Fourth Industrial Revolution. However, the concept of deskilling extends far back to early capitalism and the introduction of efficiency-increasing production techniques. Therefore, this Chapter will also provide an historical analysis of deskilling, centred around Braverman (1998) who criticised the Labour Process of monopoly capitalism and by extension, scientific management, developed by Frederick Taylor.

The Chapter is structured as follows: Section 7.1 discusses Braverman's deskilling thesis, the debates that revolve around it and its potential weaknesses. Section 7.2 analyses the conventional view of deskilling that occurred during past industrialisation. Section 7.3 considers a more contemporary, nuanced view, arguing that there is evidence of reskilling having taken place during industrialisation with an increase in demand for highly-skilled workers. Section 7.4 concludes the Chapter.

7.1 Braverman's Deskilling Thesis

"Along with the tool, the skill of the workman in handling it passes over to the machine… In the factory, we have a lifeless mechanism independent of the workman, who becomes its mere living appendage" (Marx, 1906:61). Marx, along with Braverman (1998), believed in the pessimistic view that the First Industrial Revolution was deskilling. Braverman's (1998) deskilling thesis dealt with the effects of Scientific Management and introduced the Labour Process debate, where he aimed to show how the labour force is dominated and shaped by the accumulation of capital. The greater control of employers over the Labour Process allowed for the intensification of work, as well as cheaper labour. These were all made possible by innovations introduced by Scientific Management, or Taylorism as it is also known. The importance given by Braverman to Scientific Management is because Taylor was the first management theorist to recognise the vital importance of control. Braverman's (1998) deskilling thesis underlines that both labour-intensive and mental work was being deskilled. His view that modern

capitalism advances the proletarianization of today's workforce is merely a vindication of Marx's earlier arguments of deskilling and proletarianization, which Marx also viewed to be the result of capitalism. The principles that underlie Scientific Management formed the basis of his deskilling argument. Understanding how Braverman (1998) conceptualised the fundamentals of Scientific Management provides insight into the extent to which he claimed workers and work were being deskilled, as well as allowing room for debate regarding the actual extent to which the claimed deskilling has actually occurred.

7.1.1 Taylor vs Braverman

Braverman's (1998) thesis is that the pursuit of capitalist interests resulted in the increasing application of the deskilling logic of Taylorism to work tasks. Taylor developed a series of principles, summed up as:

> *"The managers assume… the burden of gathering together all of the traditional knowledge which in the past has been possessed by the workmen and then of classifying, tabulating, and reducing this knowledge to rules, laws, and formulae".*
>
> Taylor (1911:39)

The first principle is the belief that knowledge of work has always been in possession of the worker. Scientific management aimed to reduce this information and knowledge through *"The dissociation of the Labour Process from the skills of the workers"* (Braverman, 1998:78). Braverman (1998) argues that the way in which work is carried out depends on the design of the work process by management, rather than the skills of the workforce. Furthermore, management must acquire all the knowledge and skills that would be necessary for the performance of the production process. Thus, it would render the Labour Process independent of *"craft, tradition and workers* knowledge" (Braverman, 1998:113).

> *"All possible brain work should be removed from the shop and centred in the planning or laying-out department…"*
>
> Taylor (1911:63)

The second principle was *"The separation of conception from execution"*, which Braverman (1998:78) claimed was the division of responsibility between managers and workers, where managers plan tasks that workers must execute. This is regarded as the dehumanisation of the Labour Process. Managers achieve this by separating the Labour Process from the skills of the workers and by not allowing workers to decide how they go about their tasks. Braverman claimed that management prescribes exactly how tasks must be performed by stating that *"the greater knowledge of, and* *improvements in, production become the exclusive property of management; workers have merely to undertake simplified jobs governed by simplified instructions"* (Brown, 1992:186).

> *"The work of every workman is fully planned out by the management at least one day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work … This task specifies not only what is to be done, but how it is to be done and the exact time allowed for doing it … Scientific management consists very largely in preparing for and carrying out these tasks".*
>
> Taylor (1911:98)

The third principle is *"The use of this monopoly over knowledge to control each step of the Labour Process and its mode of execution".* Braverman (1998:78) argued that the increasing incorporation of science into the Labour Process leads to the worker understanding less of the process. The more sophisticated the machine becomes, the less control the worker has over it. Through task specification, management, dictates what work is to be done, the way it is to be performed and the time allowed for it.

Braverman (1998) argues that the application of these principles has destroyed any craftsmanship, and has degraded the work carried out by most labours. Braverman thus favoured Marx's theory of alienation and elaborated it further by claiming that alienation was, in fact, a process, which was continually being recreated by capitalist management.

7.1.2 The Weakness of Braverman's Arguments

Edgell's (2012) critique of Braverman's deskilling theory underlines what he believes is the inadequacy of Braverman's objectivist conceptualisation of the working class, which fails to address how the class struggle combined with the development of the capitalist Labour Process. Edgell (2012) argues that Braverman (1998) romanticised the notion of the skilled craft worker, as his conceptualisation of skill was embedded in craftsmanship. This was due mainly to the context of his study of manual labour. As mentioned in Chapter 3[12], the notion of skill is, in fact, multifaceted and extends beyond craftsmanship to include both the manual skill and knowledge, the existence of tacit skills, as well as the degree of autonomy that these components open for the worker.

---

[12] Refer to 3.3.3.1 Skill

Edgell (2012) further argues that Braverman (1998) overestimates the extent to which capitalists were able and willing, to implement Taylorism. He claims that Braverman underestimates the degree to which workers, especially craft workers, individually and collectively resisted the deskilling impact of Scientific Management and mechanisation. Skilled workers were forced to form craft unions, to maintain exclusive control over the production process and to control the reproduction of skilled work. This counters Braverman's (1998) belief that there was no working-class resistance against capitalist efforts to control the workforce.

Lastly, Edgell (2012) claims that Braverman (1998) views Fordism as the single management strategy employed in contemporary capitalist workplaces. Edgell (2012) argues that while the techniques of work rationalisation and control developed by Scientific Management are apparently critical to the development of many work environments, they are not present in all workplaces. Scientific Management is just one of many forms of controlling labour and is not necessarily the most efficient. There are other contemporary forms of work organisations, such as the Japanese management techniques, that are people-orientated, and Just-in-Time production systems which are more work-orientated (Thompson, 1989).

This is over and above the argument that, in some cases, the capitalist Labour Process did see it as advantageous to upgrade (reskill) rather than downgrade (deskill) jobs. Friedman (1977) states that while deskilling did occur, there is evidence of simultaneous upskilling. This leads to the next discussion, which departs from the view that industrialisation leads to deskilling, and instead analyses the extent to which deskilling actually took place, as well as explores evidence of upskilling.

7.2 A Conventional View: Deskilling

Thompson (1989) argues that classical capitalism still exists and that consequently deskilling (Neo-Fordism) exists. Fordism based its entire production process on the skill set of the worker. By deskilling the worker, it allowed the production process to become standardised (Braverman *et al.*, 1998). Fordism evolved during the span of the Second and Third Industrial Revolutions, becoming more sophisticated and efficient in its production, but more *"dehumanising"* in its effect on workers and their skills (Grint, 1998:287).

However, the notion of *deskilling* precedes its formalised effects, under Fordism and Scientific management, to as early as the First Industrial Revolution. de Pleijt & Weisdor's (2017) analysis of skills[13] composition of the English workforce from 1550 to 1850 reveals that there was already extensive deskilling, marked by a notable shift in the skills composition of manual labours. The composition of manual labourers in 1550 comprised 25% who were unskilled, with the remaining 75% including either low or medium skilled. By 1850, there was a substantial increase in unskilled workers, having reached 45% while the share of low and medium-skilled workers had fallen to 55%. de Pleijt & Weisdor (2017) support the Marxist idea that proletarianization did occur and concluded that there was a downward social mobility of the English workforce underlined by extensive deskilling. This argument supports the conventional view that deskilling already took place during the early stages of industrialisation and that there was a high degree of substitutability between physical capital and Human Capital, or the intention of implementing skills-saving capital. de Pleijt & Weisdor (2017), and Goldin & Katz (1998) argue that due to the rise in manufacturing and the rise of the factory, there was an increase in demand for unskilled workers and a reduced need for the skilled-worker. Their argument focuses primarily on the first Industrial Revolution.

However, this conventional view is contested, specifically to the extent that deskilling took place, the biases towards a skill set, or whether skill levels were rising or falling during the Industrial Revolution. Mitch (1999), for example, states that both Marx and Thompson believed that skill levels fell overall, evident by the substitution of machinery for skilled labour. However, Mitch (1999) concludes that the Industrial Revolution, in fact, presents no uniform propensity towards either skills-demanding or skills-saving. This is because the quantitative evidence on the labour forces' overall worker composition is deficient.

7.3 A Nuanced View: Reskilling

The conventional view of deskilling is also refuted by several authors such as Ljungberg (2004), Svensson (2004), Reis (2004), Mokyr & Voth (2010), Squicciarini & Voigtländer (2015) and Feldman & van der Beek (2016). They provide a more nuanced view regarding the extent of deskilling. Their arguments draw from various viewpoints, such as the need for reskilling and the disregard for redundant and irrelevant skills, rooted in the belief of capital-labour complementarity and skill-demanding capital. Of importance is the need for (Useful) knowledge and skills, which were required

---

[13] Literature is often amorphous and contradictory in their distinctions between skilled and unskilled, and more notably, the differences between highly-skilled, medium-skilled and low-skilled. It is impossible to categorise each of the various conceptualizations into encompassing manner as each piece of literature is unique in the way they conceptualise each of the respective 'skill' terms. Therefore, when analysing literature, the use of these respective terms, it needs to be taken at face value and interpreted consistently. Drawing a comparative analysis between the various interpretation of these terms leaves room for discretion.

for the mechanisation and innovation during the First Industrial Revolution, and indeed, as Mokyr (2005) argues, made it possible.

