SUPPORTING ECONOMIC TRANSFORMATION

DIGITALISATION AND THE FUTURE OF MANUFACTURING IN AFRICA

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EXECUTIVE SUMMARY

The approaching Fourth Industrial Revolution, with increasing use of advanced technologies such as 3D printing and robotics, is expected to have a major impact on the manufacturing process globally. The question we address is whether developing countries can harness the digital revolution to boost their industrial growth and employment or whether they will be left behind. We examine how a growing digital economy affects developing countries' manufacturing labour productivity, with a special focus on sub-Saharan African (SSA) countries, and we discuss the policy implications.

A key message of this paper is that governments need to better prepare for the digital future. New evidence in this report suggests that African countries not only face a significant digital divide but also benefit less from increasing levels of digitalisation. To digitalise manufacturing, African countries need to increase access to the internet and other information and communications technologies (ICT). This can be achieved through implementation of effective policies that will alter country-specific conditions and contribute towards improving the investment climate, firm capabilities, national innovation systems and ICT infrastructure, direct financing opportunities, and participation in global value chains (GVCs). Taxes and incentives can serve as important drivers for bridging the rural–urban digital divide, while policies targeting public-access solutions can increase access to digital technologies. Financial support from the government needs to be extended – not only to manufacturing and services start-ups but also to ecosystem enablers such as technological and innovation hubs.

With technology increasing at a faster rate than skills, the risk of a skill mismatch is also rising. To increase the development impact of digitalisation, it is crucial for African countries to develop complementary skills. Becoming future-ready involves revising and reorienting the curriculum in African educational institutions around science, technology, engineering and mathematics (STEM) subjects. A special focus needs to be given to technical and vocational education and training (TVET), with better public–private sector collaborations a must.

In the meantime, as African countries are adapting to the digital future, there is a window of opportunity for the countries to develop those sectors that are less automated, where technology installation has been slow. African countries urgently need to build up industrial capabilities that can help them to move into higher-value-added activities. The window of opportunity for existing operations is likely to be less than 30 years, although inevitably new jobs will also be found. In the case of furniture manufacturing, we find that while in the United States (US) robots may become cheaper than US labour in the year 2023, the inflection point for Kenya comes only a decade later, in 2034, indicating a window of opportunity that is roughly 10 years longer than in the US. And US robot costs (lower financing or operating costs) will become cheaper than Kenyan wages in furniture in 2033. Ethiopia faces the inflection point between 2038 and 2042.

African countries are still facing an uphill struggle to promote labour- and export-intensive manufacturing (the share of manufacturing gross domestic product (GDP) in many African countries has remained at around 10%, and has been falling in some countries recently). Export-based, employment-intensive and higher-value-added manufacturing will continue to be core objectives for the near future, indicating the importance of first addressing standard constraints facing the manufacturing sector such as electricity costs and management practices. Improvements in basic infrastructure – a reliable power supply, telecommunications and roads – combined with a targeted approach to building industrial capabilities is needed (and we discuss this at length in other SET papers).

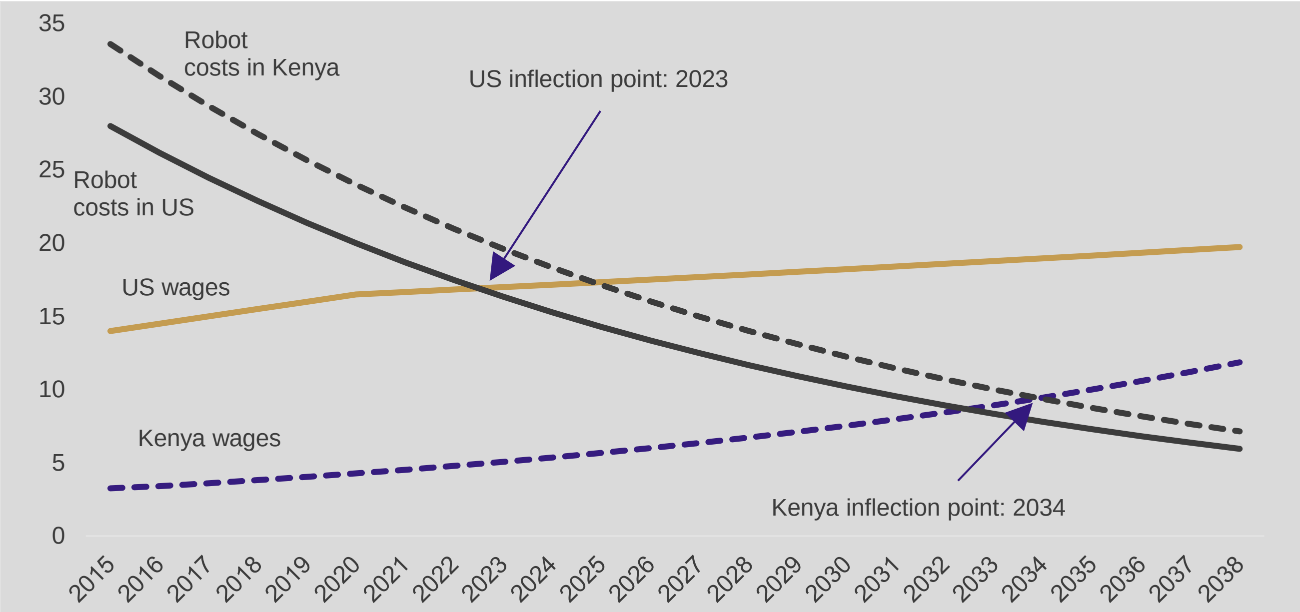
The digital divide may increase

This paper defines digitalisation as the digital transformation of the economy, achieved through an interaction of digital technologies such as cloud computing, artificial intelligence (AI), Internet of Things (IoT) etc. with physical ICT infrastructure. This can lead to significant advancements, such as the development of smart machines, smart platforms and digital products. This digital economy is supported by an enabling environment comprising 'digital skills'; 'policies and regulations' that encourage development of ICT, innovation, digital business models etc.; and 'digital accelerators' such as public–private partnerships and behavioural and cultural aspects of the economy.

Compared to developed countries, the growth of the digital economy has been higher in developing countries. However, there is a persistent global digital divide, between developed and less-developed countries as well as between developing and least-developed countries (LDCs). SSA countries are found to be significantly lagging in access to internet; in 2016, the average internet penetration rate (IPR) (% of population with access to the internet) in SSA was 10 percentage points lower than that in South Asia. SSA countries are also lagging in the use of internet for digital technologies such as cloud-computing applications, e-commerce, and deployment of smart machines such as robots and 3D printers. Africa's share in robots sold in 2015 (around 0.2% of world sales) is 15 times lower than its share in world GDP (around 3%).

A crucial factor contributing to this digital divide is that capital is more expensive in African countries, both in absolute value and relative to labour. As noted above, our analysis finds that in the case of the furniture industry, robots will become cheaper than US labour in the year 2023, but only cheaper than Kenyan labour a decade later (in 2034).

Figure A1: Window of opportunity for developing countries – the case of furniture manufacturing



Notes: Data for US furniture wages and operation costs of robots come from https://www.bcgperspectives.com/content/articles/lean-manufacturing-innovation-robots-redefine-competitiveness/ . Kenyan wages are hourly US$ calculated as total annual compensation per employee in the furniture sector (from Kenya Economic Survey 2016), divided by 2000 hours; annual nominal wage growth in the furniture sector over 2012–2016 was 7.5% a year. Kenyan operation costs of robots assumed to be 20% higher due to an approximately 10–15 percentage point difference in interest rates and higher operating (e.g. energy) costs. We estimate labour productivity increases in Kenya (real value-added per employee) to be 1.7% a year. Comparing Kenyan wages with costs of Kenyan robots applies to a closed economy model, while comparing with costs of US robots applies to an open economy model with low transport costs.

Even if the cost of robots, automation and digitalisation falls, African countries will still find it hard to *finance* digitalisation due to the high cost of financing faced by these countries. Other likely factors causing the digital divide include low digital readiness of African countries in terms of having poorer customs, trade facilitation, logistics, absorptive capacity and skills. The cost of operating and installing a robot (e.g. energy) is also more expensive in Africa.

Digitalisation, productivity and labour market

If African countries address the constraints to digitalisation, this will open up several important opportunities to improve output and exports; create jobs; reduce the cost of production, allowing small and medium-sized enterprises (SMEs) to enter the market; and reduce the costs of trading, which can enable greater GVC participation. However, if the digital divide persists in the context of a growing global digital economy then African countries will face important challenges. As the cost of capital falls in developed countries, and capital becomes cheaper than labour in offshored regions (for example, robots in US becoming cheaper than Kenyan labour in the furniture manufacturing industry by 2033 – Figure A1), developed economies will find it more efficient to re-shore manufacturing activities. This can have a significantly adverse impact on jobs in offshoring destinations. Recent evidence for the US in the period 2010–2016 suggests that for every company that re-shores production, 126 African jobs are lost.

Other international pathways through which digitalisation affects African countries include: exclusion from GVCs, concentration of digitally advanced goods in developed countries and falling wages in Africa to remain competitive. See Summary table A2.

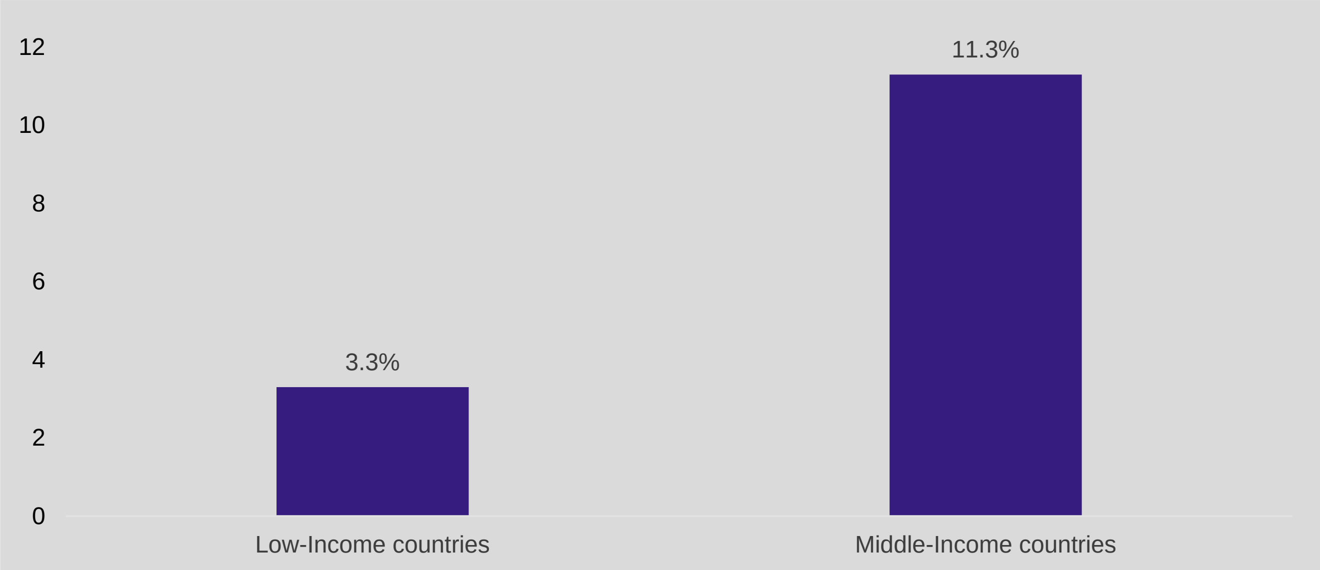
Summary table A2: Impact of digitalisation on developing countries

National-level impacts on African countries	Pathways of impact	Likely labour market impact
Opportunities	Increase in productivity	Increase in jobs
	Increase in demand for new and existing products	Increase in jobs
	Reduction in costs of production enabling new entrants and SMEs to enter the export market	Creation of new jobs
	Reduction in cost of trading leading to strengthening of GVC participation	Increase in jobs
Challenges	Substitution of labour with automation	Decrease in jobs, unskilled workers are likely to be more affected
	Cognitive robots can be used to replace skilled labour	Decrease in skilled- jobs; skilled labour moves to less-skilled jobs; increasing skill mismatching
	Increase in precarious work on digital labour platforms	Reduction in ‘good’ jobs
International-level impacts on African countries	**Pathways of impact**	**Likely labour market impact**
Challenges	Re-shoring of manufacturing	Reduction in jobs
	Automation can have a back-stopping effect; robot deployment in developed countries can pressure developing countries to become more competitive	Fall in wages for labour
	Exclusion from GVCs and concentration of future production of digitally-advanced goods in developed economies	Loss of potential jobs

In recent years, both robot densification in developed countries and re-shoring from developing regions have increased. Global trade has thus slowed down, reducing the opportunities for developing countries to catch up. While our new econometric evidence suggests there is unconditional convergence in manufacturing labour productivity across 155 countries, this slowed down in the period 2002–2013 compared to 1991–2002. For example, the rate of convergence in Sub-Saharan Africa slowed between the two periods. A slowdown in convergence, because of digitalisation, indicates that less-developed countries have fewer opportunities for catch-up.

Our empirical results also confirm this: while a doubling of the internet penetration rate (roughly what happened in Kenya between 2007 and 2012, or between 2012 and 2016) increases labour productivity by around 10% on average, this impact is 8% lower for low-income countries (LICs), at 3.3%, as compared to lower-middle- and upper-middle-income countries, at 11.3% (see Figure A3). This has also been true for SSA countries compared to others. As the economy becomes more digital, the impact of technological progress on productivity increases, but again this effect is lower in LICs and SSA.

Figure A3: Average impact of doubling internet penetration on manufacturing labour productivity (%)



Note: See Table 6 for empirical estimates of the impact of internet penetration on labour productivity.

These results suggest that digitalisation may be reducing convergence; LICs are not able to adopt the new technologies due to rising tacit knowledge and increasing complexity of digital technologies. To increase the impact of digitalisation, skill development is needed. A more skilled workforce can increase the impact of internet penetration and technological progress on manufacturing labour productivity.

Impact of digitalisation in Kenya

Kenya has emerged as an African leader of digitalisation. Internet penetration increased by roughly 25 percentage points in the period 2001–2016, with firms in the machinery–electronics–transport sector being the most digitalised, followed by firms in the chemicals–plastics–rubber sector. This increasing trend of digitalisation is tracked to improvements in telecommunications, electricity, customs and regulations. Combined and continued efforts by both the public and private sectors have been crucial. Important steps in the development of Kenya's digital economy include introduction of M-Pesa, recognition of ICT as a development pillar in the government's 2030 vision, setting up undersea fibre-optic cables, introduction of the National Broadband Strategy and the National Cybersecurity Strategy, improvement in ease of doing business, and government and private sector support to tech hubs and networks. However, while overall digitalisation has increased in Kenya, there is still a 40% to 50% difference between the percentage of firms having access to computers and internet and the percentage of firms engaging with it (for instance, having a web-presence or buying and selling online), reflecting a digital gap in access and use.

Similar to digitalisation, labour productivity also increased in Kenya in the period 2001–2016, but not by as much (roughly 2% annual growth). Formal manufacturing employment also steadily increased, and while the labour share fell, it recovered somewhat in recent years, indicating the increased volume of high-productivity manufacturing activities taking place in Kenya. Kenyan firms with internet are found to be more productive and have a higher share of skilled workers than firms without access to internet. However, employment growth is not found to be significantly different for firms with and without internet, indicating that digitalisation has not led to substitution of labour in Kenya. As firms become more digital, the share of skilled workers in total employment increases, again suggesting the importance of targeted skill-development in coordination with private sector needs.

CONTENTS

ACRONYMS

B2C	business-to-consumer sales
DVA	domestic value added
ET	electronically transmitted
FDI	foreign direct investment
GDP	gross domestic product
GVA	gross value added
GVC	global value chain
ICT	information and communications technology
IFR	International Federation of Robotics
IT	information technology
LDC	least-developed country
LIC	low-income country
RAM	remote additive manufacturing
SMEs	small and medium-sized enterprises
SSA	sub-Saharan Africa
TVET	technical and vocational education and training
UK	United Kingdom
UN	United Nations
UNCTAD	UN Conference on Trade and Development
UNIDO	UN Industrial Development Organization
US	United States
WEF	World Economic Forum

1. INTRODUCTION

Historically, industrial revolutions have resulted in changing patterns of specialisation, growth and employment. The first industrial revolution (1660s–1840s) was marked by mechanisation and harnessing of steam power, with labour shifting from only manual to more machine-based tasks. This was followed by the second industrial revolution at the start of the 20th century, with electricity-enabled mass production based on division of labour. As technology evolved, manufacturing processes were further automated with electronics and information technology (IT), bringing in the information and communications technology (ICT) revolution or the third industrial revolution. During this period, many developing countries, barring a small group of Asian counties, saw elements of ‘premature deindustrialisation’ (Rodrik, 2016). This refers to the falling shares of manufacturing in output and employment in these countries long before they achieved income levels comparable to those of developed economies.

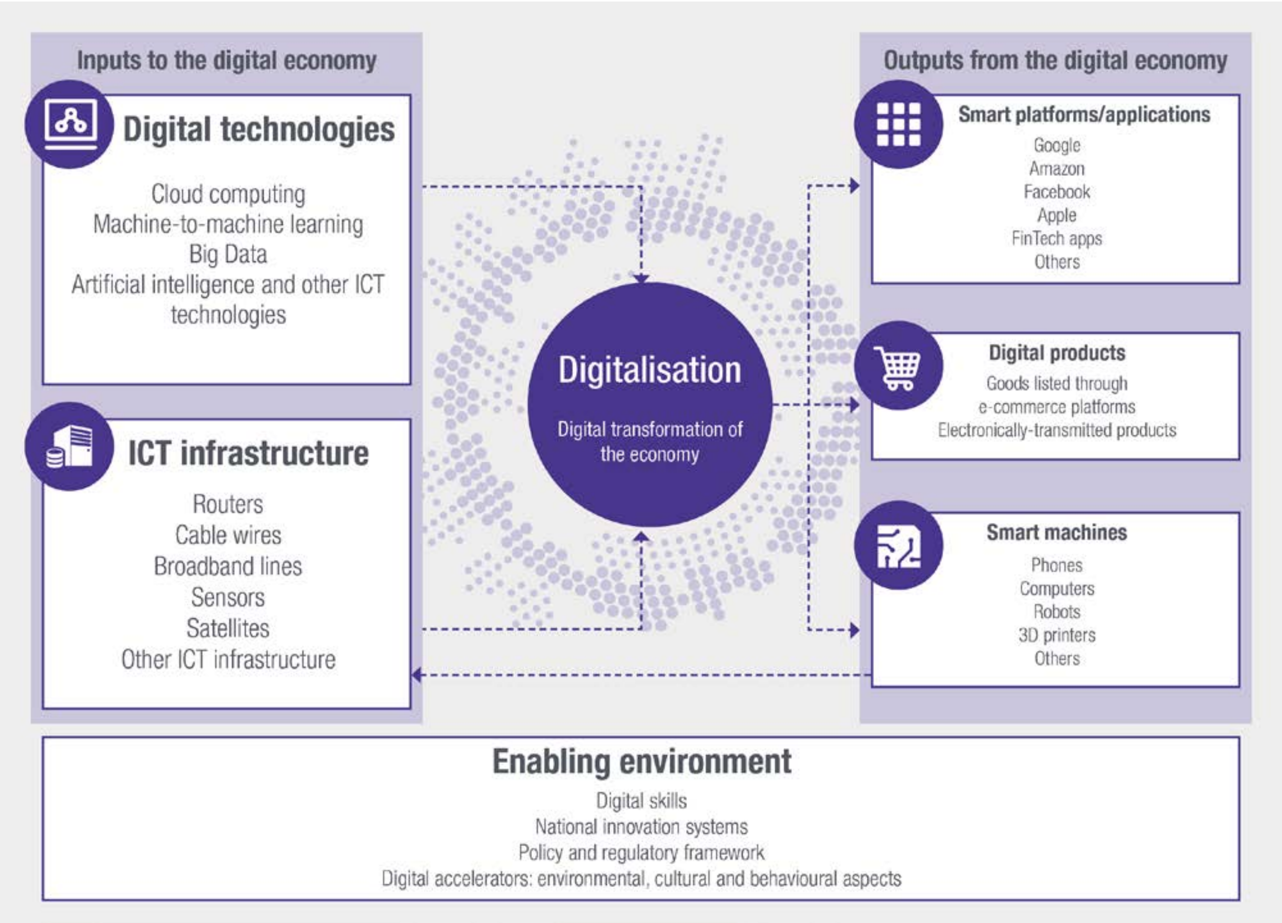
Many believe that we are on the verge of the fourth industrial revolution, with around 22% of world gross domestic product (GDP) already belonging to the digital market (Knickrehm et al., 2016). Rising digitalisation and the increasing spread of advanced technologies, like 3D printing and robots, suggest that manufacturing is being increasingly automated, which is expected to have a major impact on the manufacturing process. A question now arises: Will developing countries be able to harness the digital revolution to boost their industrial growth and employment, or will they be left behind? Given this context, the study examines how a growing digital economy is affecting developing countries’ manufacturing labour productivity, with a special focus on sub-Saharan African countries.

The structure of this paper is as follows. We first define and conceptualise digitalisation (Section 2), and then discuss the size of the digital economy (Section 3). We note the existence of a persistent digital divide between developed countries and less-developed countries, which is further explored in Section 4. Section 5 discusses conceptual pathways from digitalisation to growth, labour productivity and employment. Section 6 discusses our empirical work on the effects of digitalisation on labour productivity in African economies. Section 7 presents a case study of Kenya. Section 8 discusses the future of manufacturing in Africa, in the light of falling costs of robots and increases in wages. Section 9 concludes the study.

2. DEFINING DIGITALISATION

Definitions of the 'digital economy' have evolved over time, reflecting continuous advancements in technologies. When Tapscott (1997) coined the term, the emphasis lay on networking of humans through technology, which expanded to include the emerging phenomena of e-business and e-commerce in the early 2000s. More recently, the digital economy has been understood as a world-wide network of economic and social activities, enabled by digital technologies. For a more comprehensive understanding of the concept of digitalisation, Figure 1 maps its several aspects.

Figure 1: Conceptualising the digital economy: inputs, outputs and enabling environment



Source: Authors (2018).

The digital economy contains a range of technologies with an enormous potential to affect the organisation of production, as well as the efficiency of the production process. These include (a) mobile networks – communication networks deployed by telecommunications providers where the last link (accessed by the consumer) is wireless; (b) cloud computing – delivering technology to consumers digitally using internet servers for processing and data storage; which facilitates (c) machine learning, where machines learn from data and algorithms, without being explicitly programmed, and can communicate directly with other machines using wired or wireless channels. Through machine learning, it becomes possible to revolutionise the automation of (d) Internet of Things (IoT), defined as 'the use of sensors, actuators, and data communication technology built into physical objects' from roadways to pacemakers. This allows IoT-enabled objects to be tracked, coordinated, or controlled across a data network or the internet (Manyika et al., 2013b). IoT often generates (e) 'big data', which is characterised as data high in volume, variety, velocity and veracity and which leverages cloud computing to be cost-effective. Managing and processing of such data can be facilitated through (f) artificial intelligence (AI) – the intelligence demonstrated by machines.

These digital technologies are clearly interconnected and dynamic but need physical ICT infrastructure for operation – including routers, sensors, broadband and cable wires and satellites –as well as ICT services. A combination of physical infrastructure and digital technologies (mapped in Figure 1 as 'inputs in the digital economy') allows the economy to go beyond 'digitisation' – the process of converting data from analogue to digital form – to 'digitalisation', the process of adopting and applying digitisation to economic activities (Brennen and Kreiss, 2014). Digitalisation can therefore be understood as the digital transformation of the economy, which leads to significant advancements, such as development of 'smart machines', 'smart platforms/applications', and 'digital products'. These can be understood as 'outputs of the digital economy'.

Smart machines – driverless vehicles and cognitive robots, for example – have been enabled by cutting-edge technologies such as AI. An industrial robot is defined as 'an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications' (ISO, 2012).[1] These industrial robots are completely self-governing and do not require a human operator. Moreover, they can be programmed to perform several manual tasks, including painting, handling of material, packaging, welding etc. Contemporary robots have also gained significantly enhanced dexterity and are showing the ability to undertake complex high-skilled and cognitive tasks (TDR,[2] 2017).

