THE FOURTH INDUSTRIAL REVOLUTION: PROSPECTS AND CHALLENGES FOR AFRICA

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ABSTRACT

The unprecedented convergence of cyber, physical and biological technologies – popularized in the 2016 world economic forum (WEF) as the fourth industrial revolution (4IR) – is altering long established methods of producing goods and providing services. 4IR technologies such as, internet of things (IoT) and artificial intelligence (AI) enable consumers to request customised products and services. Firms that would emerge as leaders are those that reconfigure their production processes through cyber-physical technologies from mass production to customised products and services. For firms to successfully transition they would require, among others, understanding and adoption of new business models, and a workforce skilled in 4IR technologies. Africa has the youngest population with a potential to spur an accelerated economic growth known as a demographic dividend. For Africa, who is viewed as a potential economic powerhouse, the 4IR promises a socio-economic development through better access to technologies and increased productivity. However, the promises of the 4IR for Africa are often told alongside concerns that the 4IR might render the continent's workforce obsolete and reinforce already existing inequalities. The extent to which Africa could benefit from the 4IR would largely be a function of the continent's readiness to put in place policies that equip Africans with the skills needed to play an active role in shaping and benefiting from the 4IR. Yet Africa still lags behind when it comes to transitioning to the 4IR. This research investigated prospects and challenges for Africa in the era of the 4IR. A desktop literature study approach was followed, using published studies in journals, conference proceedings, book chapters and books for the period 2011 to 2020. The findings are translated into policy suggestions to help improve the position of Africa for success, and scope for further research.

Key words: 4IR; IoT; AI; Digitalisation; Demographic Dividend; Africa

INTRODUCTION

Society today is grappling with the fourth industrial revolution (4IR), for Africa which remains largely underdeveloped the challenge is enormous. The first industrial revolution mechanised labour through the discovery and application of steam power, bringing about massive improvements to manufacturing facilities; the second industrial revolution significantly increased capacity of manufacturing facilities through the discovery of electrical power and its use in electric motors, this era saw the flourishing of new industries at an unprecedented scale; the third industrial revolution developed semiconductors, computers and other electronic devices that enabled automation of factory repetitive tasks, thus improving efficiency and the speed of production (Ślusarczyk, 2018; Schwab, 2016).

During these three industrial revolutions, Africa was largely a supplier of low cost labour in extraction of its minerals and precious metals, supplying these to developed economies for further processing, and inversely an importer of expensive manufactured goods (Amin, 2002). Most African states remain technology colonies, where their industrial – mining, energy, construction, etc - activities are serviced and supported by developed economies (de Wet, 1999). The implication is that citizens participate in only a fraction of economic activities, leaving a large number of those ready to be part of the workforce outside. It is not surprising that on average the overall unemployment rate in Africa is more than double the global unemployment rate of 8%, youth unemployment rate is even worse, as reported in 2011 (Mamphiswana & Sinha, 2019).

4IR touches and cuts across all spheres of society, from private and public sector management, and it entails unprecedented convergence of cyber, physical and biological technologies (Schwab, 2016; Ślusarczyk, 2018). The convergence is non-linear, thus the scale, impact and effect of the transformation remains largely unknown. It is recognised that the first industrial revolution took place in Britain (Nuvolari, 2004), the second and third in the United States of America (USA) (Lamoreaux, et al., 2004), and the third was widely spread through growth of low cost manufacturing in Asia (Mowery, 2009). The leader of 4IR remains open, or could it be that society would finally achieve shared and inclusive success. Speculations are that Germany, Japan and the USA are the leaders of 4IR (Stăncioiu, 2017).

Africa has the youngest population which has been hailed as a demographic dividend, yet with a high youth unemployment rate, and it is not clear how to best move forward. It is worth noting, however, that age has not been a contributor to leading previous industrial revolutions. China was able to capitalise on their youth bulge into youth dividend (Inayatullah, 2016). This research is motivated by this gap, it aims to bring to light both prospects and challenges faced by Africa, and offer some insights to guide the development of plausible pathways for policy makers and researchers.

LITERATURE

Demographic dividend

A youth bulge can – depending on created conditions - go either into a social conflict or dividend (Inayatullah, 2016). The demographic dividend (DD) is the accelerated economic growth that a country could achieve as a result of the change in age structure of its population. As the birth and death rate of a country declines, the number of the dependent age group of a population, usually aged 0 - 15 and >64 declines relative to the working age population which is aged 15 – 64. The decline of dependent population relative to the working age population creates a window of opportunity for increased saving and investment, where, if accompanied by the design and implementation of appropriate policies could lead to an accelerated economic growth known as the demographic dividend. While a demographic transition caused by a steady decline in birth and death rates are necessary conditions, they do not guarantee the demographic dividend. In order to maximize its prospects of achieving the demographic dividend, countries need to invest on the development of their human capital, on strengthening the economy to accommodate employment needs, and fostering good governance to allow for an efficient provision of public goods and services (Admassie, et al., 2017; Bloom, et al., 2003). The next section is the literature on 4IR surfacing possible prospects and challenges for Africa.