Harris (1976:167) claims that a whole new skill set was required and that the First Industrial Revolution created a demand for a *"whole range of new trades, [The Industrial Revolution] subdivided old ones, and created new types of skilled worker, some of which became a permanent feature of the industrial scene"*. Ljungberg (2004) and Babbage (2010) argue that with the increase in the division of labour, the demand for more diversified skills increases. Babbage's (2010) idea of the role of skills is based on the belief that the production process was not merely the dismantling in a series of events that increased output, but rather a series of events coordinated by workers that possess no more skills than necessary to complete the task at hand. Based on this view, Babbage (2010) explains that the worker is only paid for work that is based on a specific set of skills that the worker possesses, and is not assigned any form of unskilled work, i.e. work that is not suited to their skill set. This finding is aligned with Goldin & Katz's (1998) argument, which does not dismiss the fact deskilling did take place during early periods of industrialisation but does consider that, later, the capitalist production required a new type of skilled work. Goldin & Katz (1998) aimed to account for capital and labour complementarity in the early 20th-Century. They found that during the Industrial Revolution, technology and skills were substitutes. However, with the onset of the second Industrial Revolution, both technology and skills became complements, underscored by the introduction of electricity. Electrification of the production process saw a reduced demand for unskilled work, such as hauling and conveying, and the increase of continuous process production. Furthermore, it marked the reduced demand for unskilled production workers and increased demand for higher skilled maintenance and installation workers. The reason for this secular transition, Goldin & Katz (1998) state, is due to the evolving nature of technology.

7.3.1 Transformation and Rationalisation

Svensson (2004) argues that technological change creates opposing biases in the demands for skills during the different phases of structural cycles of economic growth. The reason for these opposing biases towards skills is due to the investments during specific periods being directed towards the renewal of processes and products. This creates an increasing pressure to transform labour market institutions. Svensson (2004:80) outlines alternate periods of convergence and divergence that occur during industrialisation, where the cycles move from phases of *"transformation"* to phases of *"rationalisation"*. *Transformation* (Svensson, 2004) is the impact that new products and production techniques have on economic and industrial growth. Competition steadily increases because of market adaption and diffusion. Resultant profit squeeze creates a slowdown of investment and focus on short-term efficiency increasing investment, described as an economy entering *rationalisation*.

Svensson (2004) states that convergence in growth coincides with phases of rationalisation, while divergence occurs during transformation. Periods of divergence are linked by Svensson (2004) to New Growth Theory, as increases in both Human Capital and knowledge are greater during periods of transformation rather than periods of rationalisation. The reasoning behind Svensson's (2004) exposition of rationalisation and transformation is the link to skills and labour. This link resonates within the realm of technological-specific labour, stating that the implementation of new technologies can be adopted and efficiently used only if the workforce has the appropriate skill. Svensson (2004) therefore, puts forwards that technological change is, in fact, skill-biased and that there is complementarity between capital and high-skilled labour.

Svensson (2004) claims that this capital skills complementarity is at its strongest during periods of transformation rather than periods of rationalisation because significant technological advancements are more evident and concentrated during periods of transformation. Evidence of this is based on the logic that any investment towards the advancement of new capital entails the possibilities for new combinations of resources. Svensson (2004) refers to Goldin & Katz's (1998) argument, which maintains that there was evidence of capital-skill complementarity during the early 20th-Century, yet there was a notable once-off shift towards this complementarity after 1920, before which there was variance between complementarity and substitutability. The shift towards capital and labour complementarity, since 1920, is claimed by Svensson (2004) to bear characteristics of transformation to the introduction of new technologies, specifically from the 1980s onwards. This contrasts with periods of rationalisation, which signify the standardisation and simplification of products and production techniques. Investment in Human Capital is reduced during this time for physical capital due to their increased productivity gains. This reduces the demand for high-skilled labour. The fluctuation between rationalisation and transformation does not necessarily coincide with Goldin & Katz's (1998) belief of a once-and-for-all shift to capital-skill complementarity, but rather the expectations of cyclical variations in skill-bias of technology.

7.3.2 A Different Skill Set

Reis (2004) also challenges the conventional views that deskilling took place due to the high level of substitution of capital and unskilled labour for skilled labour, which effectively depicted a low degree of Human Capital and technology complementarity. This argument is embedded in the role that Human Capital plays within economic growth, which, it is argued, had limited importance during the First Industrial Revolution. This view links directly to that of Goldin & Katz's (1998) argument in which they found that during the First Industrial Revolution, technology and skills were substitutes, yet with the onset of the Second Industrial Revolution, both technology and skills became complements due to the introduction of electricity. Reis (2004) states that during the 19th-Century, and the Second

Industrial Revolution, the most important aspect of Human Capital were the skills that pertained directly to the job that was being carried out. These skills encompassed numeracy and literacy obtained through formal education and school but mostly comprised of practical skills that were achieved throughout the work experience and enhanced worker productivity. Reis (2004) argues that the division of labour that was coupled with industrialisation does not necessarily exclude the need for skills, but in fact created a demand for skills that were merely *different* from those required for craft-based production. This belief is in line with Edgell's (2012) dismissal of Braverman *et al.*'s (1998) notion of skilled-craft work. Braverman *et al.*'s (1998) conceptualisation of skill was embedded in craftsmanship, yet as Brown (1992) and Webster & Leger (1992) agree, the notion of skill is multifaceted and extends beyond craftsmanship. These new sets of *different* skills, which were not inferior in any way to craft-based production, became of growing importance, long before the onset of the Second Industrial Revolution. With the implementation of machinery and capital intensity, there was an urgent need for workers to gain a new, different set of skills, that allowed workers to keep up with production and maintain greater consistency. Thus, as technology evolved, skills did too, propelled by the need for more maintenance and installation focused jobs, aligning with Goldin & Katz's (1998) argument.

Mokyr (1997) similarly argues that skilled labour and new technology are complementary in contemporary times. He sides with Williamson (1985) in arguing that before the 1850s the demand for skilled labour lagged its supply. Mokyr (1997) claims that the conceptualisation of *skill* does not embody the skills that factory owners needed during the 19th-Century, such as punctuality, docility and the need to follow orders. What Mokyr (1997) is proposing is that skills may have mattered less for jobs before the Second Industrial Revolution. Mokyr (1997) favours Greenwood & Yorukoglut's (1997) argument that rapid technological change favours high-skilled labour due to their ability to adapt to early stages of innovation. As this technology becomes more simplified and universal, there is increased demand for unskilled labour. This resonates with Svensson's (2004:80) phases of *"transformation"* and *"rationalisation"*, where Human Capital and knowledge are at their greatest during periods of transformation rather than during periods of rationalisation. Mokyr (1997) further argues that profound technological change reduces the demand for labour and creates technological unemployment, refuting Rifkin's belief that sustained innovation eliminates jobs. Instead, Mokyr (1997) sides with Blanchflower & Burgess's (1998) view that new technology instead complements rather than substitutes labour. Thus Mokyr (1997) concludes that there is *"not a grain of evidence for sustained, long-term periods of involuntary unemployment in 19th-Century Britain"*.

7.3.3 A Higher Skill Set

Feldman & van der Beek (2016) argue that technological changes between 1710 and 1772, in the lead up to the Industrial Revolution, marked a skill bias, due mainly to the expansion of the machinery sector. Feldman & van der Beek (2016) claim that the technological changes and the implementation of machinery in cotton mills had significant effects on the demand for skilled-mechanical workers. They hypothesise that during this period there were a vast expansion of the production, development and maintenance needs of cotton machinery, which caused the demand for highly-skilled workers, or more specifically, highly-skilled mechanical occupations. This supports the views of Reis (2004) and Goldin & Katz (1998). Feldman & van der Beek (2016) analyse skill formation through apprenticeship and their response to the inventions that were taking place. It reveals that most significant impact of innovation on apprenticeships was what was regarded as *“ingenious”* trades (Feldman & van der Beek, 2016:6). The craftsmen of these ingenious trades mainly constituted of Wrights, who were a highly specialised class of machine workers, and were both highly demanded and significant contributors to the First Industrial Revolution (Feldman & van der Beek, 2016). These ingenious craftsmen possessed the skill that saw to the improvements and implementation of new technological ideas.

These findings show that there was a skill demand for highly-skilled workers, but simultaneously, the factory system increased demand for unskilled workers. They suggest that technological change did indeed increase the demand for skilled, ingenious craftsmen relatively more than for the unskilled worker, which points to a skill-bias. What is of equal importance is the recognition of ingenious craftsmen. This concept of ingenious craftsmen is more formalised by Squicciarini & Voigtländer (2015), who assess the role of Human Capital and Mokyr & Voth (2010:29) who discuss the notion of upper-tail knowledge.

7.4 Conclusions

In this Chapter, historical analysis was used to achieve the aim of establishing to what extent deskilling and reskilling took place during past industrialisation. It demonstrated that while deskilling did occur through technological change and the early parts of industrialisation, there was also, later, an increased demand for new types of skilled work and machinery that was complementary to labour. The literature has revealed the historical importance of re-skilling, and for disregarding acquired redundant and irrelevant skills. Furthermore, through technological progress, new jobs and new industries were created. The next Chapter brings together the main findings which can be identified from this thesis and their relevance for the Fourth Industrial Revolution and 21st-Century skills.

Chapter 8: Readiness for The Next Industrial Revolution

Schwab's (2016) concept of the Fourth Industrial Revolution is based on a culmination and convergence of rapidly developing technologies, that will provide changed supply-side and demand-side opportunities. His idealistic explanation of a new Industrial Revolution is embedded in industrialisation and economic growth brought about by Human Capital formation through the development of 21st Century Skills.

The nature of such skills is unclear, as is the impact of changing technology on the workplace. Schwab (2016) and the World Economic Forum (2015) claim that there is a need to develop *"21st-Century Skills"*, which Human Capital will need to succeed in the Fourth Industrial Revolution. The absence of such skills, it is suggested (World Economic Forum, 2017), is producing a growing skills gap, which must be countered through a combination of improved education and technology. Schwab (2016) argues that when they are both effectively deployed, the combination of education and technology, instead of resulting in rising unemployment as machines replace workers, will instead create a new skill set amongst employed workers.