Another manufacturing-revolutionising smart machine enabled through digitalisation is a 3D printer. With 3D printing, a product can be assembled by layering materials using electronic data sources or digital model data, such as additive manufacturing files. This development is indicative of manufacturing progressively shifting from trade in physical goods to trade in 'electronic goods' such as software and design files, and the consequent shortening of the manufacturing process. Consider firm A in country X, which imports plastic handbags from firm B in country Y. With 3D printing, country A can switch from importing handbags to digitally importing the computer-aided design (CAD) files from firm B, which it can then 3D print for the target market (Arvis et al., 2017). As 3D printers become cheaper, products can also be directly printed by the consumers, making production increasingly 'on demand'. For the economy, this could suggest significant changes in the way the global value chains (GVCs) are organised. More recently, new industrial 3D printers, including ones by MakerBot and Ai Build, are also AI enabled. These are essentially types of robots with 3D-printing arms, creating a scalable additive manufacturing process. Some smart machines, such as computers, robots and 3D printers, may also form part of the ICT infrastructure.

Smart platforms/applications include multifunctioning digital and e-commerce platforms such as Google, Apple, Facebook, Amazon and Alibaba (informally labelled GAFAA). These online giants store and process greater quantities of digital data than any other company, allowing them to leverage big data and algorithms to remain at the top. They also act as intermediaries between content producers and users of the platforms, essentially making them mass companies. Together these companies have market capital of around $1.5 trillion, which is almost four times the size of the five largest media conglomerates (UNCTAD, 2017). As the economy becomes further digitalised with the use of cloud computing, AI and IoT, GAFAA's power is expected to rise exponentially, rapidly eating away the competitive edge of developing countries in manufacturing trade. Consumer and enterprise mobile applications, such as FinTech apps and transport services apps like Uber, also play an integral role in the digital transformation of the economy.

As for goods being created in this digital economy, the literature has identified: (1) e-commerce products, which are physical goods being ordered digitally through the internet; and (2) electronically transmitted (ET) goods, such as music files and movies, which are available through

[1] This definition has been used in the International Organization for Standardization (ISO) Robots and robotic devices – Vocabulary. Geneva, Switzerland: ISO, 2012. (ISO 8373:2012). [Standard]

[2] Trade and Development Report.by UNCTAD

digital downloads. These ET products can also include remote additive manufacturing (RAM) products, which are created by exchange of software, CAD files etc.

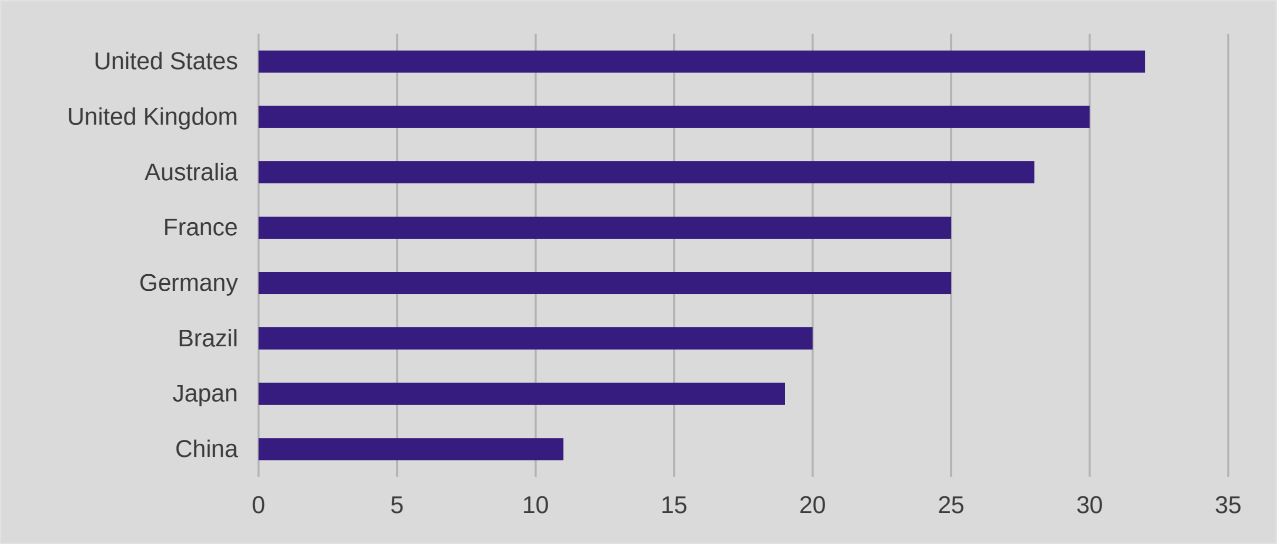
The development, access and use of both inputs and outputs in the digital economy is supported by a digitally enabling environment. This includes: access to digital skills such as programming, web development, digital design, product management, digital marketing and big data analytics; policies and regulations encouraging development of ICT, innovation and digital business models; and digital accelerators[3] such as government support, national ICT, public–private partnerships and behavioural and cultural aspects of the economy.

3. THE SIZE OF THE DIGITAL ECONOMY

Measuring digitalisation or 'the digital transformation of the economy' is a complex task; it would include measuring the share of GDP enabled through different the digital inputs and outputs, described in Figure 1. Since there is no consensus yet in the existing literature on the specific measures to quantify digitalisation, various proxies have been used. For instance, Knickrehm et al. (2016) uses an index (Digital Economic Opportunity Index) that combines information on skills, productive assets such as hardware, software and communication equipment, and other aspects of the digital economy (environmental, cultural and behavioural). Using these indicators, the top five digitalised economies in the period 2014–2016 were the United States (US), the United Kingdom (UK), Sweden, the Netherlands and Australia. While the digital share of GDP (in stock) features US, UK, Australia, France and Germany at the top (see Figure 2), the highest compound annual growth rate between 2015 and 2020 is predicted to be in China.

Using data from 11 economies, Knickrehm et al. (2016) estimates the size of the digital economy to be roughly $16.2 trillion, around 22% of the world's GDP.

Figure 2: Digital contribution to GDP across countries in 2016 (%)



Source: Reproduced from Knickrehm et al. (2016)
Notes: The horizontal-axis represents the percentage of total GDP in the country, which is digitally enabled. Japan ranks above Brazil in the Digital Economic Opportunity Index but the digital share of GDP is slightly higher in Brazil than in Japan. This may be linked to Japan's lower capacity in using its digital skills; according to Knickrehm et al.'s (2016) estimates, Japan needs to invest 60% of its efforts into making smarter use of its digital skills.

[3] The term 'digital accelerators' has been adapted from Knickrehm et al. (2016), which uses it to refer to national communication infrastructure, government prioritisation of digital and digital business environment.

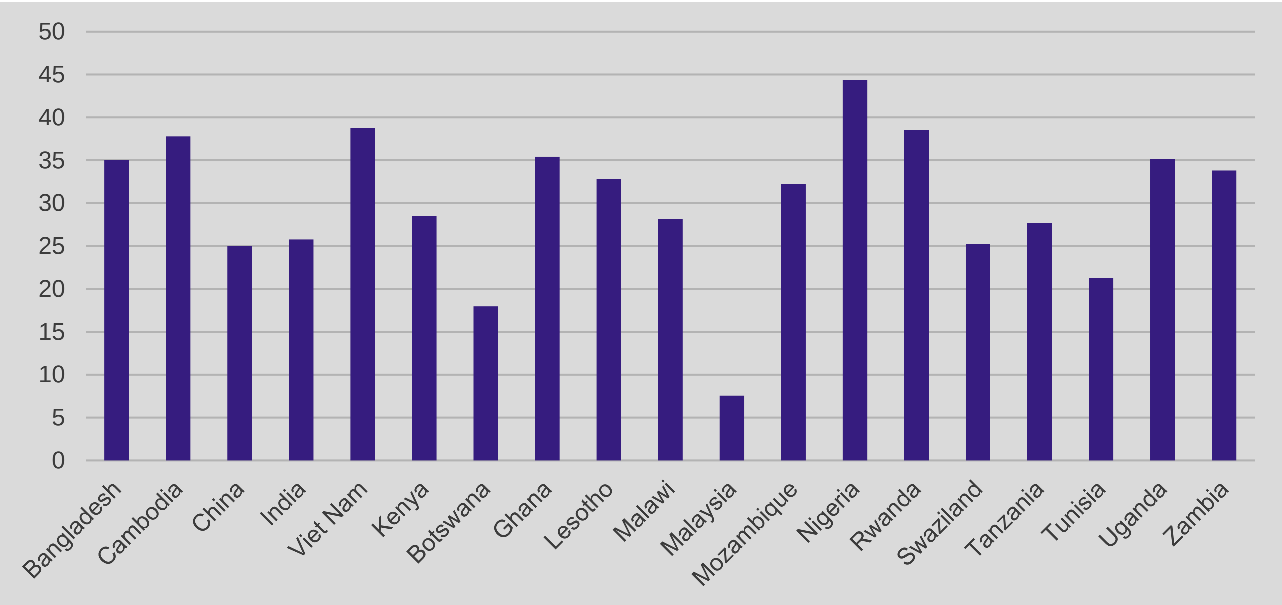
While the Digital Economic Opportunity Index can be used to compare countries in terms of potential to digitalise, it falls short in quantifying advancements as a result of digitalisation: smart machines, smart platforms and digital products. Section 3.1 compares economies by their level of digitalisation, using the different indicators mapped out in Figure 1.

3.1 Measuring digital technologies

Ideally, to measure a country's access to or use of digital technologies, we would want country-level information on cloud computing, IoT, AI etc. Since such information is not widely available, many studies have used data on internet penetration – the share of a country's population using the internet – as a proxy.

The World Economic Forum (WEF, 2015) finds that while the internet/digital economy in the G20 countries grew at 10% a year, growth in developing countries was higher – around 15%–20%. Bukht and Heeks (2017) also conclude that the digital economy is growing faster than the overall economy, particularly in the Global South. Plotting growth in internet penetration, in the period 2000–2013, across selected Asian and African economies, we find that on average African economies had higher growth, particularly Nigeria, Rwanda, Uganda and Ghana (Figure 3).

Figure 3: Growth in internet penetration (%) over the period 2000–2013



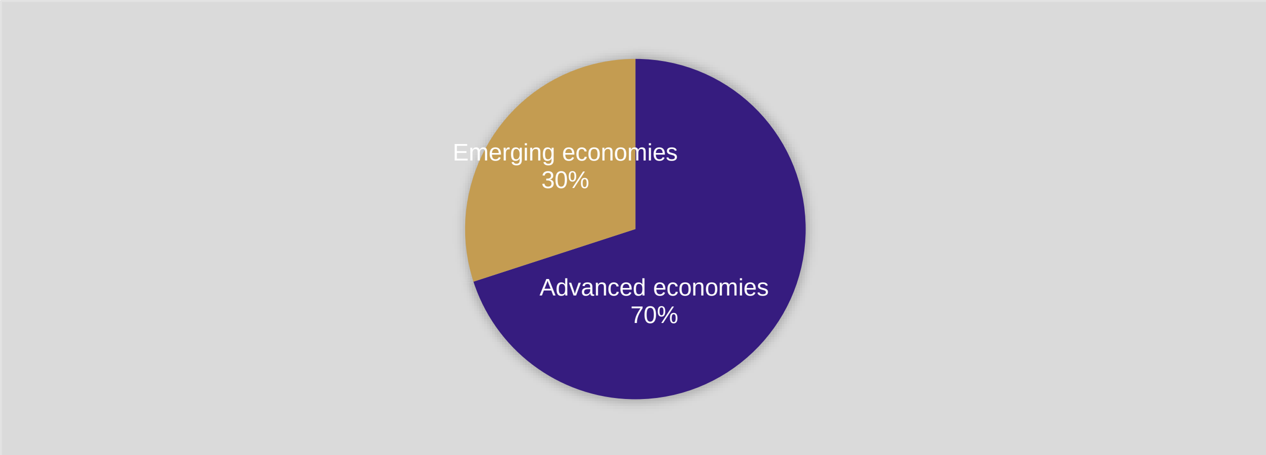
Source: Authors (2018), based on ITU data.
Notes: The vertical-axis represents the average growth rate in internet penetration in the period 2000–2013. It is calculated as log-difference in internet penetration between 2013 and 2000, divided by the number of years.

However, looking at internet penetration levels reveals that developing countries still have a long way to go to catch up with developed countries. In the overall internet economy, the developed countries still occupy a significantly larger portion (Figure 4). Further, the contribution of internet-enabled activities to GDP is around 3.4% in developed countries, but only around 1.9% (Manyika et al., 2013) in emerging[4] countries. For Africa, this share is even lower – below 1% (Figure 5).

[4] "Aspiring country" data is from 2010- it includes Russia and some relatively higher-income nations of Africa, Asia and Latin America.

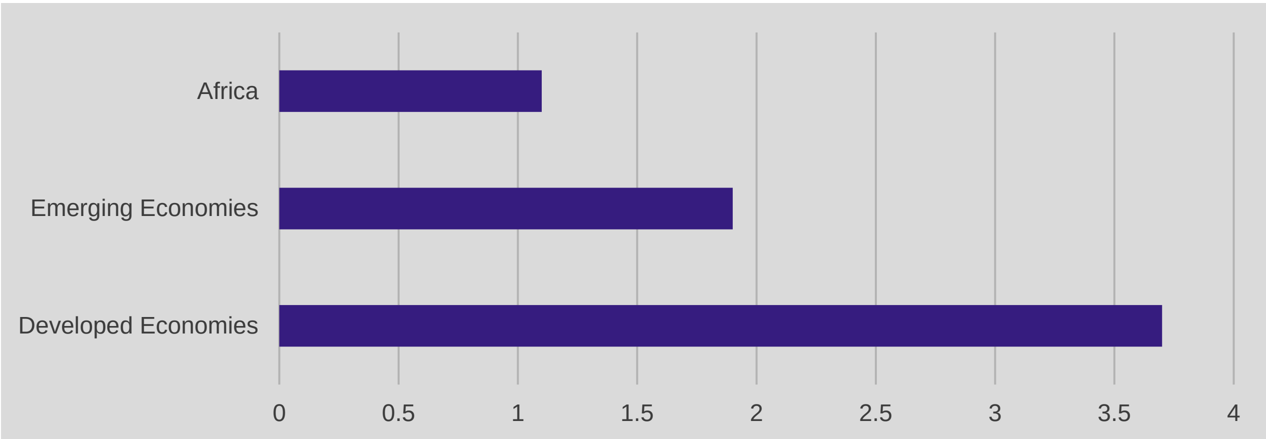
Figure 4: Share in internet economy (%)

Source: Constructed from Sabater and Garitty (2010)



Note: Data refers to 2010. Internet economy combines information on internet users, average per capita income and an adjustment factor accounting for income disparities.

Figure 5: Internet-enabled GDP (%)

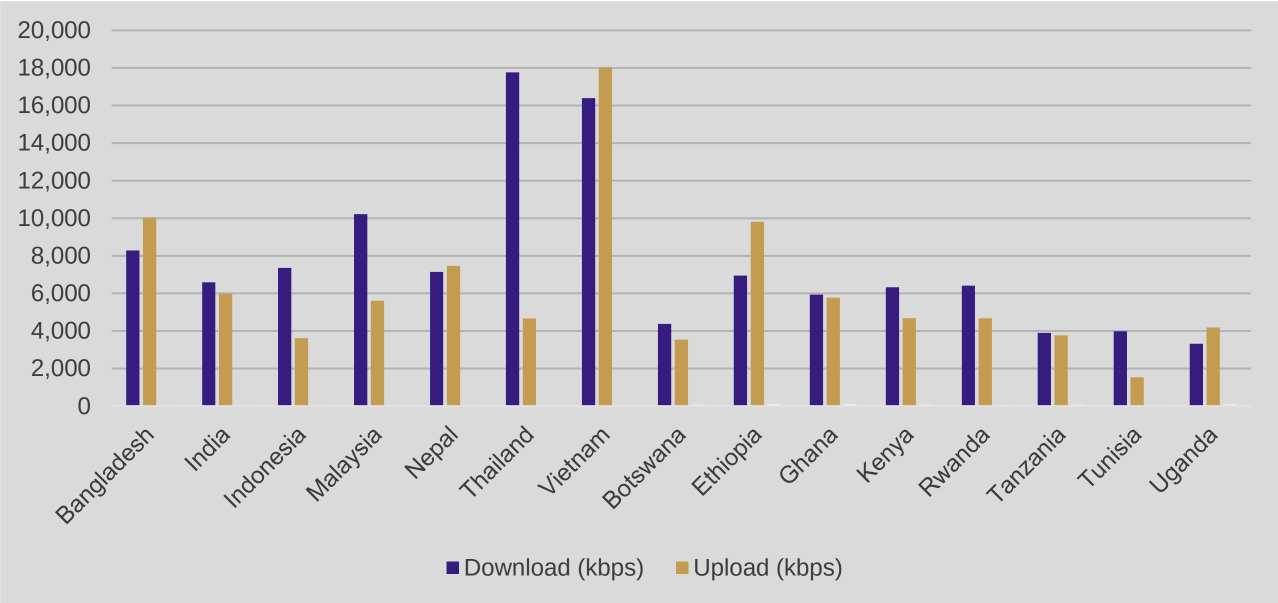


Source: Constructed from Manyika et al. (2013)
Note: Data refers to 2012. The horizontal axis represents percentges.

Comparing the extent of digitalisation across developing and least-developed countries (LDCs), UNCTAD (2017) finds that most of the developing countries with relatively higher income levels have internet penetration rates between 50% and 60%, while low-income developing economies and LDCs have below 40% internet penetration on average. Most of countries with less than 10% internet penetration are African, pointing towards the low capability of LDCs in developing competitiveness in digitalised trade, especially trade in ET and RAM products. With the RAM market expected to grow by over $9 billion between 2013 and 2018 (Wohler's report, 2014), it is likely that the African economies will be excluded from this market if such low internet penetration rates persist.

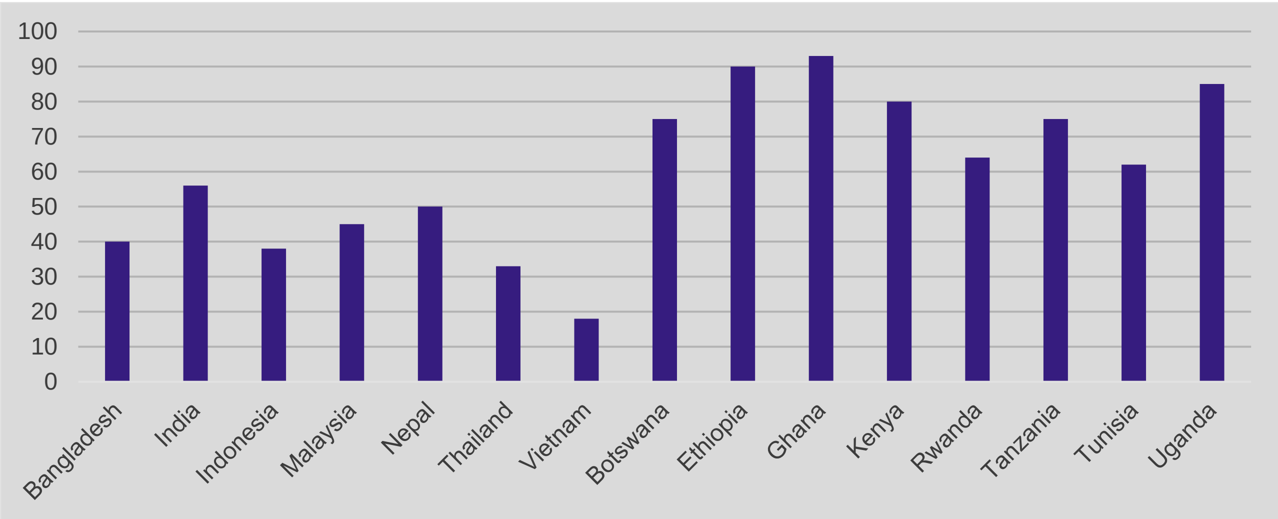
In addition to lower access to internet, African countries also suffer from poorer performance of the internet – Figure 6 shows that on average the download and upload speeds are significantly lower in African countries, as compared to Asian countries – and face higher delays in processing network data (Figure 7).

Figure 6: Internet performance across selected Asian and African countries (kbps)



Source: Cisco Global Cloud Readiness tool (2017).
Notes: The vertical axis represents the speed of internet in kbps.

Figure 7: Delays incurred in processing of networking data (milliseconds)



Source: Cisco Global Cloud Readiness tool (2017).
Notes: The vertical axis represents milliseconds.

Based on the quality of internet, countries will most likely differ in the ability to use digital technologies, such as cloud computing and machine-to-machine learning, which have the potential to significantly improve the efficiency of the manufacturing process. Take the case of cloud-based manufacturing – it can allow workers to expand their reach by providing them access to remote sites, delivering real-time on-demand video and data access to domain experts. This can further enable workers to participate in remote operations, assist in remote audio/visual collaborations and make training of workers more effective. Table 1 shows that while selected African and Asian countries have the potential to use basic to intermediate cloud computing applications such as email, web browsing etc., Botswana, Ethiopia, Ghana, and Tanzania have the potential to use only one out of the four advanced cloud applications considered. Kenya, Tunisia, and Uganda do not have the potential for any.

Table 1: Cloud-readiness by country (measuring the quality of internet)

Country	Potential to use basic to intermediate cloud applications	Potential to use advanced cloud applications				Score
	Web browsing, e-mailing, streaming, etc.	Tele-medicine	Ultra HD streaming	High-frequency stock-trading	HD video conferencing	
Bangladesh	Yes	Yes	No	No	Yes	2
China	Yes	Yes	Yes	No	Yes	2
India	Yes	Yes	No	No	Yes	2
Indonesia	Yes	Yes	No	No	No	1
Malaysia	Yes	Yes	No	No	Yes	2
Nepal	Yes	Yes	No	No	Yes	2
Thailand	Yes	Yes	Yes	No	No	2
Vietnam	Yes	Yes	Yes	Yes	Yes	4
Botswana	Yes	Yes	**No**	**No**	**No**	**1**
Ethiopia	Yes	**No**	**No**	**No**	Yes	1
Ghana	Yes	**No**	**No**	**No**	Yes	1
Kenya	Yes	**No**	**No**	**No**	**No**	**0**
Tanzania	Yes	Yes	**No**	**No**	**No**	**1**
Tunisia	Yes	**No**	**No**	**No**	**No**	**0**
Uganda	Yes	**No**	**No**	**No**	**No**	**0**

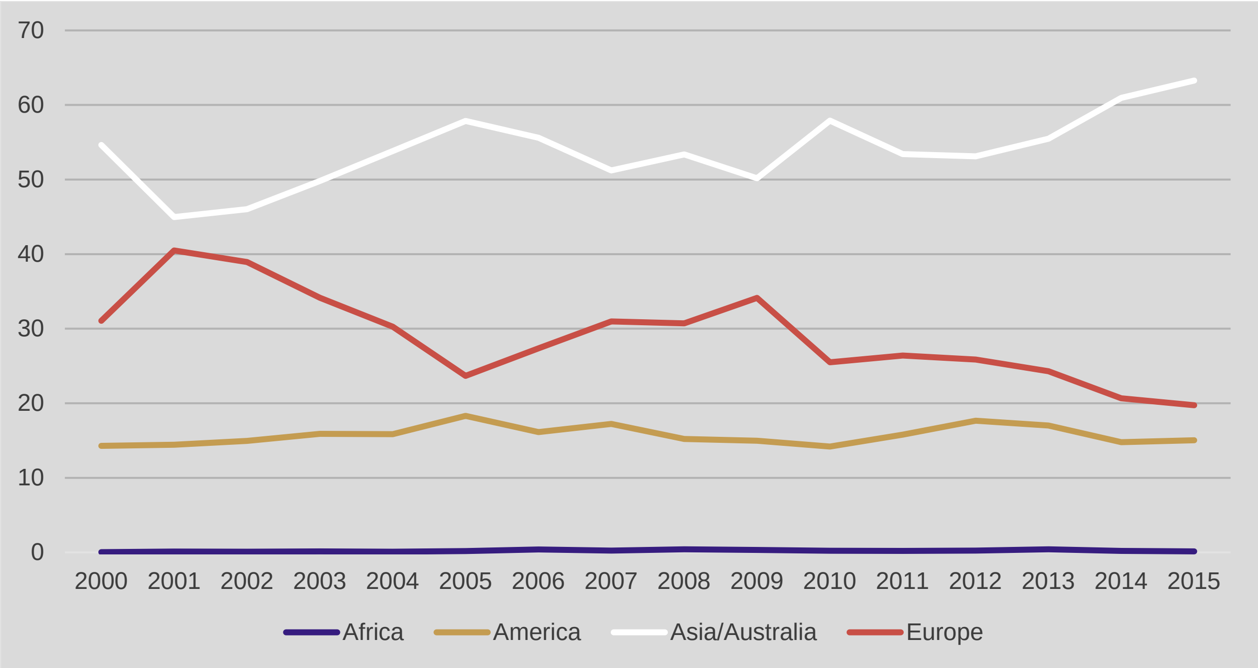
Source: Cisco cloud readiness concurrency map tool 2017.
Notes: Basic or intermediate applications require download speed up to 2500kbps, upload speed up to 1500 kbps and latency (delays) above 100 ms. Advanced applications require download speed higher than 2500kbps, upload speed higher than 1500 kbps and latency (delays) less than 100 ms.