Fourth Industrial Revolution

4IR Technologies

A key feature of previous industrial revolutions was fast speed at which technologies were developed, now for 4IR it is the fast speed at which emerging technologies are converging (Morrar, et al., 2017). As argued by Li et al (2017), 4IR is unique to previous industrial revolutions in the following ways: three domains of technologies – cyber, physical and biological - are advancing and integrating; rapid distribution over the internet of a number of products at a cost affordable to many; and there is a potential through social media platforms to reach every corner of society. AI is considered the central technology of 4IR (Singh, et al., 2018; Mahomed, 2018). AI is not new, however, the global connectivity enabled by IoT technologies, cloud computing and higher speed computers offer possibility for AI to perform at the highest level (Stăncioiu, 2017).

It is also argued that at their core, the technological changes that are features of the 4IR are mere continuations of the third industrial revolution (also referred to as the digital revolution) which was marked by the development of the electronic computer. In this sense, the 4IR is sometimes regarded as a hyperbolic term for the opportunities and challenges of technological changes that people have been grappling with since previous industrial revolutions (Garbee, 2016; Thornhil, 2018). Regardless of the terming, fast-paced technological changes are beginning to influence economies and the way people interact and work. The connectivity and speed of computing has opened up a whole new era, 4IR, where there is rapid convergence of a number of technologies (Maynard, 2015).

As AI helps machines to be more intelligent, their share in production will rise to replace human – machine interface with machine - machine interface (Singh, et al., 2018). More jobs will be lost through what is coined “technological unemployment” (Peters, 2017). If this is realised then Africa’s young population is not an asset but rather a liability. Romero et al (2016) argue that a full on machine – machine work environment is not possible, on the basis that the operator plays a key role on complex operations not catered for during the side phase. The view is that it will be human – machine workforce, requiring a human centric arrangement for humans to be enabled to provide their best efforts, this would include suitable interface technologies (Romero, et al., 2016). Another view is that ethical considerations would limit full on replacement of jobs by AI (Mitchell, 2019).

4IR, Africa and the Globe

India is preparing its citizens for 4IR through a number of pro rural digital policies, a key early lesson is that the approach must be a blend of bottom-up and top-down (Lele & Goswami, 2017). This is an important point to note for Africa with her diverse states, people and cultures; top-down must offer high level desire and direction, while bottom-up must enable adaptation for local settings and provide feedback to improve overall national policy. Citizens’ lack of understanding what Thailand 4.0 entails is another reminder of the failure of a top-down approach (Jones & Pimdee, 2017). What is worth noting for Thailand is that they have previous strategies: Thailand 1.0 was on agriculture; Thailand 2.0 was on light industry; and Thailand 3.0 was on heavy industry (Jones & Pimdee, 2017). 4IR is the first industrial revolution that African states are attempting to participate in since they gained independence.

Some key global trends in strategies and implementation of 4IR: Germany and Japan are on efficient production processes through digitisation for improved quality of their products; United States of America (USA) is on development of alternate and digital savvy business models for quick delivery of

products and services; and China is on cost cutting to emerge as the global supplier and leader of manufactured goods (Stăncioiu, 2017). Due to connectivity, end users participate in production of the goods they buy and these arrive at their door steps much quicker than before (Prisecaru, 2016). As 4IR cuts across all sectors of the economy, an interdisciplinary approach to teaching, research and innovation is now mandatory (Xing & Marwala, 2017). The silo mentality and approach that characterise higher education and training must come to an end. Adoption of 4IR in higher education in South Africa is hampered by challenges such as lack of 4IR skills by the workforce and investment in 4IR infrastructure (Kayembe & Nel, 2019). Only one university in South Africa was found to have made significant progress in training 4IR skills for industrial engineers (Sackey, et al., 2017; Sackey & Bester, 2016).