This thesis has sought to examine the historical relationship between Human Capital, skills, education and industrialisation to uncover, in broad terms, the nature of such requirements and changes.

Loi (2015) and Hodgson (2016) have argued that technological innovation has resulted in an increased demand for more sophisticated, yet human, sets of skills. They suggest that rather than workers being replaced by machines, the Fourth Industrial Revolution requires the equipping of Human Capital, especially middle-skilled workers, with a skill set that is less susceptible to automation, which involves creativity, intuition and human judgement. This requirement is supported by Squicciarini & Voigtländer (2015), Feldman & van der Beek (2016) and Ljungberg (2004) who find that historically physical capital was not a substitution for Human Capital. Instead, there was a need for re-skilling, founded on evidence of capital-labour complementarity and skill-demanding capital. Historically, it is clear there was a need for both re-skilling and disregarding existing redundant and irrelevant skills.

The evidence of the previous Chapters is not that deskilling never occurs, nor that industrialisation does not ever result in job loss. It shows that while deskilling did initially take place during early periods of industrialisation, there was also later a demand for new types of skilled work. New jobs and new industries were created because of technological progress.

These findings reinforce the need to create new skill sets amongst both the Average Worker and the Knowledge Elite that are flexible, adaptable and mobile. These new skills and competencies can be developed by integrating technology into education, through life-long learning and on-the-job training.

The historical conditions required to achieve such changes are summarised in the sections that follow. Section 8.1 considers the complementarity of both Mokyr's (2002) and Allen's (2009) theories and how together they can create an enabling environment for the Knowledge Elite. Section 8.2 considers the reinstated importance of education and the measures that an economy would require to ensure the development of both the Average Worker and the Knowledge Elite. Section 8.3 explains that Schwab's approach to developing 21st-Century Skills is too simplistic and that conceptualising between the Knowledge Elite and the Average Worker is necessary to ensure successful industrialisation. A high-level attempt to measure country progress in meeting these requirements is made in sections 8.4 and 8.5. Section 8.6 concludes the Chapter.

8.1 Culture, Ideology and Induced Innovation

Mokyr & Voth (2010) and Squicciarini & Voigtländer (2015) argue that it is necessary to distinguish between the Knowledge Elite and Average Human Capital to understand the importance of Human Capital for economic growth. Historically, technological progress was driven by the Knowledge Elite that possessed Useful Knowledge. The importance of the Knowledge Elite was particularly evident during the First Industrial Revolution, which Mokyr (2002) claims was a result of the culture and ideology of the enlightenment movement, which drove the social and economic changes of this era. It allowed the social depth and cultural conditions in which the Knowledge Elite could see innovation as a valuable activity, that through its application, improved human condition. It also provided the environment for innovation to succeed. The importance of Useful Knowledge is combined with the need for networks and institutional systems that allowed Useful Knowledge to be exploited in commercially useful ways.

Allen (2009) proposes an induced innovation explanation for the Industrial Revolution, believing that incentives were needed for innovation to occur and contribute to economic growth. It was the combination of the low prices of energy and the high cost of labour in Britain that provided industrialists with an incentive to innovate and adopt labour saving innovations. It was this unique combination that made it cost-effective to industrialise in Britain. Other countries lagged in adopting new technologies due to their different relative prices for labour and energy.

This thesis has argued that these two accounts are mutually inclusive of one another. It suggests that the existence of the Knowledge Elite and technological advancement in the contemporary world rests on both Allen (2009) and Mokyr (2002) theories. Allen's (2009) explanation of induced innovation falls within the realm of Mokyr's (2002) view of the importance of culture or ideology.

No such distinction between these two forms of Human Capital is acknowledged by Schwab (2016) or the World Economic Forum (2015) when they analyse the Fourth Industrial Revolution or its requirements for "21st-Century Skills". To drive technological change will require the skills of the Knowledge Elite. However, at the same time, raising the skills of the Average Worker is also essential because (as Mokyr & Voth (2010) reveal) the skills of the Average Worker are necessary for the adoption and diffusion of new technology in the workplace.

This environment needs to be encapsulated in an economy that provides the necessary framework and economic factors that will further induce technological progress and economic growth. Technological creativity needs to be induced by an economy that provides the resources and incentives that affords the Knowledge Elites with a sense of economic security, intellectual freedom and financial reward.

Furthermore, Useful Knowledge needs to be distributed through networking and institutional systems that allow it to be further exploited in commercially useful ways. In this regard, Allen (2009) reminds that for new technologies to be viable it is necessary that they make economic sense. This is argued by examining the famous inventions that occurred during the Industrial Revolution, which he suggests were British because R&D was more profitable there than anywhere else. Other European countries lacked the economic benefits to justify putting aside resources towards such research. It was only later in the century when capital and energy intensities had declined through the expansion and improvement of technology that it too became more cost-effective to implement the new technologies elsewhere in Europe.

Extending this view of technology to Schwab's (2006) vision of automation suggests that such changes will initially be economically viable only where labour costs are highest, coupled with other economic factors, such as those that Allen points to, i.e. high labour costs coupled with cheap energy. This combination may initially be found in rich, developed countries. It will only be that when new technologies have been incrementally improved, and their costs reduced, will they become economically viable in developing countries.

8.2 Education

The thesis has also shown that there is a significant amount of interplay between skill and industrialisation and education and industrialisation. While these concepts are discussed separately, this is done only to avoid confusion and maintain consistency. It does not suggest that they are mutually exclusive concepts. Uncertainty in the literature regarding the importance of Human Capital and education during industrialisation was due to the conflation of the terms schooling and education and failure to recognise the differences between their contemporary meaning, and their meaning during the First Industrial Revolution (Mokyr, 2013). Thus, if measurements of literacy and numeracy are used, it is evident that most workers were “uneducated”. However, Ljungberg (2004) shows that literacy and numeracy were unimportant in the early stages of Industrialisation. They became increasingly important at the later stage of industrialisation, which is when mass education became the norm.

However, the importance during the First Industrial Revolution of ‘education’ more broadly understood, is reinforced when informal modes of education are included, notably apprenticeships (Mokyr, 2013). The transmission of Useful Knowledge, in its tacit form, was through apprenticeships, where apprentices gradually acquired their skills through imitation and learning-by-doing rather than in the classroom. This institution of apprenticeship created a high-level, sustainable technical competence that was critical during the Industrial Revolution.

When applying this distinction to the contemporary world, the concept of schooling and education are not as cut-and-dry as they were during the First Industrial Revolution. It will be necessary to educate and develop the Average Worker for an economy to adopt and carry out technological advancements that will lead to economic growth in the Fourth Industrial Revolution. However, it will be equally important to develop the Knowledge Elite to ensure that technological advancement takes place.

The question that arises is how does an economy ensure the development of both the Knowledge Elite and the Average Worker, in a contemporary education setting that will allow sustained technological advancement and economic growth?

8.2.1 The Extensive and Intensive Margin

In answering this question, the most significant issue is how does an economy focus its resources on developing both these instances of Human Capital? Mokyr’s (2013) exposition of intensive and extensive margins provides a framework for answering this question. Mokyr (2013) states the ordinarily an economy is faced with either developing the Extensive Margin (educating more individuals) or instead concentrating on expanding the Intensive Margin (focusing on educating a limited number of individuals, better). As is evident, from the later stages of the First Industrial Revolution and onwards, there was a combined interest by both the state and industrialists to focus on expanding the Extensive Margin. Therefore, there was a concerted effort in expanding the extensive margin, rather than focusing mainly on the intensive margin. In a modern setting, this suggests it would be best to concentrate initially on the intensive margin, that would see the development of the Knowledge Elite needed to propel an economy successfully into the Fourth Industrial Revolution. Mokyr (2013), however, argues otherwise, stating that expanding the extensive margin is critical to sustaining technological progress.

Mokyr (2013) believes that expanding the extensive margin means that more people (i.e. the Average Worker) are better educated and this gives them the ability to operate and maintain complex machinery. This is supported by Ljungberg's (2004:6) notion that literacy is an efficient *"transaction technology"*. The more literate, or 'enlightened' a population is, the more easily a country can adopt innovations and technological advancements.

Mokyr (2013) argues that technological progress requires, firstly, front-loading scientific knowledge in inventing new machinery and equipment. However, when it is installed, knowledge is focused on making it simpler to operate. This means there is a significant differential between the Useful Knowledge needed for the inventor to build and design the machine, and the skill required to operate it.

For an economy to ensure that the required knowledge of both the Knowledge Elite and the Average Worker is generated, Mokyr (2013) suggests it is best to expand the Extensive Margin and that this will expand the Intensive Margin at the same time. Expanding the extensive margin allows the Knowledge Elite to be discovered and further invested in. As controversial as this may seem, Mokyr (2013) argues it makes economic sense to focus scarce resources on educating the most talented individuals, as he believes that they will drive industrialisation as they did in the First Industrial Revolution. However, he recognises that this would accentuate inequalities. Therefore, he suggests providing schooling for everyone. This will have a twofold effect. Educating the masses develops the abilities needed to operate and maintain complex machinery. At the same time, it allows the best and brightest to be discovered. Furthermore, expanding the extensive margin, allows schools to instil obedience and docility, that enables Average Workers to operate in complex work environments and follow the instructions of their superiors. These are skills that can easily be transferred between employers, and so negates the need for individual employers to invest in them.

8.3 Skill

Schwab (2016) states that through a combination of education, technology and Human Capital, both economic growth and jobs can be created which will propel an economy into the next Industrial Revolution. This claim rests primarily on the successful execution of an education system that produces a skill set allowing adaptability and mobility. However, it is clear from the previous Chapters that Schwab's (2016) view of merely developing 21st-Century Skills is too simplistic. When analysing how an economy can successfully transition into the Fourth Industrial Revolution, it is important to recognise that both the Knowledge Elite and Average Worker are necessary for successful industrialisation. It is evident, too, that expanding the Extensive Margin, will subsequently expand the Intensive Margin. This will allow for mass education and the development of the Average Worker, while also allowing for the emergence of the Knowledge Elite.

