KONRAD ADENAUER STIFTUNG

Automation and the Future of Work in Sub-Saharan Africa

By Alexander Gaus and Wade Hoxtell

GPPi
GLOBAL PUBLIC POLICY INSTITUTE

www.kas.de

Automation and the Future of Work in Sub-Saharan Africa

By Alexander Gaus and Wade Hoxtell

Impressum

Acknowledgments

This discussion paper was made possible through the generous financial support of the Konrad-Adenauer-Stiftung. In particular, we would like to thank Winfried Weck and Martina Kaiser, both from the Konrad-Adenauer-Stiftung in Berlin, for their support during the writing of this paper. The authors would also like to acknowledge the expertise, knowledge, and support from the following people during the research, writing, and review processes of this discussion paper: Fisayo Alo, Nishani Chankar, Mirko Hohmann, Nico Landman, Dr Jamal Msami, Benjamin Rosman, Sofia Schappert, Martin Sprott, Anna Wasserfall, Dr Clara Weinhardt, and Sebastian Weise. Shazia Amin edited the paper. Any errors are solely the responsibility of the authors.

Contact the authors:

Dr Alexander Gaus, agaus@gppi.net
Wade Hoxtell, whoxtell@gppi.net

Global Public Policy Institute
Reinhardtstr. 7, 10117 Berlin, Germany

Contact the Konrad-Adenauer-Stiftung:

Martina Kaiser, martina.kaiser@kas.de

Published by:

Konrad-Adenauer-Stiftung e. V. 2019, Sankt Augustin and Berlin, Germany
Cover page image: © louis-reed, nesa-by-makers/unsplash
Images: S. 4 © anandaBGD/istock by getty images; S. 8 © JohnnyGreig/istock by getty images; S. 22 © chuttersnap/unsplash; S. 34 © skynesher/istock by getty images; S. 48 © subman/istock by getty images; 56 © Ivan Bandur/unsplash
Design and typesetting: yellow too Pasiek Horntrich GbR
The print edition of this publication was climate-neutrally printed by Kern GmbH, Bexbach, on FSC certified paper.
Printed in Germany.

Printed with financial support from the German Federal Government.

ISBN 978-3-95721-530-7

Table of contents

1. Introduction

Many industrialized economies are being transformed by the increasing automation of work. Self-driving cars upending the taxi and trucking industries will be one of the most visible signs of these changes in the near future, but these transformations will go beyond the transportation sector. With ongoing and continuous technological advancements, a number of countries are entering "the second machine age" or, as the World Economic Forum (WEF) has labeled it, the "fourth industrial revolution."[1] Regardless of monikers, an era characterized by a rise of autonomous robots and self-learning software is upon us. The direct or indirect impact of these transformations on industrial societies, emerging economies, and developing countries is already quite profound and will only expand over time.

Yet, predictions vary on what automation will eventually mean for the future of work. On the one hand, experts claim that automation will lead to greater efficiency and productivity, while also freeing humans from unsafe or unpopular tasks. They point to the evidence of history where technological innovation has led to the creation of entirely new economic sectors and ultimately to new jobs. On the other hand, some experts argue that the application of rapidly advancing automation technology across numerous sectors simultaneously will lead to unfavorable consequences, including widespread unemployment, greater wealth inequality, and social unrest.

The purpose of this discussion paper is not to argue that either of these two perspectives is the correct one, nor is it to downplay the potential significant benefits of the fourth industrial revolution, but rather to direct attention toward those particular factors that influence the uptake of automation technologies. In doing so, this paper calls into question the common assumption that what may be possible technically will materialize inevitably in practice. There is a tendency in the current discourse on automation and the future of work to presuppose that impressive advances in hardware and software mean that widespread automation – and its consequences – are inevitable.

Further, research findings on automation rise to prominence when calculations on what percentage of labor in particular sectors *could be* replaced through automation are turned into striking headlines in the popular media about jobs that *will be* replaced. The research on, and media exposure of, the potential for job displacements due to automation are important for drawing attention to the issues and presenting potential scenarios of the future. However, these estimates are not particularly helpful for understanding the phenomenon of automation or, more importantly, as guidance on how to react. As such, a more critical look at the drivers and inhibitors underlying the automation revolution is needed. Just as technology in general is not deterministic of the future, advancements in robots and algorithms are not the sole drivers of automation.

History shows that a range of factors determine the uptake of new technologies and innovations across countries and sectors, such as public sentiments toward such innovations, availability of labor with needed skills, the regulations and policies at play, the availability of necessary infrastructure and capital, as well as the economic viability of developing and implementing these technologies.

This discussion paper aims to contribute to a growing body of research on the potential impact of automation on Sub-Saharan African economies, as well as to help frame future debates on the topic. In this respect, the primary audience for this paper is the Sub-Saharan African policy community, (international) development practitioners, and researchers, rather than the experts in automation technologies. It is also important to note that the approach taken in this paper does have limitations: the paper takes a birds-eye view of developments in automation technologies and of the factors that may, or may not, lead to their implementation in different contexts. In addition, it is beyond the scope of this paper to dive too deeply into the economic, social, regulatory, or infrastructural particularities of each country in the region. The analytical framework is broadly defined and, consequently, the paper can only draw broad conclusions using specific country or sectoral examples. Ultimately, the goal of this paper is to spark discussion and to inspire more rigorous research into these areas.

Beyond an initial review of the basic tenets of automation (Chapter 2) and the factors influencing technological uptake (Chapter 3), this discussion paper analyzes to what extent these factors are driving or inhibiting automation and the future of work in Sub-Saharan Africa (Chapter 4). Using this approach, the paper concludes that wide-scale automation in most areas of the region's economies will be limited (Chapter 5). This is largely true because of the area's large-scale informal economy, and its lack of necessary digital infrastructure, available capital, and forward-looking industrial policies. In addition, the low pay and total cost for hiring the majority of Sub-Saharan African workers will remain cheaper than the total cost of implementing automation technology. Further, given the high percentage of workers currently making a living in the informal economy and particularly in small-scale farming – sectors that are especially immune to automation in pre-industrialized societies – the impact will be even more limited.

Yet, Sub-Saharan Africa does have areas of economic activity where digital infrastructure is highly developed, where capital is available, and where the economic calculus favors automation. In Sub-Saharan Africa's high-wage and internationalized manufacturing sector and in its high-wage service economy, for example, increasing usage of automation technology is likely. In such a scenario, the expansion of automation technology will strongly affect Sub-Saharan Africa's growing middle class who are employed in the formal economy. For them, hard times are likely coming sooner rather than later.

1 Brynjolfsson, Erik; McAfee, Andrew (2015): The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. (New York: W. W. Norton & Company).

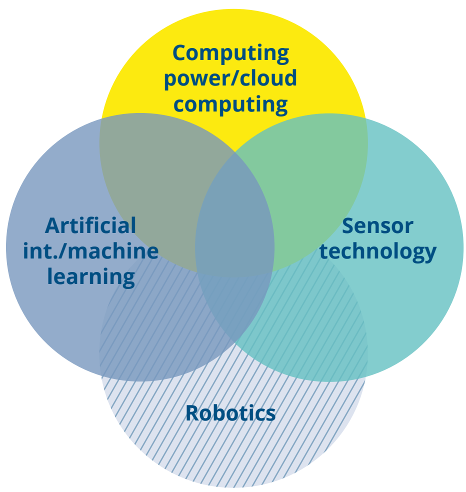
2. What is Automation and How Widespread Is It?

Artificial intelligence (AI), machine learning, predictive analytics, robots, cobots, and robotic process automation are all terms that are often (mistakenly) used interchangeably when discussing automation. Given the plethora of technical terms for automation – not to mention the spectrum of terms and concepts related to the fourth industrial revolution – it is worth breaking down what exactly is meant by automation

Automation is technology that assists humans, with limited guidance, in the production, maintenance, or delivery of products or services, or autonomously produces, maintains, or delivers those products or services.[1] This definition encompasses a large number of applications, from physical robots programmed to do manual tasks – for example, moving an object from point A to point B, to software applications – for example, cloud-based computer software capable of complex cognitive tasks, such as processing files, recognizing and analyzing images, or translating a sentence into multiple languages. There are many more applications in between these with varying degrees of complexity, requiring more or less dexterity and/or computer power. The critical aspect of this definition is that automation technology works without continuous human guidance because it is preprogrammed or because it is a self-learning system capable of making decisions without human interference.

Rapid developments in automation have come about through the convergence of technological advancements in the areas of computing power, cloud computing, and artificial intelligence on the software side, coupled with energy storage, sensor technology, actuators, and flexible object handling on the hardware side (Figure 1). Each of these areas has seen significant developments over the past years, and combinations therein have sparked true innovation in the automation industry.

Figure 1: Technological components of the automation revolution



First, advancements in computing hardware, in particular the growth of processing power, enable computers to conduct increasingly complex computational tasks.

In what has proved to be remarkable foresight, Gordon Moore predicted in 1965 that computer processing power would double every 18 months – a trend that has roughly held true to the present day. The result of this growing computational power has been an astounding integration of computers, in particular smartphones, into many aspects of our daily lives. While Moore's Law may be breaking down as space to store more transistors on a microchip runs out, technologies will nevertheless advance – even if they do so more gradually. For example, we will increasingly be able to leverage processing power more efficiently, and potentially groundbreaking ideas such as "chiplets" (the three-dimensionalization of chip engineering) will open up even more possibilities for the replacement of human thinking with machine processing.[2]

At the same time, the development of more advanced fiber optics and mobile data transmission, such as 4G and now 5G technology, together with vast improvements in internet access and bandwidth, have allowed greater connectivity as well as the storage and sharing of information across the globe through cloud computing. This has already had a considerable impact, from how multinational companies organize their human resources and customer relations to how small nonprofits communicate and share financial transactions with their tax advisers.[3]

Second, advances in artificial intelligence increasingly allow computers to conduct non-routine manual (through robots) and cognitive (through software) tasks. The basic tenet of machine learning, a key factor for achieving higher degrees of artificial intelligence, is to use algorithms to enable programs to learn from data analysis, as opposed to direct instructions from a programmer. As such, machine learning enables programs to react to non-standardized situations based on previous experiences and to conduct self-optimizing assessments of its own activities.[4] In this respect, a key future potential of machine learning is to give computers the capability of performing tasks traditionally perceived to require human intelligence. Some of the better-known recent breakthroughs in AlphaGo or poker AIs, as well as advanced image or pattern recognition, point to the rapid developments in machine learning.[5]

Third, advancements in sensor technology are giving robots much more accurate "eyes," "ears," and "touch" capabilities. Autonomous systems, and robots in particular, require sensing technology to evaluate their environment and to handle objects precisely. Sensor technology assessing light, distance, sound, contact, pressure, proximity, and weight, as well as sensors to determine the position of a robot, are critical components. While such sensor technology exists already, we are seeing a new wave of developments, such as soft robotics sensing, increasing miniaturization, higher accuracy, better energy efficiency, and substantially lower costs.[6] These continuous improvements open up numerous new opportunities for autonomously operating systems to conduct a wider array of manual and cognitive tasks.[7]

Finally, advances in robotics such as soft materials, improved actuators, flexible object handling, and greater dexterity in non-routine environments are enabling robots to effectively, and with increasing efficiency, sort objects, package goods, or prepare materials for further work. For example, a humanoid robot from the robotics company Boston Dynamics was recently shown jumping and running in fluid movements, while a small industrial robot designed by researchers from the University of California at Berkeley is able to autonomously detect, safely pick up, and handle random objects at around half the speed of humans.[8] The Berkeley researchers expect that their robots will soon exceed humans in these tasks.

Automation in different sectors

A closer look at current automation technology in different economic sectors shows a stunning variety of applications in a number of areas, including mining, agriculture, manufacturing and warehousing, textiles, financial services, and health care, among many others. While automation technologies will bring productivity gains, better services, and improved user experience, they are also likely to bring disruption to the labor market and change the demand for human workers in these sectors.

Automation in the primary sector

The primary sector of the economy centers on the extraction of raw materials, for example through mining, fishing, and agriculture. A variety of automated solutions already exists in these sectors. First, mining and oil and gas exploration are activities where humans have long sought the help of machines, but robotic technologies will increasingly replace traditional machine operators. In fact, this is already happening. The multinational mining company Rio Tinto claims it has hauled ore and waste materials weighing over one billion tons (as of January 2018) using autonomous trucks operating in Australian mines – a number only set to increase as more trucks are put into operation.[9] The South African company Randgold Resources has also begun using robotic loaders and automated material handling systems in its Kibali gold mine in the Democratic Republic of the Congo.[10] Other existing applications include automated drill rigs that blast holes on a predetermined path without human control, as well as mining equipment that uses predictive maintenance systems to reduce costs and interruptions to operations.

Market projections for automation in the mining sector claim that automated systems such as those highlighted above will become increasingly common. One market research report suggests that the prospect of increased productivity and safety, in combination with lower costs, may cause the mining automation market to grow by almost 50 percent in the next six years, reaching $3.29 billion by 2023.[11] Estimates of cost savings and efficiency gains are equally staggering. In April 2017, McKinsey Global Institute suggested that by 2035, data analytics and robotics could produce between $290 and $390 billion in annual productivity savings for oil, natural gas, thermal coal, iron ore, and copper producers across the globe.[12]

Extractive industries in particular will be at the forefront of automation, given the ability of extractives companies to shoulder large up-front investments. Moreover, the industry's relatively high wages and overall employee costs (particularly for operations located in industrialized countries) and stringent safety regulations, as well as potential disruptions in production from labor disputes, all provide incentives for automating tasks and relying less on human labor.[13] Importantly, the extractive industries are also not necessarily dependent on improvements in national infrastructure (e. g., high-speed internet connectivity), which are necessary for connecting autonomous machines and running Internet of Things (IoT) applications. This is because leading telecommunication equipment manufacturers already offer proprietary solutions for building local communication systems, such as those needed for greater mining automation.