4IR and Africa

Despite the lack of suitable human capital, governments in emerging economies are urged to embrace new technologies and 4IR (Shava & Hofisi, 2017). This is a challenge for governments of African states who are grappling with a number of developmental challenges. Hunger is a major challenge in Africa, technologies of 4IR such as AI and big data could be used to provide weather and climate predictions for improved yields, and other new technologies for reduced wastage along the agricultural value chain as per study in Nigeria (George Fomunyam, 2019). Supply of electricity could also be unlocked through distributed renewable energy technologies so that Africans can keep their devices online. Creation and adoption of suitable business models is the key enabler to make these kinds of investments feasible (Kiel, 2017; Kiel, et al., 2016). Unlike China and India, Africa has 54 independent states which limit the power of technology due to location and mismatch policies. Africa is also challenged by the reality that technologies such AI were first developed and trained to functionality from abroad, thus they could discriminate if tailoring and localisation is not conducted for fields such as health care and legal (Mahomed, 2018).

RESEARCH

This research is conceptual in nature, follows a desktop literature study approach for the period of 2011 to 2020. The concept of 4IR originated in Germany as Industry 4.0, later popularised as 4IR by WEF in 2016 (Schwab, 2016; Kiel, 2017). The large majority of the literature, except for a few, were published within the period of 2011 to 2020. Few of the studies published outside this window were used to elaborate further on the concepts of industrial revolutions, Africa's role and contribution during previous industrial revolutions, technology development path dependency and technology colony. The rest of the literature, within the indicated timeline, are on 4IR and DD with the lens of surfacing prospects and challenges for Africa. Google scholar was selected as the search engine for this study for practical purposes to coordinate among co-authors in different parts of Africa.

The study makes an important contribution by bringing literature on 4IR and DD of the past ten years into a single paper, to showcase areas for collaboration among African states as they tackle prospects and challenges. The weakness of the study is that it does not dive into finer details within each of the 54 African states, in face the literature seems to be biased to South Africa, Kenya, Egypt, Eritrea and Nigeria. Due to the infancy of 4IR, it is not anticipated that the key findings of the study would be fundamentally different.

IMPLICATIONS FOR AFRICA

Features of the 4IR, which are disruptive technological trends such as the IoT, AI and machine learning promise enhanced productivity through digitalisation across sectors – energy, transport, health, communications, and productions (Schwab, 2016; Samans & Davis, 2017). The 4IR also has implications for the nature of jobs and service delivery, which could be utilized for social and economic growth of African countries (Ayentimi & Burgess, 2018). This section further details a number of trends on prospects and challenges for Africa in the era of the 4IR.

Prospects

New Markets and Industries

The decline in the cost of producing and incorporating robots into the production value chain could open up possibilities for more African countries to produce and use robots to enhance their production efficiencies (Naudé, 2017). There is an opportunity for increased entries of individuals and more small and micro enterprises into new markets and industries. Whether or not additive manufacturing, robotics, or IoTs, thrive in Africa will rely on the availability of and access to energy and network infrastructure (Naudé, 2017). It appears that the cost of extending access to electricity through centralised energy is too high, with advances in renewable energy technologies there is an opportunity to provide access to half of Africans who lack access to electricity. Such an advance could also open possibilities for off the grid water supply systems for drinking and agriculture. This could further curb high rates of urbanisation as citizens, currently, see no opportunities in rural villages. Perhaps this could be a pathway towards smart villages, as it has been observed in early pilots in India (Chesbrough, 2020).

Enhanced Productivity (Upgrade of Existing Industries)

The 4IR will feature the increase in machines that could more efficiently do people's work, particularly in the manufacturing sector. Globally, there is an increasing trend in the production of new industrial robots. The International Federation of Robotics estimates that 1.4 million new robots would be used globally in the manufacturing sector for the second half of the last decade (Naudé, 2017). Studies show a positive link between automation and increased productivity. Centre for Economics and business Research (CEBR) estimated that 10% the gross domestic product (GDP) growth of the Organisation for Economic Corporation and Development (OECD) countries from 1993 – 2016 is attributed to an increase in investment of robots (CEBR, 2017).

The proliferation of robotics, for instance, drones could also be applied to circumvent the continent's geographical constraints and poor infrastructure that are shackling the growth of the manufacturing sector. This is evidenced for instance in the increasing use of drones for monitoring construction, delivery of services among other things (Naudé, 2017). The proliferation of robots in the manufacturing sector could be an opportunity for Africa to enhance the productivity of its manufacturing sector and increase export through reduced cost of production. With the right policy conditions in place, the continent's expanding working age population could also mean an increase in demand for existing and new products.

In addition to the manufacturing sector, Africa could also have opportunities for increased productivity in the agricultural sector. Technologies like additive manufacturing offer people more options of buying customised products or even producing the products themselves. Such technologies could also

help in reducing barriers to entry into the market, especially for women (Naudé, 2017; Banga & Velde, 2018). Initiatives such as projects that help women smallholder famers develop and use agricultural tools, 3D-printing academies in Kenya and Nigeria that targets young women signal a promising shift toward increased agricultural industrialisation as well as reduced barriers to entry into markets (Naudé, 2017).