As obvious as this attempt might be perceived, it allows for a framework that will permit the application of 21st-Century Skills to be applied to all forms of Human Capital. This is important, as literature linking the two forms of Human Capital with 21st-Century Skills is absent. Historical accounts of Industrialisation warn that merely developing "skills", as the World Economic Forum (2015) and Schwab (2016) argue, is not enough. Successfully transitioning into the Fourth Industrial Revolution requires formulating strategies to provide both the Average Worker and the Knowledge Elite with the different set of 21st-Century Skills necessary for successful industrialisation.

8.4 The 21st-Century Knowledge Elite and Average Worker

Policies and proposals by the World Economic Forum (2017a) for preparing for the Fourth Industrial Revolution can be judged against the requirement to develop the skill set needed by both the Knowledge Elite and the Average Worker. Strategies for acquiring the 21st-Century Skills needed to progress into the next Industrial Revolution are elaborated upon in what the World Economic Forum (2017a) refers to as a "Future-Ready Education Ecosystem" and the "Transition to A New World of Work". An analysis of these proposals allows them to be compared with what historical experience revealed to be essential for a technological revolution.

A "Future-Ready Education Ecosystem", as the World Economic Forum (2017a) forwards, is a suggested global blueprint of key action areas that are intended to guide policymakers, the private sector and education specialists to ensure that education systems transition to being more responsive and relevant to the Fourth Industrial Revolution. It suggests a strategy that will transform education systems and reduce the disconnect between current labour markets. Its focus areas include early childhood education, robust and respected technical and vocational education, digital fluency, future-ready curricula, a professionalised teaching workforce, early exposure to the workplace, openness to education innovation, and a focus on lifelong learning.

When looking at Sub-Saharan Africa, the World Economic Forum (2017b) states that focusing on all eight of the above areas is vital to ensure a long-term education system that is susceptible to a constant pace of change. However, (World Economic Forum, 2017b) four areas of specific strategic focus are identified: namely, investing in digital fluency; ensuring the 'future-readiness' of curricula and ICT literacy skills; creating a culture of lifelong learning, and providing robust and respected technical and vocational education and training (TVET). The emphasis on technical and vocational education and training as a requirement for advancing industrialisation echoes the findings of previous Chapters. It urges a move away from the purely academic orientation of education to the more technical and practical focus that it has been shown was historically important in aiding industrialisation.

The World Economic Forum (2017b) states that Sub-Saharan Africa economies are currently not fully leveraging the opportunities offered by technical and vocational education and training. Countries need to focus not only on improving the job-relevance of technical and vocational education and training but should also substantially increase their offerings of both formal and informal apprenticeships. The World Economic Forum (2017b) urges Sub-Saharan African countries to focus on creating a culture of lifelong learning, drawing from the need to ensure adult training and upskilling infrastructure.

The need for constant reskilling, upskilling and building more resilient talent pools is emphasised. This must be achieved through governments, schools, universities and non-formal education providers. This recommendation resonates with Infosys' (2016:23) concept of *"liquid skills"*, namely a skill set founded on flexibility that will allow workers to respond to the demands of changing careers, and with Baweja *et al.*'s concept of flexibility, the ability to be skilled in change, and adaptability to address the impending skills gap. The World Economic Forum (2017b:10) aims to ensure a "future-readiness" of curricula, with a specific focus on STEM fields. There should be a greater focus on the skills needed in the future that will allow Human Capital to leverage technological change.

This requires a dual focus. Firstly, on developing critical thinking, creativity, cognitive flexibility and emotional intelligence. This aligns with O'Connor's (2016) belief in that there needs to be a shift towards more creative education investment and the ability to exercise intuition, creativity and persuasion. Likewise, Hodgson (2016) argues that there needs to be a shift towards a skill set that displays professional human judgement, that is both flexible and capable of displaying empathy, creativity, and intuition. Secondly, increased emphasis is needed on education in science, technology, engineering and mathematics education. This should be achieved through both secondary and tertiary level education, as well as through technical and vocational training.

The World Economic Forum (2017b) states that jobs globally are requiring more intensive and high-level skill sets that are embedded in digital technologies. It is for this reason that the World Economic Forum (2017b) believes that there should be a focus on investing in digital fluency and ICT literacy skills. This will ensure a set of basic and vocational curricula that is "future-proof". This emphasis is supported by Hodgson (2016), who states that historical evidence demonstrates that machines enhance skills more rather than reducing them, and this means a growing requirement for a more significant and more complex skill set.

In addition to the focus on transforming education and skills development, the World Economic Forum (2017b) also emphasises the importance of preparing Human Capital for a changing workplace brought on by the Fourth Industrial Revolution. Details of these requirements are spelt out in the "Transition to A New World of Work" strategic action plan (World Economic Forum, 2017b). It outlines a set of strategies that the World Economic Forum (2017b) believes are vital to allow Human Capital to transition seamlessly into a large digitised workplace and economy. Its focus areas include updated social protection, recognition of all work models, rapid implementation of new regulations, adult learning and continuous re-skilling, and proactive employment services. Although not the immediate focus of this research, it is interesting to note that the policy proposals extend beyond merely suggesting a robust and future-proof skill set and into the workplace itself.

In this regard, the World Economic Forum (2017b) proposes that employment law and regulations need to be reformed to better-enable independent workers to benefit from new opportunities presented by a digitised workplace. More so, the World Economic Forum (2017b), states that there needs to be more social protection for workers who might either be displaced or need to transition between work. Proactive employment services see the World Economic Forum (2017b) focus on the issue of workforce polarisation. This concern is shared by Baweja *et al*. (2016:14) who state that *"workforce polarisation"* in the short run, will see the Fourth Industrial Revolution increase frictional unemployment amongst lower-skilled and middle-skilled workers, unless workers *"re-skill, relocate or adapt".*

To deal with this problem, the World Economic Forum (2017b) proposes that there should be greater emphasis on creating mechanisms linking workers with jobs and jobs with workers, with a specific focus on adult skilling and training. This leads on to the proposal (World Economic Forum, 2017b) of

Adult learning and continuous reskilling, a principle drawn from the *"Future-Ready Education Ecosystem"*. The World Economic Forum (2017b) suggests that increasing relevance be placed on developing lifelong-learning and diverging from *"education for employment"* to *"education for employability"*. This can be achieved by incentivising governments, companies, academic institutions and vocational training providers to provide general and customised learning and training opportunities which can be utilised by those currently employed and those who are searching for work.

The next section of this research attempts to assess how different countries currently rank regarding implementing the outlined policy advice and strategies to meet the critical areas that the World Economic Forum (2017b) deems essential to progress their economies into the next Industrial Revolution. In attempting such an assessment, several indicators can be used. These are drawn from the Networked Readiness Index compiled by the World Economic Forum (2016) which consists of a set of indicators for ten pillars and four major components which assess an economy's readiness for the Fourth Industrial Revolution.

8.5 Cross Country Comparison

This thesis has argued that the Existence of both the Knowledge Elite and Average Worker are necessary for a country to transition into the Fourth Industrial Revolution successfully. However, difficulty arises when attempting to conceptualise both these forms of Human Capital to allow for a cross-country comparison. The problem of measuring skills, or more particularly education, using for example literacy and numeracy rates was demonstrated by Mokyr & Voth (2010). Such measurements are problematic when identifying the causes of the First Industrial Revolution and are likely to be equally so in a contemporary setting when looking at preparedness for the Fourth Industrial Revolution. Measurements such as literacy rates cannot be helpful if, in fact, the uptake of STEM subjects and education enrolment rate are the most encompassing and measurable forms of ascertaining the level of required skills in any given economy.

As much as one can *define* what the Knowledge Elite and Average Worker are, it is difficult to find a set of indicators and measurements that measure the prevalence of these concepts of Human Capital. As much as the term can be defined, the very idea of the Knowledge Elite, for example, is not fixed in measurable criteria that allow for comparative analysis. Any attempt to gather measurable data will be challengeable due to its subjective nature. The Knowledge Elite were those that drove the First Industrial Revolution through their ingenuity and technical ability towards essential inventions, yet that is a posthumous assessment. There is no doubt that there are also Knowledge Elite today. However, measuring their prevalence is difficult. It could be argued that the Knowledge Elite are amongst those who are enrolled in STEM subjects, or completed a form of tertiary education. However, as this research has proven, informal education attainment, such as vocational training, historically played a far more significant role in the creation of the Knowledge Elite than formal study. The inability to apply a set of indicators to account for the Knowledge Elite and the Average Worker means that there is no clear-cut way to account for these respective forms of Human Capital.

Therefore, a broader approach needs to be taken in trying to assess a country's readiness for the Fourth Industrial Revolution. Instead of basing a country's likelihood of success on measures of the composition of the Knowledge Elite and Average Worker, the Network Readiness Index (World Economic Forum, 2016) will be used as an admittedly imperfect alternative. The Networked Readiness Index outlines the competitiveness landscape of 140 economies to quantify the impact of several key indicators, that the World Economic Forum (2016) believes, depict how countries are coping with the digital world based on their use of information and communications technologies. The Networked Readiness Index therefore to some degree depicts the readiness of countries to make the transition into the Fourth Industrial Revolution.

The basis of the Networked Readiness Index is embedded in whether a country possesses the necessary drivers that will allow digital technologies to meet their potential. By extension, it measures whether these digital technologies are impacting on the economy and society. The drivers measured are divided into three sub-indexes namely, the *overall environment*, *readiness* and *usage* (World Economic Forum, 2016). Their *impact* is measured in terms of both economic and social impact. *Readiness* further comprises of affordability, infrastructure and skills, while *usage* is divided into businesses, individuals and the government.