Second, numerous technological advancements in the agricultural sector have increased productivity while decreasing the need for human labor, including driverless and autonomous tractors, fruit and vegetable picking systems, and drones for monitoring crops. However, most disruptive for the agricultural sector is the combination of self-learning autonomous robots doing manual work, (e. g., harvesting crops) with sensors and pattern recognition that can detect soil specifics and irrigation needs, weeds, ripeness of fruits and vegetables, or animal health. These systems can autonomously analyze a situation and react to their own unique circumstances, minimizing human supervision. The incentives for automating agriculture are compelling, particularly efficiency gains from higher crop yields and from reduced material and labor costs. Farming, particularly on a large, commercial scale, is poised to go beyond using a single machine, (e. g., an autonomous tractor) and connect different farming technologies to achieve largely autonomous farming operations ranging from crop planting to harvesting. The organization "Hands Free Hectare" recently demonstrated in a trial that a fully autonomous farming operation is possible, and a market research study from June 2018 estimates that the global agricultural tractor robots market alone will grow from $185 million in 2017 to $3.2 billion by 2024.[14]

Automation in the secondary sector

The secondary sector – so-called blue-collar work – is where raw materials are processed into more refined goods. It includes manufacturing and construction. In industrialized countries this sector's share of labor as a total of overall employment is moderate, given the transition to service economies. Nevertheless, manufacturing is the backbone of many industrialized or industrializing countries and employs millions of workers.

Manufacturing has many variations, from simple manipulation or assembly of raw materials to highly complex engineering. While literally meaning "the creation of something by hand," the era of purely handmade products is long gone. For many decades, machines have supported humans in the manufacturing process, and machines of varying complexity enabled the three previous industrial revolutions.[15] Yet, these machines were largely limited to specific routine manual tasks, such as repeatedly bolting pieces together as they went by on an assembly line. Now, the fourth industrial revolution is set to bring intelligent machines to the manufacturing process that can increasingly handle both routine and non-routine tasks autonomously. The International Federation for Robotics points out that the demand for industrial robots has accelerated considerably due to the ongoing trend toward automation and continued innovative technical improvements in industrial robots.[16]

While the automotive and electronics industries have embraced automated solutions for many years, other sectors are steadily increasing the use of automated machinery and robots as well. The labor-intensive garment and textiles industry – a critical sector for both employment and exports among many (particularly South Asian) developing countries and emerging economies – is showing first signs of greater automation with semi- or full automation of the sewing process. For example, the US-based company SoftWear Automation now offers a fully automated SEWBOT and claims that one "SEWBOT operator produces the same number of T-shirts as 17 manual sewers."[17] The disruptive potential of such technology is evident, particularly as sewing is the most complex step in clothing manufacturing, and accounts "for more than half the total labor time per garment."[18] The speed of disruption is also staggering: A World Bank report from 2016 on the future of the garment industry in South Asia makes no mention of automation, while a 2018 report from McKinsey estimates significant levels of automation in that sector by 2025.[19]

Another key development of automation in the secondary sector is smaller robots that can safely interact with humans. These so-called cobots – short for collaborative robots – are designed to work directly with humans. They are increasingly being integrated into work domains formerly exclusive to humans, for example, in the non-routine handling of materials. The key innovations in this respect are smaller size and simplified "training" of the cobots coupled with advancements in sensor technology, machine learning, and greater capabilities in movement and dexterity that make it possible to more closely integrate cobots in the production process alongside humans.

The automation revolution in manufacturing also hinges on sensors and predictive maintenance. By fitting machines with sensors to collect real-time information on their status and to then compare this with data collected from the same machine operating in other locations, the robots can detect and address potential malfunctions in advance, thus decreasing robot downtime and increasing productivity, further making the case for automated technologies.[20]

Automation in the tertiary sector

The tertiary sector, or services, includes a wide number of industries, including logistics, financial services, health care, education, retail, and research and development. In most industrialized, high-income countries, the tertiary sector employs the majority of workers – collectively about 74 percent of total employment. In comparison, the share is significantly lower at 31 percent in Sub-Saharan Africa.[21] In these areas of the economy, the automation revolution is not only about physical robots, but also about software that enables, for instance, robotic process automation or customer service through chatbots.

There are abundant examples of how automation is transforming various areas of the tertiary sector, and a few cases where impact is already quite large. The retail and consumer packaged goods industry is, for instance, undergoing rapid changes due to automation. This is an industry close to consumers, where many manufactured products hit the shelves and await purchase, either in brick-and-mortar stores or through online shopping. In this area, firms are increasingly introducing automated systems for warehousing and stockpiling goods, inventory checking, self-checkout, and automated cashier systems. With regard to automating the payment process, many large retailers, such as Walmart in the United States or Tesco in the United Kingdom, are experimenting with self-checkout services or even fully automated payment and cashier system – an unsurprising development, given that the largest operating costs in the retail industry are employees.[22]

Moreover, some companies are beginning to establish fully cashier-less stores in the retail sector. For example, the Beijing-based retail company JD.com opened China's first fully automated store in December 2017 and has since increased coverage within and beyond China.[23] Amazon is moving in a similar direction with its Amazon Go stores in the United States and, in addition, is utilizing a mobile application together with facial recognition technology to manage purchases. While such automated retail trials show the potential of such technologies, many retailers still face high costs for automated systems. In Western countries, the pace of such changes is moderated by legitimate privacy concerns, customer uneasiness about using new technologies, or (expectations of) higher levels of theft when humans are absent.[24] Yet, the cost advantages are clear, and it is likely that the retail sector will increasingly automate. A market analysis projects that the global retail automation market will grow from $10.31 billion in 2017 to $18.76 billion by 2023 – an annual growth rate of around 10 percent.[25]

The logistics and transportation sector is another area where experts expect substantial levels of automation. The key developments in this regard are the push for autonomous vehicles operating in both structured (closed) and unstructured (open) environments, as well as automated surveillance and the optimization of logistics processes. DHL, a global logistics company, pointed out that autonomous vehicles are particularly attractive for the logistics sector due to the limited liability of transporting only goods and not humans.[26] Such advantages have spurred increasing automation in some warehousing and port operations.[27] Further, car manufacturers such as BMW, Daimler, Tesla, or Volkswagen, as well as technology companies such as Alibaba, Alphabet, Apple, Baidu, Uber, or Yandex are engaging in fierce competition over their future positions in the autonomous vehicle market.[28]

Status of the debate: The optimists vs. the skeptics

The debate about the consequences of automation for society and the future of work is largely polarized.[29] One side comprises the "techno-optimists" who embrace automation and point to the advances it brings and will continue to bring.[30] In their view, automation and artificial intelligence will not only bring new services, but also put an end to many unpleasant jobs – particularly those deemed dirty, dangerous, and dull – while new professions and types of work will emerge.

The optimists have history on their side. After all, mechanization and automation in their historical iterations are nothing new. Century after century has brought inventions such as windmills, looms, cars, and automated teller machines (ATMs) that led to the demise of jobs and entire industries, but also created new professions, products, industries, and services. The invention of the automobile, essentially a machine replacing human or animal-powered transportation, led to the creation of the automotive industry, estimated to employ around nine million people across the world directly and around 50 million people indirectly.[31] Moreover, the continuous mechanization and industrialization of agriculture has cut down farm labor dramatically. Yet the sector continuously increases its productivity while different, sometimes entirely new economic activities have absorbed those affected. Further, although the invention of personal computers ended the careers of typists, it helped create millions of jobs in the service industries and opened up vast new opportunities for work.

The optimists' key argument is that while individuals losing jobs because of new technologies may not necessarily find employment again, the overall effect on the labor market is net positive. For instance, evidence from the United States and Germany shows that the much-feared long-term technological unemployment never happened on a broad level.[32] As David Autor argues, "automation has not wiped out a majority of jobs over the decades and centuries. Automation does indeed substitute for labor – as typically intended. However, automation also complements labor, raises output in ways that lead to higher demand for labor, and interacts with adjustments in labor supply."[33] Despite (or because of) a massive growth in automation in recent years, unemployment in industrialized societies is quite low. For example, Japan, the United States, and Germany, three of the most automated countries in the world, currently have unemployment rates of roughly 2.3 percent, 3.7 percent, and 4.9 percent, respectively.[34] The optimists point to such examples when arguing that automation in the coming years and decades will bring more benefits than harm. The World Economic Forum acknowledges job losses, but also predicts greater job creation in the period up to 2022.[35] According to another group of researchers, the employment scenario for 2030 will be one in which "many occupations have bright or open-ended employment prospects."[36]

Other experts are less worried about imminent and large-scale job losses because they see technology not as advanced as the hype suggests. The usability of non-stationary robots, for instance, still hinges on energy supply, and existing battery technology is not miniaturized and advanced enough to provide enough energy for extensive usage.[37] Further, developing customized software necessary to run autonomous robots is far from easy. While many researchers and companies aim for a "strong AI" – namely an artificial intelligence capable of thinking like a human and learning by itself irrespective of the circumstances – it remains challenging to develop even a "narrow AI" for a very limited use case, and it is costly to reprogram (industrial) robots for different tasks.[38] As a leading robotics researcher explains, "It is no secret today that the robot itself and the associated hardware are not the cost drivers ..., but [rather] the programming effort," and that the "Hollywood-influenced expectations of intelligent, autonomous robots cannot be fulfilled in the short- and medium-term in any way."[39] As such, the optimists argue that neither hardware nor software developments will allow for a rapid shift away from a human-centered workforce to a fully automated one. Rather, the introduction of automation technology will be more an incremental development than a sudden event, providing societies and decision-makers time to adjust to changes.

On the other hand, the "techno-skeptics" view the automation revolution as an unprecedented transformation that will lead to massive unemployment, greater wealth inequality, and social disruption.[40] For them, robots and software will bring "technological unemployment" that will eventually make almost all human work unnecessary and, unless there is some form of social protection, society will fail.[41] While it may not happen overnight, the view is that ongoing advances in hardware and software will chip away at the breadth of human labor with increasing speed.

In this context, the skeptics present four main arguments: First, they point out that existing technology is already at a level capable of displacing a high percentage of jobs. Technological developments have progressed far enough that jobs and occupations previously thought to be insulated from automation, namely non-routine cognitive and manual tasks, are increasingly susceptible to automation as well. Combining, for instance, light non-stationary robots with movable grippers capable of a wide range of motion and accuracy, together with sensor technology and cloud-enabled pattern recognition and communication, allows for more autonomous functioning of technology and, thus, completely different uses than those of comparatively crude industrial robots introduced in previous decades. While results are highly dependent on methodology, researchers have begun calculating the automation potential of jobs across countries and sectors. In a landmark study, Carl Benedikt Frey and Michael Osborne argue that around 47 percent of total US employment is at high risk of being automated over the next decade or two.[42] A recent study by the McKinsey Global Institute finds that 60 percent of occupations have at least 30 percent of constituent work activities that could be automated, and that, on a global level, between 75 million and 375 million workers may need to switch occupational categories by 2030.[43] While others calculate much lower figures of job displacement for the countries represented by the Organisation for Economic Co-operation and Development (OECD), the conclusion of all studies that assess tasks and occupations and their susceptibility to automation is similar: current technology is already capable of automating a sizable portion of occupations across a number of professions.[44] As technology advances, this share will grow.

Second, the skeptics argue that this time the advancement in automation technologies is not limited to a specific sector or occupation. Instead of an invention upending a single profession, as often seen in the past, the newest technological advancements in automation cut across the entire economy and many areas of work. Location sensors, for instance, can have many different applications, while entire robots, such as Boston Dynamics "SpotMini" or software suites, are developed as platform technologies that allow adaptation to different usages. The software behind a self-driving car can, for instance, be transferred to other types of vehicles and uses, such as autonomously operating trucking and warehouse vehicles. These technologies are also maturing rapidly and seeing greater adoption across sectors and countries.

Third, the skeptics argue that advances in technology are accelerating at a rate beyond the human ability to adapt to the loss of occupations. The changes we see are rapid and broad, not gradual and limited. The basis for this claim is found in the many stories of recent technological progress around artificial intelligence such as DeepStack, a poker software on par with professional poker players, or AlphaGo, a software that has beaten one of the world's leading players of Go, a game so complex that brute-force algorithms do not work. These advances demonstrate that forms of complex cognition – a distinctively human feature – are no longer exclusively the domain of humans. While computers and robots have long been capable of simple cognitive and manual routine tasks, software applications that are increasingly capable of handling complex cognitive and non-routine tasks are ubiquitous, together with simultaneous advances in robotics.[45] The consequences for human labor may be profound.

Finally, and perhaps most critically, skeptics point out that the significant advances in automation across all sectors is not a one-time revolution with a predetermined end date. Rather, they posit that change will continue at an ever-increasing rate and that the boundaries of what can be automated will constantly be pushed further out. Even if we were to adopt perfect policies now for hedging against the coming risks of automation in a specific sector or field, we would need to immediately begin to readapt to new changes – and we would need to do so at an ever-increasing speed.[46] The basis for this claim lies in the acceleration of technological developments and the expectation that certain technologies, such as quantum computing or a strong AI, will represent tipping points in the field of automation that open up entirely new applications.

1 This definition is based partly on the German standard for automation: DIN V 19233.

2 Simonite, Tom (2018): To Keep Pace with Moore's Law, Chipmakers Turn to 'Chiplets'," *WIRED*, November 16, 2018, accessed November 12, 2018, https://www.wired.com/story/keep-pace-moores-law-chipmakers-turn-chiplets/.

3 Should plans for the provision of global broad-band access from satellites in low-earth orbit, as envisioned by SpaceX and others, come to fruition, opportunities for digitalization and automation of services are set to increase even more.

4 Theobald, Oliver (2017): Machine *Learning for Absolute Beginners* (Stanford, CA: Scatterplot Press).

5 Gerrish, Sean (2018): How *Smart Machines Think* (Cambridge, MA: MIT Press).

6 Wang, Hongbo; Totaro Massimo; Beccai, "Toward Perceptive Soft Robots: Progress and Challenges," A*dvanced Science 5*, no. 9.

7 *Routine* cognitive or manual tasks denote those tasks whereby computers follow explicit rules; that is, they are preprogrammed to accomplish a limited and well-defined set of cognitive activities or manual labor. *Non-routine* cognitive or manual tasks, on the other hand, denote activities undertaken by a computer to accomplish more abstract tasks such as solving problems or using physical flexibility and sensor technologies to accomplish manual tasks by adapting behavior to different environments or situations. See, for example: Autor, David (2013): The task approach to Labor Markets: An Overview," *Journal for Labor Market Research* 46, no. 3.

8 Knight, Will (2018): Exclusive: This Is the Most Dexterous Robot Ever Created," *MIT Technology Review*, March 26, 2018, accessed October 4, 2018, https://www.technologyreview.com/s/610587/robots-get-closer-to-human-like-dexterity/.