Future Jobs

The expansion of disruptive technologies across all industries is shifting the understanding about the nature and environment of jobs with a promise of flexibility that allows people to work outside of a traditional setting – flexible workspace, work time. However, the fluidity of nature of work will increasingly manifest in shift of demand for non-routine and less physical types of work. Occupations with relatively more women, for instance, healthcare services (therapists, psychologists), service industries, and occupations such as graphic designers, computer scientists will be in high demand (Schwab, 2016; World Economic Forum, 2017).

The shift in the nature of jobs could create opportunities for a more culturally appropriate work-life balance (Banga & Velde, 2018). However, maximising the prospect of enhanced productivity would require, among other things, investing in human capital i.e. building the skills of young Africans, upskilling and reskilling. It is estimated that reskilled men and women will have about 80 and 49 job transition options respectively while the transition options would be 22 and 12 without reskilling (World Economic Forum, 2018). For instance, trends from countries like United States of America and Germany who have already started experiencing the 4IR show that the shift toward a less physical work has translated into more women being able to get high-paid and less labour-intensive jobs. However, it is important to note that this increased participation in employment happened for the better-educated women (World Bank Group, 2016).

Efficiency of Service

Another prospect of the 4IR for Africa comes through the expansion of digital services that reduce bureaucracy and inefficient delivery of services (World Bank, 2019). While still at relatively nascent stages, Africa leapfrogging to mobile services and the increase in access to internet signal a promising start toward efficiency of service delivery. More and more African countries are using digital platforms to deliver critical government services. Kenya's M-Pesa, one of the largest money transfer systems in the world, is often cited as an example in this regard.

Increased efficiency of service delivery has a positive influence on productivity across sectors. For instance, ability to access real-time market and whether alerts through short message service (SMS) to applications that help farmers detect reproductive problems of their livestock (Banga & Velde, 2018). The increasing application of technology to reduce transaction costs, increase market transparency, raise farmers' incomes and ultimately improves the sector (World Bank, 2019).

The digitalisation of services that promise enhanced registration and maintenance of assets such as land could help enhance access to financial services, and help people, especially women, to invest more. Digitalisation of services could help Africa expand access to services like mobile banking, insurance, to marginalized groups (AfDB, ADB, EBRD, IDB, 2018; World Bank, 2016). For instance, women's greater control of mobile financial transfer of payments has increased their decision-making in their respective households (World Bank, 2016). The proliferation of the digital technologies could

enhance women's labour force participation by enabling them to work virtually and producing new work opportunities.

It is worth noting that African's access to digital technologies is a function of their economic and social standing and the availability of a strong information and communication technology (ICT) infrastructure. Sub-Saharan Africa has one of the lowest mobile penetrations with 73% as opposed to an average penetration rate of 98% for developed countries outside of Africa. The difference in access to digital technologies is more pronounced in the case of access to internet. About 37% Africa's population uses the internet with variation across countries (Kenya has the highest penetration rate at 85% while Eritrea has less than 2%). Women are 50% less likely to use the internet than men (World Bank, 2016). Investing in ICT infrastructure, enhancing peoples' skills, and fostering a favourable environment for entrepreneurs will be important for expanding digital technologies.

Challenges

Scarcity of jobs

Labour is considered one of Africa's comparative advantages. In this regard, fast-paced technological changes could render much of Africa's human labour obsolete within established firms. This has serious implications for the state of security within and across African states. It is imperative for African states to understand the trade-offs and balance them for social cohesion. In certain instances, it might be necessary to strategically delay adoption of 4IR technologies, however, such an endeavour would require public sector workforce to be highly skilled. The challenge of low skilled workforce is addressed next.

Low skilled workforce

To participate and contribute to growing the economy would require technology skills and knowledge of all sorts (Singh, et al., 2018). Else Africa risks being a consumer and not a contributor of 4IR. Africa's population is large and growing at a fast rate, fast economic growth can only be achieved when there is rapid absorption of the workforce into productive sectors of the economy (Cilliers, 2018). Manufacturing sector could aid with higher productivity and economic growth. However, the trend in Africa is deindustrialisation and imports of manufactured goods (Cilliers, 2018). The skills level of Africa's local workforce remains low, result in low productivity, thus not ready to compete with the likes of China. However, to deindustrialise means that Africa removes herself from the possibility of growing her manufacturing sector. The education system would be required to rethink its offering to ensure that graduates are skilled sufficiently to work with advanced machines – made of a combination of technologies (Shahroom & Hussin, 2018).