The data utilised in measuring these variables are derived from administrative data produced by internationally recognised agencies, such as the International Monetary Fund (IMF), and the World Health Organization (WHO), as well as from the World Economic Forum's annual Executive Opinion Survey (World Economic Forum, 2016).

The Networked Readiness Index is presented for individual countries as well as for seven country groupings. The focus of this analysis is on South Africa. South Africa's performance is compared with the country groupings of Sub-Saharan Africa, Latin America and the Caribbean, the Advanced Economies, as well as with Singapore. Sub-Saharan Africa is considered an appropriate comparison both because of South Africa's location, but also because the countries in this region face similar economic constraints to South Africa and are all developing economies. For these last reasons, comparisons are also made with Latin America and the Caribbean. Singapore is ranked by the World

Economic Forum (2016) as the economy best-prepared to benefit from the Fourth Industrial Revolution. Comparing South Africa to the strongest competitor allows an illustration of how it and the chosen country groupings rank up against the best performer. For similar reasons, the comparison is also made with the countries grouped as “advanced economies”.

The performance of these comparator countries is measured according to the four sub-indexes, namely *environment*, *readiness*, *usage* and *impact* (World Economic Forum, 2016). These four sub-indexes are made up of 10 pillars and measured according to 53 indicators. Under the *Environment* Sub-Index, for example, are the *Political and Regulatory Environment* Pillar and the *Business and Innovation Environment* Pillar. Under the *Readiness* Sub-Index are the *Infrastructure*, *Affordability* and *Skills* Pillars. Under the *Usage*, Sub-Index are the *Individual Usage*, *Business Usage* and *Government Usage* Pillars (World Economic Forum, 2016). Lastly, under the *Impact* Sub-Index are measures of both the *Economic Impacts* Pillar and the *Social Impacts* Pillar.

Executives from each of the 139 participating WEF countries were asked a set of questions linked to these ten pillars and were requested to rank various indicators on a 1-7 scale, with higher average scores being indicative of increased readiness. The scaling of these indicators gives a rather rudimentary and subjective measure for assessing economic performance and more specifically the ability to rank country performance according to specific indicators.

The radar chart in *Figure 1,* compares South Africa to Sub-Saharan Africa, Latin America and the Caribbean, the Advanced Economies and with Singapore, based on the four sub-indexes. Each country’s or group of countries’ scores for the four sub-indexes is shown by the size of their respective “diamond”.

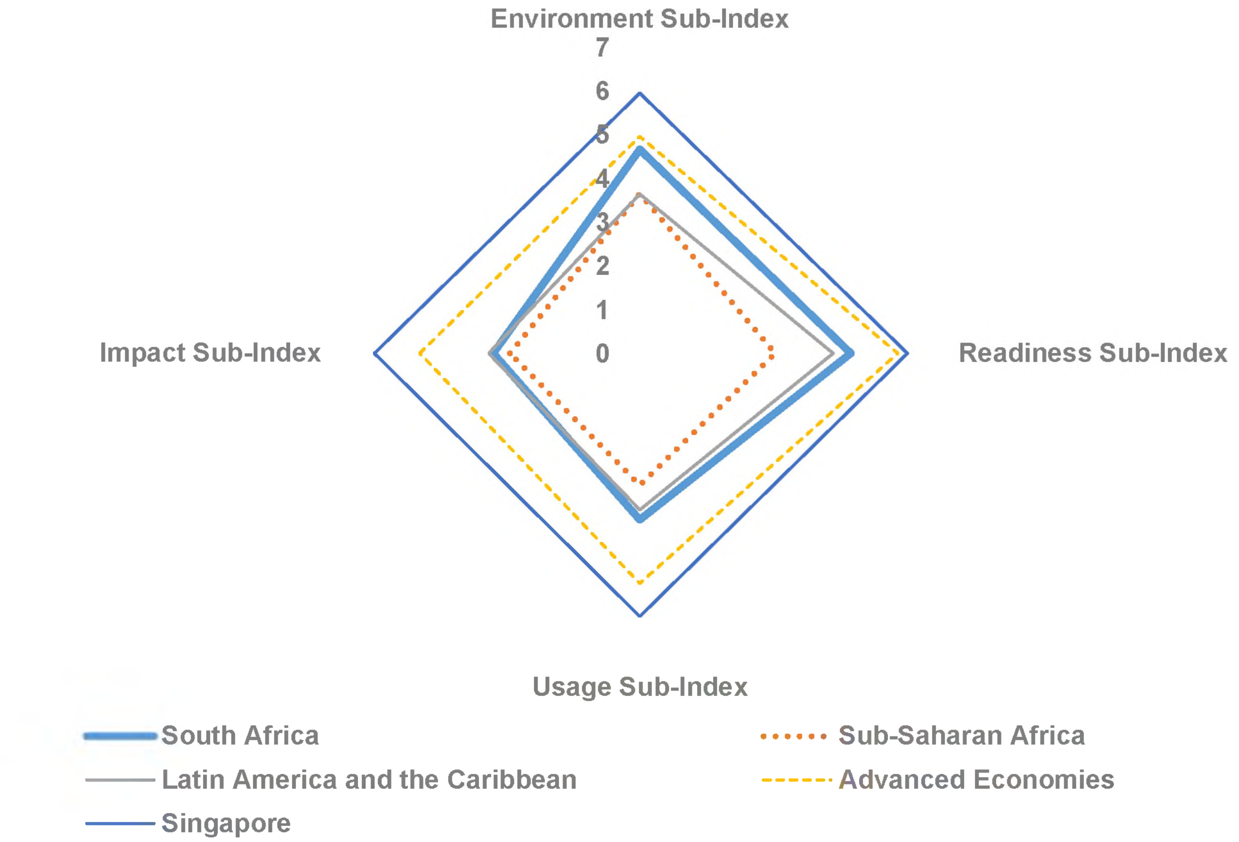

Figure 1: Adapted Networked Readiness Index
Source: World Economic Forum, 2016

South Africa's measured performance exceeds that of Sub-Saharan Africa regarding all four sub-indexes. It also exceeds Latin America and the Caribbean, except for the Impact Sub-Index where South Africa's measure of 3.4 (out of 7) is marginally less than Latin America and the Caribbean's 3.5. However, there is a notable underperformance when South Africa is compared to Singapore and the Advanced Economies. For the Environmental Sub-Index South Africa performs quite well relative to the Advanced Economies (with a score of 4.7 versus 5.0). This is because South Africa performs similarly to the Advanced Economies regarding leveraging information and communications technologies. South Africa's regulatory framework and market conditions are also deemed favourable towards innovation, entrepreneurship and information and communications technologies (World Economic Forum, 2016). However, South Africa's most significant shortfall relative to the Advanced Economies is regarding the Impact Sub-index. For this sub-index, South Africa's measure of 3.4, is higher than the 3.0 of Sub-Saharan Africa and slightly less than Latin America and the Caribbean's 3.5 but is far behind the Advanced Economies (5.0) and Singapore (6.1). South Africa also performs substantially below the Advanced Economies and Singapore regarding the Readiness and Usage sub-indexes

A more detailed indication of the reasons for the performances regarding the sub-indexes is provided by an examination of the ten pillars on which these four Sub-Indexes are based. This is done in *Figure 2* which again compares South Africa to Sub-Saharan Africa, Latin America and the Caribbean, the Advanced Economies and with Singapore, but this time based on scores for each of the ten Pillars.

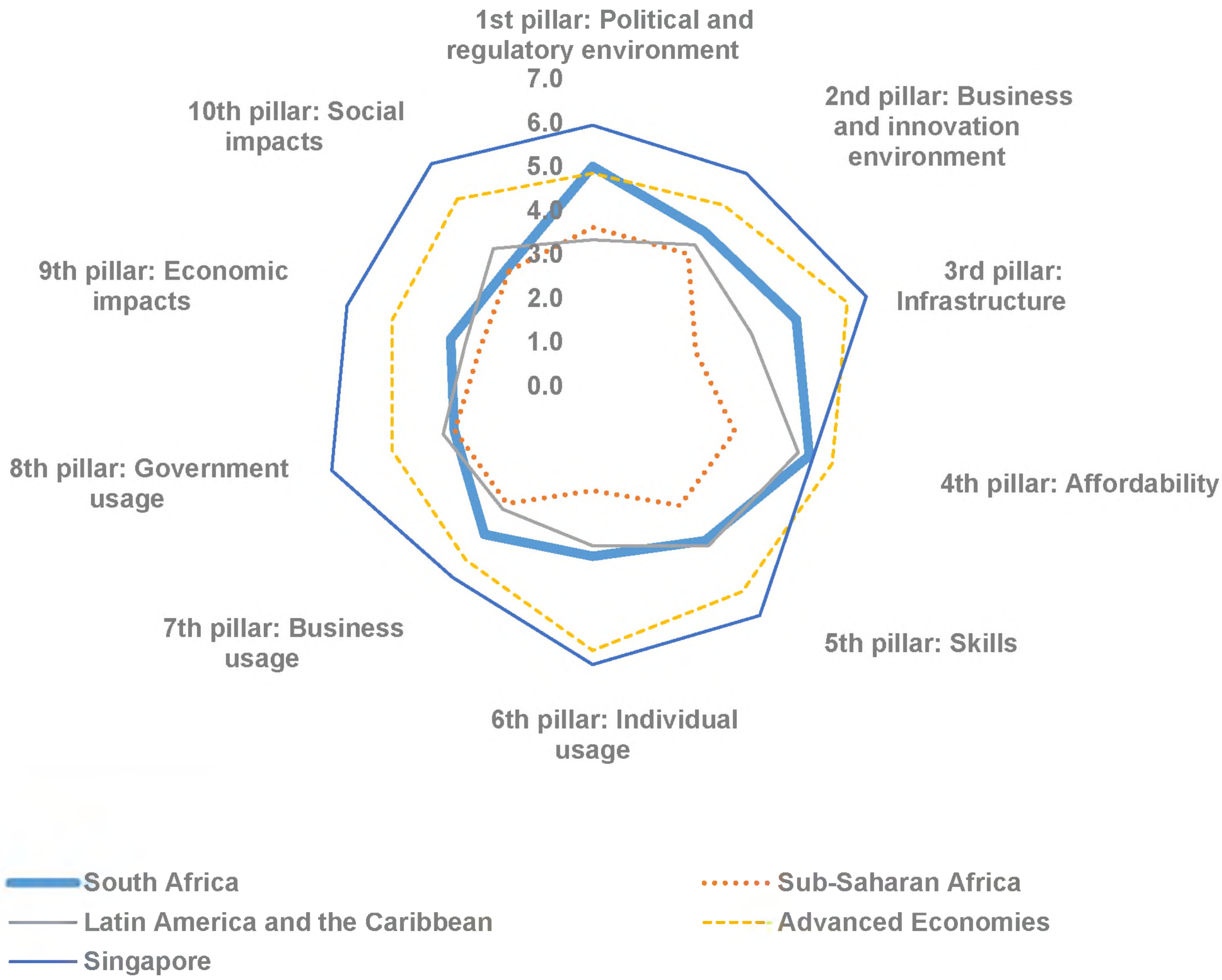

Figure 2: Adapted Networked Readiness Index in detail
Source: World Economic Forum, 2016