9 See https://www.riotinto.com/documents/180130_Rio_Tintos_autonomous_haul_trucks_achieve_one_billion_tonne_milestone.pdf, accessed January 21, 2019.

10 See http://www.miningweekly.com/article/commissioning-of-automated-underground-mine-drives-growth-at-randgolds-kibali-mine-2018-04-24/rep_id:3650, accessed January 21, 2019.

11 Market and Markets, *Mining Automation Market by Technique, Type (Equipment, Software, Communications System), Equipment (Autonomous Hauling/Mining Trucks, Autonomous Drilling Rigs, Underground LHD Loaders, Tunneling Equipment) and Region – Global Forecast to 2023* (2018), accessed October 4, 2018, https://www.marketsandmarkets.com/Market-Reports/mining-automation-market-257609431.html.

12 McKinsey Global Institute (2017): "Beyond the Supercycle: How Technology Is Reshaping Resources. Executive Summary", accessed August 12, 2018, https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability%20and%20Resource%20Productivity/Our%20Insights/How%20technology%20is%20reshaping%20supply%20and%20demand%20for%20natural%20resources/MGI-Beyond-the-Supercycle-Executive-summary.ashx.

13 PricewaterhouseCoopers (2018): *Mine 2018: Tempting Times*, accessed November 14, 2018, https://www.pwc.com/id/mine-2018.

14 See http://www.digitaljournal.com/pr/3809023, accessed October 15, 2018.

15 Stearns, Peter N. (2013): *The Industrial Revolution in World History* (Boulder, CO: Westview Press).

16 International Federation for Robotics (2018), "Executive Summary World Robotics 2018 Industrial Robots", accessed November 14, 2018, https://ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf.

17 DevicePlus (2018), "SewBot Is Revolutionizing the Clothing Manufacturing Industry", accessed September 22, 2018, https://www.deviceplus.com/connect/sewbot-in-the-clothing-manufacturing-industry/.

18 McKinsey & Company (2018), "Is Apparel Manufacturing Coming Home? Nearshoring, Automation, and Sustainability – Establishing a Demand-Focused Apparel Value Chain", accessed October 15, 2018, https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/is%20apparel%20manufacturing%20coming%20home/is-apparel-manufacturing-coming-home_vf.ashx.

19 World Bank (2016): "Stitches to Riches. Apparel Employment, Trade and Economic Development in South Asia" (Washington, DC: World Bank and McKinsey).

20 For example, at the 2017 Hannover Messe, a representative from the company Bosch Rexroth claimed that their new predictive maintenance tool OdiN ("Online Diagnostic Network") could identify problems with a 99 percent success rate, compared to the 43 percent of a human expert conducting regular checks. See: Deutsche Messe AG Hannover, „MDA zeigt Predictive Maintenance Anwendungen Digitalisierung, Vernetzung und Kommunikation der Instandhaltung" (2017), accessed September 22, 2018, https://www.presseportal.de/pm/13314/3528467.

21 World Bank (2018), "Employment in Industry (% of total employment) (modeled ILO estimate)", accessed November 14, 2018, https://data.worldbank.org/indicator/SL.IND.EMPL.ZS?end=2017&name_desc=false&start=1991&view=chart.

22 NCR (2012), "NCR to Install 10,000 Self-Checkout Devices at More Than 1,200 Walmart Locations", accessed November 14, 2018, https://www.ncr.com/news/newsroom/news-releases/retail/ncr-to-install-10-000-self-checkout-devices-at-more-than-1-200-walmart-locations; Jamie Rigg (2015), "Tesco's Self-Service Checkouts Are Getting A Lot Less Irritating," *Engadget*, July 30, 2015.

23 JD (2018), "JD's Unmanned Store Goes Global", accessed January 11, 2018, https://jdcorporateblog.com/jds-unmanned-store-goes-international/.

24 Rene Chun (2018), "The Banana Trick and Other Acts of Self-Checkout Thievery," *The Atlantic*, March 2018, https://www.theatlantic.com/magazine/archive/2018/03/stealing-from-self-checkout/550940/.

25 Oristep Consulting (2018), *Global Retail Automation Market – by Type, Component, Operator Type, Implementation, End User, Region – Market Size, Demand Forecasts, Company Profiles, Industry Trends and Updates* (2017–2023).

26 DHL Trend Research (2014), "Self-Driving Vehicles in Logistics. A DHL Perspective on Implications and Use Cases for the Logistics Industry", accessed November 22, 2018, https://delivering-tomorrow.com/wp-content/uploads/2015/08/dhl_self_driving_vehicles.pdf.

27 McKinsey & Company (2018), "The Future of Automated Ports", accessed January 22, 2019, https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/the-future-of-automated-ports.

28 Engineers distinguish between five levels of autonomous driving: level zero means no automation at all, and the driver is fully in charge; whereas level five is the opposite: the car drives without any human action or interference. At this point, level three cars are commercially available, and firms are racing to reach level four within the next two to four years.

29 For an overview of the historical roots of the debate, see: Spencer, David A. (2018): "Fear and Hope in an Age of Mass Automation: Debating the Future of Work." N*ew Technology, Work and Employment* 33, no. 1.

30 It is not really clear who coined the term *techno-optimists*. We give credit to Duncan Green because this is where we read the term first. See: Green, Duncan (2017): "20th Century Policies May Not Be Enough for 21st Century Digital Disruption: From Poverty to Power", accessed November 22, 2018, https://oxfamblogs.org/fp2p/20th-century-policies-may-not-be-enough-for-21st-century-digital-disruption/.

31 International Organization of Motor Vehicle Manufacturers (OICA) (No date), "Employment", accessed November 14, 2018, http://www.oica.net/category/economic-contributions/auto-jobs/.

32 Muro, Mark; Maxim, Robert; and Whiton, Jacob (2019): "Automation and Artificial Intelligence. How Machines Are Affecting People and Places" (Washington, DC: Brookings Institution); Jens Südekum (2018), "Robotik und ihr Beitrag zu Wachstum und Wohlstand" (Berlin: Konrad-Adenauer-Stiftung).

33 Autor, David (2015): "Why Are There Still So Many Jobs? The History and Future of Workplace Automation," *Journal of Economic Perspectives* 29, no. 3.

34 See https://www.stat.go.jp/english/data/roudou/results/month/index.html (Japan); https://data.bls.gov/timeseries/LNS14000000 (USA); https://statistik.arbeitsagentur.de/Navigation/Statistik/Statistik-nach-Themen/Arbeitslose-und-gemeldetes-Stellenangebot/Arbeislose-und-gemeldetes-Stellenangebot-Nav.html (Germany) – all accessed November 13, 2018.

35 Based on a survey among companies representing 15 million workers. See World Economic Forum (2018), *The Future of Jobs Report 2018* (Geneva: WEF).

36 Bakhshi, Hassan et al. (2017): The Future of Skills: Employment in 2030 (London: Pearson and Nesta). Yet, one also needs to factor-in the aging societies that characterize Japan and Germany.

37 Crowe, Steve (2018): "10 Biggest Challenges in Robotics. The Robot Report", accessed November 17, 2018, https://www.therobotreport.com/10-biggest-challenges-in-robotics/. Also, an interview conducted by the authors.

38 Turck, Matt (2018), "Frontier AI: How Far Are We from Artificial 'General' Intelligence, Really?" *Medium*, April 18, 2018, accessed November 17, 2018, https://hackernoon.com/frontier-ai-how-far-are-we-from-artificial-general-intelligence-really-5b13b1ebcd4e.

39 Automatica (no date): „Der Hype um Künstliche Intelligenz ist übertrieben", accessed November 17, 2018, https://automatica-munich.com/ueber-die-messe/newsletter/meinung/kuenstliche-intelligenz/index.html.

40 See, for instance: Kaplan, Jerry (2015): *Humans Need Not Apply: A Guide to Wealth and Work in the Age of Artificial Intelligence* (New Haven, CT: Yale University Press); Ford, Martin (2015): *Rise of the Robots: Technology and the Threat of a Jobless Future* (New York: Basic Books; Blit, Joel; Amand, Samantha, and Wajda, Joanna (2018):, "Automation and the Future of Work: Scenarios and Policy Options," (Waterloo, Ontario: Centre for International Governance Innovation).

41 John Maynard Keynes had already introduced the term *technological unemployment* in 1930 in his famous essay "Economic Possibilities for Our Grandchildren." Keynes, however, saw such unemployment as a transitory phenomenon and not as a final state for entire societies. The essay is available at http://www.econ.yale.edu/smith/econ116a/keynes1.pdf, accessed August 12, 2018.

42 Frey, Carl Benedikt; Osborne, Michael (2013): *The Future of Employment: How Susceptible Are Jobs to Computerisation?* (Oxford, UK: Oxford Martin School, University of Oxford).

43 McKinsey Global Institute (2017), "Beyond the Supercycle: How Technology Is Reshaping Resources, Executive Summary", accessed August 12, 2018, https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability%20and%20Resource%20Productivity/Our%20Insights/How%20technology%20is%20reshaping%20supply%20and%20demand%20for%20natural%20resources/MGI-Beyond-the-Supercycle-Executive-summary.ashx.

44 See, for instance: Arntz, Melanie et al. (2016): "The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis" (Organisation for Economic Co-operation and Development [OECD] Social, Employment and Migration Working Papers, no. 189, Paris).

45 Frey and Osborne (2013).

46 Skipper, Clay (2018), "The Most Important Survival Skill for the Next 50 Years Isn't What You Think," GQ, September 30, 2018, accessed November 17, 2018, https://www.gq.com/story/yuval-noah-harari-tech-future-survival.

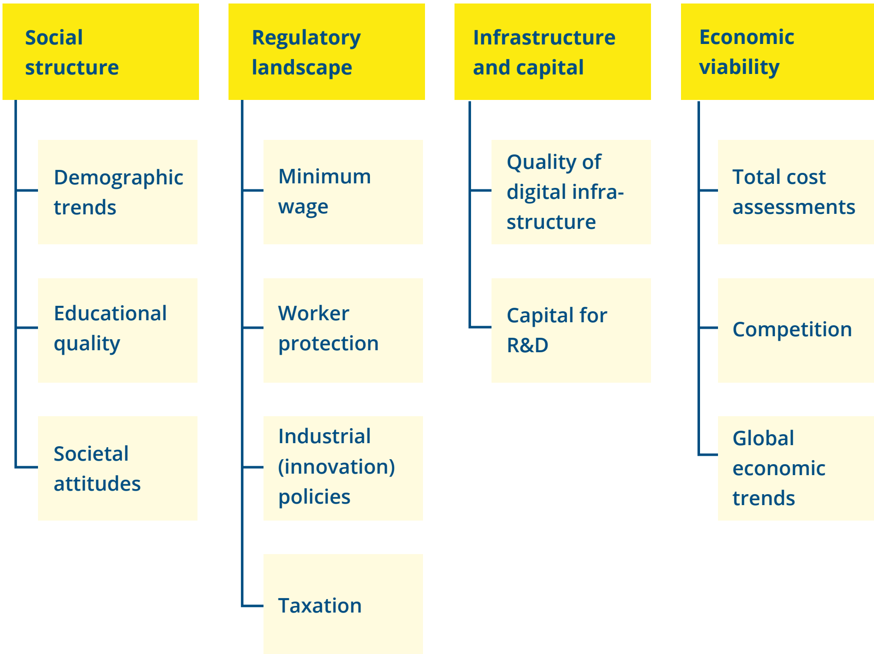

TT203 PSA

3. Analytical Framework: Factors Driving or Inhibiting Automation

While it is clear that advances in technology have enabled various types of automation across different sectors, it is nevertheless erroneous to assume that technological advances alone are driving the automation revolution. The adoption of automation technology is not simply a consequence of its availability, rather, a number of underlying factors either enable or stall the use of automation technologies. Based on existing research around industrial innovation, this paper presents four key factors driving or inhibiting automation that serve as a basis for assessing the implications of automation in Sub-Saharan Africa.

The first factor is social structure, which refers here to demographic trends and educational quality, and societal attitudes toward automation shaped primarily through public discourse. The second is the regulatory landscape, for example, minimum wage policies and worker protection rights, but also industrial policies or laws that allow for the testing and usage of certain technologies. The third factor is the availability and quality of infrastructure and the availability of finance for new technologies. Finally, the fourth factor driving or inhibiting automation is the actual economic viability of utilizing automation technologies (Figure 2).[1]

Figure 2: The drivers and inhibitors of automation



Source: Authors.

While these factors provide a useful basis for analyzing likely pathways for the use of automation technologies, two caveats exist. First, these factors vary by country, sector, and even subsector, making it difficult to make conclusive statements about the extent to which automation technologies are, or may be, used. Second, the factors also do not have equal weight in determining potential paths, and their respective influence can again vary by country, sector, and subsector. In particular, economic viability is a highly contextualized factor that strongly affects a firm's decision to automate. Nevertheless, this list of factors provides an adequate framework to draw broad conclusions on the likelihood, or the improbability, of automation occurring across Sub-Saharan Africa. In this respect, one of the key aims of this discussion paper is to spark a wider discussion on this issue and to inspire further research. It is not to make definitive statements or calculate the likelihood of automation for a country or a sector.

Social structure

The rate at which a particular society embraces automation is in part dependent upon its social structure, particularly its demography, educational policies, and societal attitudes toward technology. First, demography is quite important for the labor market. An aging society, for instance, can lead to labor shortages that make it difficult for firms to fill vacancies. On the other hand, a comparatively young society with many job seekers may find it difficult to create enough entry-level positions for those with limited work experience and work-related skills. In both cases, automation technology offers a potential alternative. In Germany and Japan – both aging societies with low population growth – researchers regularly express the notion of automation as a sensible way to fill the positions of soon-to-be-retired workers. One study estimates that, in the next decade, automation and other efficiency measures can fill an expected gap of roughly 10 million workers in Germany without increasing overall unemployment.[2] The International Monetary Fund (IMF) makes a similar argument in the case of Japan, arguing that "with labor literally disappearing [in Japan] and dim prospects for relief through higher immigration, automation and robotics can fill the labor gap and result in higher output and greater income rather than replacement of the human workforce."[3] Such demographic circumstances influence automation uptake considerably.