3.2 Measuring the use of smart machines

Recently, studies have started using data on robots to quantify the level of digitalisation. Data are collected from the International Federation of Robotics (IFR) database and report on the number of robots sold from top robot suppliers to different countries. The IFR estimates that there are currently between 1.5 and 1.75 million industrial robots in operation, a number that could go up to 4 to 6 million by 2025 (Boston Consulting Group, 2015). The most robots are employed by the automotive sector (39%), followed by the electronics industry (19%), metal products (9%), and the plastic and chemicals industry (9%).

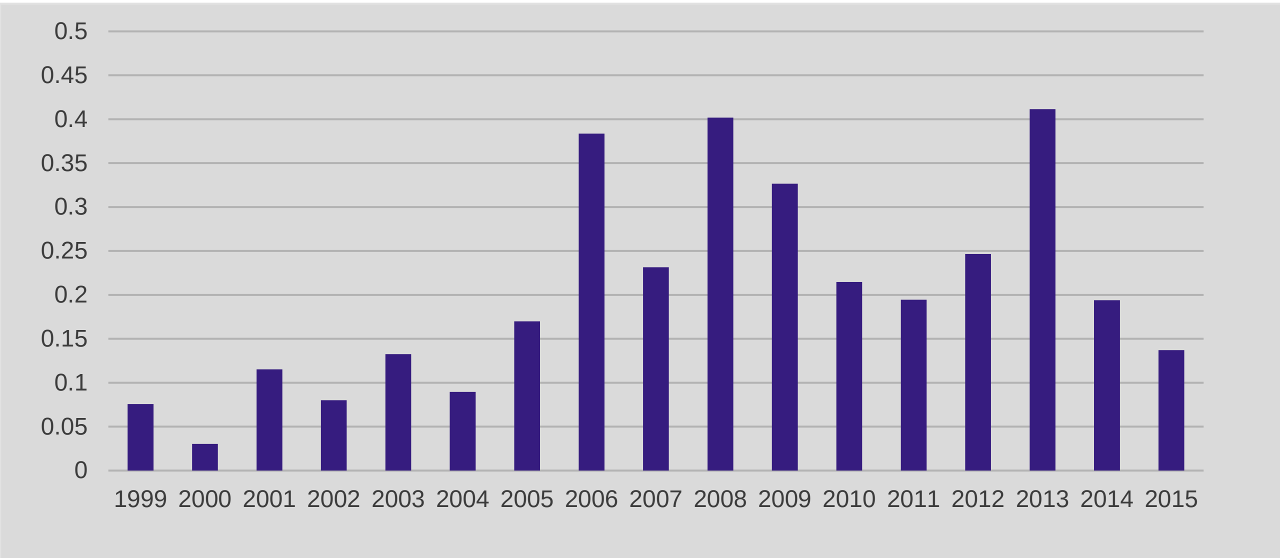
Figure 8 shows that post 2001, the share of Asia/Australia in total robots sold has increased (due to increasing robot deployment in a few countries such as China, Japan and Korea), while Europe's share has declined. The share of Africa has remained negligible compared to other regions, and has in fact declined since 2013, reaching just 0.14% in 2015 (Figure 9).

Figure 8: Regional share in sales of industrial robots (%)



Source: International Federation of Robotics (IFR) database.
Notes: The vertical axis represents share of a region in the total number of robots shipped globally from top robotics suppliers. America includes North, Central and South America.

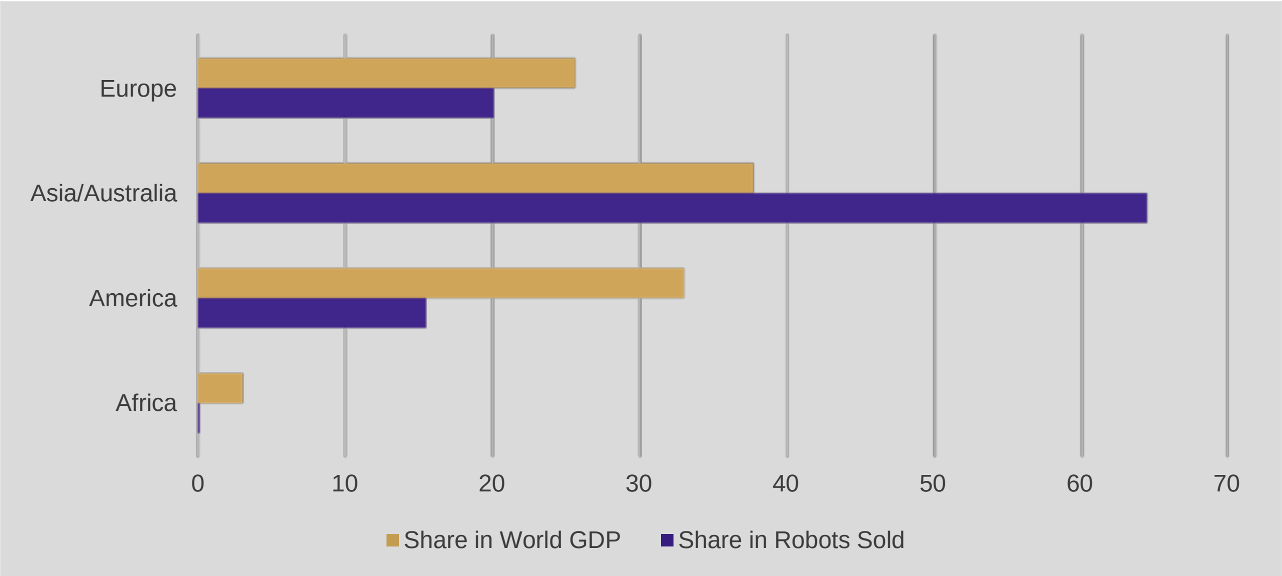
Figure 9: Africa's share in robot sales (%)



Source: International Federation of Robotics.
Note: Vertical axis represents robot shipments (in units) to Africa as a share in total shipments of robots from top global suppliers. Data on Africa includes robots sold to South Africa, Tunisia, Morocco, Egypt and Rest of Africa.

The total number of robots sold increased globally by 15% in 2015, with China occupying the biggest share of 27% (IFR, 2017). Around 75% of robot sales (in units) were, however, concentrated in just five markets: China, the Republic of Korea, Japan, US, and Germany. Figure 10 shows that while the share in number of robots sold and in global GDP was observed to be the highest for Asia and the Pacific region (due to high demand by China) in 2015, it was the lowest for the African region. At roughly 0.2%, Africa's share in robots sold in 2015 is 15 times lower than its share in GDP (around 3%), indicating a significant digital divide in deployment of robots.

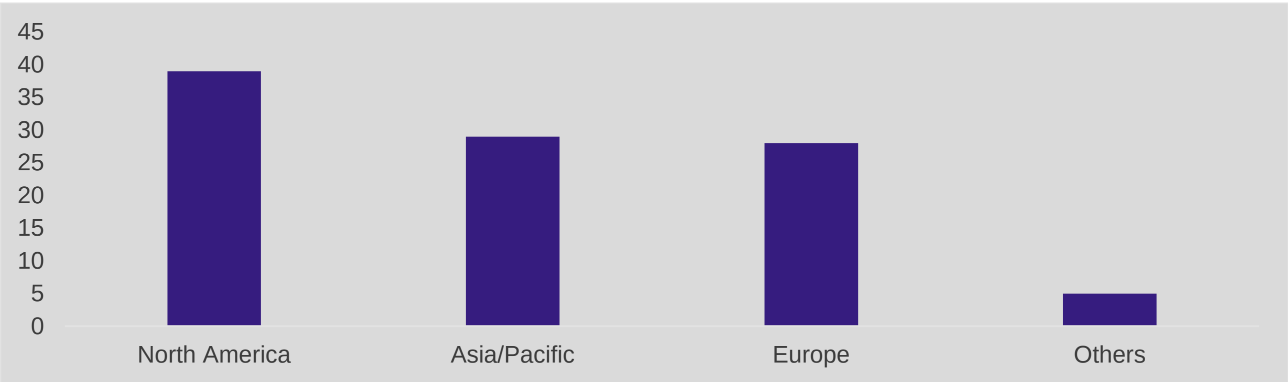
Figure 10: Regional share in number of robots sold (2015)



Source: International Federation of Robotics, World Economic Outlook (2017).
Notes: Share in World GDP is calculated using Nominal GDP data (billions of US dollars). The x-axis represents percentages. America includes North, Central and South America.

Similar to robot deployment, the sales of 3D printers have also witnessed an impressive growth: in the year 2016, global shipments of 3D printers rose by approximately 32%, owing mainly to increased shipments of personal/desktop 3D printers, which now cost as little as $1,000 (CONTEXT, 2017). The average cost of a 3D printer saw a 4.7% decline between 2012 and 2015, and in the three years to 2018, the prices have fallen at an estimated average annual rate of 5.5%. While globally prices have gone down, sales of 3D printers are still concentrated in developed countries. Figure 11 shows that the highest investments in 3D printing are made by North America (39%) followed by Asia/Pacific (29%) and Europe (28%). The Asia/Pacific region is likely picking up high investments in 3D printing by China, Korea, and Australia. The share of 'others', which includes African countries, is just 5%.

Figure 11: Regional share in global investments made in 3D printers (%)

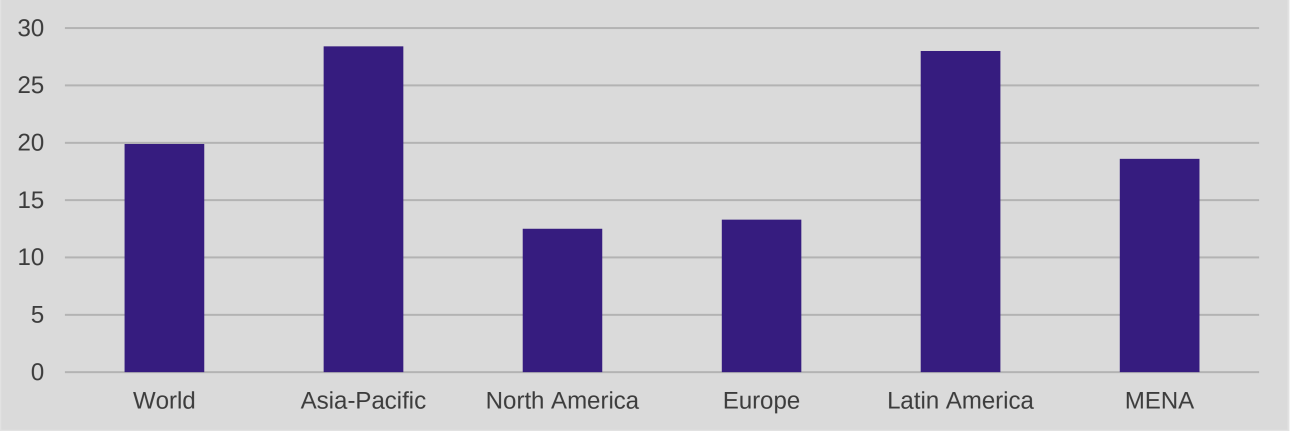


Source: ING (2017).
Notes: Data refers to 2016. The vertical axis is in percentages, it represents the share of a region in global investments in 3D printers (desktop or commercial).

3.3 Measuring the use of smart platforms and digital products

Another common measure for digitalisation has been the size of the e-commerce market. E-commerce refers to buying and selling of goods and services using the internet. This includes physical products traded through e-commerce platforms, as well as trade in electronically transmitted goods – such as audio files, video files, video games etc. – and electronically transmitted services such as computer software services and data processing services. As per UNCTAD (2016) estimates, e-commerce has grown rapidly, rising from $16 trillion in 2013 to around $22.5 trillion in 2015, with fastest growth in developing countries (see Figure 12). These estimates include business-to-business and business-to-consumer transactions, respectively valued at around $19.9 trillion and $2.2 trillion, according to the UNCTAD data. While most of this trade is within-border or domestic, international e-commerce is also growing at a fast pace.

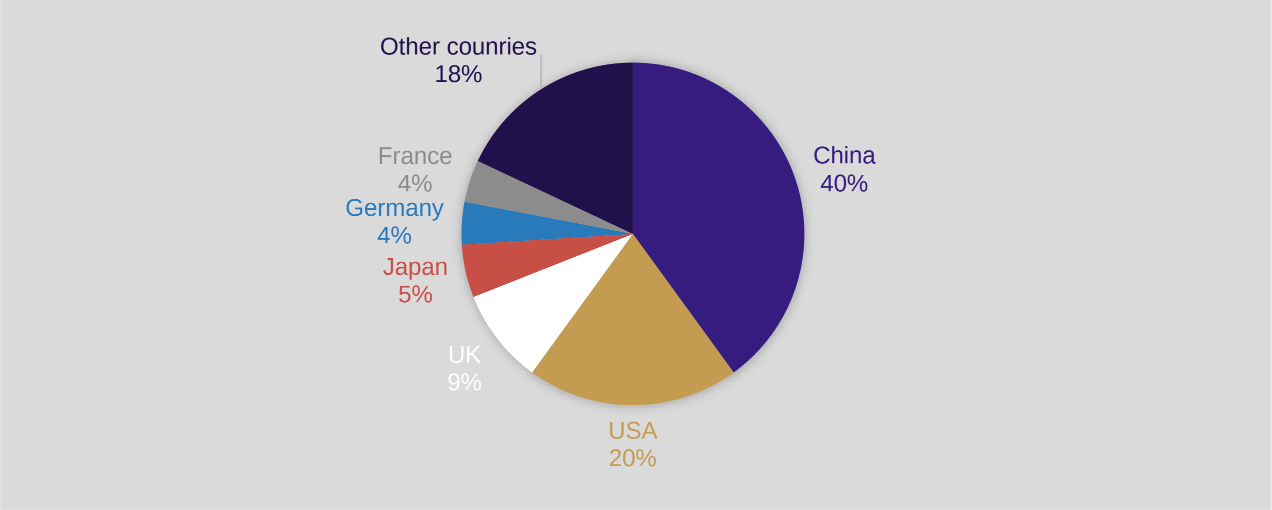
Figure 12: Regional growth in e-commerce in 2015 (%)



Source: E-commerce Foundation (2016).
Notes: E-commerce here refers to business-to-consumer sales (B2C) only. The vertical axis represents annual percentage change.

Various reports[5] show that in the year 2015, cross-border e-commerce accounted for around $1.6 trillion, which is 14% of the e-commerce market. A closer look at the country shares in cross-border e-commerce (Figure 13) shows vast disparity across developed and developing countries, with the exception of China. Only six countries together capture 85% of the international e-commerce market, namely China, US, UK, Japan, Germany, and France (UNCTAD, 2017). The share of 'other countries', which includes developing countries (except China) and African economies, is around 18%.

Figure 13: Country shares in cross-border e-commerce



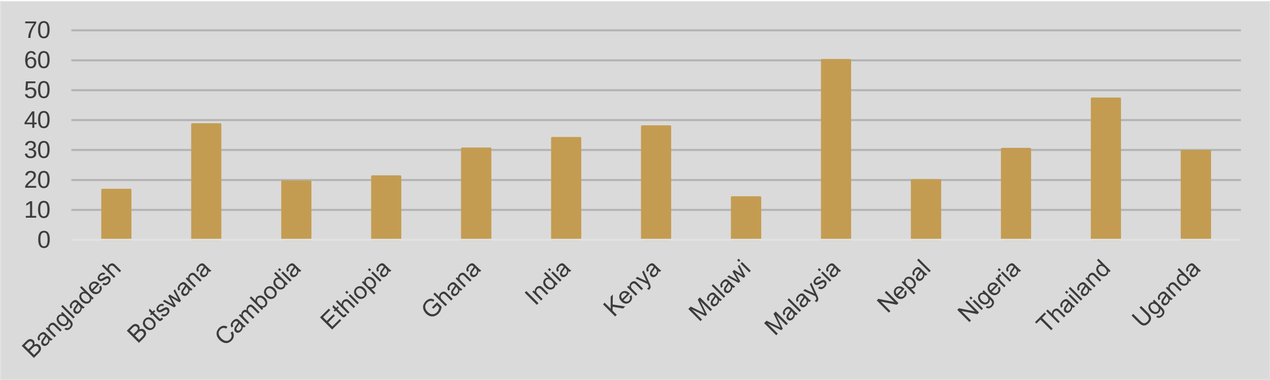
Source: UNCTAD (2017).

To further compare e-commerce readiness of selected Asian and African countries, we use UNCTAD's e-commerce index, which draws on data for internet users, web presence, delivery and payment to reflect B2C transactions undertaken by countries. Figure 14 shows that in the year 2015, the Asian economies of Malaysia and Thailand ranked higher on the e-commerce index

[5] E-Marketers; Paypers; ACAPTURE – various country reports.

compared to African economies. Amongst the African countries, Botswana, Kenya, Uganda, and Ghana ranked higher.

Figure 14: UNCTAD'S E-commerce Readiness Index, 2015

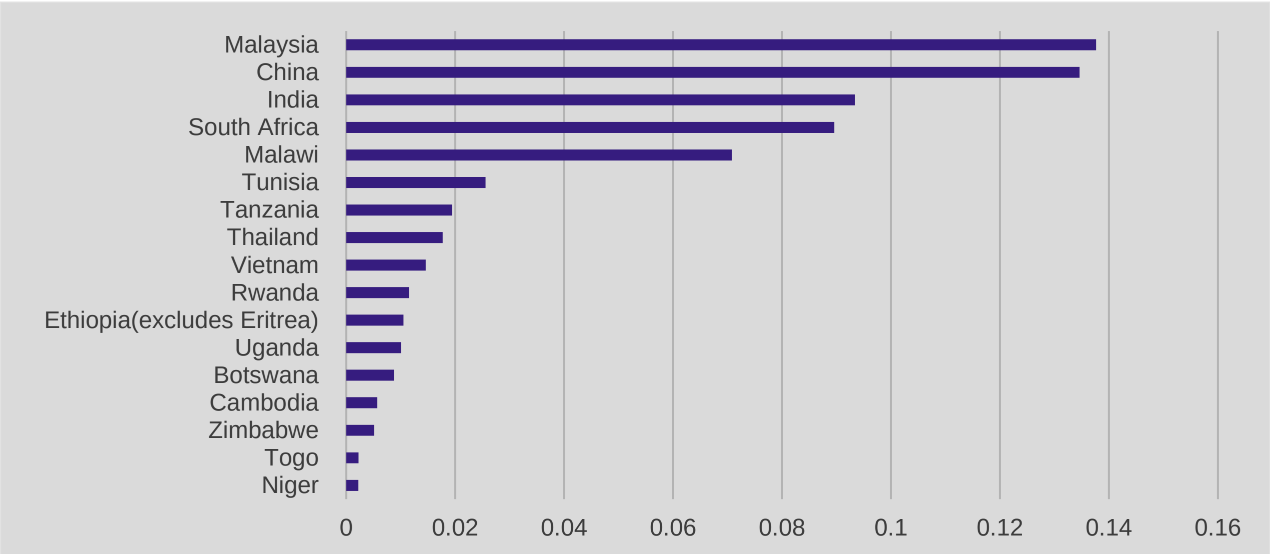


Source: WITS e-trade indicators.
Notes: Vertical-axis represents value for UNCTAD's e-commerce index, which uses data on internet users, web presence, delivery and payment for B2C transactions.

Electronically transmitted goods (ET goods) also form an important part of e-commerce; in the year 2015, trade in digitalised products through electronic transmissions[6] accounted for $66 billion[7] in cross-border e-commerce trade (UNCTAD, 2017). The top 15 exporters of ET products are found to be developed countries, with the exception of China, and together they account for 82% of the global ET exports.

To examine how African countries are faring, Figure 15 compares the export share of ET products across African and Asian countries. It is observed that while the share of ET exports is low in both (less than 1%), it is on average much higher in Asian economies such as Malaysia, China, and India.

Figure 15: Share of ET products in total exports (%)



Source: Constructed from data in UNCTAD (2017) and WITS.
Notes: ET products as based on UNCTAD's (2000) classification and refer to goods under HS chapters – 37(films), 49(printed matter), 8524 (sounds, media and software) and 9504 (videogames) as per UNCTAD's (2000) classification. The x-axis represents a country's exports of electronically transmitted goods, as a share of its total exports. Data is for 2015.

[6] Harmonised System Codes (HS) chapters – 37 (films), 49 (printed matter), 8524 (sounds, media and software) and 9504 (videogames) as per UNCTAD's (2000) classification.

[7] This does not include RAM products.

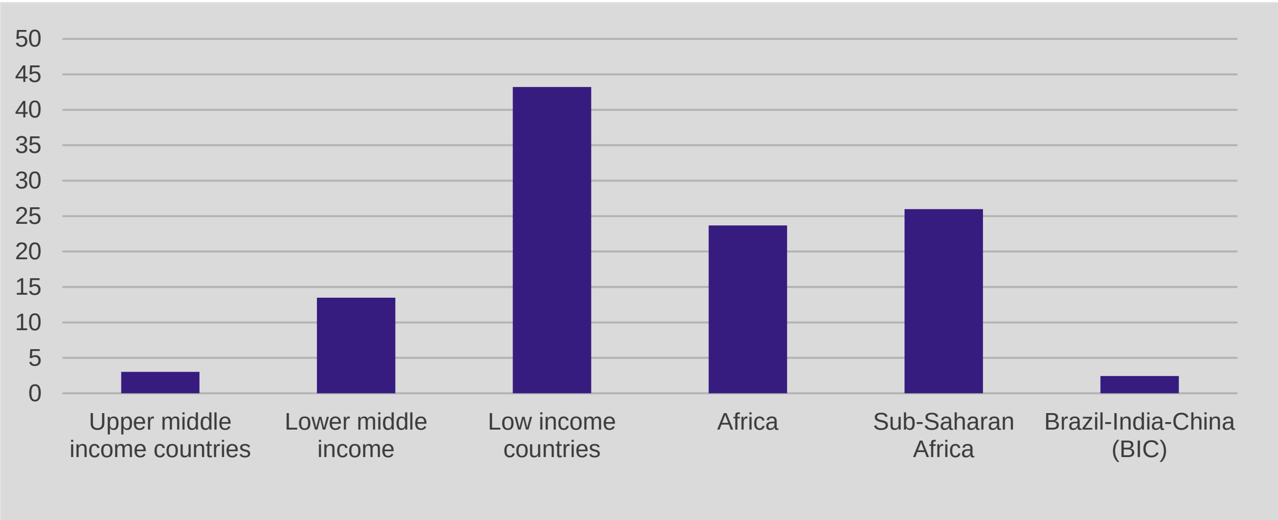
4. WHY IS THERE A DIGITAL DIVIDE?

Sections 2 and 3 have clearly demonstrated that while the digital economy occupies a significant share of the global economy, and is expected to grow continuously, there is a persistent digital divide between developed and developing countries. There is also a digital divide between developing and least-developed countries. This section considers key factors that may be responsible for this gap: the higher cost of capital and the lower digital readiness in terms of infrastructure, skills and customs and logistics.