The workforce in Africa is low skilled and largely capable of routine and repetitive tasks that are the first victims for efficiency – cost cutting initiatives - innovation in firms. African states must divert and/or reduce investment from established firms to emerging firms creating new markets (Christensen, et al., 2019). Unlike established ones that require highly skilled workforce, emerging firms are best suited to employ low skilled and low cost workforce. As an example, a renewable energy start-up supplying electricity to a village that previously did not have electricity can afford to provide low quality service – not available all day - while the workforce learns on the job. In such a scenario the start-up competes against nonconsumption - nothing – and that is the power of market creating

innovation (Christensen, et al., 2019). Other domains include data labelling for AI algorithms, which exposes the workforce to computers and some elements of machine learning (Mitchell, 2019).

Deindustrialisation

As much as 4IR technologies offer opportunities for improved productivity for industries, the trend in Africa and other emerging economies is deindustrialisation. The current low productivity is not competitive with Asia and other developed economies. African states need to identify sectors that they have an advantage and proceed with investment even if not competitive in the beginning. Some level of industry protectionism while productivity improves should be considered. The other option is to invest in industries that only offer products for local use or within the continent of Africa, such industries would then develop and flourish without the interference from international forces. An example could be low cost housing materials only available from within the African continent, such advances in materials are central to physical technologies of 4IR.

No 4IR infrastructure

The 2016 global manufacturing index reported only three African countries – South Africa, Nigeria and Egypt – in the top 40, all three ranked in the middle and lower tier (Iyer, 2018). The concept of technology leapfrog is often cited as a pathway for Africa, however, what is not clear is how African states would be able to sustain the leapfrog position and continue to move forward. As sections of production are handed over to machines, highly educated workforce would be required for research, design and manufacturing of the machines (Iyer, 2018). Understanding and advancing areas such as nanomaterials, 3D printing and robotics would require deep knowledge in science and engineering. These areas are at the heart of intelligent machines and smart devices of 4IR (Iyer, 2018; Singh, et al., 2018). Emerging economies in Africa as it is suggested for India must clearly identify their potential advantages such as a growing youth population and devise strategies to turn those into real advantages (Iyer, 2018).

Development of technological innovation is “path dependence” (Teece, 1996). The fact that African states were largely consumers during previous industrial revolutions has massive implications for technological infrastructure, even more for 4IR infrastructure. As such African states cannot just, simply, embrace 4IR, the lack infrastructure limits such efforts to embrace. In essence this is a legacy issue of previous industrial revolutions. As such investment in 4IR would not immediately showcase results, this is a difficult balancing for African states who lack the financial muscles. The other option is to embrace 4IR in new and simple settings, where requirement for 4IR infrastructure is low, and initiate infrastructure development while benefiting from the start application.

Bias and Discrimination

Face recognition and language translate algorithm were piloted in developed economies, thus are suspect to discriminate against Africans (Mitchell, 2019). When applied without understanding and adapting they could lead to serious consequences in areas such as health care, transport and justice system to mention a few. Once again, the robust strategy could be to delay adoption and first ensure training in local data and context.

CONCLUSION AND SUGGESTIONS

The implications of the 4IR are multitude, covering the economic, health, education, social, and political aspects. While Africa lags behind technologically, its ability to leapfrog could allow the continent to utilise the benefits of the 4IR. However, the ability of African countries to leapfrog and utilize the benefits of 4IR and mitigate its risks will depend on the availability of and access to digital technologies and connectivity infrastructure that are foundational for the 4IR. A favourable policy environment that encourages the expansion of ICT infrastructure, data and cyber security, and closes the divide in access to digital technologies and the internet is critical.

In light of Africa's expanding working age population, a critical question is how the continent can accommodate future and current employment needs in the face of potential job loss that could result from 4IR. Addressing this question would require working towards creating a macroeconomic environment that is informed by and is able to adapt to the fast paced technological change. On the other hand, laying enduring foundations to equip todays and tomorrow's youth with the necessary skills and capabilities that will enable them to participate in and benefit from the 4IR and harness the demographic dividend.

The crosscutting nature of the 4IR warrants a multisectoral effort to understand its impacts, harness its benefits, and address its challenges. It is therefore important for African countries to place coordinated efforts, to put in place appropriate policy measures with the 4IR as a critical issue of development. If things continue on business as usual for Africa, then the worse is yet to come, however, if the necessary adaptations are identified and implemented for Africa to take advantage then Africa could emerge successfully in improving the living conditions of its citizens and lift them to prosperity.

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