Another critical social factor is education policy. The OECD calls for educational policies that promote not only basic information technology skills and programming, but also specialization in engineering and machine-learning, while also leveraging the latest research to evolve educational systems to keep up with the advancement of new technologies.[4] While the intention of such policies is to better position youth to find careers in the economy of the future, they also help shape public attitudes toward automation, namely to make more socially acceptable the increasing replacement of human workers with hardware and software. In short, educational systems that are teaching specialized skills to stay ahead of an increasingly automated workforce are quite likely helping to create the self-fulfilling prophecy of an automation revolution.[5]

Finally, societal attitudes are another important factor influencing uptake of, or resistance to, automation technologies. In Japan, a country with one of the highest ratios of robots per inhabitant, there is a strong openness toward robots and automation. Portrayed at times as the "Land of Rising Robots," such acceptance of robots "is founded on Japanese Animism, the idea of Rinri, and its rapid modernization."[6] In stark contrast, Western societies influenced by monotheistic religions tend to advance the notion that robots are objects detached from their human creators and capable of turning against them. Popular Western references in this vein are HAL 9000 from the film *2001: A Space Odyssey* and the eponymous character from *The Terminator*. Such societal attitudes likely influence specific views on automation as well. For example, in a survey conducted in the United States by the Pew Research Center in 2017, 72 percent of respondents expressed worry about "a future in which robots and computers are capable of doing many jobs that are currently done by humans."[7] In Europe, the numbers are roughly the same, with 74 percent expecting that the use of robots and artificial intelligence will lead to a net loss in jobs.[8]

The regulatory landscape

Regulatory decisions by governments greatly influence the uptake of automation technologies in a country as a whole or within specific sectors. The most critical fields of regulatory decisions with an impact on automation are minimum wage policies, worker protection programs, and industrial (innovation) and taxation policies.[9]

First, labor market policies strongly influence the rate of adoption of automation in a country or sector, particularly policies governing minimum wage and worker protection programs. Minimum wage effectively aims to shield employees from poverty by mandating a wage floor. While minimum wage prevents price competition in a labor market with a high supply of workers, it also increases unit production costs and shifts cost-benefit calculations of automating human labor. A recent study on the US labor market found that "increasing the minimum wage significantly decreases the share of automatable employment held by low-skilled workers and increases the likelihood that low-skilled workers in automatable jobs become non-employed or employed in worse jobs."[10] In other words, higher minimum wages lead to more automation. Results of a study on minimum wage effects in the United Kingdom corroborate this finding by concluding higher minimum wages and expansion of those eligible for minimum wages are linked to replacements by automation technology.[11]

Second, the extent of worker protection programs in a country also plays a role in determining the likelihood that existing jobs may be automated, at least in the short to medium terms.[12] It is difficult for companies to significantly cut jobs while pursuing automation in countries with stronger worker protection policies, such as the Nordic states, Germany, or South Africa. In the United States, the National Labor Relations Board, responsible for enforcing labor law, has already set precedents with regard to the impact of labor unions on automation and vice versa, by ruling that automation is a matter for mandatory bargaining. This clearly makes the case for automation more difficult.[13] The implication of such policies is that, while high levels of worker protection in an industry or a country can prevent job losses for those already employed, they also act as a barrier for the creation of new jobs for human workers. Consequently, worker protection regulations act as an incentive to use automated labor and forgo future hiring to avoid the need for compliance with worker protection regulations.[14]

Third, industrial (innovation) policies strongly influence how countries or sectors move toward automated economies. Publicly funded research labs advancing automation technologies, public seed funding or co-funding for pilot projects or scaling of existing initiatives, or public procurement in favor of automation technologies all lead to an environment that enables organizations to invent and invest in automation technologies. Coupled with automation-friendly regulations, such as less stringent data protection laws, allowing trials of driverless cars on public roads or adapting safety standards for more human-machine collaboration in industrial production settings, governments strongly affect how their country or specific sectors can utilize automation technologies. Moreover, in recognition of the immense first-mover advantages of automation and related technologies for the economy, governments are investing heavily in building up these sectors within their borders in an effort to secure – perhaps ironically – the jobs of the future. Further, countries are in a race to position themselves in artificial intelligence research and development.[15] China presented its "New Generation Artificial Intelligence Development Plan" in July 2017, while France released its "AI for Humanity" plan in March 2018. Further, Germany's federal cabinet agreed on a strategy in July 2018 to promote Germany's role as a global leader in research and development, and use of artificial intelligence, stressing the importance of these technologies for growth and well-being.[16] Other countries, such as the United Kingdom, are also seeking to position themselves more broadly as leaders of the fourth industrial revolution through new industrial policies.[17]

Finally, taxation policies can also determine the extent to which automation takes hold in a country. Many countries offer tax incentives on research and development spending via tax credits or tax deductions, making it more attractive for companies to develop in-house solutions.[18] At the same time, many tax systems offer some form of capital expenditure deductions, allowing for instance, the purchase of a robot or software to reduce the overall tax bill. Depending on the structure of those deductions, capital expenditures become more or less attractive. Beyond these existing rules, automation technologies replacing labor also have a tax advantage because – so far – the income tax and social security contributions (if applicable) lost as a result of automation are not recaptured through other means of taxation. As a partner from international accounting firm KPMG explains, if national insurance contributions are claimed through a payroll tax, they "unfortunately incentivize business away from the traditional employer/employee operating model – be it by moving to a self-employment model, offshoring, or automating."[19]

At present, no government has implemented a direct robot tax that would offset the (un)intentional favoring of automated technologies described above. Public opinion largely opposes such a tax as it can harm productivity growth or because it is impractical to implement.[20] Particularly problematic is determining what counts as a "robot," calculating its output, and, consequently deciding on the corresponding level of taxation. In 2017, the European Parliament rejected outright the idea of a robot tax, stressing that such a tax would stifle innovation.[21] In fact, South Korea is the only country moving in this direction: while its government did not implement a direct robot tax, it reduced the tax deduction that organizations could claim from infrastructure investments, including in automation equipment.[22]

Availability of infrastructure and capital

Another set of critical factors driving or inhibiting automation is availability of reliable (digital) infrastructure as well as capital for research, development, and deployment of new technologies. First, it should come as no surprise that having key infrastructure in place, particularly access to reliable and affordable broadband connections and uninterrupted energy supply, is critical for leveraging advancements in processing power and the myriad of opportunities provided through cloud computing and the storage and sharing of information across the globe. Fast internet connectivity is particularly critical for non-stationary automation (such as self-driving cars or warehouse robots) to access a central database or to enable swarm-like communication with other applications. The 5G mobile network plays a key role in this regard, and its launch is currently being prepared in many OECD countries.

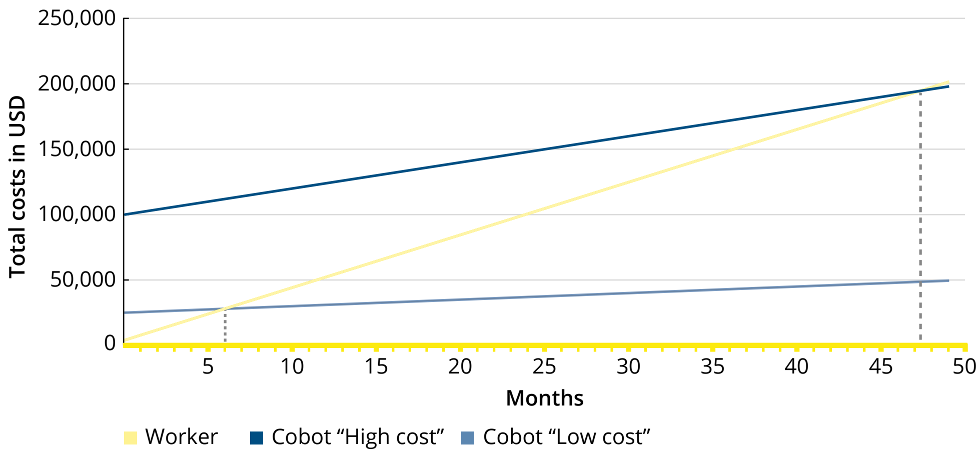
Second, the availability of capital for investment in the development of new infrastructure and technologies is a critical factor shaping automation trends. A core tenet of the capitalist system is competition among actors, which happens via pricing and through innovations lowering costs of production, while maintaining or increasing the quality of outputs. In this respect, automation is a key innovation lever for the years to come. The pressure on companies to remain competitive in a transforming economy is huge and is driving not only research and development in areas of automation but also companies' operational uptake of automation technologies. For example, Foxconn, a Taiwanese electronics maker, has a goal of 30 percent automation in its Chinese factories by 2020. Amazon has a highly automated logistics center, where 45,000 Kiva robots move entire shelves around. Alibaba, China's equivalent to Amazon, has made headlines by planning to invest $15 billion over the next five years in its logistics infrastructure, including robots. Google reportedly spent more than $ one billion between 2009 and 2015 to develop technologies for self-driving cars.[23] Many more examples of investments in robotics companies exist across the globe – indicating a general availability of capital for this type of research and development. Yet, given the significant up-front costs of researching, developing, and implementing automation technologies, companies in advanced industrial economies with cash reserves or access to capital markets are better placed to shoulder these costs. Moreover, they have a greater incentive to do so, given the regulatory factors described above, such as minimum wage policies, and economic viability factors described below, such as consumer purchasing trends.

Economic viability of automation

While policymakers can set the political and regulatory landscape, economic viability ultimately determines whether firms invest in automation technology. Given the pattern of non-frontier technologies becoming cheaper over time and of labor costs rising alongside economic growth, from a cost-benefit perspective, automating labor becomes increasingly attractive as a way of lowering costs, increasing productivity, or both. In other words, all else being equal, it makes economic sense to automate labor if the total costs of doing so are less than employing humans. While the individual calculation to utilize automation technology is a complex one and always linked to particular circumstances, the decreasing total costs for automating existing manufacturing processes or services are set to make automation increasingly attractive.

One example in this regard is the cost of "cobots" – collaborative, small-parts assembly robots – where strong annual growth is projected for the next few years.[24] A well-known cobot called YuMi, developed by ABB and launched in 2015, is currently selling for around $40,000 per robot. In addition to that price, however, it is necessary to factor in additional operating and maintenance costs for the cobot, making a cobot a considerable investment. Nevertheless, a highly simplified cost calculation based on labor costs in a high-income country such as the United States shows that a cobot – assuming a full price tag of $100,000 for purchase, installation, mandatory safety certifications, programming, and two percent annual maintenance costs – will equal the costs of employing a human worker after around 48 months. This calculation assumes full employment at an hourly wage of $21 and 20 percent additional costs such as labor taxes and social security contributions (Figure 3). Critically, this calculation also assumes equal productivity and output, a premise that neglects that a cobot can work more than a human's eight to ten hours per day, has no margins of error, and keeps its residual value. Further affecting such a cost comparison in favor of cobots are off-the-shelf and ready-to-work solutions that minimize additional costs and target small and medium-sized enterprises (SMEs), such as the "Panda" by the German start-up Franka Emika, which is priced between $15,000 and $20,000, depending on features. In contrast to the human costs used in the previous example, such a "low cost" cobot is already cheaper than a human worker after six months (Figure 3). Another pricing model looks at serviced robots for hire, where pricing is determined by the number of hours the robot is in use, which will likely make such cobots economically viable even more quickly than the 6 or 48 months presented here. This option also makes cobots accessible for SMEs unable to purchase them up front.[25]

Figure 3: A simplified cost comparison of a human worker and a cobot



Note: This example is based on the following calculation: For a cobot "high cost" costs at t0 are $100,000 and increasing each month by €2,000 as monthly maintenance costs. For cobot "low cost" costs at t0 are $25,000 and increasing each month by €250 as monthly maintenance costs. For the human worker, costs at t0 are $4,000 hiring costs and increasing each month by $4,032, which are based on an hourly wage of $21 and a working time of 160 hours per month, as well as 20 percent additional costs.[26]

Source: Authors.

Beyond case-by-case economic viability calculations to invest in automation technology, global economic factors such as tariffs, shifts in consumption and production patterns, and global value chains are also driving automation. Companies are increasingly interested in reshoring production closer to consumers due to rising wages in current centers of manufacturing such as China. Automation is conveniently compatible with reshoring as it reduces – and in some cases can eliminate – the high labor costs in the "home" market. Adidas, for example, is an oft-cited case of this phenomenon, having opened highly automated "Speedfactories" in Ansbach (Germany) and Atlanta (United States) to make highly tailored sneakers for local markets.[27] Moreover, reshoring can reduce transport costs and eliminate difficulties of doing business abroad, particularly in the area of intellectual property rights, which can increase the total costs of production abroad.

1 Adapted from an analysis on industrial innovation and technological adaptation. See, for instance: Lall, Sanjaya (1992): "Technological Capabilities and Industrialization," World Development 20, no. 2; Archibugi Daniele et al. (2009): "The Technological Capabilities of Nations: A Review of the Synthetic Indicators," Technological Forecasting and Social Change 76; as well as the Global Competitiveness Index of the World Economic Forum.

2 Amlinger, Marc et al. (2017): „Deutschland 2040: 10 Thesen zu Arbeitsmarkt und Rente, Demografie und Digitalisierung. Institut für die Geschichte und Zukunft der Arbeit.", accessed January 28, 2019, http://igza.org/wp-content/uploads/2018/10/IGZA_Arbeitspapier_2.pdf.

3 Schneider, Todd; Hong, Gee Hee; Le, Anh Van: (2018): "Land of Rising Robots," Finance & Development 55, no. 2.

4 Organisation for Economic Co-operation and Development (OECD) (2016), "Skills for a Digital World" (Policy Brief on the Future of Work, Paris).

5 In addition to the three factors listed here, cultural and historical values and experiences can also impact how a society views the benefits or threats of automation and related technologies. We did not see this as a major factor to be included in this analytical framework, but it is nevertheless an interesting question for research.

6 For more information, see Kitano, Naho (2017): "Animism, Rinri, Modernization; the Base of Japanese Robotics", accessed September 17, 2018, http://www.roboethics.org/icra2007/contributions/KITANO%20Animism%20Rinri%20Modernization%20the%20Base%20of%20Japanese%20Robo.pdf.

7 Smith, Aaron; Anderson, Monica (2017): "Automation in Everyday Life," Pew Research Center Internet and Technology, accessed October 30, 2018, http://www.pewinternet.org/2017/10/04/automation-in-everyday-life/.