4.1 Higher cost of capital in low-income countries

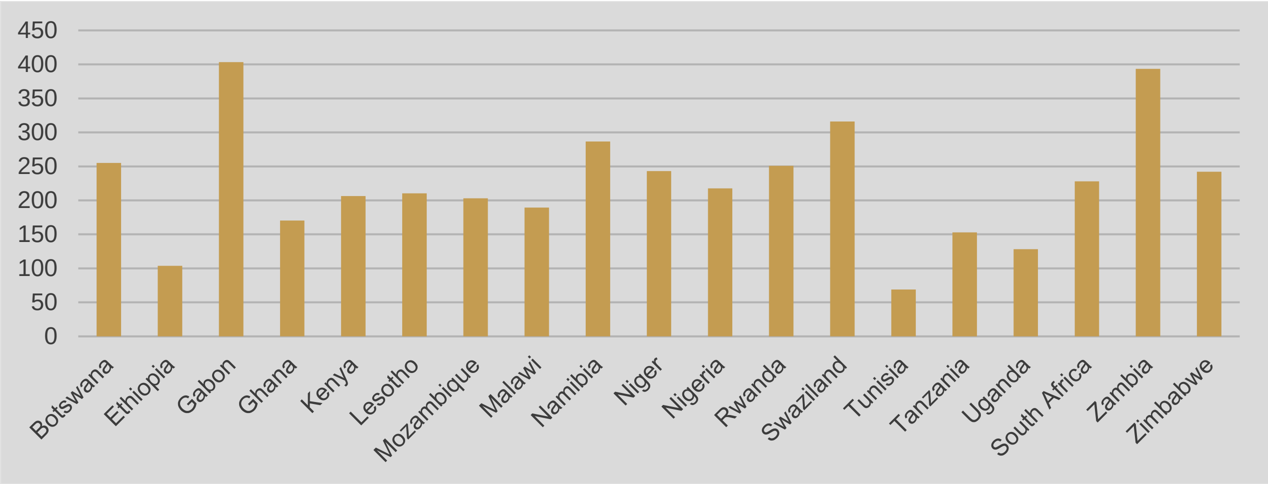
Even though the evidence suggests that the price of capital goods has reduced by 25% between 1975 and 2012 (Karabarbounis and Neiman, 2014), it is still relatively high in developing economies, particularly African economies. On the consumption side, Figure 16 shows that the ICT basket is significantly less affordable in low-income and lower-middle-income countries as compared to upper-middle-income countries. The ICT basket price for African countries, in particular sub-Saharan countries, is about 26% of gross national income (GNI), which is quite high compared to the ICT price basket of 2.4% of GNI in the Brazil, China and India region. A more disaggregate analysis of African countries shows that the ICT basket is most expensive in Gabon, Zambia, Swaziland, and Namibia and lowest in Tunisia, Ethiopia, and Uganda (see Figure 17).

Figure 16: ICT basket price (% of GNI per capita)



Source: ITU data.
Note: Data is for the year 2013. The vertical axis measures in % of the Gross National Income (GNI) per capita, the cost and affordability of the key ICT services: fixed telephony, mobile cellular (voice and SMS) and fixed broadband.

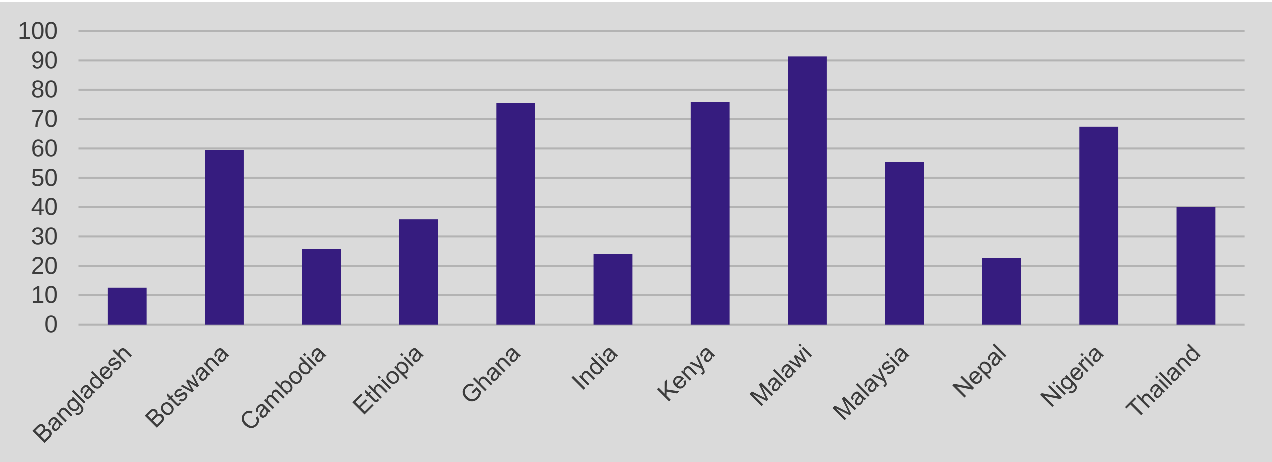
Figure 17: ICT basket price (in dollars) of African countries



Source: ITU data.
Notes: Data is for the year 2013. The vertical axis represents, in 2015 US dollars, the combined cost of key ICT services: fixed telephony, mobile cellular (voice and SMS) and fixed broadband.

Looking specifically at internet tariffs (Figure 18), we find that on average it is costlier to access the internet in African economies compared to Asian economies. Amongst the African economies in the figure below, internet tariffs are the lowest for Ethiopia and highest for Malawi.

Figure 18: Fixed broadband internet tariffs



Source: WITS E-Trade Indicators.
Notes: The vertical axis represents internet tariffs in PPP $/month.

On the production side, a recent study by Gelb et al. (2017) uses the World Bank enterprise data to calculate both labour and capital costs for a range of low- and middle-income countries. The cost of capital per worker is calculated as the market value of the firm's capital divided by the number of employees in the firm. Using this measure, the study confirms that the capital cost per worker is higher in African firms: the median African firm has a capital cost per worker of $5,163, compared to $4,218 in the median comparator firm, even though African countries are on average far poorer than the comparators. For example, in Bangladesh, the capital cost per worker is $1069, far below the levels in the African countries (see Table 2). The higher relative capital cost per worker, lower value added per worker, and relatively similar levels of human capital suggest that African firms have lower productivity and/or pay a higher premium for technology and access to capital than comparator firms (Gelb et al., 2017).

Table 2: Cost of labour and capital per worker by country

Country	Labour cost per worker ($)	Capital cost per worker ($)	Relative capital cost*
Bangladesh	835	1069	1.28
Kenya	2118	9775	4.61
Tanzania	1776	5740	3.23
Ethiopia	909	6137	6.75

Source: Adapted from Gelb et al. (2017).
Notes: *Authors' estimate; relative capital cost = cost of capital per worker/ cost of labour per worker.

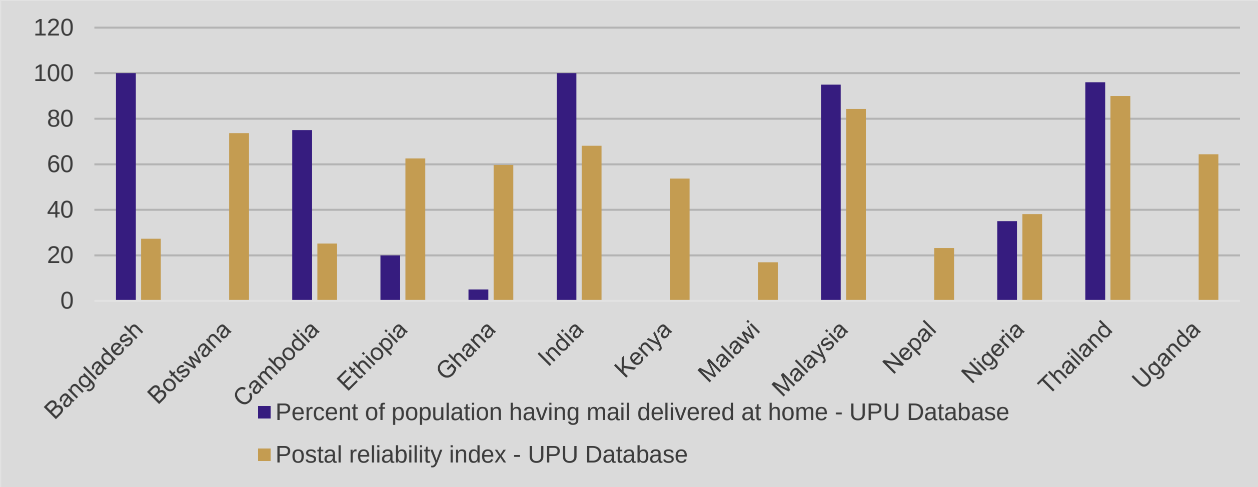
Even if the cost of capital and digitalisation falls in African countries, the cost of financing digitalisation will remain high due to poor access to finance in these countries, a consequence of market-coordination failures. A cross-regional analysis of financing costs shows that firms in Africa pay around 7% more in interest rates (nominal) than firms in East Asia and in South Asia (Iarossi, 2009). Data from the World Bank Enterprise Survey also confirms this: firms in Africa pay, on average, a 15% interest rate, which is roughly 5 percentage points higher than firms in East Asia and 2 percentage points higher than firms in South Asia (in nominal terms). Even after accounting for size, industry, export orientation, collateral, sales, value of machinery etc., a 3% to 5% difference in interest rate remains (Iarossi, 2009). The gap in the lending interest of SSA countries and US is around 10%.

4.2 Low digital-readiness

Along with the higher cost of capital, African countries also face the problem of slower diffusion in ICT and automation equipment. This is due to a number of challenges that African countries are still struggling with, including inadequate access to energy and to a reliable power supply, poorer logistics and infrastructure, lower ability to adapt and maintain hardware equipment and software, and lower positive externalities from joining a network. A combination of these issues indicates that African countries have a poorer 'systems infrastructure' in place, making them less digitally ready.

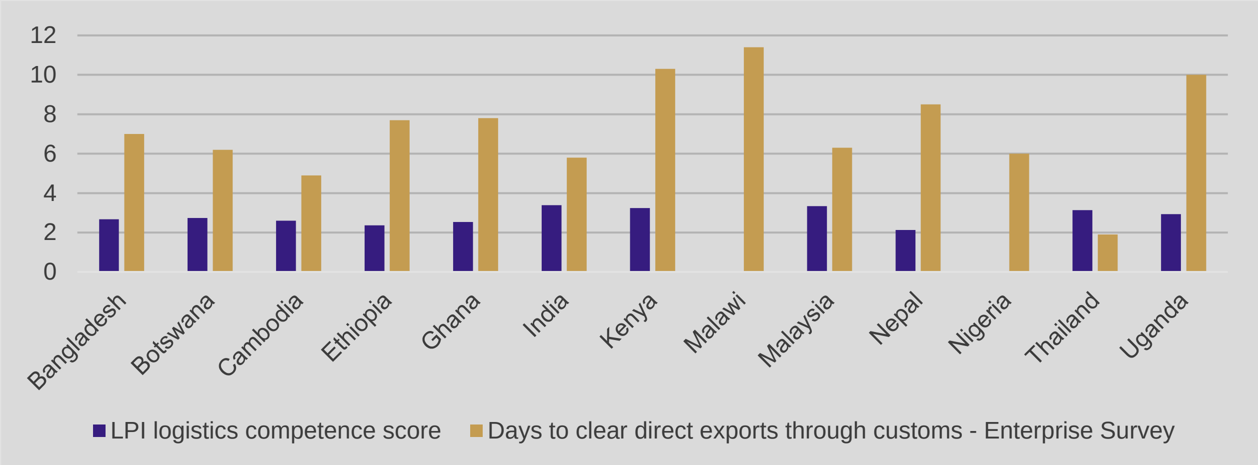
The low digital-readiness of African countries is evident from figures 19 and 20. Compared to Asian economies, African countries have, on average, a lower percentage of people getting mail delivered at home and a less reliable postal delivery system (Figure 19), which may contribute to African countries lagging behind in e-commerce activities. Further, firms in African countries have poorer logistics and customs; they rank lower on the logistics performance indicator and take a greater number of days to clear exports (Figure 20).

Figure 19: Postal competence across Asian and African countries



Source: WITS e-trade indicators.
Notes: Data is for various years: 2013, 2014 or 2015. Data for Botswana, Kenya, Nepal, and Uganda are missing.

Figure 20: Trade facilitation and logistics across African and Asian countries

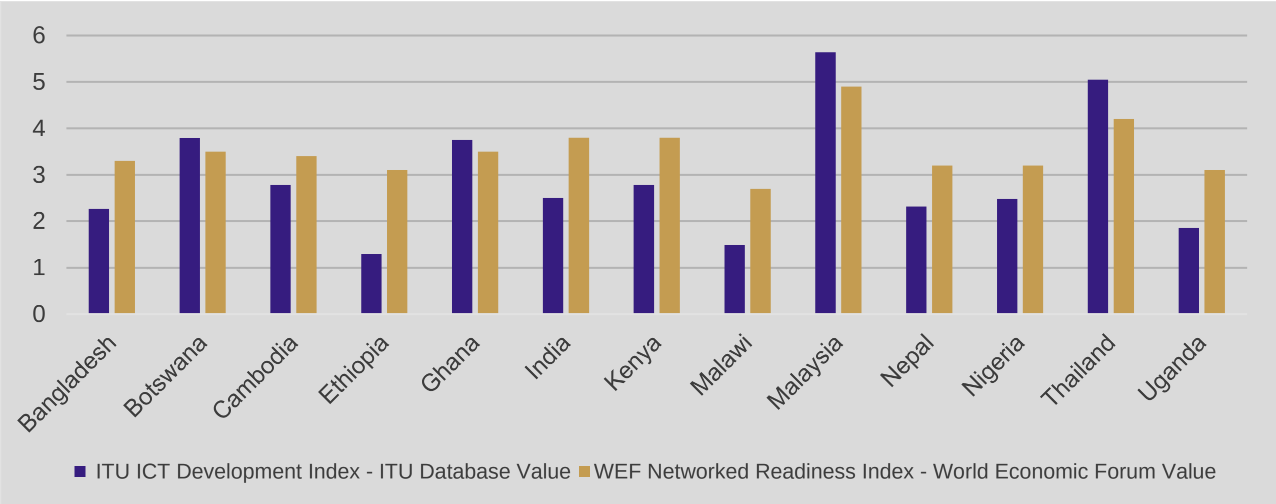


Source: WITS e-trade indicators.
Notes: Data is for various years: 2013, 2014 or 2015

Another key reason why African countries have not been able to leverage digital technologies, as of yet, is that technological capabilities are lower and there are shortages of skilled and technical labour. It is important to note that knowledge has different dimensions, which will determine the effectiveness of knowledge transfer and adoption (Kogut and Zander, 1995). While explicit knowledge can be more easily articulated, codified, and shared (via manuals, documents etc.), tacit knowledge is harder to transfer, decode and learn from. Such a conceptualisation of knowledge highlights the importance of the 'absorptive capacity' of firms, which refers to their ability not only to acquire and assimilate external knowledge but also to apply such knowledge and generate profits (Cohen and Levinthal, 1990). Application of such technologies requires investments by the firms in 'technological capabilities', defined as skills (i.e. technical, managerial or organisational) needed to utilise technology efficiently and accomplish any process of technological change or innovation (Lall, 2001).

The lower absorptive capacity of African countries is demonstrated in Figure 21, which compares selected countries based on ITU's ICT development index and the WEF's Network Readiness index. The ICT development index is based on indicators measuring ICT access, use and skills. The Network Readiness index measures the propensity of countries to exploit opportunities offered by ICT. Asian countries such as Malaysia and Thailand, which rank higher in digitalisation (as observed in Section 3), also rank higher in both ICT development and global connectedness, while a range of countries, especially the poorest, score lower.

Figure 21: ICT and network-connectedness indices



Source: WITS e-trade indicators
Notes: The vertical axis represents values for ITU's ICT development and WEF's Network readiness indicators. The ICT development index is based on indicators measuring ICT access (fixed and mobile telephone subscriptions, bandwidth etc.), ICT use (internet penetration, fixed broadband and active mobile broadband subscriptions) and skills (mean years of schooling, tertiary education etc.). The Network Readiness index measures the propensity of countries to exploit opportunities offered by ICT.

If the cost of capital in African countries remains high (especially in relation to labour costs) and digital-readiness remains low, they will not be able to finance investment into newer technologies. As a result, digitalisation in these countries will remain low, suggesting an increasingly divergent path between African countries and the rest of the world. A widening of this digital divide (gap) can have severe consequences for the developing countries in terms of loss of jobs, growing income inequality and concentration of power and wealth in the global north. On the other hand, if the developing countries increase digitalisation in their economies, by improving their existing ICT technologies, skills and physical infrastructure, it can lead to opening of new opportunities for transformation of economic growth. The different pathways by which technological progress can affect developing economies are explored below.

5. THE IMPACT OF DIGITALISATION ON GROWTH AND LABOUR MARKET: PATHWAYS

5.1 Digitalisation: implications for productivity

The existing literature documents that since the global financial crisis of 2008–2009, growth in labour productivity has slowed down, particularly in high-income countries. Those with a Schumpeterian view argue that any future productivity gains rest in digitalisation of the economy and automation of tasks. While automation can make production more efficient, by improving the marginal product of capital and/or labour,[8] it can also lead to higher substitution between the two factors and changes in the nature of demand enabled by mass production and customisation.

Using data on access to digital services, affordability, speed, reliability and ease of use of these services along with skill level, Booz and Company (2012) create a digitisation index score for 150 countries. Countries with a digitisation score below 25 are labelled 'constrained', between 25 and 30 as 'emerging', between 3 and 40 as 'transitional' and above 40 as 'advanced'. The authors then estimate the impact of digitisation on growth in GDP per capita using a classical production function. After controlling for human capital and capital formation, the authors find that a 10% increase in digitisation leads to a 0.5% increase in GDP per capita in constrained economies, but a 0.62%

[8] The impact pathways through which technical change can affect growth are given in Appendix A.

increase in the GDP per capita of digitally advanced economies. This suggests that as countries transition from low levels of digitisation to higher levels, the impact of digitisation on GDP per capita also increases. Overall, the authors find that that a 10% increase in a country's digitisation index lead to a 0.75% growth in its GDP per capita, with the impact of digitisation being the lowest for Africa and South Asia – regions which have a majority of digitally constrained economies. The result that digitisation can boost growth was confirmed in the study by Donou-Adonsou et al. (2016) which conducted analysis for 47 countries in the period 1993–2012, and found that a 1% increase in the use of internet and mobile phones increases growth by 0.12 and 0.03 percentage points respectively.

More recently, studies have used the IFR database to directly estimate the impact of deploying robots on output growth. These studies hypothesise that by performing tasks more efficiently than humans, robots can boost output and exports through the 'productivity effect'. Focusing on robotics across 17 developed economies, Graetz and Michaels (2015) find that in the period 1993–2007, robot densification led to an increase in annual GDP growth and labour productivity of 0.37 and 0.36 percentage points respectively. Robots are also found to affect total factor productivity and value-added positively. However, larger increases in robots are associated with smaller gains in productivity, implying that there are diminishing returns to increased robot use. The authors find no evidence of robots reducing aggregate hours worked, but do find some evidence of robots reducing hours worked by low-skilled workers and, to a lesser extent, medium-skilled workers. This is in line with the skill-biased technological progress literature. Expanding the time period, a recent study shows that investments in robots in 1993–2016 contributed to 10% growth in GDP per capita in Organisation for Economic Co-operation and Development (OECD) countries, and an increase in robot density leads to 0.04% increase in labour productivity (Centre for Economics and Business Research, 2017). Consistent with the view that robots can complement labour, Dauth et al. (2017) confirm that in Germany during the period 1994–2014, robots improved average productivity in the local labour market.

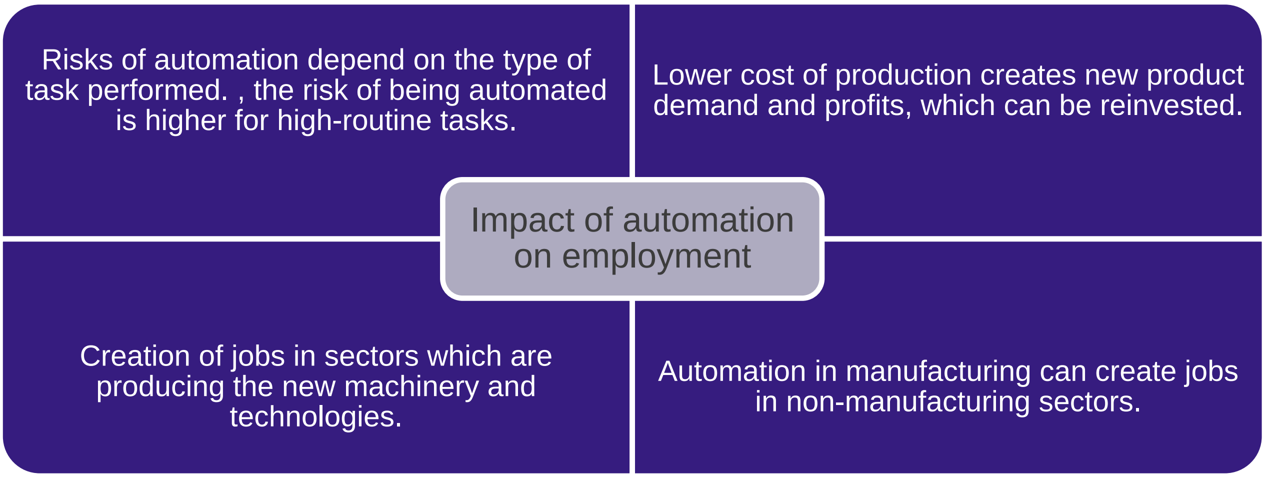
Extending analysis to include developing economies of Asia and Latin America (TDR, 2017) finds that in the period 2005–2014, robot deployment increased labour productivity growth for countries that have a high stock of robots, such as Japan, as well as for countries like China, which are gradually expanding their robot stock. The report also finds a positive relationship between manufacturing sector's share in total value added and use of robots, particularly for those economies with a higher robot density. Looking ahead, the McKinsey Global Institute report (2017) predicts that automation could increase productivity growth by as much as 0.8% to 1.4% annually. Similarly, Accenture's (2016) report estimates that automation will double the gross value added across 12 developed economies by 2035, with labour productivity levels rising by up to 40%. As the relative unit labour costs fall in developing economies and small and medium-sized enterprises (SMEs) take to production using robots, productivity can rise by 30%, as predicted by Boston Consulting Group (2015).

5.2 Digitalisation: implications for employment and wages

There is ambiguity in the literature on the impact of digitalisation on the labour market, the analysis of which has mainly been carried out for developed countries. On one hand, automation can threaten several kinds of jobs and lead to displacement or substitution of labour, affecting employment negatively. This will in turn result in downward pressures on low-skilled workers and increasing returns to the owners of capital (Sachs and Kotlikoff, 2012). On the other hand, the resulting decrease in the average cost of production due to application of new technologies can significantly boost output and exports and consequently increase the demand for labour used in those products and services. Moreover, instead of labour being displaced/substituted by advanced technology such as robots, it is likely that workers are absorbed in different sectors or switched to tasks that are complementary to the robots. This effect of technology boosting employment, by generating higher output, is illustrated in the case of the A to Z factory in Tanzania (Box 1), where modern laser fabric-cutting machines displaced workers employed for cutting, but generated more output and jobs in 'stitching', a relatively higher-skilled task. Further, as process innovations make the way for product innovations, more jobs can be created in the long term (Perez, 2016).