Figure 2 allows a more detailed analysis of South Africa's relative performance. South Africa performs better than Sub-Saharan Africa in all measures, except for Government usage and Social impacts, where the measures are the same. South Africa performs better or the same as the Latin American country grouping in all measures except Government usage and Social impact, where its measure is poorer. South Africa is worse than Singapore on all measures and worse than the Advanced Economies on all measures except the Political and regulatory environment where it measures higher than the Advanced Economies. What stands out is South Africa's relatively poor performance regarding Government usage and Social impacts and its relatively good performances regarding Political and Regulatory environment and Affordability.

South Africa's relative performance regarding the four sub-indexes in *Figure1* is better understood by referring to *Figure 2*. South Africa's surprisingly good performance regarding the Environment Sub-Index (4.7) is owed to its surprisingly good measure regarding its Political and regulatory environment (5.0), which is its ability to facilitate ICT penetration and the development of business activities. This is less of the case for Business and innovation environment (4.3), which is the extent to which the business environment supports entrepreneurship and innovation.

Bad government usage (3.3) and individual usage (3.9) measures account for a relatively poor showing for the Usage Sub-Index (3.8) and Impact Sub-Index, with Business Usage (4.2) only slightly higher. These measures assess the level of ICT adoption by government, businesses, and individuals.

The Poor performance of the Impact Sub-Index (3.4) is because of low measures for both Economic (3.4) and Social (3.3) impacts, which assess a country's progress and competitiveness regarding ICT's and the broad economic and social impacts accruing from ICTs.

The Readiness Sub-Index sees South Africa (4.8) ahead of its Sub-Saharan Africa (3.1) and Latin America and the Caribbean (4.4) counterparts. However, South Africa is significantly behind when compared to Singapore (6.1) and the Advanced Economies (5.9). When analysing the indicators that make the Readiness Sub-Index, i.e. the Infrastructure Pillar, Affordability Pillar and Skills Pillar, they provide a clear indication of how ready a country is, regarding their infrastructure, to support the uptake of information and communications technologies (World Economic Forum, 2016). South Africa's relatively good performance regarding the Readiness Sub-Index (4.8) is owed to its Affordability Pillar (5.2), which assesses the affordability of ICTs in the country, and, secondly, the Infrastructure Pillar (4.9), which depicts the country's current ICT infrastructure.

Of specific relevance to this research is the Skills indicator (the 5th pillar). The skills indicator assesses the ability a country to make efficient use of information and communications technologies based on secondary education enrolment rate, the quality of the overall education system particularly with regards to STEM education, and, lastly, adult literacy rates (World Economic Forum, 2016). It is evident that South Africa with a measure of 4.4 does better than Sub-Saharan Africa (3.4). However, its measure is very similar to Latin America and the Caribbean's (4.5) and is a long way behind the Advanced Economies (5.8) and Singapore (6.5). South Africa is lagging in terms of the quality of education. This is inhibiting the creation of a skill set that allows for the performing of complex tasks and the ability to complement highly automated production techniques.

This is a problem because Hodgson (2016) notes that there is a growing need in the workplace for Human Capital to take on a more significant and more complex skill set. This is supported by the World Economic Forum (2017b) which argues that countries should invest in digital fluency and ICT literacy skills, which together will ensure a set of basic and vocational skills that are future-proof. The Skills indicator also includes the need to create a skill set that is both embedded in developing critical thinking, i.e. creativity, cognitive flexibility and emotional intelligence; as well as on increasing education in science, technology, engineering and mathematics education at secondary and tertiary level education, as well as through technical and vocational training.

Overall, the World Economic Forum (2016) ranks South Africa 65 out of 139 Countries. Singapore ranks 1. The World Economic Forum (2016) states that South Africa's rise in the ranks from 75 in previous reports, is owed almost entirely to advances in infrastructure and affordability, with its digital transformation driven by businesses. The World Economic Forum (2016) notes, however, the innovation and business environment of South Africa is deteriorating significantly, specifically regarding technology and government procurement of the latest technologies. In contrast, the World Economic Forum (2016) notes that Singapore's leading position is owed to strong government commitment to creating an environment capable of taking advantage of the Fourth Industrial Revolution. The World Economic Forum (2016) states that this commitment by Singapore's government has seen an increase in ICT adoption, excellent utilisation of digital technologies and ensuring that all levels of education are connected to the internet.

8.6 Conclusions

Schwab's (2006) vision of automation suggests that such changes will initially be economically viable only where labour costs are highest, which is in rich, developed countries. It will be only when new technologies have been incrementally improved, and their costs reduced that will they become economically viable in developing countries. While the measures shown above are far from perfect, they suggest that while South Africa is better placed than many developing countries regarding its ability to adapt to the requirements of future technology, it lags quite far behind the developed economies and leading countries. The circumstance that the best performers are mainly developed countries, is owed to their high level of labour costs. This, according to Allen's (2009) theory, sets the perfect environment to induce innovation and adopt labour saving innovations. Allen's (2009) argument proves that an increase in technological advancement will be a response to economic incentives, which are more likely to be offered by developed economies. Allen (2009) argues, for new technologies to be viable, they must make economic sense. Developing countries that perhaps have the inverse combination, i.e. cheap labour and relatively expensive energy, would see a lag regarding their adoption of new technologies. Evidently, this would result in a more extended waiting period for high-end automation and technological advancement to arrive in developing countries. This disparity between levels of technological advancement will perpetuate the loss of competitiveness and jobs in developing countries. Furthermore, a lack of an incentive-inducing and economically viable environment will inhibit the development of the Knowledge Elite, which Mokyr & Voth (2010) and Squicciarini & Voigtländer (2015) argue are necessary for economic growth and to drive industrialisation through their ingenuity and technical ability. Combined with Allen's (2009) argument, an economy needs to provide an environment that offers the necessary framework and economic factors that will further induce technological progress and economic growth. Furthermore, it needs to induce technological creativity through the provision of resources and incentives which provide the Knowledge Elite with a sense of economic security, intellectual freedom and financial reward.

Conclusion

Schwab's (2016) concept of the Fourth Industrial Revolution has been widely adopted by commentators and policymakers alike. The focus has been on the implications for the workplace and required skills. It is evident that his claim has met a variable amount of conflict and support, firstly regarding the validity and actual existence of a new (Fourth) Industrial Revolution and, secondly, the effect that such a Fourth Industrial Revolution will have on workers and their skills. In critically examining Schwab's, (2016) claim of a Fourth Industrial Revolution, Chapter 2 identified the factors which distinguish the Fourth Industrial Revolution from various past iterations. It became clear that the Fourth Industrial Revolution encounters varying amounts of resistance, both regarding its name and its actual existence. These criticisms stem particularly from the concept of *Industry 4.0*, and the arguments that Schwab has done nothing more than popularise an existing "buzzword" and that he is simply re-treading past iterations of industrialisation.

The overwhelming consensus points to the conclusion that the world is in fact not entering a new Industrial Revolution as Schwab (2016) has argued. However, in critically examining Schwab's, (2016) claim of a Fourth Industrial Revolution, this research nonetheless established the need to assess the concerns that Schwab (2016) raises, predominantly with regards to the effect of technological change on Human Capital. Instead of negating the existence of Schwab's claim of a Fourth Industrial Revolution, the research instead considered that his claims encapsulate the current, and near-future effects that technological change is having, and will in future have, on Human Capital and economic growth. This required a framework to examine the consequent impact and requirements upon Human Capital of future economic growth, based on the belief that the Fourth Industrial Revolution does indeed exist.

In analysing Schwab's (2016) further claim that labour and capital can be complements in the Fourth Industrial Revolution, Chapter 3 established that there is a degree of consensus regarding the need to develop a skill set that is less susceptible to automation, which involves creativity, intuition and human judgement. By allowing the establishments of such a skill set would grant Human Capital a sense of flexibility, intuition and creativity, attained through education. Chapter 4 recognised that there are differing perceptions of the role that Human Capital, and by extension, education had played in past industrialisation. The perceived minimal role that Human Capital played during the First Industrial Revolution, based on measurements of educational attainment, was countered by the fact that these measures of educational attainment form veiled the Knowledge Elite, due to their inability to account for informal education. This, in turn, revealed another conceptualisation of Human Capital, namely the Average Worker. Distinguishing between these two forms of Human Capital reinstates the importance of Human Capital, and by extension, education during past industrialisation.

Economic theory, specifically the New Growth Model, states that investment in innovation and knowledge, and in Human Capital are all key contributors to economic growth, because of their spillover effects that help advance new technologies. Evidence in the literature, therefore, suggests that the Knowledge Elite are both necessary and able to keep up with advances at the technology frontier, allowing an outward shift of the production function, leading to increased total output by increasing total factor productivity. The Average Worker can account for changes in output by movements along a given production function. This, therefore, created the need to understand how these two conceptualisations of Human Capital emerged, the effect they both had on industrialisation, and how industrialisation, specifically technological change, affected their respective skills and knowledge.