8 European Commission (2017): "Special Eurobarometer 460: Attitudes towards the Impact of Digitisation and Automation on Daily Life". See also: Loffredo, Donald; Tavakkoli, Alireza (2016), "What Are European Union Public Attitudes towards Robots," Systemics, Cybernetics and Informatics 14, no. 1.

9 With the exception of taxation, these three areas are also the basis for the Automation Readiness Index by the Economist Intelligence Unit.

10 Lordan, Grace; Neumark, David (2018): "People Versus Machines: The Impact of Minimum Wages on Automatable Jobs" (Bonn, Germany: IZA Institute of Labor Economics).

11 Cribb, Jonathan; Joyce, Robert; Keiller, Agnes Norris (2018): "Will the Rising Minimum Wage Lead to More Low-Paid Jobs Being Automated?" (London: Institute for Fiscal Studies).

12 Eichhorst, Werner (2017): "Labor Market Institutions and the Future of Work: Good Jobs for All?" (IZA Policy Paper no. 122, Institute of Labor Economics, Bonn, Germany).

13 Wilson, Patrick T (2017): "Competing with a Robot: How Automation Affects Labor Unions," Journal of Business & Intellectual Property Law, August 22, 2017. Accessed October 29, 2018, http://ipjournal.law.wfu.edu/2017/08/competing-with-a-robot-how-automation-affects-labor-unions/.

14 Interview conducted October 22, 2018.

15 For a detailed assessment of different national AI strategies and capabilities, see Groth, Olaf J., et al. (2018): „Vergleich nationaler Strategien zur Förderung von Künstlicher Intelligenz (Teil 1); and Groth, Olaf J. et al. (2019), „Vergleich nationaler Strategien zur Förderung von Künstlicher Intelligenz (Teil 2), both Konrad-Adenauer-Stiftung, available in German only.

16 Bundesregierung (2018): „Eckpunkte der Bundesregierung für eine Strategie Künstliche Intelligenz"; Foundation for Law and International Affairs (FLIA), „China's New Generation of Artificial Intelligence Development Plan" (2017), accessed October 29, 2018, https://flia.org/notice-state-council-issuing-new-generation-artificial-intelligence-development-plan/; AI for Humanity (2018), "French Strategy for Artificial Intelligence", accessed October 29, 2018, https://www.aiforhumanity.fr/en/.

17 Government of the United Kingdom (2017), "Industrial Strategy: Building a Britain Fit for the Future," (Industrial Strategy White Paper), accessed October 29, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf.

18 Pfeifer, Olena; Spengel, Christoph (2017): "Tax Incentives for Research and Development and Their Use in Tax Planning" (Mannheim, Germany: Liebniz Centre for European Economic Research).

19 KPMG (2017): "Does the UK Need a Robot Tax?", accessed October 29, 2018, https://home.kpmg.com/uk/en/home/insights/2017/08/does-the-uk-need-a-robot-tax.html.

20 See Economist (2017), "Why Taxing Robots Is Not a Good Idea," February 25, 2017, accessed October 29, 2018, https://www.economist.com/finance-and-economics/2017/02/25/why-taxing-robots-is-not-a-good-idea.

21 Reuters (2017), "European Parliament Calls for Robot Law, Rejects Robot Tax," February 16, 2017, accessed October 29, 2018, https://www.reuters.com/article/us-europe-robots-lawmaking/european-parliament-calls-for-robot-law-rejects-robot-tax-idUSKBN15V2KM.

22 Korea Times (2017), "Korea Takes First Step to Introduce 'Robot Tax'," August 7, 2017, accessed October 29, 2018, http://www.koreatimes.co.kr/www/news/tech/2017/08/133_234312.html.

23 Harris, Mark (2017), "Google Has Spent Over $1.1 Billion on Self-Driving Tech." IEEE Spectrum, September 15, 2017, accessed October 29, 2018, https://spectrum.ieee.org/cars-that-think/transportation/self-driving/google-has-spent-over-11-billion-on-selfdriving-tech#disqus_thread.

24 CobotsGuide (2017), "Collaborative Robots Market to $4.28 Billion 2023," September 18, 2017, accessed September 22, 2018, https://cobotsguide.com/2017/09/collaborative-robots-market-to-4-28-billion-2023/.

25 Slepov, Dmitry (2016), "The Real Cost of Robotics," TechCrunch, March 27, 2016, accessed October 20, 2018, https://techcrunch.com/2016/03/27/the-real-cost-of-robotics/?guccounter=1.

26 The average hourly wage in manufacturing in the United States is currently at $22.91; see https://tradingeconomics.com/united-states/wages-in-manufacturing.

27 Wiener, A. (2017), "Inside Adidas' Robot-Powered, On-Demand Sneaker Factory," WIRED, November 11, 2017, accessed October 20, 2018, https://www.wired.com/story/inside-speedfactory-adidas-robot-powered-sneaker-factory/.

4. Automation in Sub-Saharan Africa

How will Sub-Saharan Africa change as a result of the automation revolution outlined above? How likely is a broad uptake of automation technologies in the region, given its particular economic and political circumstances? What policies should African countries prioritize to reap the rewards and mitigate the undesired consequences of the automation revolution? A rapid increase in the number of studies, scenarios, and projections, for example from the African Development Bank,[1] the International Monetary Fund,[2] the Overseas Development Institute,[3] the World Bank,[4] and many others,[5] testify to the increasing importance of automation in developing countries in general and in Sub-Saharan Africa in particular.

While these reports offer a variety of information on many different aspects of the automation revolution for developing countries and particularly Sub-Saharan Africa, a framework for assessing industrial innovation and technological adaptation specific to automation technology has not yet been systematically developed. Yet, to judge the likely future of automation technology in Sub-Saharan Africa, it is critical to go beyond the underlying assumption that, just because automation technology exists, widespread automation in Sub-Saharan Africa is a given. Instead, this discussion paper provides a preliminary analysis of the extent to which the social, regulatory, infrastructural, and economic factors introduced in the previous chapter apply to Sub-Saharan Africa, and if and how they will shape the fourth industrial revolution on the continent. This approach provides a fresh perspective for policymakers seeking to understand in more detail the likely pathways and possible constraints Sub-Saharan African countries face on their paths to development.

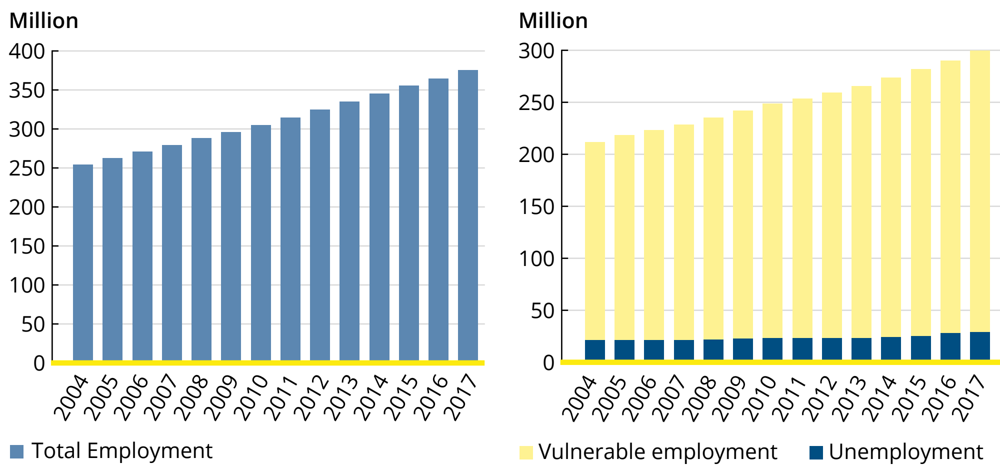
However, a key limitation of this approach is that it is beyond the scope of this discussion paper to determine the strength of each of these factors, or the interaction among factors, in determining automation uptake in each Sub-Saharan African country. Consciously choosing breadth over depth, this section continues instead with a more general discussion of the above mentioned factors, using illustrative examples of different Sub-Saharan African countries or sectoral cases to draw out key areas of further discussion and research.

Social structure: Population growth and education levels at odds for automation uptake

Two key aspects of Sub-Saharan Africa's social structure influence whether automation technology will take hold in any particular country or sector: the dynamics of the working-age population and the quality of education. These two aspects have opposing effects on automation uptake. First, unlike aging societies with slow population growth, such as Japan or Germany, the countries of Sub-Saharan Africa have, across the board, a young and growing population. From 2000 to 2015, the population on the continent increased from around 800 million to close to 1.2 billion – an increase of 50 percent in just 15 years.[6] *The State of World Population 2018*, a report by the United Nations Population Fund (UNFPA), predicts further population growth on the continent of 1.3 billion people to rise to 2.5 billion by 2050 – the highest population growth in the world.[7] While the final headcount will greatly depend on the interplay of many uncertain factors such as economic development, education, access to contraceptives, and urbanization, a growing population translates undisputedly into an increasing number of job seekers. A report from the International Labour Organization (ILO) projects that the youth population will increase by around 94 million by 2030. Breaking this down, the report further estimates workforce growth in Sub-Saharan Africa at around 200 million people between 2017 and 2030.[8] The United Nations Economic Commission for Africa (UNECA) has similar figures and argues that "10 million new formal jobs are needed each year to absorb the massive youth population entering the market."[9]

While new jobs are created every year, the problem Sub-Saharan Africa faces is that growth in jobs and employment is not developing fast enough to absorb all job seekers. While total employment has grown from around 254 million in 2004 to around 375 million in 2017, vulnerable employment and total unemployment have also increased, leaving a large number of people in troubling economic conditions (Figure 4).[10] Across African cities, there are countless individuals offering their labor and seeking jobs in some form or another to earn a livelihood.

Figure 4: Total employment and vulnerable employment in Sub-Saharan Africa



Source: ILO, "World Employment Social Outlook: Trends 2018."

Population growth with non-matching job growth translates into a fast-developing labor glut across Sub-Saharan Africa, particularly in non-specialized occupations, resulting in greater competition for existing jobs, where workers are easily interchangeable. This leads to much greater bargaining power for employers and, consequently, their ability to drive down wages unless mitigated by minimum wage laws or collective bargaining. Low wages, in turn, affect the cost-effectiveness calculations of introducing automation technologies and make large-scale automation unlikely in sectors characterized by labor abundance and low wages. A labor glut simply provides fewer incentives for firms to automate since labor is cheap. Moreover, the more unemployment a country faces, the less likely it will be that policymakers would promote policies that may lead to further unemployment in the short run – even if there is a net-positive effect on the job market in the long run.

Second, while cheap labor throughout most of Sub-Saharan Africa likely stymies the use of automation technology, the level of education, on the other hand, acts largely as a driver for greater automation. Across Sub-Saharan Africa primary, secondary, and tertiary education does not yet match the higher quality education provided in emerging economies or industrialized countries. Despite sevenfold increases in public expenditures on education over the past 30 years, basic metrics, such as school enrollment numbers, average number of years of education, school dropout and literacy rates, all show that the quality of education accessible for the majority of young Africans is comparatively poor.[11] The World Bank speaks plainly about it: "For children in school, learning outcomes have been persistently poor, leading to huge gaps in basic cognitive skills – literacy and numeracy – among children, young people, and adults. The literacy rates of the adult population are below 50 percent in many [African] countries, and functional literacy and numeracy are lower."[12] As a result, too few people develop mid-level or advanced skills needed in the economy. This, together with emigration of educated workers, translates into a skills shortage that, according to surveys among private sector organizations, is a key challenge for African companies seeking to grow.[13] Employers report that, despite large numbers of people looking for employment, they have difficulties finding workers with the right (particularly mid-level) skills, that it takes time to fill vacant positions, and that they manage at present by either forgoing growth, outsourcing tasks to service providers outside of Africa, or by hiring expatriate workers. Moreover, the considerable lag time required for both education reform and for training and developing new skills means that the impact of such activities is measured in years, not months or weeks. Given this lag time, skill shortages across Sub-Saharan Africa are likely for years to come.[14]

In sum, growth, particularly in manufacturing and the service sectors, requires skilled labor. Yet, the relatively low levels of education in many Sub-Saharan countries are constraining this growth.[15] In an environment where job seekers lack the necessary skills or where wages are high because of a demand for specific skills, rapidly advancing automation technology offers an alternative both as substitute for missing skills and as replacement for high-wage workers.

Regulatory landscape: Competing effects from labor market regulation and industrial policies

Regulatory and institutional factors play a key role in determining the extent to which automation technologies take hold in a particular country, sector, or organization. In the context of Sub-Saharan Africa, there are two regulatory and institutional factors that are particularly influential: labor market policies and industrial policies. These factors run counter to one another with regard to their effects on automation uptake in Sub-Saharan African economies. First, many Sub-Saharan African countries, in particular those with comparatively large formal economies and strong union activity, have introduced labor market regulations in an attempt to reduce job losses and limit working poverty. Most prominent in this regard are worker protection laws that seek to rein in the ability of firms to lay off workers, as well as minimum wage regulations that mandate a wage floor for certain professions. In terms of worker protection laws, 34 out of 47 Sub-Saharan African countries surveyed by the World Bank for their *Doing Business Report 2018* require third-party notification if a worker is to be dismissed.[16] Such worker protection laws shield workers from easy dismissal and unjust treatment, but they also make firms more cautious in the hiring process, given the difficulty in letting employees go once they have been hired.

Moreover, a number of African countries have mandated minimum wages. Haroon Bhorat and colleagues provide an in-depth review of minimum wage regulations in Sub-Saharan Africa and conclude that, despite regulations by many countries, minimum wage policies actually cover only a small fraction of workers.[17] This is because large parts of Sub-Saharan Africa's economy are informal and because compliance with regulations is very limited. Nevertheless, Bhorat and colleagues argue that this will change as African economies formalize and as stronger institutions are created to help workers enforce their rights.[18]

Second, Sub-Saharan African countries are grappling with the issue of industrial policy and how to promote industrialization. The conventional wisdom is that economic development requires some form of broad industrialization, particularly labor-intensive manufacturing, which brings employment to large numbers of people and shifts labor from the agricultural to the manufacturing sector. Historically, we have seen that if countries integrate their manufacturing sectors into global value chains, substantive economic growth follows. Asian economies, for example, are the prime illustration of this development path. Unfortunately, African countries are by-and-large hamstrung in their attempts to follow this path. Instead of rapid industrialization, African countries are experiencing either stagnating industrialization or worse, "premature deindustrialization," where industrialization slows down before it even really begins.[19] As a result, Africa is the least industrialized region of the world with the lowest value addition in manufacturing. In terms of creating employment, industries and manufacturing unsurprisingly play only a minor role in Sub-Saharan Africa today. Only around six percent of wage employment is in the manufacturing sector, the lowest level globally.[20] In this scenario, Sub-Saharan Africa is missing out on a tried-and-tested engine of economic and social development.