The World Trade Organization (WTO, 2017) discusses several pathways through which automation can positively affect employment, which we summarise in Figure 22, below. First, the risk of automation depends upon the type of economic activity being carried out. With AI and digitalisation, the risk of being automated is higher for high-routine tasks, such as assembly, than for managerial tasks (Marcolin et al., 2016). As robots perform these tasks more efficiently than humans, they can complement the labour input and boost production, leading to more jobs. Second, the lower costs of production achieved through automation can results in lower prices, increasing product demand and higher profits (Vivarelli, 2015). If these profits are reinvested into the firm, new jobs can be created. Third, while workers are displaced in sectors that introduce the technology incorporated in the new machinery, additional workers may be needed in the industries producing the new machinery (WTO, 2017). Fourth, as manufacturing becomes more automated, it can create jobs in other sectors due to spillover effects.

Figure 22: Automation and job creation



Source: Compiled from WTO (2017).

Studies documenting a rise in jobs due to automation includes Gregory et al. (2016), which examines the economy-wide effect of routine-replacing technological change. This report finds that computerisation between 1999 and 2010 in the European Union (EU) led to the creation of 11.6 million jobs, due not to the absence of labour replacing capital but to an increase in product demand and spillover effects in the non-tradable sectors. Likewise, Booz and Company's (2012) estimates show that digitisation created 19 million jobs in the global economy between 2009 to 2010 (Booz and Company, 2012). After controlling for gross capital formation, foreign direct investment (FDI), other financial investments and school enrolment ratio, the authors find that a 10% increase in digitisation reduces a country's unemployment rate by 0.84%. Analysis undertaken by the Brookings Institution also shows that countries that invested more in robots lost fewer manufacturing jobs than countries that did not (Muro and Andes, 2015).

Box 1: The A to Z factory: challenging the growing fear of 'jobless growth' in Africa.

A to Z Textile Mills Ltd (A to Z) is a family owned and operated company that produces light manufacturing goods including garments, household plastics and long-lasting insecticide-treated bed nets. A locally owned, diversified, vertically integrated firm with over 7,000 employees, it produces and supplies a large volume and range of goods to domestic markets, and exports internationally. The firm is an 'innovative manufacturer', which uses scientific research to create products with positive development outcomes (it has built the Africa Technical Research Centre on site) but also uses technology to increase output, while maintaining and even generating more jobs.

One example is the use of a modern laser fabric-cutting machine for garment manufacturing. This machine is used to cut fabric that is knitted on site (it is also one of the largest vertically integrated manufacturing plants in East Africa), and produces 25,000–30,000 pieces in one shift. To produce a similar amount manually requires 25–35 people; the laser machine requires 17 people (2 people to operate the machine and 15 people to lay and sort the fabric). Whereas initially this appears to be a net job loss, the increased output rate has led to a higher volume of accurately cut fabric. This in turn has led to more input for the next stage of the production – stitching. The stitching stage at A to Z is manual, given the specialist skills required to operate sewing machines, and the owners have increased the labour employed in this more skilled area due to increased input. As per the firm's estimates, roughly 300 extra jobs were created.

The productivity effect can be seen in this example as not only increasing and improving output using technology but also generating more jobs for skilled labour downstream in the production process. By seeking efficiencies without reducing manpower, this example shows that by becoming more efficient in some processes using technology, it is possible to create more jobs elsewhere.

An A to Z employee operating modern laser-cutters, controlled by computers.
Credit: Sonia Hoque/SET programme. All rights reserved.

(Left) Part of the stitching process is automated. (Right) Automation in printing designs onto fabric.
Credit: Sonia Hoque/SET programme. All rights reserved.

The overall impact of automation on employment can, however, be negative if the substitution effect dominates the productivity effect, i.e. the number of workers replaced with machines is greater than the number of jobs created. Moreover, even in the context of the productivity effect, it is important to note that progress in AI has led to development of modern robots that can recognise patterns, allowing them to substitute for labour in a broader range of tasks, including more complex and cognitive tasks. There is already evidence of hollowing out of middle-skilled jobs, and substitution of a substantial part of routine jobs, irrespective of skill level (OECD, 2013). Further, while a lower cost of production can create new demand and jobs, profits are reinvested in the same technology, implying that the rate of job creation will be lower. Lastly, jobs in other sectors being created due to spillovers also run the risk of being gradually substituted by automation. It is also most important to acknowledge that the movement of labour from one sector to other could be very difficult in developing-country labour markets, such as India, which have high labour market frictions.

Evidence of a negative impact of automation on employment was found in Frey and Osborne's study (2013) of the US local labour market. The authors analysed the impact of computerisation on 702 occupations and found that around 47% of the jobs in the US labour market were at high risk from automation. The authors also find that computerisation had a negative impact on wages. In an extension paper to Frey and Osborne (2013), the authors examine the impact of automation on the global economy using World Bank data on over 50 countries. Interestingly, the study finds that the negative impact of automation on employment is higher for several other countries compared to the US: 57% of jobs in the OECD, 69% in India and 77% in China are at risk of being automated. Adopting Frey and Osborne's (2013) methodology, Bowles (2014) takes the case of computerisation in EU and find that technological change can displace between 40% and 60% of the labour force, particularly affecting the labour markets of Romania, Portugal, Bulgaria, and Greece.

These alarming estimates have, however, been criticised in the literature for assuming that occupations as a whole can be automated; there is a great variability in the tasks within each occupation, and this is not accounted for (Autor and Handel, 2013). A better approach, therefore, when examining the impact of automation or digitalisation on jobs, is to examine the task content of individual jobs rather than the average task content of all jobs. The debate of examining 'tasks' versus 'jobs' becomes particularly important since the scale of the job losses predicted may be very different depending on the methodology. On breaking down occupations into tasks, with different levels of automatability, the share of jobs that can be automated in the OECD falls to 6–12 %, with significant differences across countries (Arntz et al., 2016). For example, it is observed that the share of automatable jobs in Korea is about 6% while in Austria it is about double that (Arntz et al., 2016).

More recently, studies have started to analyse the impact of robots on the labour market. Using the IFR dataset, Graetz and Michaels (2015) undertake cross-country analysis for 17 economies in the period 1993–2007 and find that robot densification leads to increases in wages, and while it does not affect employment overall, it does reduce employment of low-skilled workers. It may be argued that it is important to take a general equilibrium approach since robots can directly substitute workers when holding output and prices constant, but the resulting cost reductions can also increase product and labour demand. Moreover, workers can be soaked up by different industries, and specialise in new and complementary tasks. Taking this approach, Acemoglu and Restrepo (2017, 2016) examine the case of the US in the period 1993–2014 and find that one additional robot displaced around 3 to 6 jobs. In terms of types of jobs, the authors find robots to negatively affect employment and wages of workers with less than a high school degree, with a high school degree and, in some cases, with a college degree. No significant impact, either positive or negative, is found on workers with education beyond a college degree, indicating that industrial robots may not be complementing any well-defined group of workers in the US local labour market.

Also using the IFR dataset, and adopting both a local labour market approach and an individual worker approach, Dauth et al. (2017) focus on the case of Germany. Their findings suggest that, unlike in the US labour market, there is no evidence of robots leading to reduction in total employment in Germany. However, they do find a negative impact of robots on manufacturing jobs in Germany; more specifically, one additional robot is found to destroy 2 jobs on average. The authors estimate that roughly 275,000 full-time jobs in the manufacturing sector were destroyed by robots in the period 1994 to 2014. In terms of labour income, no effect of robots on average wages is found.

Interestingly, Dauth et al.'s (2017) worker-level analysis suggests that workers exposed to robots have a higher probability of retaining jobs in their original workplace, hinting at movement of workers towards other tasks within the workplace. This is in line with several studies arguing that automation does not lead to job substitution but rather to changes in the composition of the labour force. It is well documented in the literature that current technological progress has caused skill-biased division in the labour market, contributing to growing wage inequality (Autor et al., 2003; Autor and Dorn, 2013; Goos et al., 2014). From their cross-country panel, Graetz and Michaels (2016) find that robots impact overall wages positively but decrease the hours worked by low-skilled workers. Focusing on the US local labour market, Acemoglu and Restrepo (2017) show that in the period 1993–2007, one additional industrial robot reduced employment by 7 jobs (6.5 once adjusted for national gains through trade), and one robot per thousand workers reduced wages by 1.6% (1.2% once adjusted for national gains through trade). The aggregate impact of industrial robots on employment remained small; increase in robot density (one more robot per thousand workers) led to a 0.65 percentage-point decline in employment. However, the most adversely affected were low-skilled workers undertaking routine tasks. On average, the demand for workers in high-skilled, non-routine jobs has increased in advanced economies, accompanied by some increase in the demand for workers in low-skilled, non-routine jobs such as caring and personal services (OECD, 2016). With a decline in middle-skilled jobs, there is evidence of job polarisation in many OECD countries (Autor, 2015; Berger and Frey, 2016).

The evidence of job polarisation in developing countries is still scarce. In the case of Chile, while evidence of job polarisation was found by Messina et al. (2016), there is also evidence of advanced digital technologies by Chilean employers shifting employment away from skilled workers, creating more employment in routine and manual tasks (Almedia et al. (2017). Examining 21 developing countries, Maloney and Molina (2016) find evidence of a relative reduction, and potential polarisation, of routine jobs in only Brazil and Mexico.

It is also important to distinguish the job creation or substitution effect from other labour market effects. Along with lower growth in labour productivity in the recent years, high-income countries have witnessed a clear decline in the share of labour in total value added (Autor et al., 2017; Kehrig and Vincent, 2017), which is frequently associated with increasing automation. According to Dauth et al. (2017), digitalisation seems to be primarily benefiting the owners of capital and profit, but not labour at large. In the case of Mexico, too, automation seems to be resulting in falling labour income share, which decreased by around 10 percentage points (ILO and OECD, 2015). The fall in unit labour costs in sectors that rely on automation in Mexico is much faster on average than sectors which did not rely on automation.

For developing countries, Ugur and Mitra (2017) reason that the effect of rising technology adoption on employment is likely to be positive if it is related to skilled labour employment and product innovation. Conducting a review of 43 qualitative studies and 12 empirical studies,[9] the authors find that the overall employment effects are more likely to be positive in the presence of strong linkages between innovative firms and the rest of the economy, and government institutions facilitating technology adaption. Based on World Bank Enterprise Surveys, the recent work of Cirera and Sabetti (2016) also analyses the overall employment effects of technology in developing economies by using a sample of 15,000 firms in Africa, Central Asia, Eastern Europe, Middle East and North Africa and South Asia. The authors report that new sales associated with product innovation in

[9] Countries reviewed in these studies include India, China, Nigeria, Philippines, LDCs in South Asia, Ghana, Tanzania, Uganda, Kenya, South Africa, Thailand, lower-middle-income countries.

these firms continue to require high labour intensity, indicating a positive impact of product innovation on short-run employment. However, the extent to which new products can generate additional employment is found to be directly related to the impact of process innovation on efficiency. This suggests that in LICs, and especially in Africa – where firms are still lacking in terms of technological development and therefore have low efficiency gains from process innovation – the impact of product innovation on employment is higher.

A summary of the national pathways of digitalisation (within-country digitalisation as opposed to global digitalisation) to labour productivity, employment and wages is given in Box 2 below.

Box 2: National pathways by which digitalisation affects growth and labour market

Countries that digitalise can experience direct gains or direct losses from digitalisation:

1.1 Direct gains

1.1.1 Increase in productivity. Automation in manufacturing and technologies of robots and 3D printing can make production more efficient, improving productivity.

1.1.2 Job creation. Emerging technologies of artificial intelligence, robots, 3D printing, e-commerce can lead to (a) increase in demand and trade of new products; (b) increase in demand of existing products; (c) more efficient organisation of production leading to boost in output and exports; (d) reduction in cost of production, enabling new entrants and entrepreneurs to enter the export market; and (e) increase in 'digital' jobs. These 'productivity' pathways can lead to creation of new job opportunities.

1.1.3 Benefit to consumers. With technologies such as 3D printing and e-commerce, consumers have (a) a wider variety of choices in products; (b) the option of buying more customised 3D printed products; and (c) the ability to make the products themselves (once 3D printers become affordable). Women consumers, in particular, can take advantage of e-business opportunities to overcome barriers to entry into the market.

1.2 Direct losses

1.2.1 Job destruction. It is possible that deployment of robots, 3D printers and automation can result in substitution of labour in traditional labour-intensive (routine) manufacturing tasks. This can lead to changes in the traditional division of labour in tasks and increasingly to skill mismatches. As industrial robots improve in dexterity and perform cognitive tasks increasingly well, substitution of labour can expand to skilled tasks.

1.2.2 Rise of precarious work. Even if the net effect of digitalisation is job creation, the rise of digital labour platforms can lead to an increase in informal and unregulated jobs. As barriers to entry fall due to digitalisation, competition increases, which can lead to pressure on wages and an increase in precarious work.

Source**:** Authors (2018).

5.3 Digital divide: implications for developing countries

Some studies maintain that the impact of digitalisation on developing countries is hyped. These studies argue that substitution of labour by automation will only happen in those countries where it is economically feasible to employ such technology, i.e. where the relative price of capital versus labour is falling. For this reason, automated production is mostly still concentrated in developed economies, except for China. The TDR (2017) also states that despite the hype surrounding rise of the robots and automated production, the use of industrial robots was quite low in the year 2015 (around 1.6 million robots), with the share of Africa in total number of robots sold in 2015 being less than 0.1% and its share in total operational stock of robots only 0.25% (IFR, 2016).

It is, however, predicted that by 2019, over 2.5 million robots will enter the market (IFR, 2016a), pointing towards rapid growth in robot deployment in the near future. Moreover, some studies have estimated that more than half of occupations across all sectors are at risk of being automated by emerging technologies (Bowles, 2014; Frey and Osborne; 2013). Frey et al. (2016) harness World Bank data and use the methodology in Frey and Osborne (2013) to estimate the impact of computerisation for 702 detailed occupations. They find that that across Africa, the peril of jobs becoming automated varies from 65% to almost 85% in Ethiopia. However, after breaking down jobs into tasks, the threat of automation to employment falls to 2%–8% for low- and middle-income countries (Ahmed and Chen, 2017), much lower than predictions using the Frey and Osborne methodology.

In contrast, McKinsey's recent report (2017) estimates a high percentage of automatable jobs in developing economies – 41% of jobs in South Africa, 50% in Brazil, 52% in Kenya, 46% in Nigeria, 50% in Ethiopia and 55% in Thailand. It is observed that countries with lower GDP per capita, particularly African economies, are relatively more vulnerable to automation. This may suggest that as automation rises in such countries, shifting workers from agriculture to higher-paid factory jobs might no longer work in promoting rapid growth, unlike in the case of Asian economies (Frey et al., 2016).

TDR (2017) maintains that robot-based production is mainly concentrated in just five sectors: automotive; computer and electronics; electrical; rubber, plastics and chemicals; and machinery. Even though it is found that the textile, apparel and leather sector ranks very high on the technical feasibility of automation, it has the lowest deployment of robots. Some argue that this suggests it is not yet economically feasible to install robots in labour-intensive manufacturing sectors, limiting the threat of digitalisation for employment in developing economies. While that might be true, it is important to acknowledge the backstopping effect of robots on labour income in the less-automated sectors. It may not be economically feasible to deploy robots in traditional sectors, due to robot densification in more automated sectors indirectly putting pressure on wages in traditional sectors. Moreover, the Creativity vs Robots report (Bakhshi et al., 2015) finds that three traditional activities that are major employers in Africa – growing cereals, growing fibre crops, and raising dairy cattle, sheep and goats – are all occupations with very high probabilities of being automated in the near future: 100%, 91.2% and 89.3% respectively.

Another international pathway through which digitalisation can have important implications for developing countries is the process of re-shoring. Citigroup and the Oxford Martin School (2016) link this trend of re-shoring to increasing robot density in developed countries and de-acceleration of global trade since 2011. As the cost of capital falls for producers in developed economies, they may find it increasingly efficient to re-shore production from offshored plants back to their own 'smart' factories. As per the Reshoring Initiative (2015), 250,000 jobs have already been re-shored to the US since 2010. While countries like the US have the most to benefit from re-shoring, developing economies that are offshoring hubs have the most to lose.

Evidence suggests that re-shoring until now has occurred on a small scale. Between 2010 and 2012 only 2% of all German manufacturing companies and only 4% of firms in Austria, Denmark, France, Germany, Hungry, Portugal, Netherlands, Slovenia, Spain, Sweden, and Switzerland re-shored their production. For each company that has re-shored production, there are still more than three companies that offshore production (De Backer et al., 2016). However, it is important to note that some leading firms have already re-shored historically labour-intensive manufacturing closer to the end market. Popular examples include Philips shavers in the Netherlands and Adidas shoes in Germany (Bloomberg, 2012; Economist, 2017). Adidas has also made considerable investments in 3D printing of athletic footwear, a sector where additive manufacturing is not widespread. It established two ‘speed factories’ in Ansbach, Germany, and Atlanta, US, for mass production, which is estimated to have created 160 jobs but eliminated around 1,000 jobs in Viet Nam (Hallward and Nayyar, 2017). Other examples of firms bringing back manufacturing processes closer to home include the Ford Motor Company, Whirlpool, and Caterpillar (Reshoring Initiative).

Also, it is important to note that while the number of firms or percentage of firms re-shoring activities may not be very high right now, for every company that re-shores, a sizeable number of jobs can be lost. Using data from the Reshoring Initiative, we calculate the number of jobs lost per US company re-shored from a region (see Table 3). The greatest number of companies and job losses have been in Asia – 47% of the total US jobs re-shored came from this region. It is observed that while only 7 US companies re-shored production from Africa, it led to a loss of 885 jobs, implying that roughly 126 jobs are lost when a US company re-shores production from this region.[10]

Table 3: Impact of re-shoring of US companies on employment in offshoring destinations (2010–2016)

Country/region	Number of companies re-shored	Number of jobs lost	Share in jobs re-shored (%)	Number of jobs lost per re-shored company
Asia	1112	138450	47.6	124
Western Europe	528	103879	35.7	196
North America	235	35186	12.0	149
Middle East	34	5991	2.0	176
South America	21	3963	1.3	188
Australia	20	1398	0.4	69
Eastern Europe	21	1045	0.36	49
Africa	7	885	0.3	126

Source: The Reshoring Initiative.
Notes: Jobs re-shored in South Africa may be forming a major component of re-shoring in Africa.

Re-shoring can also indirectly lead to a loss of potential jobs. The adoption of newer and advanced technologies by high-income countries can prevent further production from being migrated to developing countries. While it is difficult to put a number on potential jobs lost, evidence of this happening is seen in Xu et al.’s (2017) latest survey of Chinese manufacturing firms. Out of the light-manufacturing Chinese firms surveyed, 28% declared rising wage costs in China to be the greatest challenge in firm operations and 31% ranked ‘technology upgrading’ as the preferred response to rising costs, rather than investing abroad in regions where labour is cheaper. And if they did invest abroad, South Asia was chosen over Africa as the preferred destination. In line with this, survey data from a recent study by Gelb et al. (2017) shows that Africa is not yet on the path of manufacturing-

[10] To further understand the significance of re-shoring, it would be useful to examine the share of offshored jobs being re-shored and the number of newly offshored jobs. However, this data is not publicly available yet.

led take-off. Both lower- and middle-income African countries are, on average, found to have high manufacturing labour costs relative to GDP as well as high capital costs relative to their comparators, questioning the potential of Africa to emerge as an important manufacturing hub.

The impact of re-shoring, as a result of the digital divide, is not just limited to employment; it can also have adverse implications for developing countries' economic growth and development. Many LICs have been able to achieve rapid economic growth by industrialising and moving from low-productivity agricultural activities to high-productivity export manufacturing in traditional sectors such as textiles, footwear etc. The third industrial revolution and its significant advancements in communications helped further this process of 'structural transformation' by lowering the costs of coordinating complex activities spread over different countries (Baldwin, 2016). This allowed the spread of vertically integrated supply chains, with developing countries acting as cheap manufacturing hubs.

This process of 'structural transformation' lies at the centre of convergence in the wealth levels of rich and poor countries. There is also evidence of 'unconditional convergence' in the labour productivity of the manufacturing sector (Rodrik, 2011). Productivity in low- and middle-income countries has grown faster, due to the larger stock of unexploited technologies and knowledge, and will eventually converge with the global technological frontier, irrespective of national policies and institutions. Evidence suggests that 50% of the catch-up in relative aggregate productivity across countries 11 is driven by high productivity growth in the manufacturing sector (Duarte and Restuccia, 2010). This is most likely due to production of tradable goods in the manufacturing sector, which enables diffusion of technology embodied in the goods and other spillover effects.

However, over time, barring a few Asian economies, developing countries have witnessed 'premature de-industrialisation' – declining shares of manufacturing activities (Rodrik, 2016). As digitalisation increases in developed countries, and manufacturing tasks begin to be re-shored, there is a risk of further slowdown in global trade, as we saw post 2011. De-acceleration in global trade will mean lower technology diffusion, and slowdown in convergence, diminishing the ability of the manufacturing sector in developing countries to 'catch-up'. This can lead to further de-industrialisation. Therefore, a persistent digital divide, in the face of growing digitalisation globally, can exacerbate global inequalities (Norton, 2017).

This can be better understood by moving from the macro perspective to using Andrews et al.'s (2016) recent micro-level approach. Using data for the period 1997–2014 on manufacturing and services (excluding financial business sector) firms in 24 OECD countries, Andrews et al. (2016) find that the global productivity slowdown in OECD countries is not so much slowdown in productivity growth at the global level, but rather rising productivity at the global frontier coupled with a widening productivity gap between the global frontier (top 5% of OECD firms in terms of labour productivity) and laggard firms. The authors find that the increasing labour productivity gap is largely reflective of divergence in revenue-based labour productivity as a result of divergence in technology. This is indicative of diverging capacities of firms to technologically innovate and successfully combine intangibles (such as computer programmes) into the production process. Findings in the study suggest that the labour productivity divergence may be due to: (a) digital divide increasing the productivity performance gap with laggard firms; and (b) slowdown of technological diffusion; laggard firms in the OECD are not able to adopt new technologies due to rising tacit knowledge and the increasing complexity of these technologies requiring more sophisticated complementary investments.

[11] The countries covered are Argentina (1950–2004), Australia (1964–2004), Austria (1960–2004), Belgium (1956–2004), Bolivia (1950–2002), Brazil (1950–2003), Canada (1956–2004), Chile (1951–2004), Colombia (1950–2003), Costa Rica (1950–2002), Denmark (1960–2004), Finland (1959–2004), France (1969–2003), Greece (1960–2004), Ireland (1958–2004), Italy (1956–2004), Japan (1960–2004), Korea (1972–2003), Mexico (1950–2004), Netherlands (1960–2004), New Zealand (1971–2004), Norway (1956–2004), Portugal (1956–2004), Spain (1960–2004), Sweden (1960–2004), Turkey (1960–2003), United Kingdom (1956–2004), United States (1956–2004), and Venezuela (1950–2004)

In this case, it is also likely that the new product lines in the digital economy will remain limited to developed countries, where it is both economically and technologically feasible to carry out capital-intensive production. Goods in industry 4.0 (the fourth industrial revolution) reflect a basket of new digitally enabled smart goods, such as driverless cars, that require advances in production equipment (including robotics, 3D printers etc.) and data tools and analysis across the value chain. They would thus require advanced infrastructure, R&D and skilled labour at every point along the chain rather than at the extreme ends of high-value-added activities. If new goods are increasingly based on a 'digital thread' connecting pre- and post-manufacturing tasks with manufacturing and assembly activities, then it is unlikely that manufacturing of goods in the digital economy will be shifted to developing countries, particularly African economies with limited digitalisation. This will potentially lead to further concentration of manufacturing in developed economies (Hallward and Nayyar, 2017), limiting opportunities for technological diffusion and spillovers to the developing economies.

Thus, even if LICs have a limited digital economy, a combination of re-shoring and concentration of new manufacturing in developed countries can have important adverse implications for LICs. These indirect international impact pathways are summarised in Box 3 below.

Box 3: International pathways by which digitalisation can affect developing countries

1. **Re-shoring of activities**. As cost of capital relative to labour falls in developed economies and manufacturing becomes increasingly automated, the developed countries are likely to re-shore their production from offshored plants in developing economies to in-house production in R&D and automation enabled plants. This reshoring of activities can have a significant impact on the role of developing economies as manufacturing hubs in global value chains, and on employment and growth.

2. **Fall in wages**. Falling costs of capital and growing digitalisation in developed countries can keep wages in the less-automated developing countries lower as an attempt to become more competitive.