Chapter 5 discussed Mokyr's (2002) account of why the First Industrial Revolution took place in the time and location that it did, in the process revealing how the Knowledge Elite emerged. Mokyr's (2002) account sees the First Industrial Revolution having occurred because of the Industrial Enlightenment, which created the cultural conditions that nurtured both innovation and the supply of the Knowledge Elite, which carried out this innovation driving economic progress, based on the development of Useful Knowledge. The contradictory account by Allan (2009), who believes that the First Industrial Revolution was the result of a unique wage and price structure that induced innovation, brings to light the important issue that there is ongoing contention between labour and technology, or more specifically the issue of labour substitution and deskilling. This chimed with Schwab's (2016) concern regarding the need to ensure that labour and capital are complements in the Fourth Industrial Revolution.

Chapter 6 and 7 revealed the increasing prevalence of deskilling and the interplay that capital and labour have on one another through the discussion of the how the Average Worker emerged, and how their knowledge and skills were affected by technological change. These changes were conveyed through a discussion of the evolution of technology over the previous Industrial Revolutions, where there was a growing distinction between the Productive Forces and Production Relations and a growing importance of the Average Worker. The evolution of work and labour marks, in contemporary times, that work is socially constructed and could be perceived as any transformative activity, where Labour, sees the commodification of the concept of work. Effectively, it is depicted as the contractual relationship that is entered between the worker and the employer, where the employer is purchasing that worker's Labour Power, which is enhanced by capital equipment, as a commodity, owning the goods produced by that worker. The worker's *willingness* to subject themselves to the exploitation of their surplus value accentuated the need to discuss the concept of deskilling. The Average Worker, it was shown, is believed to have lost a considerable portion of their skill set during the changes in systems of economic production.

The conventional school of thought is that deskilling did occur and that the Average Worker lost its extensive skill set, becoming a low-skilled worker on the production line. However, Chapter 8 revealed that there is evidence that suggests the opposite; namely, that the important inventions and subsequent technological advancement during the period of the First Industrial Revolution, were, in fact, reskilling, founded on evidence of capital-labour complementarity and skill-demanding capital. Any rapid technological change favours high-skilled labour due to their ability to adapt to early stages of innovation. As this technology becomes more simplified and universal, there is increased demand for unskilled labour. Through technological change, implementation of machinery and capital intensity, there became an urgent need for workers to gain a new, different set of skills, that allowed them to keep up with production and maintain greater product consistency. Therefore, as technology evolved, skills did too. However, as the World Economic Forum (2017b) has noted, the constant reskilling, upskilling and building more resilient talent pools requires a dual focus. Firstly, on developing critical thinking, creativity, cognitive flexibility and emotional intelligence; and secondly, the increased emphasis on education in science, technology, engineering and mathematics education. This is coupled with the need to create mechanisms that link workers with jobs and jobs with workers, with a specific focus on adult skilling and training.

The Network Readiness Index (World Economic Forum, 2016), used as an admittedly imperfect alternative for accounting for the composition of the Knowledge Elite and Average Worker within any country setting, ranked South Africa 65 out of 139 countries. Its rank is owed to a combination of good performance in advances in infrastructure and affordability and poor ranking because of the deterioration of the innovation and business environment. This contrasts with Singapore, which ranked number 1, due to its strong government commitment in creating an environment capable of taking advantage of the Fourth Industrial Revolution.

Chapter 8 concluded that Schwab's (2006) vision of automation, being likely to be economically viable in developed countries, resonates with Allen's (2009) argument that for new technologies to be viable, they must make economic sense. Therefore, a lack of an incentive-inducing and economically viable environment will inhibit the development of the Knowledge Elite. It concluded that through this enabling environment, technological creativity could be induced through the provision of resources and incentives which provide the Knowledge Elite with a sense of economic security, intellectual freedom and financial reward.

Future research would include a practical application of both the Average Worker and the Knowledge Elite to that of 21st-Century Skills. As this research has shown, the nature of these 21st-Century Skills and their relationship to the Average Worker and the Knowledge Elite is absent in the literature to date. This research has attempted to link these two forms of Human Capital to these 21st-Century Skills. Therefore, it would prove useful to investigate how economic growth will be affected by the Average Worker and the Knowledge Elite when equipped with 21st-Century Skills.

References

Adams, C. & Mouatt, S., 2010. *The Information Revolution, Information Systems and the 6th Kondratieff Cycle.*, Paper presented at MCIS 2010 Proceedings, Tel Alvi, 1/09/10,.

Allen, R. C., 2009. *The British Industrial Revolution in Global Perspective.* Cambridge: Cambridge University Press.

Allianz, 2010. *The sixth Kondratieff – long waves of prosperity,* Frankfurt: Allianz Global Investors.

Atkinson, R. D. & Wu, J., 2017. *False Alarmism: Technological Disruption and the U.S. Labor Market, 1850–2015,* Washington, D.C.: Information Technology and Innovation Foundation.

Babbage, C., 2010. *On the Economy of Machinery and Manufactures.* Print ed. Cambridge: Cambridge University Press.

Baldassari, P. & Roux, J. D., 2017. *Industry 4.0: Preparing for the Future of Work*: People & Strategy. Summer2017, 40(3), pp. 20-23

Baweja, B. et al., 2016. *Extreme Automation and Connectivity: The Global, Regional, And Investment Implications Of The Fourth Industrial Revolution,* Davos: UBS.

Belussi, F. & Garibaldi, F., 1996. Variety of pattern of the post-Fordist economy: Why are the 'old times' still with us and the 'new times' yet to come? *Futures,* 28(2), pp. 153-171.

Blanchflower, D. & Burgess, S., 1998. New Technology and Jobs: Comparative Evidence From A Two Country Study. *Economics of Innovation and New Technology,* 5(2-4), pp. 109-138.

Braverman, H., 1998. *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century.* New York: Monthly Review Press.

Braverman, H., Sweezy, P. M. & Foster, J. B., 1998. *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century.* 25th anniversary, new ed. New York: Monthly Review Press.

Brenner, R., 1977. *The Origins of Capitalist Development: A Critique of Neo-Smithian Marxism.* [Online]
Available at: https://newleftreview.org/I/104/robert-brenner-the-origins-of-capitalist-development-a-critique-of-neo-smithian-marxism
[Accessed 01 01 2016].

Brown, R., 1992. *Understanding Industrial Organizations: Theoretical Perspectives in Industrial Sociology.* 1st ed. London and New York: Routledge.

Brynjolfssonn, E. & McAfee, A., 2016. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies.* 1 edition ed. New York: W. W. Norton & Company.

Burawoy, M., 1985. The Labour Process in Capitalist Society. In: *The Politics of Production.* London: Verso, pp. 21-84.

Christoph, R., 2015. *A Critical Look at Industry 4.0.* [Online] Available at: http://www.allaboutlean.com/industry-4-0/ [Accessed 29 07 2017].

de Pleijt, A. M. & Weisdor, J. L., 2017. Human capital formation from occupations: the 'deskilling hypothesis' revisited. *Cliometrica,* 11(1), p. 1–30.

Deloitte, 2015. *Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies,* Zurich: Deloitte AG.

Dewey, J., 1944. *Democracy and education: an introduction to the philosophy of education.* Print ed. New York: Macmillan.

Edgell, S., 2012. The Historical Transformation of Work. In: *The Sociology of Work: Continuity and Change in Paid and Unpaid Work.* London: SAGE Publications Ltd; pp. Chapter 1: 1-39.

Engels, F., McLellan, D. & Kelley, F., 2009. *The Condition of the Working Class in England.* 6th ed. London: Oxford University Press.

Feldman, N. E. & van der Beek, K., 2016. Skill choice and skill complementarity in eighteenth-century England. *Explorations in Economic History,* Volume 59, p. 94–113.

Frey, C. B. & Osborne, M., 2013. The Future of Employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change,* 114(C), pp. 254-280.

Friedman, A. L., 1977. *Industry and labour: class struggle at work and monopoly capitalism.* Print ed. London: Macmillan.

Galor, O., 2005. From Stagnation to Growth: Unified Growth Theory. *Handbook of Economic Growth,* 1(A), pp. 171-293.

Garbee, E., 2016. *This Is Not the Fourth Industrial Revolution.* [Online] Available at: http://www.slate.com/articles/technology/future_tense/2016/01/the_world_economic_forum_is_wrong_this_isn_t_the_fourth_industrial_revolution.html [Accessed 16 04 2016].

Germany Trade and Invest, 2014. *Industrie 4.0 Smart Manufacturing for the Future,* Berlin: Germany Trade and Invest.

Goldin, C. & Katz, L. F., 1998. The Origins of Technology-Skill Complementarity. *Quarterly Journal of Economics,* 113(1), pp. 683-732.

Goode, R. B., 1959. Adding to the Stock of Physical and Human Capital. *The American Economic Review,* 49(2), pp. 147-155.

Greenwood, J. & Yorukoglut, M., 1997. 1974. *Carnegie-Rochester Conference Series on Public Policy,* 46(1997), pp. 49-95.

Grint, K., 1998. *The Sociology of Work: An Introduction.* Print ed. Cambridge: Polity Press.

Harris, J. R., 1976. Skills, coal and British industry in the eighteenth century. *History,* 61(202), pp. 167-182.

Harvey, D., 2003. *The New Imperialism.* London: Oxford University Press.

Hicks, J., 1932. *The Theory of Wages.* 6th ed. London: Macmillan.

Hodgson, G. M., 2016. The Future of Work in the Twenty-First Century. *Journal of Economic Issues,* 50(1), pp. 197-216.

Hodson, R. & Sullivan, T. A., 2008. *The social organization of work.* 4 ed. Belmont: Thomson/Wadsworth.