A number of reasons exist for this pattern, namely a lack of integration into world trade and global value chains, poor governance, missing infrastructure, lack of capital and skills, relatively high wages for manufacturing jobs,[21] and an industrial sector that is outpaced by foreign producers in terms of the availability, price, and quality of products. Moreover, in an effort to avoid a prescriptive, top-down approach to development, African governments were discouraged from playing an active role in the industrial development of their economies in earlier decades.[22] The policy prescriptions of the Washington Consensus, together with earlier policies promoted by international financial institutions such as the World Bank, emphasized the potential for development through free market capitalism and by allowing market forces – rather than government – to work in designing national industrial policies and regulations.[23] In recent years, however, as the failures of this "one size fits all" approach have become more pronounced, this has begun to change, and industrial policies in Sub-Saharan African countries have become much more common.[24] Countries such as Kenya, South Africa, Ethiopia, and Nigeria, for example, are developing industrial policies promoting more labor-intensive manufacturing and industrialization.

As is the case with the social structure described above, the regulatory policies in Sub-Saharan African countries, particularly labor market and industrial policies, are having competing effects on automation uptake. On the one hand, labor market policies such as minimum wage and worker protection laws are generally conducive to greater automation, as they can be a disincentive for firms to hire workers in the future. This is because, as automation technologies become cheaper, the cost-benefit calculation for replacing workers with automated labor becomes more attractive. Moreover, organizations can avoid costly litigation and compliance measures of worker protection laws by substituting automated replacements for humans in the future.

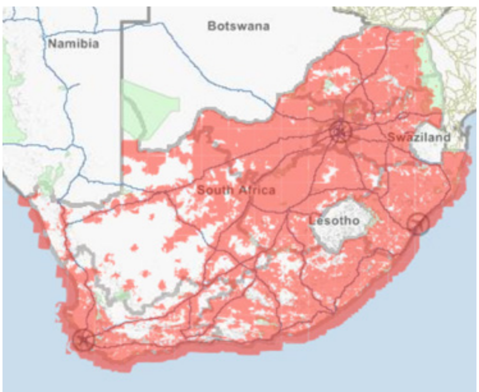
On the other hand, existing industrial policies in Sub-Saharan African countries, even those from Kenya, South Africa, Ethiopia, and Nigeria, are currently not conducive to greater automation. At this point, no African country has an official industrial policy that promotes the use of automation technology or that positions itself in a global economy that increasingly leans toward greater automation.[25] The pan-African resolve of the Third Industrial Development Decade for Africa (IDDA III), set to cover the period of 2016 to 2025, also makes no mention of digitalization and automation in its ten priority areas in support of Africa's industrialization.[26] The lack of focus on automation should not come as a complete surprise. While experts often discuss leapfrogging toward the fourth industrial revolution as a solution for Sub-Saharan African development, and highlight innovative African approaches, such as the mobile phone payment service M-Pesa or the start-up scenes in Ghana, Kenya, Nigeria, or Rwanda as signals of such a path, the fact is that widespread leapfrogging may not be realistic due to several existing challenges. The lack of infrastructure and capital (see below), inability to compete with more advanced economies, weak integration into global value chains, and insufficient regional trade, among other issues, all represent fundamental challenges to bypassing the second or third industrial revolution and entering the second machine age directly. African states increasingly pay heed to prioritizing these issues in industrial policies. Reforms aimed at addressing such challenges are long overdue, yet their prioritization leaves little space for pursuing automation as a potential driver of industrial competitiveness, at least for now.

Infrastructure and capital: Widely lacking and heavily constraining automation uptake

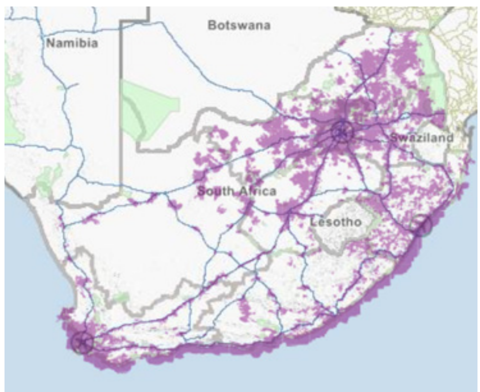
Deficiencies in the availability of capital as well as in infrastructure represent two key factors that will inhibit the uptake of automation technology in Sub-Saharan Africa. First, capital is critical for financing investments to bring organizations into the future. Yet, despite reforms and recent growth, the financial and banking system in Sub-Saharan Africa is largely underdeveloped, and access to finance in Sub-Saharan Africa is among the lowest in the world, presenting a key obstacle to the activity and growth of enterprises.[27] While capital is available in some parts of the economy, most African small and medium-sized companies have neither the financial means nor the access to capital. As a rule of thumb, credit for firms seeking to invest comes with high interest rates and service fees, making borrowing money less attractive unless the investment is set to pay off. This situation is due to an often oligopolistic banking sector that limits competition among banks, high-cost operations, strong hedging against non-performing loans, credit default by banks, and high central bank interest rates.[28] All this contributes to high interest rates, which themselves make credit defaults more likely, further reducing the appetite of banks for potentially risky loans, such as those financing future technologies. As a result, SMEs across Africa are constrained in their access to both credit and international capital markets.[29]

Second, deficient or outdated infrastructure will inhibit greater automation. Automation hinges on a reliable infrastructure – both physical and digital. Concerning the former, energy supply is a critical component. Yet power cuts are common and electricity supply remains unstable across much of Sub-Saharan Africa.[30] The digital infrastructure, in particular internet access, remains severely limited. While the region has the fastest-growing proportion of internet users, internet penetration is still comparatively low in Sub-Saharan Africa, ranging on the low end from 12 percent in Central Africa to 51 percent in Southern Africa.[31] Not only is internet penetration small, it is also largely based on mobile connections with limited speed and high costs. 2G and 3G are common, whereas the Long-Term Evolution (LTE) standard is heavily restricted and often limited to urbanized areas – as the example of South Africa below shows (Figure 5). Those on the continent with access to mobile internet pay comparatively high prices – particularly in relation to average monthly earnings.[32]

Figure 5: Mobile data coverage in South Africa (by Vodacom)



3G coverage (Vodacom)



LTE coverage (Vodacom)

Source: https://www.vodacom.co.za/vodacom/coverage-map.

Further, the likelihood of a 5G rollout, the data standard necessary for many Internet of Things (IoT) applications and automated industrial processes, is limited since telecommunications providers must continue to invest in legacy structures such as 2G and 3G, their main source of revenue, and face limited markets for data-intensive applications that would generate revenue to pay off the 5G investments. As the chief executive officer of MTN, one of Africa's largest telecommunication companies, explained, "[5G] is the technology that would be used for very specific cases. It would not be a technology for everybody because most people don't need it, your phone works fine on just 3G … and 3G is much more relevant in most of our markets."[33] Right now, only a few countries, namely Nigeria, Kenya, and South Africa, are beginning to prepare for 5G networks.

Since 5G applications for industries are generally not in demand across Sub-Saharan Africa, it is a chicken and egg problem resulting in comparatively slow 5G investment. The infrastructure to run 5G networks is particularly expensive given the nature of the 5G spectrum where signals must be repeated extensively, requiring a much higher number of antennas and repeaters than the older technology. While 40,000 new cellular towers are expected to be installed across Africa by 2021 for the existing spectrum, the fiber optic infrastructure needed to support moving mobile traffic from cell towers to network centers also remains limited.[34] Further, the potential for Africa to leapfrog in terms of digital infrastructure by going fully mobile is quite unlikely given the continent's historical trouble with affordability and regulatory inefficiency that plagued the development of 3G and 4G networks.[35] That said, some firms with deep pockets might develop their own closed 5G infrastructure to enable automation and IoT applications. These would then be proprietary systems operating only in particular locations, such as in mines or factories.

Beyond the unlikely availability of 5G networks across Africa in the short to medium terms, high-bandwidth fixed internet connections are largely concentrated in Africa's urbanized areas, such as Abidjan, Lagos, Nairobi, or Johannesburg. A study by Hamilton Research found that between 2010 and 2017, network expansion had brought more than 262 million more people within access to high-capacity national and international backbone networks.[36] Private sector investments are particularly noticeable in this regard, with US technology firms laying fiber optic cable as an investment to allow African customers to better use their services. Google, for instance, laid 1,000 kilometers of cable each in Kampala, Uganda, and in Accra, Ghana while Facebook plans for around 800 kilometers of fiber optic cable in Uganda.[37] Africa's rural areas, however, will remain largely without access to fixed-line and high-bandwidth internet. This is not surprising given that fiber optic cables require large investments, and their economic viability in rural Sub-Saharan Africa is limited. The last mile – where end users actually connect to the internet – is overwhelmingly served by mobile broadband, a factor that ultimately limits the extent to which automation can take place across rural Sub-Saharan Africa. In rural areas, the last mile problem will prevail for a long time, making it less likely for new technologies to reach, for instance, smallholder farmers as quickly as larger commercial enterprises located near economic centers. Another indicator of limited information technology (IT) readiness is the number of data centers that enable companies to rent server space or install IT infrastructure. The city of Hong Kong, for instance, has almost exactly the same number of colocation data centers as all of Sub-Saharan Africa combined.[38] Given that supply is generally a consequence of demand, the data center example aptly illustrates the lack of demand among local businesses for data storage and points to their non-digitalization.

In sum, the lack of capital, particularly for SMEs, and unfavorable borrowing conditions for investing in new technologies, together with still underdeveloped digital infrastructure across most of Sub-Saharan Africa, represent critical factors inhibiting widespread automation across Sub-Saharan Africa.

Economic viability: Automation only viable for some

The last major factor influencing the trajectory of automation technologies in Sub-Saharan Africa is the economic viability of doing so. It is not possible to credibly discuss this with respect to all economic activities across Sub-Saharan Africa; economic viability is a highly contextualized calculation that each firm must undertake on its own. Nevertheless, broadly speaking, low wages generally favor workers over costly automation technology, and we can reasonably expect little to no uptake across Sub-Saharan Africa in sectors where labor remains cheap in the long term. At the same time, there is much greater economic viability of automation technology in those segments of Sub-Saharan African economies characterized either by high individual salaries, where profit margins are low due to high total payroll costs, or where competition in the market is high. In Sub-Saharan Africa, two groups fit these criteria, namely scaled-up retail and consumer market companies, as well as the high-wage manufacturing and service sectors.

First, the scaled-up retail and consumer market companies are a consequence of a rapidly growing African consumer market. While poverty remains widespread, a lower-middle class, a middle class, and affluent segments of Africa’s population are expanding rapidly and driving growth in the consumer market – in particular in urban areas where retail chains operate.[39] Even though the definition of *middle class* and the economic threshold for qualifying as such are debatable, economic data show that a new class of consumers is emerging that accounts for around a quarter of Sub-Saharan Africa’s population; these are active earners getting by on $2 to $5 per day and straddling the formal and informal worlds.[40] This growth in household income strongly affects producers and service providers of consumable goods. Unsurprisingly, the consumer market in Africa has remained on an upward trajectory for the past several years: Boston Consulting Group, an international management advisory, puts the figures at an annual growth rate of seven percent from 2005 to 2015.[41] Looking toward the future, it expects further growth in the African consumer market of around 12 percent annually over the next two decades. Yet, firms operating in the consumer market often require a high volume of employees, which in turn results in high staff costs and lower margins. Current automation technology designed for the retail market offers a means to lower costs, and some African companies have tested such technology: South African grocery chain Pick n Pay, for instance, tested self-service checkout in 2016 in one of its supermarkets – it was, however, forced to stop the trial due to strong labor union opposition for supposedly jeopardizing workers' jobs.[42] Nigerian start-up OyaPay seeks to bring an app-based self-checkout system to select supermarkets in Lagos in early 2019.[43] Such automation – if other limiting factors do not intervene – will likely advance further in the African retail sector and adjacent sectors, particularly in back-end retail logistics, since these economic activities are labor intensive and are increasingly automatable, given existing technologies. Automation in the consumer market ecosystem hereby also hinges on economies of scale that significantly affect cost-effectiveness calculations. A number of pan-African or regional retail chains such as Pick n Pay, Shoprite, and Nakumatt have already reached such scale, making the use of automation technologies more likely.

Second, Sub-Saharan African countries have seen growth not only in the consumer market, but in the services sector as well. As of 2015, services represented 58 percent of Sub-Saharan Africa's gross domestic product (GDP), and services continue to fuel economic growth on the continent.[44] The service sector can be split into two broad areas: low-productivity/low-wage services and high-productivity/high-wage services.[45] While the overwhelming majority of those finding work in the service economy are part of the first category, a growing number of Sub-Saharan Africans are finding work in the formal service economy characterized by work contracts and salaried employment, such as in the banking, insurance, and consulting industries. Work in such occupations with a strong focus on cognitive tasks are paid comparatively well, and automation through software offers a way to lower costs for some cognitive tasks. South African banks have introduced robotic process automation to automate rules-based and repetitive tasks. Rand Merchant Bank (RMB), for example, has opened a Robotics Centre of Excellence that uses ten bots in 14 different projects. In a press release, the company made an unambiguous business case for robotic process automation: "Robots are 'a virtual workforce' that operate 24 hours a day, with 100 percent efficiency, and can reduce costs by between 25 and 40 percent ... It is projected that one of the robotics projects introduced in RMB's Corporate Banking division's finance department will save about 4,000 hours per year."[46] 4,000 hours per year is the equivalent of two human employees working

40 hours per week for 50 weeks. The economic viability of a digital coworker is clear, and we can expect that other Sub-Saharan African firms will consider such automation technology if they find themselves in similar circumstances, particularly when wages are high and skills are not readily available.