3. **Exclusion from new GVCs**. As manufacturing of goods in industry 4.0 is expected to be increasingly based on a digital thread running across the different stages of production, it is likely that developing countries with their limited digital abilities will be excluded from new GVCs.

Source**:** Authors (2018).

6. NEW EMPIRICAL ANALYSIS OF DIGITALISATION IN AFRICA

There is very little analysis of the impact of digitalisation on economic performance in African countries. This section examines the background on labour productivity and provides new evidence of the impact of technical change in general, and of digitalisation, on labour productivity in the manufacturing sectors of low- and middle-income countries.

6.1 Using internet penetration as a proxy for digitalisation

For the purpose of empirical analysis, we will use internet penetration as a proxy for digitalisation. This is measured as the percentage of a country's population with access to internet.[12] In no way are we claiming that internet penetration is a perfect proxy for digitalisation or that it can capture the different aspects of the digital economy that we have mapped out in Figure 1. Digitalisation goes

[12] Internet users are individuals who have used the internet (from any location) in the last three months. The internet can be used via any device including computers, mobile phones, personal digital assistants etc.

much beyond having access to the internet. However, the use of internet penetration to capture digitalisation in our study is justifiable for several reasons, discussed below.

First, ***access to internet is important in its own right***, and is no longer a luxury. It is a powerful tool, which can generate efficiencies for all actors in the economy – from a rural farmer, to a large multinational corporation, to the government. It does so by providing better access to information and communication; improving transparency; facilitating better governance, better healthcare, better education and better services; and by introducing new ideas. Second, ***it forms the very basis of digitalisation***, making it a necessary (but not sufficient) condition for digitalisation. An important component of the digital economy is the Internet of Things (IoT) – which is predicted to have a total potential economic impact of $3.9 trillion to $11.1 trillion a year by 2025, with maximum value accruing to factories (McKinsey Global Institute, 2015). Applied to the manufacturing sector, the Industrial Internet of Things (IIoT) can connect sensors on a large number of objects to computing systems through the internet. Other digital technologies such as cloud computing and big data technologies will also need the internet to operate. Third, using internet penetration enables us to ***encompass a broader spectrum of technologies***, allowing the measure of digitalisation to be more generalised and not specific or biased towards a particular technological development. On the more methodological side, internet penetration allows us to compare countries in terms of meeting the basic condition of digitalisation – having access to the internet – and compared to other proxies (such as data on internet speed) it is available with a good coverage for developing countries and years, allowing us to observe country-specific trends in digitalisation. Data on other indicators of digitalisation, such as robot density, is not available for African countries, restricting the use of such indicators for our study.

Therefore, we use internet penetration to examine the potential impact of digitalisation on labour productivity in the manufacturing sector of countries. Internet penetration at the country level, instead of at the manufacturing sector level, allows us to deal with reverse-causality issues in our empirical analysis and also allows us to compare the overall digital-preparedness of countries. This is important since digitalisation has led to an increasing 'servification' of manufacturing processes, blurring the lines between manufacturing and services. We confirm the validity of using internet penetration as a proxy by checking the correlation of internet penetration with other commonly used digitalisation indicators. We find that internet penetration is highly correlated (more than 60%) with all indicators examined (see Appendix B). We also carry out robustness checks for our empirical results using other proxies for digitalisation.

6.2 Trends in labour productivity

Labour productivity in an economy can be improved within sectors through technological progress and capital accumulation, and through structural change by shifting labour from less-productive activities into more-productive activities. During the 1990s, African labour entered the agricultural sector rather than exiting it, thereby suppressing overall labour productivity growth (McMillan and Rodrik, 2011). This also applies to manufacturing; the lack of overall labour productivity growth in African manufacturing can be seen in Table 4 below (SET, 2017). African productivity in manufacturing has risen more slowly over 1991–2013 than elsewhere, indicating that there has been too little productivity-enhancing technical change in SSA. However, in the period 2006–2013, annual productivity growth was higher in the region compared to 1991–2013, suggesting some improvements in labour productivity in recent years. A key factor in this was labour exits from agriculture (McMillan et al., 2014), not into manufacturing but into (low-productivity) services.

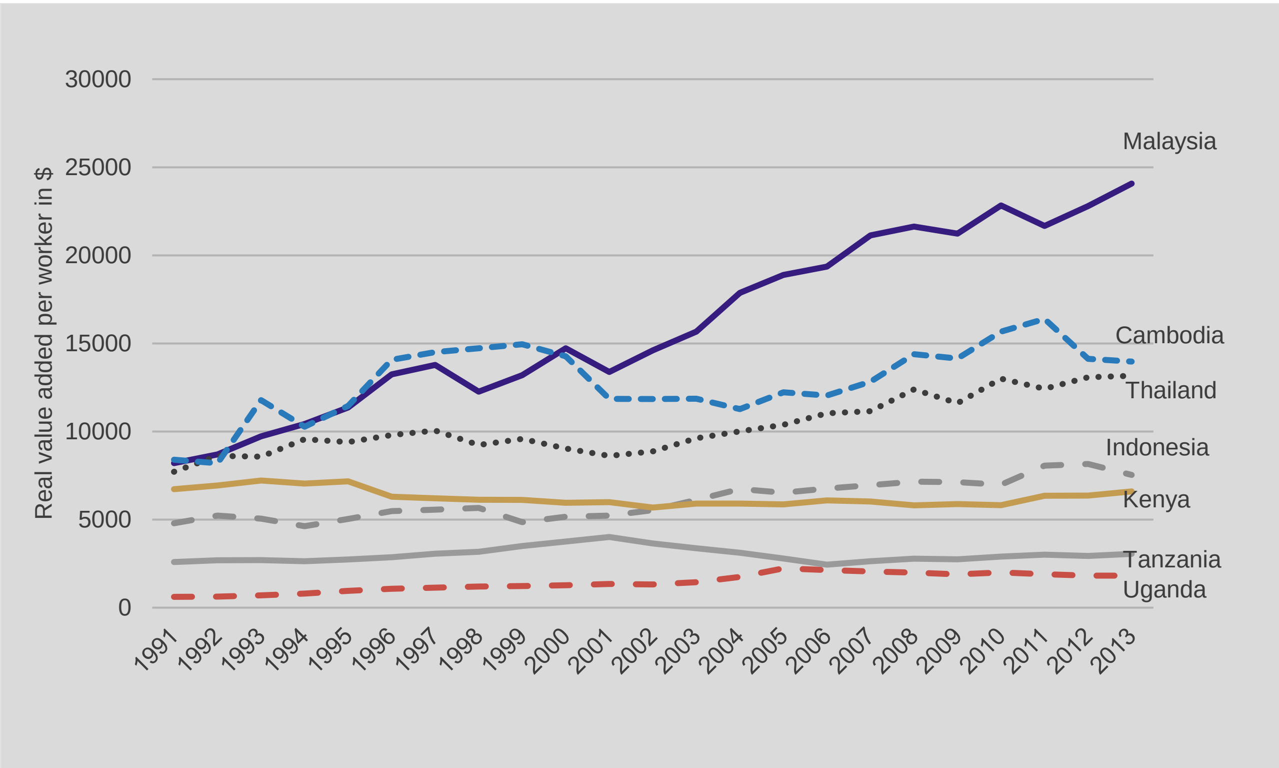
Table 4: Annual labour productivity growth % in manufacturing

Region	2006–2013	1991–2013
East Asia and Pacific	4.3	3.1
Europe and Central Asia	5.9	2.5
Latin America	5.7	2.5
Middle East and North Africa	0.7	2.2
South Asia	2.6	2.2
Sub-Saharan Africa	1.8	1.2

Source: ODI/SET database (2017), matching UN and ILO data
Note: Labour productivity = manufacturing real value-added per worker.

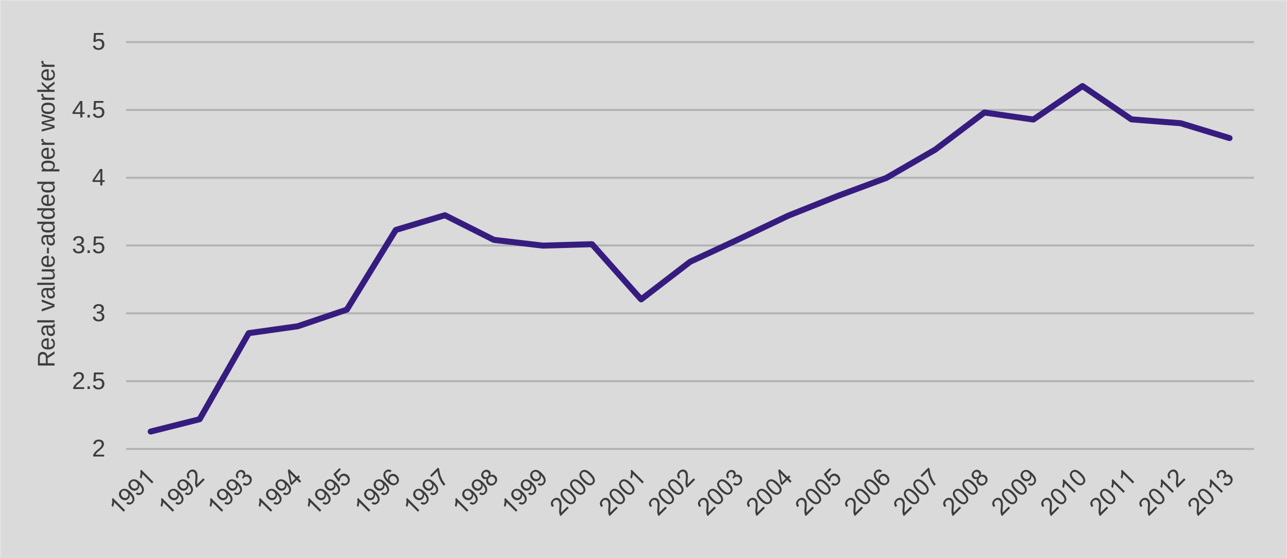
Figure 23 below plots labour productivity in the manufacturing sector of selected African countries (Tanzania, Uganda, and Kenya) against selected Asian economies. Both labour productivity levels and labour productivity growth in African economies is much lower than in Asian countries. While labour productivity on average has gone up over time for Asian economies, it has remained more or less constant for African countries. Plotting labour productivity of selected Asian economies relative to selected African economies (Figure 24), reveals that the productivity gap between Asian and African economies rose sharply post 2000, but there is a downward trend after 2010 indicating a fall in the productivity gap.

Figure 23: Manufacturing labour productivity in African and Asian countries



Source: ODI/SET database, matching UN and ILO data.
Note: Labour productivity is measured as Real Gross Value Added (GVA)/ number of people employed.

Figure 24: Relative labour productivity between Asian and African countries



Source: (ODI/SET database, matching UN and ILO data).
Note: Relative labour productivity = average labour productivity of Asian countries/ average labour productivity of African countries. Asian countries included: India, Malaysia, Thailand, Cambodia, and Indonesia. African countries included: Uganda, Ethiopia, Ghana, Kenya, and Tanzania.

6.3 Convergence in labour productivity

According to Rodrik (2012), the manufacturing sector experiences unconditional convergence in labour productivity. This implies that developing countries that are further away from the frontier will grow faster and catch up with the developed world. This is because the manufacturing sector relies heavily on tradable goods, which allows countries to link into global production networks, further facilitating technology transfer and adoption. To check for this unconditional convergence in our cross-country sample, we estimate the following model:

$$Growth\ in\ LP_t = \alpha + \beta Log(\ LP)_{t-1} + u_i$$

where a negative sign on the β coefficient implies convergence of countries in labour productivity of the manufacturing sector. We divide our sample into all countries and only sub-Saharan countries between the period 1991–2002 and 2002–2013. The above model is run on all four samples and results are reported in Table 5. In all four cases, we obtain a negative sign on the β coefficient, supporting the convergence hypothesis. However, we notice that for both, the all-countries sample, as well as the sub-Saharan sample, the β coefficient is lower and insignificant for the period 2002–2013 as compared to 1991–2002, suggesting slowdown in convergence or weaker evidence of convergence. The rate of convergence in SSA more than halved, comparing 2002–2013 to 1991–2002.

Table 5: Convergence results

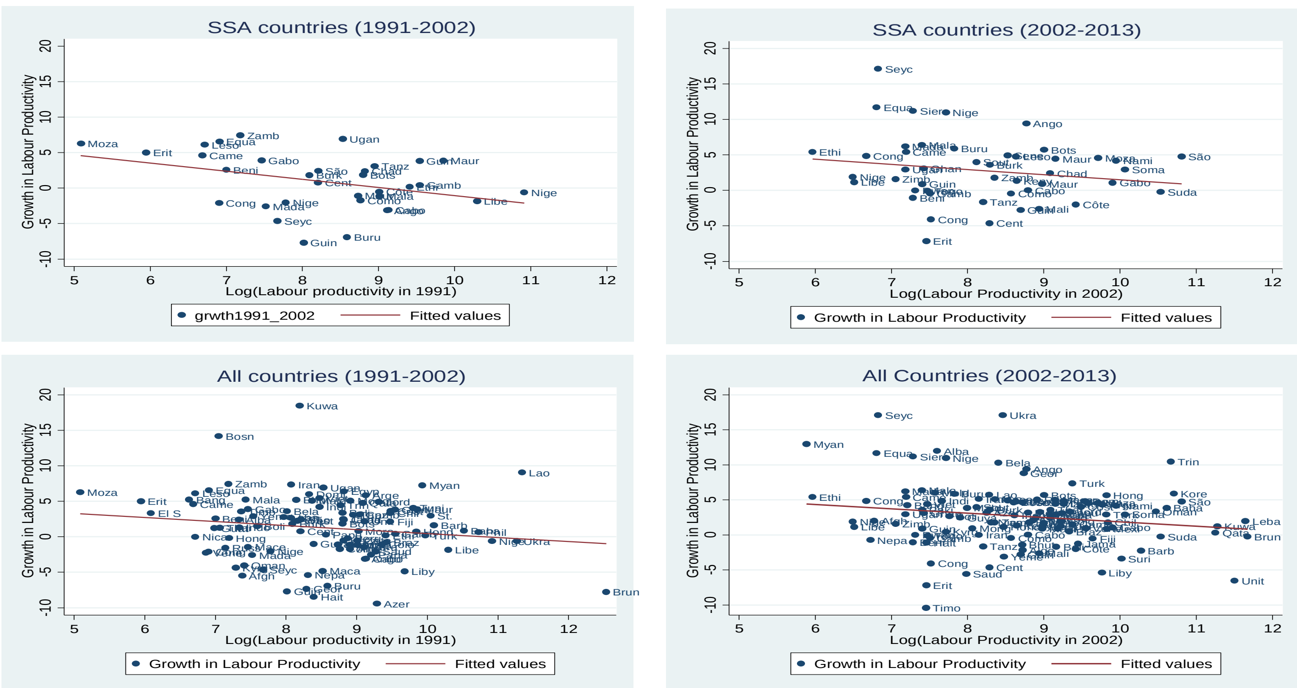
Dependent variable	Growth in 1991-2002	Growth in 1991-2002	Growth in 2002-2013	Growth in 2002-2013
Labour productivity in 1991	-0.695* (0.380)	-1.581** (0.657)		
Labour productivity in 2002			-0.678 (0.424)	-0.726 (0.594)
Constant	7.028** (3.268)	13.48** (5.510)	8.906** (3.705)	8.749* (4.890)
Sample	All countries	SSA countries	All countries	SSA countries
Observations	106	34	126	46
R-squared	0.031	0.153	0.020	0.033

Notes: Dependent variable is growth in labour productivity in the manufacturing sector. Labour productivity is measured for the manufacturing sector and is calculated as Real GVA/ number of employees. Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$. To confirm conditional convergence, we run the model with country fixed effects; β remains significant and negative.

We also plot annual growth in labour productivity for the period 1991–2002 and 2002–2013. The downward sloping line in the graphs of Figure 25 confirms that labour productivity is converging, irrespective of the initial endowments.

If the cost of capital continues to be high in African economies, as we saw in Section 4.1, this will make it increasingly difficult for them to finance investment into new technologies. As a result, these countries will not be able to digitalise, which may lead to their exclusion from global production networks and technology flows. Moreover, falling relative cost of capital in the developed countries can incentivise them to re-shore production, which can severely limit the opportunities for African countries to catch up.

Figure 25: Unconditional convergence in manufacturing labour productivity

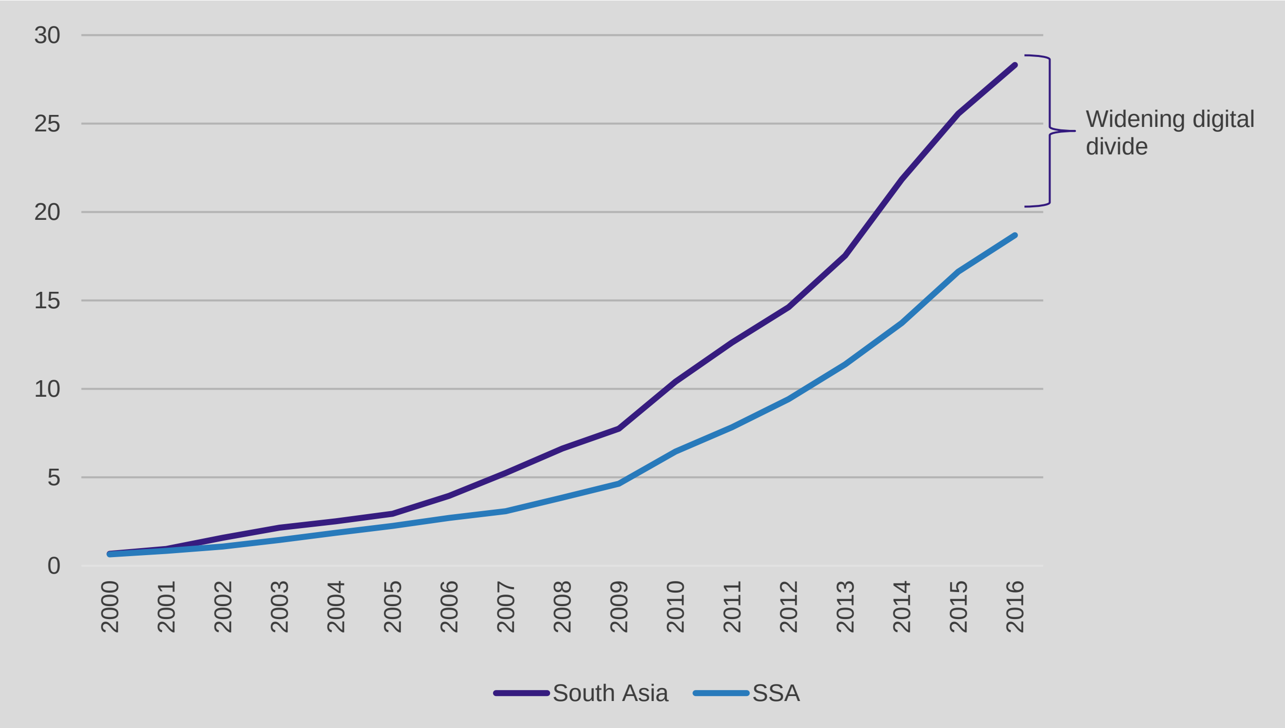


Source: Authors (2018).
Note: Data is from ODI/SET database, matching UN and ILO data.

6.4 Digitalisation trend in Africa

In Figure 26, we plot the average internet penetration rate in African and South Asian countries over the period 1991–2013. Until 2001, internet penetration was negligible in both Asia and Africa, but since then it has steadily increased in both regions. Post 2005, the internet penetration rate (IPR) in Asia was well above that in the African economies, and we witness a growing divergence in the period 2005–2013.

Figure 26: Average internet penetration in Africa and Asia (%)



Source: ITU database.
Notes: The vertical axis represents percentage of population with access to the internet.

6.5 Empirical specification and strategy

To examine the effect of technological change on labour productivity, we derive and estimate a labour demand equation which estimates the effects of technological changes on labour productivity (left hand variable). In doing this, we follow Barrell and Te Velde (2000) and Kingombe and Te Velde (2012) and use a two-factor CES production function with labour (L) and capital (K) as the two inputs.

The CES production function is represented as follows:

$$f(L_t K_t) = Y_t = \{\lambda(\psi_{Lt} L_t)^{\rho} + (1-\lambda)(K_t)^{\rho}\}^{\frac{1}{\rho}}$$

Where L_t is the labour input, K_t is the capital input. The elasticity of substitution between the two inputs is $\sigma = 1/(1-\rho)$ where ρ is less than 1. Since the elasticity of substitution in the CES function can differ from 1, it is less restrictive than the Cobb-Douglas function which assumes unit elasticity of substitution between the two inputs. The parameter $\psi_{Lt} = e^{\phi_{Lt}}$ is a labour efficiency index capturing skill-specific technology level or accumulated human capital.

In the neo-classical theory, the standard assumption is that technology is 'on the shelf', i.e. it assumes exogenous technological change. However, patterns of technological change can shift, depending on endogenous country-specific capabilities to absorb technical change. For example, FDI or access to internet in a country can enable the transfer of knowledge to more productive firms that can further generate productivity spillover effects, increasing aggregate labour productivity. To capture effects of both exogenous and endogenous technological change on labour productivity, we model labour-augmenting[13] technological change as:

$$\phi_{Lt} = \text{Ln}(\psi_{Lt}); \phi_{Lt} = \gamma_{1L} + \beta_L \sum X_t$$

Next, using the first-order condition that marginal productivity of labour is equal to real wage, we have:

$$MPL_t = \frac{w_t}{P_t}; \frac{df(L_t K_t)}{dL_t} = \frac{w_t}{P_t}$$

Using the first-order condition, we derive the demand for labour inputs as:

$$Ln\left(\frac{L_t}{Y_t}\right) = \sigma Ln(\lambda) - \sigma Ln\left(\frac{W_t}{P_t}\right) + \gamma_L(\sigma - 1)t + \beta_L(\sigma - 1)\sum X_t$$

where the time trend (t) captures the unobserved technological change, X_t captures endogenous factors affecting labour productivity; when $\sigma > 1$, it is expected that the coefficient on time trend t will be positive.

Rearranging the above equation and adding time-invariant country fixed effects, we get:

$$Ln\left(\frac{Y_t}{L_t}\right) = \delta_1 Ln\left(\frac{W_t}{P_t}\right) + \delta_2 t + \delta_3 \sum X_t + \alpha_i + \varepsilon_t \quad \text{[Model 1]}$$

where X refers to endogenous labour augmenting technological changes and controls, α_i captures country fixed effects and ε_t is the error term.

6.6 Digitalisation and labour productivity

We estimate model 1 using a cross-country panel that covers low-income, lower-middle income and upper-middle income countries using annual data for the period 1990–2013.[14] This panel has data on manufacturing labour productivity, real wages, digitalisation, FDI, trade openness etc. The construction of these variables and data sources used are given in Appendix C.

We now turn to the results of the estimations for model 1, presented in tables 6–9. All estimations are based on a Fixed Effects model in order to control for the time-invariant country fixed effects. Robustness checks using Generalised Method of Moments (GMM) estimations and other proxies for digitalisation (broadband subscription, mobile subscription and use of secure internet servers) are given in appendixes D and E respectively.

Column 1 in Table 6 regresses labour productivity on lagged real wage and a time trend. The lagged value of real wage is taken instead of current real wage to avoid reverse causality (or endogeneity) from the dependent variable, i.e. the effect of more productive labour being offered higher wages. It is observed that as wages increase, labour productivity rises. The time trend is taken as a proxy for unobserved technological progress, and is observed to significantly and positively impact labour productivity.

Since we cannot observe digitalisation in the manufacturing sector, we use internet penetration in the country as a proxy in model 2. We observe that if internet penetration doubles (for example, in Kenya it went up from around 5% in 2007 to10% in 2012) then labour productivity will go up by 10%. The coefficient on internet penetration does not change much when we add controls in model 3. An

[13] We use a Harrod-Neutral (only labour augmenting) model of technological progress, which is the only model consistent with equilibrium steady-state ratio k* (Uzawa,1961). This model assumes that that technological progress is labour-augmenting, while holding capital-output ratio constant over time. In this model, Y= f (K, A(t) L).