Howes, A., 2015. *Inducing Ideas for Industrialisation.* [Online]
Available at: http://antonhowes.tumblr.com/post/107971837365/inducing-ideas-for-industrialisation
[Accessed 23 03 2017].

Howes, A., 2016. *The Relevance of Skills to Innovation during the British Industrial Revolution, 1651-1851.* Rhode Island: Brown University.

Huber, T. A., 2017. *Is Artificial Intelligence Really the Next Technological Revolution? A comparison of AI with previous technological breakthroughs.* [Online]
Available at: https://shift.newco.co/is-artificial-intelligence-really-the-next-technological-revolution-6fefe31b9765
[Accessed 23 August 2017].

Infosys, 2016. *Amplifying Human Potential: Education and Skills for the Fourth Industrial Revolution,* Bangalore: Infosys Limited.

Jalee, P., 1977. *How Capitalism Works.* Print ed. New York: Monthly Review Press.

Kaplinsky, R., 1984. *Automation: The Technology and Society.* London: Longman Group United Kingdom.

Kondratieff, N., 1925. *The Major Economic Cycles.* Moscow: Richardson & Snyder.

Kraak, A., 1996. Transforming South Africa's Economy: From Racial-Fordism to Neo-Fordism?. *Economic and Industrial Democracy,* 17(1), pp. 39-74.

Lasi, H. et al., 2014. Industry 4.0. *Business & Information Systems Engineering,* 6(4), pp. 239-242.

Ljungberg, J., 2004. Technology and Human Capital in Historical Perspective: An Introduction. In: J. Ljungberg & J. Smits, eds. *Technology and Human Capital in Historical Perspective.* London: Palgrave Macmillan UK, pp. 1-21.

Ljungberg, J., 2004. Technology and Human Capital in Historical Perspective: An Introduction. In: J. Ljungberg & J. Smits, eds. *Technology and Human Capital in Historical Perspective.* London: Palgrave Macmillan UK, pp. 1-21.

Loi, M., 2015. Technological Unemployment and Human Disenhancement. *Ethics of Information Technology,* 1(17), pp. 201-210.

Mankiw, G., 1995. The Growth of Nations. *Brookings Papers on Economic Activity,* 1995(1), pp. 275-326.

Marr, B., 2016. *Why Everyone Must Get Ready For The 4th Industrial Revolution.* [Online] Available at: http://www.forbes.com/sites/bernardmarr/2016/04/05/why-everyone-must-get-ready-for-4th-industrial-revolution/#3c7e065279c9
[Accessed 12 04 2016].

Marshall, A., 1920. *Principles of Economics: An Introductory Volume.* 8 ed. London: Macmillian.

Marx, K. & Engels, F., 1988. In: *The Economic and Philosophic Manuscripts of 1844: and The Communist Manifesto.* New York: Prometheus Books, pp. 19-52.

Marx, K., 1906. Part IV, Chapter XV, Section IV. - The Factory. In: F. Engels & E. Untermann, eds. *Capital: A Critique of Political Economy, Vol. I. The Process of Capitalist Production.* 4th ed. Chicago: Charles H. Kerr and Co., p. 61.

Marx, K., 1964. *Introduction to "Pre-capitalist Economic Formations by Hobsbawm, Eric J.* London: International Publishers.

Marx, K., 1978. Part IV: Production of Relative Surplus Value. In: *Capital: A Critique of Political Economy (Volume 2).* England: Penguin Group, p. 624.

Mitch, D., 1999. The Role of Education and Skill in the British Industrial Revolution. In: J. Mokyr, ed. *The British Industrial Revolution: An Economic Perspective.* Boulder: Westview Press, pp. 241-279.

Mokyr, J., 1993. *The British Industrial Revolution: An Economic Perspective.* 2 ed. Colorado: Westview Press.

Mokyr, J., 1997. Are we living in the middle of an industrial revolution? *Economic Review-Federal Reserve Bank of Kansas City,* 82(2), pp. 31-44.

Mokyr, J., 2002. *The Gifts of Athena: Historical Origins of the Knowledge Economy.* New Jersey: Princeton University Press.

Mokyr, J., 2005. The Intellectual Origins of Modern Economic Growth. *The Journal of Economic History,* 65(2), pp. 285-351.

Mokyr, J., 2012. *The Economics of the Industrial Revolution.* Reprint ed. Abingdon: Routledge.

Mokyr, J., 2013. Human capital, Useful Knowledge, and long-term economic growth. *Economia Politica,* 30(3), pp. 251-272.

Mokyr, J. & Voth, H.-J., 2010. Understanding growth in Europe, 1700–1870: Theory and evidence. *The Cambridge Economic History of Modern Europe,* Volume 1: 1700-1870, pp. 7-42.

Mouffe, C., 1979. Gromsci's General Theory of Marxism. In: *Gramsci and Marxist Theory.* London: Routledge & Kegan Paul, p. 117.

O'Connor, S., 2016. *How to robot-proof your children's careers.* [Online] Available at: http://www.ft.com/cms/s/2/0c7906d6-be89-11e5-9fdb-87b8d15baec2.html [Accessed 11 04 2016].

Perez, C., 2009. Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics,* 34(1), pp. 185-202.

Perez, C., 2016. Capitalism, Technology and a Green Global Golden Age: The Role of History in Helping to Shape the Future. In: M. Jacobs & M. Mazzucato, eds. *Rethinking Capitalism: Economics and Policy for Sustainable and Inclusive Growth.* Blackwell: Wiley, p. 191–217.

Pillay, D. & van der Walt, L., 2012. Introduction: assessing the politics of organised labour in Asia, Africa and Latin America at the start of the 21st century. *Labour, Capital and Society,* 44(2), pp. 1-25.

Pritchett, L., 2001. Where has all the education gone? *The World Bank economic review,* 15(3), pp. 367-391.

Reis, J., 2004. Human Capital and Industrialization: The Case of a Latecomer — Portugal, 1890. In: J. Ljungberg & J. Smits, eds. *Technology and Human Capital in Historical Perspective.* London: Palgrave Macmillan UK, pp. 22-48.

Rifkin, J., 2016. *The 2016 World Economic Forum Misfires with Its Fourth Industrial Revolution Theme.* [Online] Available at: http://www.huffingtonpost.com/jeremy-rifkin/the-2016-world-economic-f_b_8975326.html [Accessed 10 03 2016].

Romer, P. M., 1994. The Origins of Endogenous Growth. *The Journal of Economic Perspectives,* 8(1), pp. 3-22.

Rosenberg, N., 1974. Science, Invention and Economic Growth. *The Economic Journal,* 84(333), pp. 90-108.

Schwab, K., 2016. *The Fourth Industrial Revolution.* Print ed. Cologny/Geneva: World Economic Forum.

Squicciarini, M. P. & Voigtländer, N., 2015. Human Capital and Industrialization: Evidence from the Age of Enlightenment. *The Quarterly Journal of Economics,* 130(4), pp. 1825-1883.

Standing, G., 2011. Defining the Precariat. In: *The Precariat: The New Dangerous Class.* London: Bloomsbury Academic, pp. 6-13.

Stewart, P. & Zaaiman, J., 2015. *Sociology: a concise South African introduction.* Print ed. Cape Town: Juta and Company Ltd.

Svensson, L., 2004. Technology Shifts, Industrial Dynamics and Labour Market Institutions in Sweden, 1920–95. In: J. Ljungberg & J. Smits, eds. *Technology and Human Capital in Historical Perspective.* London: Palgrave Macmillan UK, pp. 79-101.

Taylor, F. W., 1911. *The Principles of Scientific Management.* Print ed. London: Harper & Brothers.

Thompson, P., 1989. *The Nature of Work: An Introduction to Debates on the Labour Process.* 2nd ed. London: Palgrave Macmillan.

Todaro, M. P. & Smith, S. C., 2009. *Economic development.* Print ed. Boston: Pearson Addison Wesley.

Turl, A., 2007. The Changing Working Class: is the U.S. becoming post-industrial?'. *International Socialist Review,* Issue 52, March–April 2007.

Van Zon, A. & Antonietti, R., 2016. Education and training in a model of endogenous growth with creative wear-and-tear. *Economia Politica,* 33(1), pp. 35-62.

von Holdt, K. & Webster, E., 2005. Work Restructuring and the Crisis of Social Reproduction: a southern perspective. In: E. Webster & K. von Holdt, eds. *Beyond the Apartheid Workplace: studies in transition.* Durban: University of KwaZulu-Natal Press, pp. 1-20.

Webster, E. C. & Leger, J. P., 1992. Reconceptualising Skill Formation in South Africa. *Perspectives in Education,* 13(2), pp. 54-67.

Williamson, J. G., 1985. *Did British Capitalism Breed Inequality.* Print ed. Boston: Allen & Unwin.

Wood, S., 1989. *The Transformation of Work?: Skill, Flexibility, and the Labour Process.* 6th ed. London: Unwin Hyman.

World Economic Forum, 2015. *New Vision for Education: Unlocking the Potential of Technology,* Cologny/Geneva: World Economic Forum & Boston Consulting Group.

World Economic Forum, 2015. *The Global Competitiveness Report 2015 - 2016,* Geneva: World Economic Forum.

World Economic Forum, 2016. *The Global Information Technology Report 2016 - Innovating in the Digital Economy,* Cologny/Geneva: World Economic Forum.

World Economic Forum, 2017a. *Realizing Human Potential in the Fourth Industrial Revolution - An Agenda for Leaders to Shape the Future of Education, Gender and Work,* Cologny/Geneva: World Economic Forum.

World Economic Forum, 2017b. *The Future of Jobs and Skills in Africa: Preparing the Region for the Fourth Industrial Revolution,* Cologny/Geneva: World Economic Forum.

Yglesias, M., 2015. *The automation myth Robots aren't taking your jobs— and that's the problem.* [Online]
Available at: https://www.vox.com/2015/7/27/9038829/automation-myth
[Accessed 23 07 2017].