While such economic viability considerations should occur more regularly in the retail sector and high-wage economic activities, the economic case for automation is not exclusively determined by a narrow calculation of total costs of labor versus total costs of automation technologies, but more broadly by concerns over productivity and competitiveness. Africa has around 400 companies with an annual revenue greater than $1 billion or more and hundreds more firms with an annual revenue above $250 million per year.[47] These firms likely have both the financial means to introduce automation technologies and the strategic outlook to grow or at least defend their market shares. Where policies do not insulate these companies from foreign competition, it is fair to assume that firms will have to react in one way or another to more productive foreign (or domestic) competitors. Automation technology is one potential way for them to increase their competitiveness.

1 African Development Bank (AFDB), Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), and Inter-American Development Bank (IDB), The Future of Work: Regional Perspectives (2018).

2 International Monetary Fund (IMF) (2018), The Future of Work in Sub-Saharan Africa (Washington, DC: IMF).

3 Banga, Karishma; te Velde, Dirk Willem (2018), Digitalisation and the Future of Manufacturing in Africa (London: Overseas Development Institute).

4 World Bank (2017), Trouble in the Making? The Future of Manufacturing-led Development (Washington, DC: World Bank); World Bank (2018), World Development Report 2019: The Changing Nature of Work (Washington, DC: World Bank).

5 See, for instance, Brookings Institution, Access Partnership (2018), “Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation” (Washington, DC: Brookings Institution); Brookings Institution (2018), Foresight Africa, “Top Priorities for the Continent in 2018” (Washington, DC: Brookings Institution); Cilliers, Jakkie (2018) “Made in Africa: Manufacturing and the Fourth Industrial Revolution” (Pretoria, South Africa: Institute for Security Studies); United Nations Economic Commission for Africa (UNECA) (2016), “Transformative Industrial Policy For Africa” (Addis Ababa, Ethiopia: UNECA); World Wide Web Foundation (2017), “Artificial Intelligence: Starting the Policy Dialogue in Africa” (Washington, DC); Pathways for Prosperity Commission (2018), “Charting Pathways for Inclusive Growth: From Paralysis to Preparation” (Oxford: University of Oxford, Pathways for Prosperity Commission).

6 United Nations Population Fund (UNFPA) (2018), "State of World Population 2018" (New York: UNFPA).

7 Ibid.

8 International Labor Organization (ILO) (2017), Global Employment Trends for Youth 2017. Paths to a Better Working Future (Geneva: ILO).

9 United Nations Economic Commission for Africa (UNECA) (2016).

10 International Labor Organization (ILO) (2018), World Employment Social Outlook: Trends 2018 (Geneva: ILO).

11 World Bank (2017), "Skills For Africa Today and Africa Tomorrow," Africa's Pulse 16.

12 World Bank (2017).

13 Ernst & Young (2014), "Sub-Saharan Africa Talent, Trends, and Practices Survey", accessed December 8, 2018, https://webforms.ey.com/Publication/vwLUAssets/EY-2014-SSA-Talent-Trends-Survey-Report/$FILE/EY-2014-SSA-Talent-Trends-Survey-Report.pdf.

14 While workers with mid-level qualifications required for typical manufacturing jobs are generally scarce, Africa's many university graduates have difficulties finding employment because they tend to be overqualified for the available positions.

15 Bhorat et al (2016)., "Understanding and Characterizing the Services Sector in South Africa: An Overview" (UNU-WIDER Working Paper no. 2016/157, Helsinki, Finland), p. 5.

16 World Bank (2018), Doing Business 2018, Reforming to Create Jobs (Washington, DC: World Bank Group).

17 Bhorat et al. (2017), "Minimum Wages in Sub-Saharan Africa: A Primer," The World Bank Research Observer 32, no. 1.

18 Bhorat et al. (2017).

19 Rodrik, Dani (2015), "Premature Deindustrialization" (National Bureau of Economics Research [NBER] Working Paper no. 20935, Cambridge, MA).

20 Rodrik, Dani (2015).

21 Alan Gelb and colleagues from the Center for Global Development pointed this out in 2017 in their study, "Can Africa Be a Manufacturing Destination?" As to why Sub-Sahara Africa generally has a high-wage structure in manufacturing is not fully determined. A number of explanations have been debated, see https://www.cgdev.org/blog/why-are-labor-costs-so-high-africa-lively-twitter-debate, accessed November 10, 2018.

22 Yong, L. (2014) "The Return of Industrial Policy in Africa," GREAT Insights 3, no. 5, accessed January 28, 2019, https://ecdpm.org/great-insights/value-chains-industrialisation/return-industrial-policy-africa/.

23 Peterson Institute for International Economics (PIIE) (2002), "What Washington Means by Policy Reform" (Washington, DC: PIIE).

24 A useful summary and critique of the Washington Consensus was presented by economist Joseph E. Stiglitz in Stockholm in September 2016. The presentation is available at https://www.sida.se/globalassets/sida/sve/aktuellt-press/stiglitz-stockholm-september-2016.pdf, accessed January 16, 2019.

25 South Africa is currently seeking to position itself and has created the Future Industrial Production & Technologies (FIP&T) unit within the Department of Trade and Industry.

26 United Nations General Assembly (UNGA) (2016), "Third Industrial Development Decade for Africa (2016–2025)" (New York: UNGA).

27 European Investment Bank (EIB) (2013), "Banking in Sub-Saharan Africa: Challenges and Opportunities" (Kirchberg, Luxembourg: EIB).

28 Most African countries have central banks rates above 10 percent. Ghana, for instance, charges its commercial banks 17.0 percent, Angola 16.5 percent, Democratic Republic of the Congo 14.0 percent, and Nigeria 14.0 percent to refinance or borrow capital for lines of credit. See http://www.centralbanknews.info/p/interest-rates.html, accessed November 26, 2018.

29 EIB (2013).

30 African Development Bank (AFDB) (2017), "The Bank Group's Strategy for The New Deal on Energy for Africa 2016–2025" (Abidjan, Côte d'Ivoire: AFDB).

31 Kemp, Simon (2018), "Digital in 2018: World's Internet Users Pass the 4 Billion Mark", accessed December 8, 2018, https://wearesocial.com/blog/2018/01/global-digital-report-2018.

32 Alliance of Affordable Internet (2018), "New Data: What's the Price of 1GB of Mobile Broadband across LMICs", accessed January 21, 2019, https://a4ai.org/new-mobile-broadband-pricing-data-2018.

33 ET Telecom (2018), "Africa Is Not Ready for Super Fast 5G Network: MTN's CEO", accessed December 2, 2018, https://telecom.economictimes.indiatimes.com/news/africa-is-not-ready-for-super-fast-5g-network-mtns-ceo/65775506.

34 Frost & Sullivan and Principal (2018), "5G in Africa: Connecting a Continent Ripe for Innovation", accessed December 2, 2018, https://www.principalglobal.com/documentdownload/80858.

35 Ibid.

36 See http://www.africabandwidthmaps.com/?p=5505, accessed November 23, 2018.

37 Sawers, Paul (2017), "Google and Partners Commit $100 million to African Broadband Project CSquared", accessed September 12, 2018, https://venturebeat.com/2017/05/16/google-and-partners-commit-100-million-to-african-broadband-project-csquared/.

38 See https://www.datacentermap.com/datacenters.html, accessed September 12, 2018.

39 Idehen, Sandra et al. (2017), "Drawing a Route to Market for Multinationals in Africa" (Boston: Boston Consulting Group), accessed November 17, 2018, https://www.bcg.com/publications/2017/globalization-winning-in-emerging-markets-drawing-route-market-multinationals-africa.aspx.

40 FSD Africa (2016), "Credit on the Cusp: Strengthening Credit Markets for Upward Mobility in Africa" (Nairobi, Kenya: FSD Africa).

41 Idehen (2017), accessed January 29, 2019, https://www.bcg.com/publications/2017/globalization-winning-in-emerging-markets-drawing-route-market-multinationals-africa.aspx.

42 Supermarket & Retailer (2018), "Why the Supermarket of the Future Won't Come to South Africa", accessed September 12, 2018, https://www.supermarket.co.za/news-article.asp?ID=7839&CatTags=15-Innovation%20and%20tecdigitalhnology.

43 See https://oyapay.me/oyapaygo, accessed December 15, 2018.

44 United States International Trade Commission (USITC) (2017), Office of Industries, "The Sub-Saharan African Services Economy: Insights and Trends" (Working Paper ID-046, USITC, Washington, DC).

45 Bhorat et al. (2016).

46 Business Day (2018), "Rand Merchant Bank Introduces Robots into the Bank," March 6, 2018, accessed September 12, 2018, https://www.businesslive.co.za/bd/companies/financial-services/2018-03-06-rand-merchant-bank-introduces-robots-into-the-bank/.

47 Leke, Acha; Yeboah-Amankwah, Saf (2018), "Africa: A Crucible for Creativity," Harvard Business Review, November 1, 2018, accessed December 12, 2018, https://hbr.org/2018/11/africa-a-crucible-for-creativity.

5. Outlook

Four key drivers and inhibitors to automation emerge when the factors framework is broadly applied to the case of Sub-Saharan African economies (Figure 6). The four key drivers are (1) a growing consumer market focused on efficiency and competitiveness, (2) cost considerations in high-wage economic activities, (3) labor market policies unintentionally favoring automation, and (4) lack of employee skills that can be offset more easily by automation than by training. The four key inhibitors of automation across Sub-Saharan Africa are (1) infrastructure problems, (2) widespread lack of capital to fund automation technologies, (3) abundance of labor and correspondingly low wages, and (4) lack of industrial policies promoting automation technologies in any way.

Figure 6: What is driving or inhibiting automation across Sub-Saharan Africa?

What makes automation more likely:

- A growing consumer market
- Cost considerations in high-wage economic activities
- Labor market policies
- The lack of employee skills

What inhibits automation across Sub-Saharan Africa:

- Limited infrastructure
- Lack of capital
- Cheap labor
- Lack of industrial policies

Source: Authors.

Given these drivers and inhibitors, what are the consequences for Sub-Saharan Africa, its employment and economic prospects? A number of well-cited and highly publicized studies estimate a high-level of African jobs at risk: A report by Citi and Oxford University, for example, estimates that in the next decade or two, 65 percent of jobs in Nigeria and 67 percent in South Africa are at risk of being replaced by automation.[1] For Ethiopia, the report projects an even higher 85 percent. The World Economic Forum (WEF) paints a similarly grim picture: 41 percent of work activities in South Africa, 44 percent in Ethiopia, 46 percent in Nigeria, and 52 percent in Kenya are susceptible to automation.[2] Other researchers project less gloomy developments, but nonetheless still see significant disruptions of African labor markets in the near future. Daniel B. Le Roux, for example, calculates that 3.6 million South African workers, or just over 27 percent of all workers in the country, are highly susceptible to computerization through advances in artificial intelligence and robotics.[3]

While these projections may (or may not) prove to be correct, this discussion paper argues that it is critical to understand that it is not only technology that will determine the likelihood of job losses, but that a range of factors are driving or hindering the widespread use of automation technologies across Sub-Saharan Africa. The existence of automation technology alone is not what will determine the future of work and how many workers *will* lose their jobs. Rather, as this paper argues, more accurate forecasting of the potential implication of automation on a country or economic sector requires a wider analysis of other more fundamental conditions, such as the social, regulatory, economic, infrastructural, and capital factors presented in Chapter 3. Having highlighted the most critical factors concerning Sub-Saharan Africa in Chapter 4, this discussion paper presents three main implications regarding the potential impact of automation on the future of work in Sub-Saharan Africa.

First, widespread automation across Sub-Saharan Africa is unlikely in the short to medium term, as there will likely be limited usage of automation technology in agriculture as well as very little replacement of workers in the informal economy. Second, some sectors and types of occupations found in Sub-Saharan Africa will likely see rapid automation and replacement of human labor in the coming years, particularly in high-wage manufacturing and the high-wage service economy. This is particularly troublesome, as these developments will strongly affect Sub-Saharan Africa's growing middle class holding formal employment, as well as those aspiring to join the middle class. Finally and largely beyond the control of African policymakers, firms that have offshored production *to* Africa may withdraw some or all operations, given that automation allows companies to reshore and produce closer to their domestic markets at lower cost.

Limited impact (for now) on those working in agriculture

While each country on the continent has distinct economic features, a few aspects particular to Sub-Saharan Africa strongly influence how quickly and deeply automation and its different use-cases will expand on the continent. First, Sub-Saharan African economies are to a large extent primary sector economies where extraction of natural resources and farming are the key drivers of GDP creation and employment. The World Bank estimates that agriculture provides work (but often not formal employment) to around 57 percent of Africa's population.[4] In some countries, the numbers are even higher, with more than 80 percent of the labor forces in Burundi, Burkina Faso, and Madagascar working in agriculture.[5]

Given an increasing demand for agricultural products, brought on largely by Africa's population growth, imports or a greater commercialization of farming in Africa, or both, will be needed. Since commercial and large-scale farming in Africa is generally mechanized already, there is potential for a greater use of automated systems if capital and infrastructure allow for the purchase and use of such systems. While this may increase farm productivity, the (un)employment effect will likely be modest given that mechanized commercial farm operations generally are less labor-intensive per hectare than smallholder farms. Smallholder farming, the dominant type of farming across Sub-Saharan Africa, will likely see a different development path with little to no automation in the near future due to poor physical infrastructure and weak extension support. At this point, there are about 51 million farms, of which roughly 41 million are smaller than two hectares in size.[6] Most individuals farming on two hectares or less are subsistence farmers who are generally not commercializing their harvests and have little financial means to buy typical farming inputs, such as seeds and fertilizers. While digitalization may bring services to smallholder farmers that allow them to increase productivity and use available resources more efficiently, automation does not pose much of a risk to human labor here.

While capital (and the lack thereof) is a key factor determining usage of automation technology, low wages and a growing labor abundance in rural Sub-Saharan Africa is another reason why small, non-commercialized farms will not introduce automation technology. Due to population growth, rural Sub-Saharan Africa will see both shrinking farm sizes (making accumulation of capital by smallholder farmers increasingly difficult) and more wage employment of those unable to secure a farm for themselves. Competition for farming jobs and the informality of the farming economy will likely lead to wage competition among young Africans seeking to secure farming work.[7] Under such conditions, human farm hands are likely to be cheaper than automated systems and do not require up-front investments.