[14] We conducted Fisher-type unit-root test on variables in our panel to check for stationarity. A significant p-value of 0.000 was obtained, rejecting the H0 that all panels contain a unit root.

important further finding is that the impact of internet penetration is found to be lower by 8% for low-income countries compared to lower-middle- and upper-middle income countries (column 4).

In column 5, we interact internet penetration with the time trend to examine the effect of technological progress as digitalisation increases. We observe that as a country digitalises, the effect of technological progress on labour productivity also improves. In column 6, we drop the main effect of internet penetration to check for robustness against multi-collinearity. We do not expect reverse causality to significantly bias our estimates since labour productivity in the manufacturing sector is not likely to affect country-level digitalisation.

Table 6: The impact of technical change and internet penetration on manufacturing labour productivity

Variables	**(1) Model 1**	**(2) Model 2**	**(3) Model 3**	**(4) Model 4**	**(5) Model 5**	**(6) Model 6**
L. Real wage	0.150** (0.0498)	0.175** (0.0564)	0.220*** (0.0537)	0.167** (0.0658)	0.118* (0.0529)	0.106* (0.0485)
Time trend	0.0363*** (0.00844)				-0.0134 (0.0154)	-0.0137 (0.0162)
Internet penetration rate (IPR)		**0.105*** (0.0208)**	**0.0933** (0.0396)**	**0.113*** (0.0243)**	0.0245 (0.0313)	
IPR*LIC				**-0.0801** (0.0298)**		
Time trend*IPR					**0.0073*** (0.0018)**	**0.00868** (0.00294)**
K/L			-0.135 (0.161)			
Import share			0.00108 (0.00242)			
FDI share			0.144* (0.0771)			
Time fixed effects			Yes			
Constant	7.658*** (0.236)	7.987*** (0.203)	8.981*** (1.632)	8.004*** (0.225)	8.288*** (0.189)	8.331*** (0.184)
Observations	739	728	625	728	728	728
R-squared	0.286	0.286	0.377	0.300	0.318	0.316
Number of countries	71	71	59	71	71	71

Note: Dependent variable is log real value added per worker in the manufacturing sector. Standard errors are cluster robust. Internet penetration is measured as the percentage of population in the country having access to the internet and is a proxy for the country's digitalisation level. One period lagged value of real wage is taken. Real wage, internet penetration, FDI share and capital to labour ratio has been logged.

We treat column 5 in Table 6 as our baseline model. To this, column 1 in Table 7 adds an interaction between low-income country and internet penetration, as well as technological progress. It is observed that the impact of technological progress on productivity is 2.3% higher for LICs, indicating convergence as a result of technological change. However, we also observe that the impact of digitalisation is lower in LICs, confirming the results of Table 5. This may be due to the inability of LICs to absorb and utilise digitalisation. In column 2, we drop the main effect of internet penetration to ensure our results are robust to multi-collinearity. In column 3, we undertake a three-way interaction which shows that as digitalisation increases, the impact of technological progress on productivity is lower for LICs. Again, in column 4, we drop internet penetration to check for robustness. In column 5, we control for capital intensity and openness. Model 6 drops internet penetration in model 5, and model 7 adds share of inward FDI stock as a control to model 5.

Table 7: The impact of technical change on labour productivity across income level

Variables	(1) Model1	(2) Model2	(3) Model3	(4) Model4	(5) Model5	(6) Model6	(7) Model7
L. Real wage	0.123* (0.0539)	0.103* (0.0518)	0.116* (0.0577)	0.0996 (0.0544)	0.201*** (0.0220)	0.186*** (0.0170)	0.210*** (0.0196)
Time trend	-0.0112 (0.0164)	-0.0122 (0.0178)	-0.0199 (0.0160)	-0.0225 (0.0164)	-0.00711 (0.0207)	-0.00824 (0.0217)	-0.0140 (0.0208)
Internet penetration	0.0403 (0.0397)		0.0324 (0.0427)		0.0337 (0.0437)		0.0312 (0.0417)
Time trend*IPR	0.0063** (0.00222)	0.0085** (0.00298)	-0.0018* (0.000930)	-0.0016 (0.000889)	-0.0049*** (0.00110)	-0.0049*** (0.00113)	-0.00546** (0.00187)
IPR*LIC	-0.103** (0.0386)	-0.0694*** (0.0117)	-0.0684 (0.0443)	-0.0355*** (0.00342)	-0.106 (0.0642)	-0.0708** (0.0229)	-0.0611 (0.0653)
Time trend*LIC	0.0231* (0.0118)	0.0151 (0.0113)	0.0604** (0.0182)	0.0614** (0.0186)	0.0930*** (0.0213)	0.0928*** (0.0218)	0.0792** (0.0229)
L-U-MIC*Time trend*IPR			0.0100** (0.00279)	0.0120*** (0.00262)	0.0121*** (0.00273)	0.0141*** (0.00264)	0.0126** (0.00363)
K/L					-0.112 (0.132)	-0.118 (0.144)	-0.0906 (0.102)
Import share in GDP					0.00440	0.00498	0.00311
Inward FDI share in GDP					(0.00432)	(0.00482)	(0.00349) 0.111 (0.0955)
Constant	8.203*** (0.174)	8.293*** (0.170)	8.259*** (0.223)	8.339*** (0.200)	8.852*** (1.117)	8.956*** (1.216)	8.443*** (0.697)
Observations	728	728	728	728	632	632	625
R-squared	0.325	0.319	0.329	0.326	0.363	0.360	0.372
Number of countries	71	71	71	71	59	59	59

Notes: Dependent variable is log real value added per worker in the manufacturing sector. Standard errors are cluster robust. L-U-MIC is a dummy variable = 1 for all lower-middle and upper-middle income countries. Import share is the share of imports in GDP and captures openness of the economy. One period lagged value for wages is taken. Variables are in logs, levels have also been used to check for robustness.

Table 8 replicates the regressions in the above tables to compare differences in impact of digitalisation on productivity across sub-Saharan African countries and other countries. From models 1, 2 and 3 in Table 8, we observe that technological progress and digitalisation affects labour productivity positively, and the impact of technological progress on productivity is higher in SSA countries by 2.8%, rendering support to unconditional convergence. On a similar line, Nyantakyi (2016) also found that closing of the technology gap between developed and developing country firms has a positive impact on productivity, especially for SSA firms (in Kenyan, Ghana, and Tanzania) with technology standards that are further away from the international frontier. However, we find that the impact of digitalisation is roughly 9% lower for this set of countries, similar to the LIC results we obtained above. Models 3 and 4 confirm that as digitalisation increases, the impact of technological progress also increases.

Table 8: The impact of technical change and internet penetration in SSA

Variables	**(1) Model 1**	**(2) Model 2**	**(3) Model 3**	**(4) Model 4**	**(5) Model 5**	**(6) Model 6**	**(7) Model 7**	**(8) Model 8**
L. Real wage	0.145** (0.055)	0.167** (0.0633)	0.121* (0.0547)	0.102 (0.0528)	0.116 (0.0595)	0.0982 (0.0567)	0.200*** (0.0266)	0.183*** (0.0233)
IPR		0.111*** (0.0260)	0.0426 (0.0416)		0.0365 (0.0428)		0.0416 (0.0450)	
Time trend	0.0374** (0.010)		-0.0169 (0.0169)	-0.0167 (0.0184)	-0.0243 (0.0206)	-0.0263 (0.0214)	-0.0108 (0.0236)	-0.0113 (0.0256)
IPR*SSA		-0.0461 (0.0385)	**-0.0970*** **(0.0462)**	**-0.0609***** **(0.0141)**	-0.0757 (0.0484)	-0.0401*** (0.00711)	-0.0892 (0.0730)	-0.0480 (0.0374)
Time trend*SSA	-0.00791 (0.0115)		**0.0283**** **(0.0106)**	**0.0190** **(0.0102)**	0.0579** (0.0201)	0.0591** (0.0212)	0.0747** (0.0229)	0.074** (0.0239)
(IPR)*Time trend			**0.0069**** **(0.002)**	**0.00917**** **(0.00289)**	0.0085** (0.0033)	0.0108** (0.00329)	0.00724* (0.0034)	0.0094** (0.0033)
IPR*Time trend*SSA					**-0.0071*** **(0.0031)**	**-0.00927**** **(0.00322)**	**-0.008**** **(0.0030)**	**-0.010**** **(0.0030)**
Import share							0.00374 (0.0041)	0.00451 (0.0047)
K/L							-0.120 (0.133)	-0.124 (0.144)
Constant	7.684*** (0.215)	8.012*** (0.215)	8.239*** (0.231)	8.324*** (0.207)	8.262*** (0.305)	8.338*** (0.283)	8.984*** (1.174)	9.05*** (1.255)
Observations	739	728	728	728	728	728	632	632
R-squared	0.288	0.292	0.325	0.319	0.327	0.323	0.361	0.357
Number of countries	71	71	71	71	71	71	59	59

Notes: Dependent variable is log real value added per worker in the manufacturing sector. Standard errors are cluster robust. SSA is a dummy variable = 1 for all sub-Saharan African countries. Import share is the share of imports in GDP and captures openness of the economy. Real wage and capital to labour ratio is in logs.

In model 5, we add a three-way interaction between internet penetration, technological progress and SSA dummy. In model 6 we drop the main effect of internet penetration from model 5. Model 7 adds controls to model 5, and model 8 adds controls to model 6. From the last four models, we can infer that while the impact of technological progress on labour productivity increases as digitalisation increases, this impact is significantly lower in SSA countries. This is in line with the previous results and indicates that SSA countries do not have the required capacity to absorb and utilise digitalisation.

Table 9 investigates how technological progress can be leveraged by low-income countries. In Table 9 model 1, we regress labour productivity on lagged real wage and a human capital index, which captures the average skill level of the country. The coefficient on human capital index is positive and significant implying that as labour becomes more skilled, labour productivity increases. In column 2 we add interaction of the human capital index with technological progress and observe that as the human capital index of a country increases by 1 unit, the impact of technological progress on productivity increases by 2.8%. This result lends empirical support to Griliches' (1969) hypothesis that physical capital and skilled labour are more complementary than physical capital and unskilled labour. Column 3 adds an interaction of human capital with low-income country. In column 4, we use internet penetration instead of time trend, and observe that the impact of digitalisation on productivity also improves as labour becomes more skilled.

In column 5, we add a three-way interaction between human capital, technological progress and low-income country. The negative and significant coefficient on this interaction implies as skilled labour increases, the impact of technological progress on productivity is higher for low income countries than other countries. In model 5 we add controls for openness and capital intensity.

Table 9: The role of skills in leveraging technological progress

Variables	**(1) Model1**	**(2) Model2**	**(3) Model3**	**(4) Model4**	**(5) Model5**	**(6) Model6**
L. Real Wage	0.166* (0.0910)	0.108** (0.0498)	0.108** (0.0498)	0.135 (0.0700)	0.108** (0.0500)	0.101** (0.0499)
Human Capital Index	1.346** (0.396)	-0.747 (0.389)	-0.749 (0.393)	-0.196 (0.179)	-0.689 (0.366)	-0.773 (0.479)
Time trend		-0.0232 (0.0332)	-0.0235 (0.0363)		-0.0385 (0.0395)	-0.0575 (0.0418)
HCI*Time trend		**0.0282* (0.0161)**	**0.0283* (0.0170)**		0.0949*** (0.0155)	0.115*** (0.00685)
IPR				-0.0874 (0.0543)		
HCI* (IPR)				0.0897** (0.0278)		
HCI*LIC			0.0353 (0.466)	-0.0363 (0.285)	-4.745*** (0.810)	-5.120*** (0.756)
Time trend*LIC					-0.0145 (0.0437)	-0.0323 (0.0372)
L-U-MIC*HCI*Time trend					**-0.0618** (0.0262)**	**-0.0754*** (0.0214)**
Import share						0.00583 (0.00492)
K/L						0.0347 (0.0566)
Constant	5.190*** (1.189)	9.529*** (0.895)	9.528*** (0.894)	8.621*** (0.559)	10.10*** (0.777)	9.832*** (0.948)
Observations	614	614	614	607	614	605
R-squared	0.192	0.312	0.312	0.334	0.321	0.333
Number of countries	54	54	54	54	54	54

Notes: Dependent variable is log real value added per worker in the manufacturing sector. Standard errors are cluster robust. L-U-MIC is a dummy variable = 1 for all lower-middle- and upper-middle-income countries. LIC is a dummy for low-income country.

In summary, our descriptive and empirical analysis confirms that low-income countries, particularly SSA, face a two-pronged problem in the future of manufacturing-led development path. First, despite impressive growth in digitalisation in some African economies, the actual level of digitalisation is still very low in LIC and SSA countries. There is a significant digital divide in the access to digital technologies. Second, even if the low-income countries manage to digitalise their manufacturing, they will not be able to utilise the technology in the same way as the developed economies. There is thus also a digital divide in how the technology can be used by different countries. To increase the impact of digitalisation, LIC or SSA countries need to invest in skill development. A more skilled workforce can directly boost labour productivity, but can also improve the impact of technological and digital progress on labour productivity.

So, what could this mean for jobs in Africa? The increase in labour productivity, as a result of digitalisation, may reduce the demand for workers, since to produce the same amount of output, fewer workers will be needed. However, higher labour productivity is also likely to boost both output and exports, creating new jobs. Empirically examining the impact of fast internet on 14 African countries, Hjort and Poulsen (2016) find improvements in firm-level productivity and large positive effects on employment rates, with a decrease in unskilled jobs being offset by a bigger increase of higher-skilled jobs. The positive productivity effect on employment was also evident from the case study of the A to Z factory in Tanzania (see Box 1).

7. DIGITALISATION AND LABOUR PRODUCTIVITY: THE CASE OF KENYA

The regressions above provide one piece of evidence on how digitalisation and internet use affects developing economies. It appears that LICs, especially in SSA, not only have fewer digital technologies installed but also generate fewer positive effects from the technology once it is installed, owing in particular to the presence of complementary assets such as less human capital. This section examines the challenges and opportunities in Kenya, a lower-middle-income country in SSA, which has been at the forefront of using new technologies such as mobile phones. Kenya’s overall ranking within the African region as measured by ITU’s ICT Development Index shows that in SSA, Kenya has the highest competency to use ICT efficiently, as a result of appropriate skills, accessibility of ICT infrastructure, and IT use.

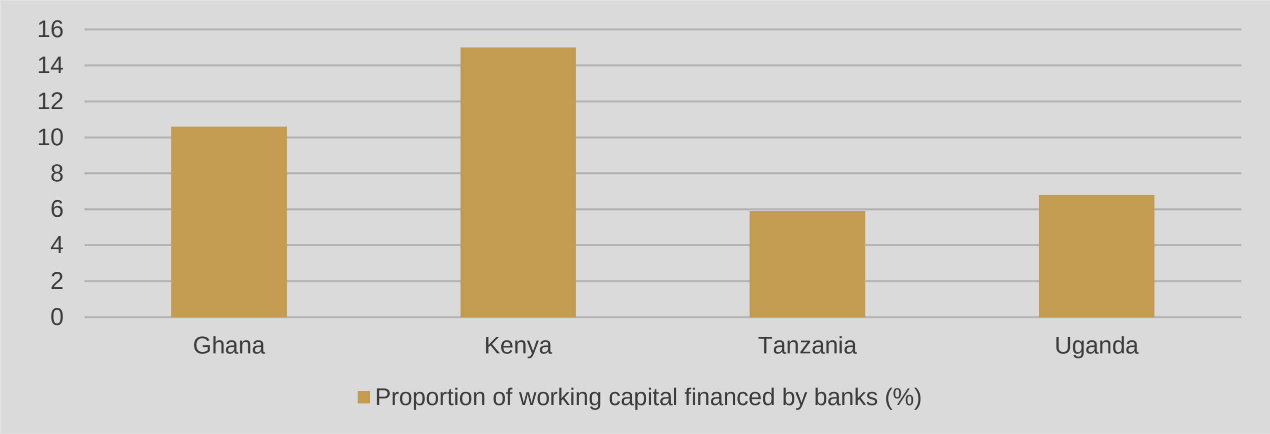
We address two questions. First, how has Kenya embraced the digital economy? (Sections 7.1 to 7.4). Second, what has been the impact of this technology on the Kenya economy, in particular on the labour market in the manufacturing sector? (Section 7.5).

7.1 Comparing Kenya’s digital-readiness

Drawing from the conceptualisation of the digital economy in Section 2, digital-readiness can be described as the ability of a country to adopt and utilise digital technologies. To examine how digitally ready Kenya is, in comparison to other African economies, we use data on: (1) access to financing; (2) connecting with the world; (3) use of ICT; and (4) skills development.

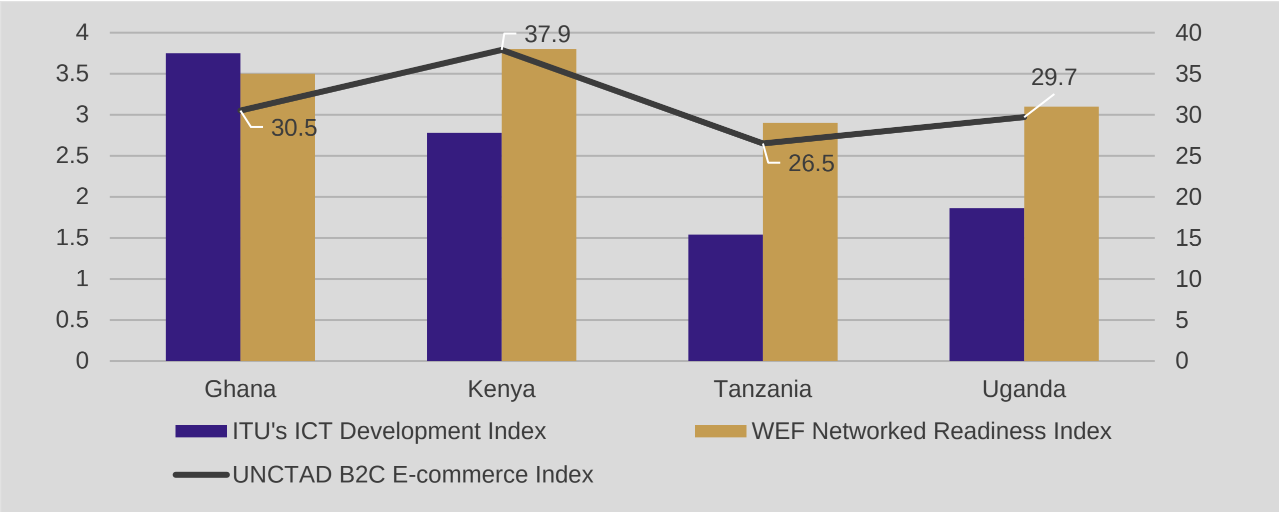
Figure 27 below shows that the proportion of working capital financed by banks is the highest in Kenya (15%), followed by Ghana. In terms of global connectedness, Ghana is ahead of Kenya in ICT development (see Figure 28) but Kenya ranks higher on the WEF network readiness, followed by Ghana, Uganda, and Tanzania. According to UNCTAD’S business-to-consumer index also, Kenya is the most connected.

Figure 27: Financing digitalisation



Source: WITS E-Trade Indicators.
Note: Data are for various years (2013, 2014 or 2015). The vertical axis shows percentage of working capital that firms finance from banks.

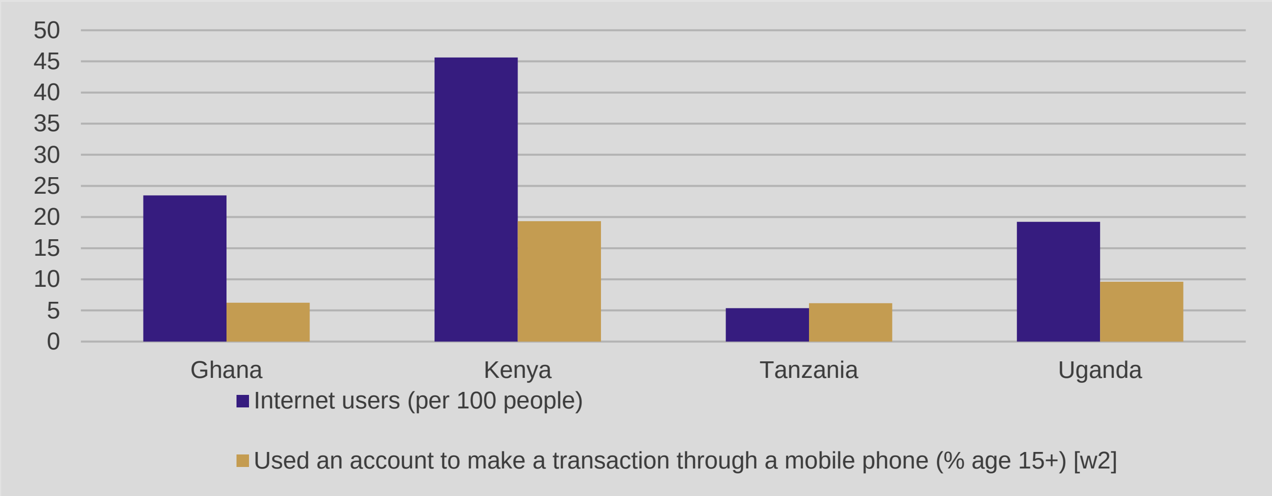
Figure 28: Connecting with the world



Source: WITS E-Trade Indicators.
Note: Data is for various years (2013, 2014 or 2015).

In terms of use of ICT, the proportion of people (per 100 people) with access to the internet is highest in Kenya, as is the proportion of people making a transaction through a mobile phone (see Figure 29). In terms of developing skills – i.e. using ICT, internet and technology – Kenya again fares better than Ghana, Tanzania, and Uganda (see Figure 30). Overall, it is clear that Kenya is more digitalised than the other African countries considered. Better access to financing, ICT use, skills and networks has enabled a number of digital technologies to pervade both the agricultural and manufacturing sectors in Kenya (see Box 4 for examples).

Figure 29: Use of ICT



Source: WITS E-Trade Indicators.
Note: Data is for various years (2013, 2014 or 2015). The vertical axis represents % of population.

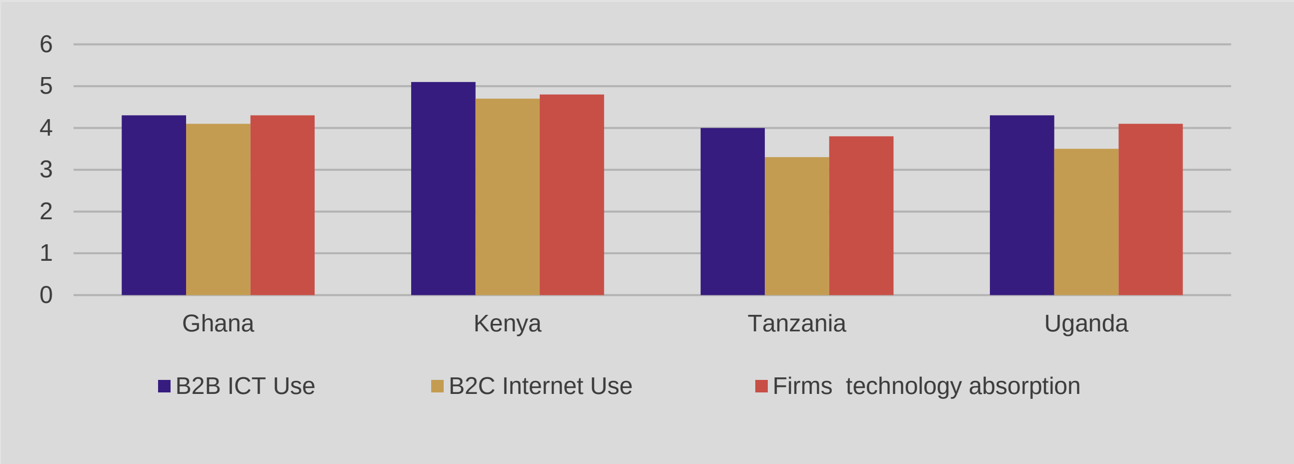
Box 4: Digital technologies in Kenyan agriculture and manufacturing sectors

The proliferation of new technologies in Kenya is evident in the agricultural sector, which accounts for around 26% of GDP directly and another 27% indirectly though linkages with other sectors. With growing use of digital technologies – such as cloud computing and open-source software – barriers to entry into farming technologies have reduced, enabling a number of Kenyan entrepreneurs to develop yield-improving solutions at affordable cost models. For example, **'ULima'** is an all-in-one app for pre- to post-harvest farming, providing tailored and step-by-step assistance to farmers. With increased climate variability, farmers can now use **'Agrobase'** for information on the optimum pest management strategy. A number of **Urban Farming** – 'how-to-grow' in garden – apps, have also helped in maximising crop yield and soil quality. Expert information on good farming practices and livestock rearing practices can now be simply accessed through SMS alerts from **'ICow'**. Some of the most critical detail on a herd is identification of reproductive problems, now made possible through the **'Breeding Wheel'** app. There are also popular downstream apps such as **'MFarm'**, which connects farmers with local buyers, and provides a real-time virtual marketplace.