In sum, automation technology will likely have very limited impact on non-commercial farming across Sub-Saharan Africa and, in turn, few direct consequences for the majority of those seeking or finding work in agriculture. It is possible, however, that this situation will change if and when commercialized farming increasingly takes hold and – besides requiring less overall labor – begins competing on price with small-scale farmers attempting to earn a living.

Limited impact on unskilled workers and informal employment

From an economic perspective, pessimistic job loss scenarios do not fully take into account the particular economic structures found in many African countries. Many Sub-Saharan economies are highly localized, with informal businesses characterized by single entrepreneurs, small firms, or family businesses. Haroon Bhorat and colleagues claim that the informal, non-wage-earning sector comprises 81 percent of the total employment in Sub-Saharan Africa.[8] This is slightly less than an earlier World Bank assessment, which states that around 16 percent of those in the labor force have wage jobs, and conversely, 84 percent are in the non-wage-earning sector.[9] While statistics on the African labor market should be taken with caution, these numbers point to a general trend: employment is highly informal and wage jobs are the exception.

The World Bank makes the grim projection that this pattern is set to stay: “Over the next ten years, at best only one in four of Sub-Saharan Africa’s youth will find a wage job – and only a small fraction of those jobs will be 'formal' jobs in modern enterprises. Most young people will end up working where their parents do – in family farms and household enterprises."[10] Given the projected population increase and the labor glut due to a growing labor force entering the job market every year and potential worker displacements by machines in other sectors, it is likely that wage competition and the easy access to low-paid manual labor jobs will make it economically unviable or unattractive for firms to invest in automated systems. Low wages simply provide employers with few incentives to automate to save labor costs. These conditions will likely shield many of Sub-Saharan Africa's economies from the consequences, both positive and negative, of automation in the decades to come.

The patterns of automation in a particular country are also partially dependent on the extent to which economic activities occur in the primary, secondary, or tertiary sectors, as well as the level of formal employment found therein. A country's economic structure creates a path-dependency and determines the areas in which automation makes economic sense. Researchers at the McKinsey Global Institute point out that, even among advanced industrial economies, there are significant differences in automation potential and that the variations are a consequence of particular economic structures.[11] They point out that Japan has a greater automation potential than the United States simply because the proportion of jobs in more easily automatable tasks, such as production and basic office administration and support, is higher in Japan compared to the United States, where a relatively higher proportion of jobs require advanced engineering, management, and other more specialized expertise.[12] Furthermore, in lesser-developed economies, the level of informal employment – namely non-wage-earning jobs in agriculture or other unregulated areas of work – is much higher and very unlikely to be automated, given intense competition for labor, and limited infrastructure and capital.

Strong impact on high-wage manufacturing and services

While Africa's informal economy, and its agricultural sector in particular, remain somewhat shielded from direct introduction of automation technologies, there will likely be greater direct impact of automation technologies on both the high-wage service economy and on high-wage manufacturing. While it is difficult to make conclusive statements on complicated economic considerations, it is likely that particularly high-wage positions are at risk, as high labor costs alter case-by-case feasibility assessments and because these occupations often occur in environments where digital infrastructure, capital, and competition exist. Counter to the common expectation that routine tasks and low-skilled labor are most at risk from automation, we see instead Sub-Saharan Africa's rising middle class under threat.

While the secondary sector is at the center of economic activities in many industrialized economies, it generally plays a less prominent role in Sub-Saharan Africa. Compared to the size of the primary sector, the secondary sector – namely manufacturing – remains quite small, playing just a small role in GDP creation except in more advanced African economies such as Kenya, Namibia, Nigeria, and South Africa. Although in absolute terms, manufacturing has increased across Sub-Saharan Africa, in relative terms it has not. A report from the United Nations Conference on Trade and Development (UNCTAD) states that, for the period between 2005 and 2014, relative to the economy as a whole, the share of manufacturing in GDP has slightly declined to around ten percent.[13] In terms of creating employment, industries and manufacturing play only a minor role in Sub-Saharan Africa, with only around six percent of wage employment in the manufacturing sector – the lowest level globally.[14]

Nevertheless, despite making up a small portion of wage employment, manufacturing jobs in Sub-Saharan Africa will likely be among the hardest hit by automation for three key reasons. First, the manufacturing sector is one of the most susceptible to automation trends, as the "easiest" professions to automate are those where work activities are primarily physical, repetitive, and non-cognitive – traits consistent with a number of production jobs. The McKinsey Global Institute estimates that more than 90 percent of common manufacturing jobs, such as welding, cutting, and soldering, are susceptible to automation based on technologies that already exist.[15]

Second, the phenomenon of reshoring production back to developed countries at the expense of manufacturing jobs in emerging and developing economies is only set to grow. Whereas in the past, the convergence of globalization and digitalization trends enabled the fragmentation of production across multiple locations, advances in automation technology enabling more non-routine and cognitive tasks – for example, sensors, artificial intelligence, and robots with greater dexterity – are eliminating the incentives for offshoring production. As the total cost of automation falls, the economic justification for offshoring – taking advantage of the differential in labor costs between developed and developing countries in the manufacturing sector – becomes less convincing. A study released in October 2018 by the International Labour Organization, for example, found that increasing automation in developed countries would negatively affect employment in emerging countries that are experiencing rising labor costs.[16]

However, where the total cost of production continues to be cheaper than the total cost of automation, for example in developing countries not yet experiencing rising wages from the maturation of an industrial economy, there is less risk that production facilities will be automated or reshored. In this respect, manufacturing in many Sub-Saharan African countries may, at least in the short to medium term, remain somewhat insulated from reshoring trends until the calculus changes. In the medium to long term, however, the impact of these developments will be more profound. With manufacturers' ability to produce at lower cost and higher quality in developed countries, together with a reduction of costs related to transport and trade due to production closer to consumers, the incentives for reshoring are adding up.

Finally, it is possible that Sub-Saharan African countries are not at risk of being completely shut out of global value chains, given their relatively low labor costs compared to costs in emerging and developed economies. The more pressing risk is the increasing digital divide between developed, emerging, and developing countries. Put more simply, Sub-Saharan African countries are at risk of falling behind the digital times. As global value chains become increasingly automated and digitalized, those countries without adequate digital infrastructure will struggle to remain competitive.[17]

1 Frey, Carl Benedikt; Osborne, Michael (2016), Technology at Work v2.0: The Future Is Not What It Used to Be (Oxford, UK: Oxford Martin School, University of Oxford, and Citi GPS).

2 World Economic Forum (WEF) (2017), "The Future of Jobs and Skills in Africa: Preparing the Region for the Fourth Industrial Revolution" (Geneva: World Economic Forum), accessed September 24, 2018, https://www.weforum.org/reports/the-future-of-jobs-and-skills-in-africa-preparing-the-region-for-the-fourth-industrial-revolution.

3 See https://theconversation.com/many-south-african-jobs-could-soon-be-automated-and-the-country-isnt-prepared-99689, accessed December 15, 2018.

4 See https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=ZG, accessed December 12, 2018.

5 Sow, Mariama (2017), "Figures of the Week: Sub-Saharan Africa's Labor Market in 2017" (Washington, DC: Brookings Institution), accessed December 12, 2018, https://www.brookings.edu/blog/africa-in-focus/2017/01/11/figures-of-the-week-sub-saharan-africas-labor-market-in-2017/.

6 Alliance for a Green Revolution in Africa (AGRA) (2017), Africa Agriculture Status Report: The Business of Smallholder Agriculture in Sub-Saharan Africa (Nairobi, Kenya: AGRA).

7 International Labour Organization (ILO) (2018), "The Future of Work in African Agriculture: Trends and Drivers of Change" (Research Department Working Paper no 25, ILO, Geneva).

8 Bhorat et al. (2017).

9 World Bank (2014).

10 Ibid.

11 McKinsey Global Institute (2017).

12 Chui, Michael; Manyika, James; Miremadi, Mehdi (2017), "The Countries Most (and Least) Likely to Be Affected by Automation," Harvard Business Review, April 12, 2017, accessed October 20, 2018, https://hbr.org/2017/04/the-countries-most-and-least-likely-to-be-affected-by-automation.

13 United Nations Conference on Trade and Development (UNCTAD) (2017), Trade and Development Report 2017. Beyond Austerity: Towards a Global New Deal (New York and Geneva: UNCTAD).

14 Ibid.

15 McKinsey Global Institute (2017).

16 ILO (2018), "Robots Worldwide, The Impact of Automation on Employment and Trade" (Working Paper no. 36, ILO, Geneva).

17 Banga, Karishma and te Velde, Dirk Willem (2018).

6. Conclusion

Is automation a major threat to Sub-Saharan African workers? For the most part, the answer is no. At least not yet. Sub-Saharan African countries, or significant parts of their economies, lack the infrastructure and capital for even a limited use of the automation technology discussed in this paper. Many countries on the continent are yet to implement earlier technological breakthroughs – including mechanization and digitalization – on a larger scale. This effectively hinders most Sub-Saharan African countries from the introduction of advanced automation technologies. Moreover, their informal economies consist largely of subsistence farmers, street vendors, and day laborers, and abundance of labor and, consequently, low pay make it cheaper to have human workers instead of robots or software doing the job.

At the same time, those segments of the African economy that are not informal, that are well-connected in terms of infrastructure, well-capitalized, or have access to financial markets, where comparatively high wages are paid and where competition is a concern will likely introduce automation technologies to some degree. Under such circumstances and with today's availability to source automation technology globally, firms *can* automate, and one should expect that they do in a short-to-medium time frame *if* it is economically viable and investments in technology pay off. In those Sub-Saharan Africa countries on par with other emerging economies or even industrialized countries, one can expect that white-collar workers in particular will be the first to see greater automation. Africa's middle class and those aspiring to be part of it will be among the most affected by automation.

While this certainly spells trouble for Sub-Saharan Africa's middle class, which has just managed to attain its status over the past few decades, the two-tier structure that effectively shields most existing jobs from modern automation is problematic for another reason: it puts the majority of Sub-Saharan African countries even further behind in terms of competitiveness. Moreover, it prevents their integration higher up within global value chains and thus makes much-needed job creation and value addition on the continent increasingly difficult. Export-led economic growth that goes beyond the extraction and selling of raw materials seems increasingly distant under such a scenario. In a way, the automation revolution currently underway is a double-edged sword for Sub-Saharan Africa: promoting the conditions to introduce automation technologies on the continent, and with firms eventually automating labor, is a problem in the short run for all those directly displaced by technology. They would have to find new employment in a labor market generally characterized by labor abundance and high levels of unemployment. Policymakers can hardly be expected to spend political capital on such unpopular policies. Not promoting the conditions to introduce automation technologies, however, will keep Sub-Saharan African economies further behind the rest of the world, as other countries continue to increase their productivity and competitiveness through such technologies. In a globalized world where cheaper foreign imports have replaced expensive domestic production, the inaction of Sub-Saharan African countries is further amplified by greater strides in other parts of the globe toward the fourth industrial revolution. All this leaves Sub-Saharan African governments with difficult choices to make.

What can be done? Detailed policy proposals are beyond the scope of this paper, but three broad actions can contribute to more informed policymaking. First, more specific country- or sector-based case studies are needed. It is important that the debates around the future of Sub-Saharan Africa's manufacturing, industrialization, and jobs in the coming age of automation moves on from aggregate numbers and percentages of jobs susceptible to automation toward a more detailed and analytical assessment of the drivers and inhibitors of automation technologies that different countries and economic sectors face. This discussion paper contributes to this to some extent, but more work is required.

Second, policies specific to Sub-Saharan Africa are needed that will maximize the benefits of automation and minimize its risks. The good news is that there are already a number of policy proposals for how to take advantage of this transformation, while ensuring the relevancy of human labor – for example, a greater focus on STEM (science, technology, engineering, and mathematics) skills in educational systems to better prepare human workers for future occupations; publicly and privately organized (re)training systems to ensure lifelong learning and skills development; income support mechanisms such as a negative income tax or universal basic income schemes to provide a safety net for those displaced by automation technologies; and tax-system overhaul ideas to fund all those expenses. Yet, while these policy options are worth serious debate in the context of Sub-Saharan Africa, the economic realities and demographic trends of the continent make it all too clear that industrialized countries' proposals may not always be appropriate or realistic. Realistic policies are, however, critical, and it is important that they are developed on the continent by African experts – this need for local expertise also extends to the previous point calling for further investigation and analysis of the drivers and inhibitors of automation technologies in specific countries and economic sectors of the region.

Third, the largely theoretical discussions about suitable policies must reach government offices in Kigali, Lusaka, Nairobi, and elsewhere on the continent, as well as become a core issue for unions, civil society organizations, think tanks, and universities. So far, there is relatively little engagement on this issue within Sub-Saharan Africa and in the African Union in particular: automation and the future of work is not yet part of the political discourse. This is particularly concerning, given the relevance of automation to existing challenges such as, (youth) unemployment and industrial development, as well as to certain areas of Sub-Saharan African economies that are already susceptible to increasing automation of human labor (see Chapter 5). While this paper joins a growing number of Western attempts to understand the current and potential impact of automation on Sub-Saharan African countries, we advocate for a much broader and deeper level of engagement by African researchers, activists, and politicians to make sure Sub-Saharan Africa keeps its agency in an era of automation.

Author Profiles

Alexander Gaus is project manager at the Global Public Policy Institute (GPPi), an independent, non-profit think tank in Berlin. His research and consulting work focuses on development and humanitarian topics. In 2013, he supported the launch of the African Policy Circle, a network of leading African think tanks and has been closely involved in it since.

Wade Hoxtell is head of operations at the Global Public Policy Institute. His research focuses on international development policy, multi-stakeholder partnerships – particularly the role of the private sector in development and humanitarian assistance – as well as technology-related topics such as automation, artificial intelligence, and cybersecurity in development.

Automation is leading to a profound transformation of the economies of industrial, emerging and developing countries alike, the impacts of which will only grow over time. Yet, the rapid advancement of technology is only part of the story of what many are calling the 'second machine age'. Understanding the more fundamental set of factors that are driving or inhibiting the automation revolution – namely social, economic, regulatory, infrastructural and capital factors – is key to unlocking potential solutions for maximizing the benefits and minimizing the risks for the future of work and humans' role within it. This discussion paper presents these factors and applies them to the case of Sub-Saharan Africa, concluding that while tough times may be coming for some, the impact of automation in the region will be limited for most.