ICT-enabled manufacturing is also taking off in Kenya. One good example of this is the maker space **Gearbox**, which provides manufacturing equipment, tools, machines, training, mentorship and networking. Start-ups at Gearbox include **Proteq Automation**, offering the latest in industrial automation technology and machine manufacturing, and **Homgenius**, which has designed and developed an automated bricklaying machine that can make more than 2,000 interlocking building blocks per day. As part of community projects, Gearbox has also built its first **CNC controlled plasma cutter for metal and wood**, which has immense potential for manufacturing, once rolled out. Another manufacturing-revolutionising technology – 3D printing – is finding its foothold in Kenya. The start-up **AB3D** has set up a one-stop shop for 3D printing in Nairobi, offering low-cost access to 3D printers, material, workshops and open-source designs. These 3D printers are being manufactured from recycled materials and e-waste, making them affordable and accessible for a wide variety of local manufactures. There are also several cloud-based business management and integration solutions in place for SMEs now, such as **Tozzaplus**, as well as business automation software systems such as **MiniERP**, which enable firms to streamline their business processes without high costs. Similarly, Olivine Technologies offers Automated Systems Inventory Management – **ASiM** – that provides a B2B mobile commerce platform, with direct marketing channels, analytics and working capital financing facilitation for SME manufacturers, distributors and retailers of fast-moving consumer goods (FMCGs).

Note: Information on digital technologies in the agricultural sectors has been contributed by Aarti Krishnan, Senior Research officer, ODI.

Figure 30: Skill development indices

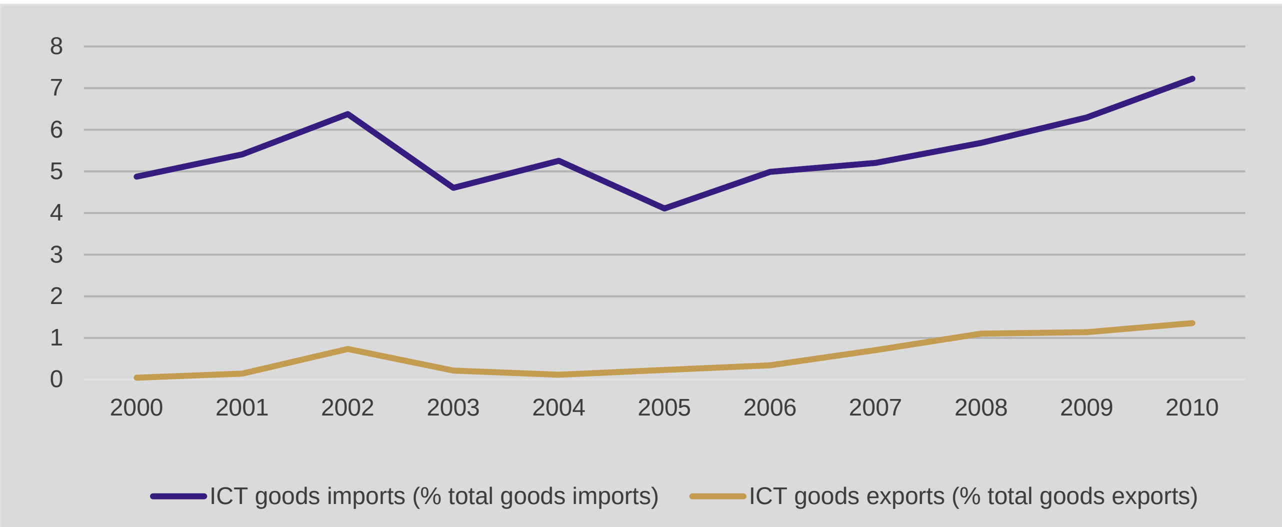


Source: WITS E-Trade Indicators.
Notes: Data is for various years (2013, 2014 or 2015). The vertical axis represents the value for the ICT indices, ranging from 1 to 7. B2B ICT Use refers to the extent to which business use ICTs for transactions with other businesses [1 = not at all; 7 = to a great extent]. B2C Internet Use refers to the extent to which businesses use the internet for selling their goods and services to consumers [1 = not at all; 7= to a great extent]. Firms' technology absorption refers to the extent to which business adopt new technology [1 = not at all; 7 = adopt extensively].

7.2 Trends in Kenya's digital economy

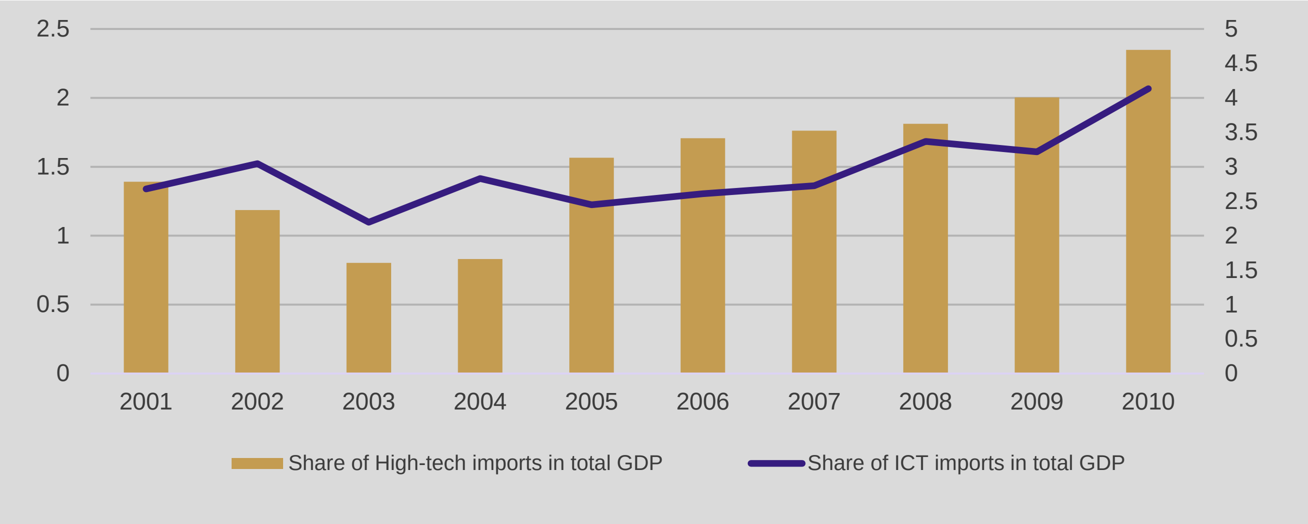
Digitalisation in Kenya has steadily increased in the period 2000–2010, as indicated by the rising importance of ICT trade in total trade undertaken (Figure 31). In terms of the share of ICT imports in total imports, there was a 2.35 percentage point increase in this period, with steady growth from 2005 onwards. Although the share of ICT exports in total exports by Kenya remained low in 2010, it increased from 0.04% in the year 2000 to 1.35% in 2010. The increased importance of ICT in Kenya can also be observed through the rising share of ICT imports in GDP; in the period 2000–2010, the share rose by roughly 55% (see Figure 32). While the share of high-tech imports declined to 1.6% in the year 2004, it has steadily increased since then, reaching almost 4.7% in 2010.

Figure 31: Kenya's ICT trade (%)



Source: World Development Indicators
Notes: The vertical axis represents % of ICT trade. ICT goods include computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous).

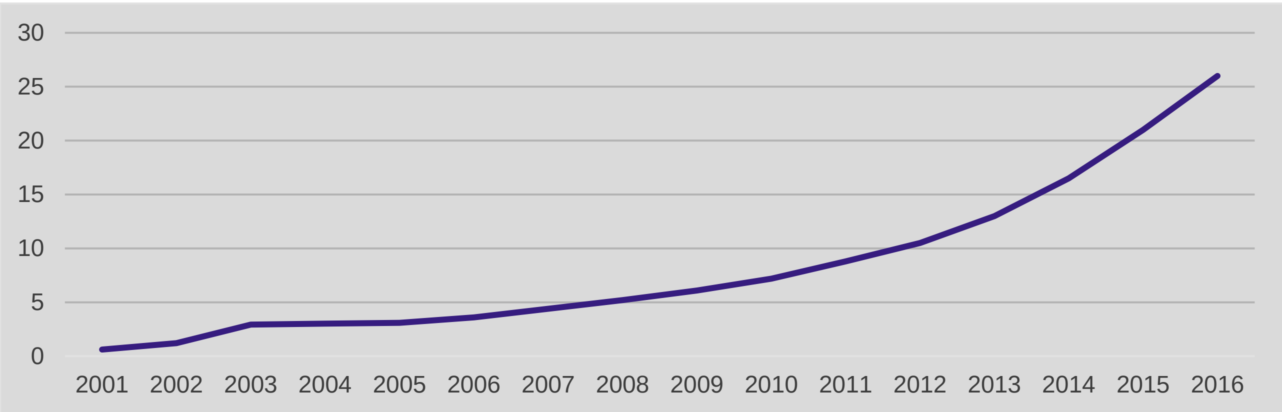
Figure 32: Share of Kenya's ICT goods in total GDP (%)



Source: World Development Indicators, WITS
Notes: The vertical axis represents share of ICT-enabled GDP. 'High-tech' goods refer to Lall's (2000) technological classification. ICT goods include computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous).

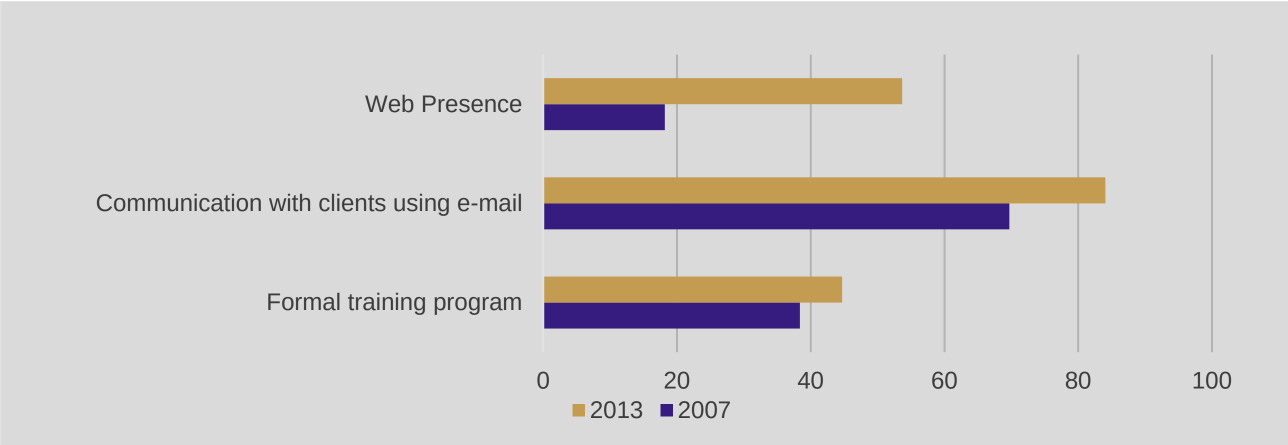
More recent data from the International Telecommunications Union (ITU) on internet penetration show that the percentage of population accessing internet in Kenya has increased from 0.5% in 2001 to 26% in 2016, with steep growth in recent years (see Figure 33). The data show that the internet penetration ratio doubled every five years (from 5% to 11% between 2007 and 2012, and from 11% to 25% between 2012 and 2016). The use of internet has also improved (see Figure 34); data from the Kenyan World Bank Enterprise Survey show that in the year 2013, 84% of manufacturing firms were using email for communication (up from 69% in 2007), 53% had a web presence (up from 18%) and 44% were offering formal training programs for workers (up from 38% in 2007).

Figure 33: Internet penetration in Kenya (%)



Source: ITU database
Notes: Internet penetration refers to the percentage of population using the internet.

Figure 34: Internet use in Kenyan manufacturing firms



Source: Kenya WBES (2013).
Notes: The horizontal axis represents % of firms. Data are for Kenyan manufacturing firms in the year 2013.

It is clear that from 2001 onwards, digitalisation in Kenya has been on an increasing trend. From 2007 onwards, Kenya has emerged as leader of digitalisation in SSA, owing to many overlapping and strategic factors at play. Development of effective public–private partnerships (PPPs), the creation of local content, skill development in the workforce, setting-up of a separate ICT authority, and growing opportunities for youth employment have all contributed towards a 'digitally enabling' environment where ICT has been used to transform the economy in Kenya. These initiatives are discussed in Box 5.

7.3 Digitalisation across Kenyan manufacturing industries

While digitalisation has increased in the Kenyan manufacturing sector over time, we use the WBES to examine heterogeneity in digitalisation across manufacturing industries.[15] Figure 35 shows a similar trend across different digitalisation indicators; firms involved in the machinery–electronics–transport sector are more likely to be digitalised, followed by firms in the chemicals–plastics–rubber sector. On average, these sectors have a higher proportion of firms using the internet, emailing clients, engaging in e-commerce and online marketing, having a web presence, using mobile money (MM) and undertaking research and development.

While the textile–garments–leather sector fares well in terms of using internet and email, firms engaged in this sector are less likely to be engaged in online purchases, undertaking R&D, using MM and having their own websites. The food sector is found to be the least digitalised.

[15] Since the WBES over-represents the food sector, we have clubbed manufacturing industries into more aggregate sectors.

Box 5: Going digital: lessons from Kenya

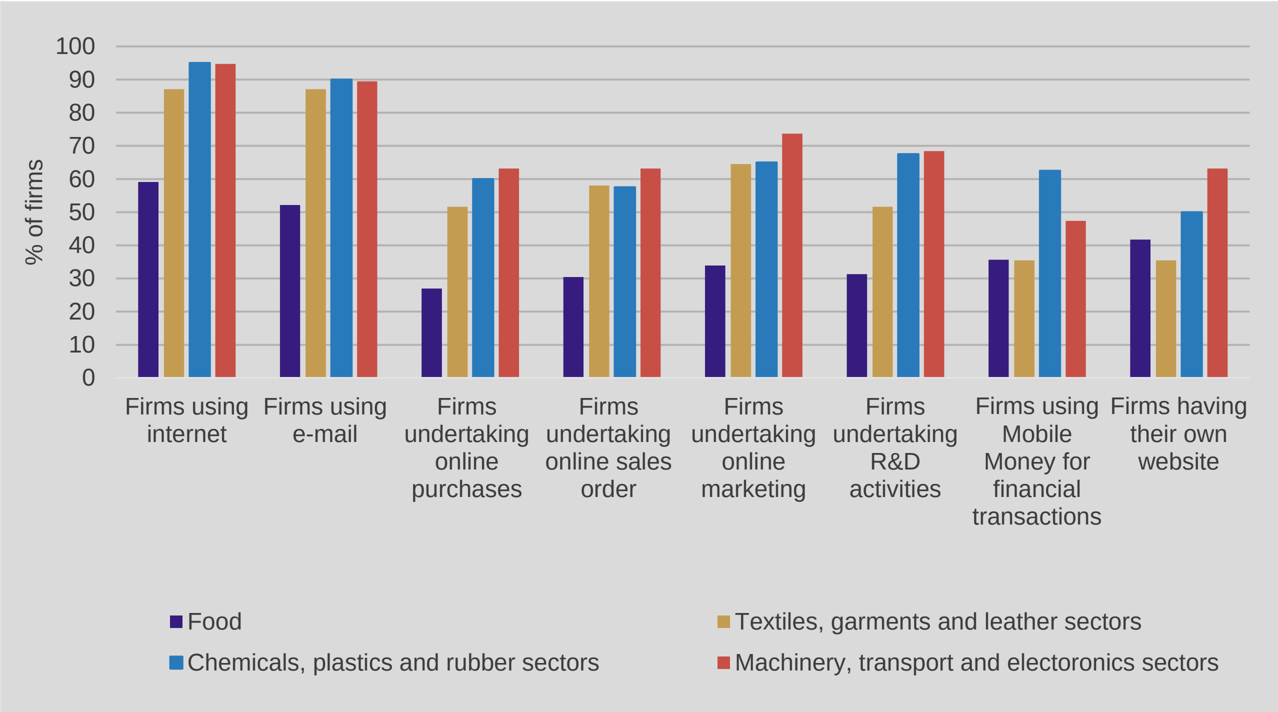
The first significant development for Kenya's digital economy was in 2007, with the introduction of mobile money in Kenya through Safaricom's **M-Pesa**. Then in 2008, ICT was incorporated as a key development pillar in the **government's 2030 vision**, with Konza Technological City ('Silicon Savanah') announced as the vision flagship project for business process outsourcing (BPO) and IT enabled services (ITeS). High-speed internet was brought into the country in 2010 through SEACOM, TEAMS, EASSY, and LION **undersea fibre-optic cables**, followed by the launch of **the Kenya Open Data Initiative** in 2011, making key government data freely available through a single online portal. In the year 2012, Kenya **spent $3,178 million on ICT services**, with a special focus on computer related services in the budget, and launched the **National Broadband Strategy (2013)**, with the aim of transforming Kenya through a nationwide high-capacity broadband network. Subsidised broadband was thus made available for all universities and technological hubs. Further efforts by the government saw the introduction of the **National Cybersecurity Strategy (2014)** to provide a secure online environment to conduct business, accompanied by the rolling out of 4G internet coverage by telecom providers. A combination of strategic public–private efforts has thus enabled Kenya to achieve higher connectivity, increased network capacity and reduced prices (Waema and N'dungu, 2012). This has also helped in boosting an entrepreneurial spirit in Kenya. While the government has supported development of infrastructure, incubators, small enterprises and small credit-providing facilities, the rise of privately driven tech hubs and networks, such as the iHUb or the Savannah Fund, have sparked innovation, collaboration and exchange of ideas.

Kenya has also undertaken many steps to improve the investment climate, to become more attractive for foreign investors. The World Bank Group's Doing Business 2017 ranks Kenya as the **third most reformed country**, with Kenya moving up 21 places to reach rank 92 of the 190 economies on ease of doing business. Between 2013 and 2017, reforms were made in the following areas: starting a business, access to electricity, registration of property and protecting minority investors. More recently, Kenya also launched the **National ICT master plan in 2017** to harness the power of ICT. It looks to further develop Kenya as an 'ICT hub and a globally competitive digital economy', with three foundations: (a) ICT human capital and workforce development; (b) integrated ICT infrastructure to enable cost-effective delivery of ICT products and services and (c) integrated information infrastructure targeting e-government services. In line with this, President Kenyatta called for **commissioning a taskforce on IoT and blockchain**, in February 2018, focusing on how the digital economy can be leveraged to achieve the 'Big Four' plan – expansion of manufacturing, affordable housing, food security and universal healthcare.

However, to develop the ICT sector further, not just regionally but also globally, Kenya must improve its **access to high-skill talent**, **financing opportunities for SMEs** and **regulatory environment for ICT services** (Akamanzi, 2016). Khanna et al. (2016) highlight the need to promote **ICT-enabled manufacturing**. To achieve digital structural transformation it is important to: (1) promote the adoption of IT/ITeS-based productivity improvements in various sectors where Kenya can enjoy the first-mover advantage by addressing the needs of other internet users in East Africa; (2) develop a policy framework for attracting FDI in captive subsidiaries from those firms that are seeking product development in the region; (3) develop private–public sector collaboration in skill development, such as programmes with industry sponsorships as supplementary courses in colleges; (5) give incentives, such as expensing software, and training to SMEs to facilitate adoption of digital technologies in these firms; and (6) geographically diversify from Nairobi to other regions in Kenya.

Source: NDemo (2017), Khanna et al. (2016)

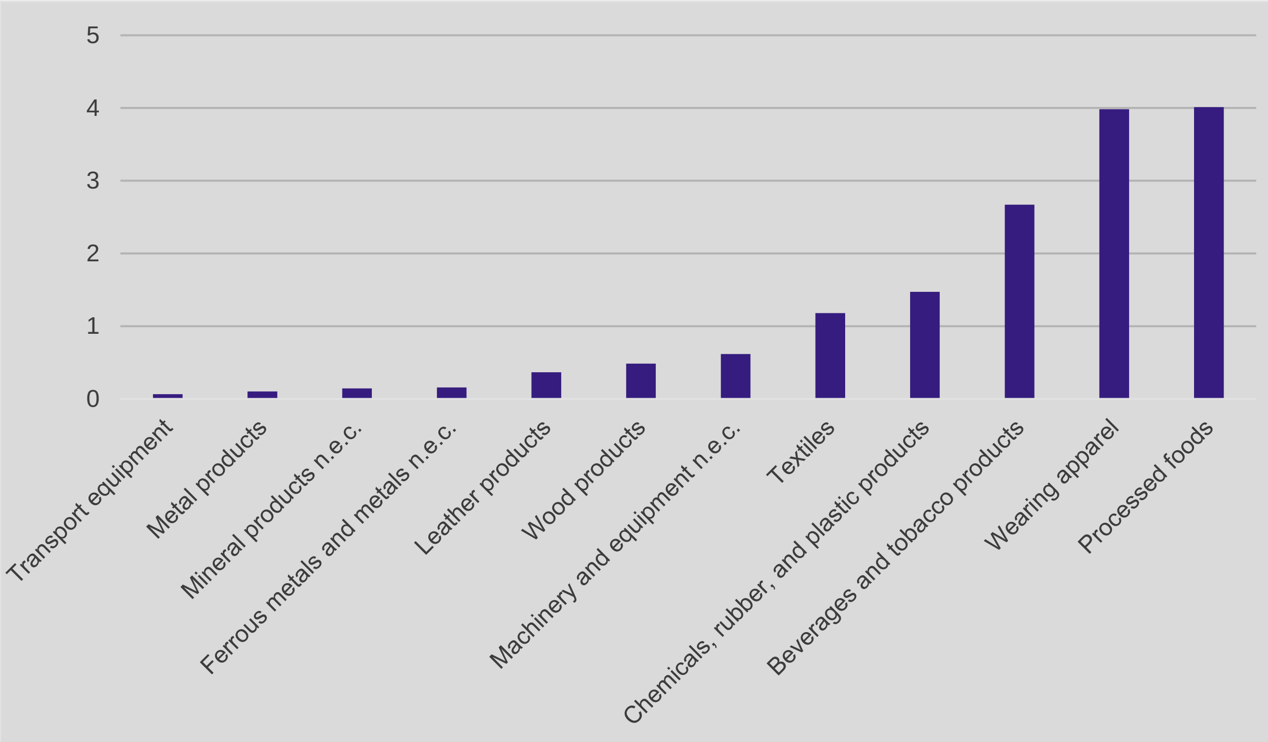
Figure 35: Heterogeneity in digitalisation across Kenyan manufacturing industries



Source: WBES Kenya 2013.
Note: Number of firms interviewed in each sector are: 114 for the food sector, 31 for textiles–garments–leather, 40 for chemicals–plastics–rubber and 19 in machinery–transport–electronics sectors.

Growing digitalisation is also expected to intensify 'servicification of manufacturing', where digital services are increasingly embedded within manufactured products. To examine which Kenyan manufacturing industries are using more domestic digital services, we use the export of value-added database in WITS, with manufacturing sectors as users and digital services such as communications and ICT and other business services as supplying sectors. Figure 36 shows that the domestic value-added (DVA) share of digital services in Kenya in manufacturing industries' production was on average only 1.3% in the year 2011, suggesting that linkages are low. The highest DVA is going into processed food and wearing apparel, followed by beverages and tobacco, chemicals, rubber and plastics, textiles, and machinery.

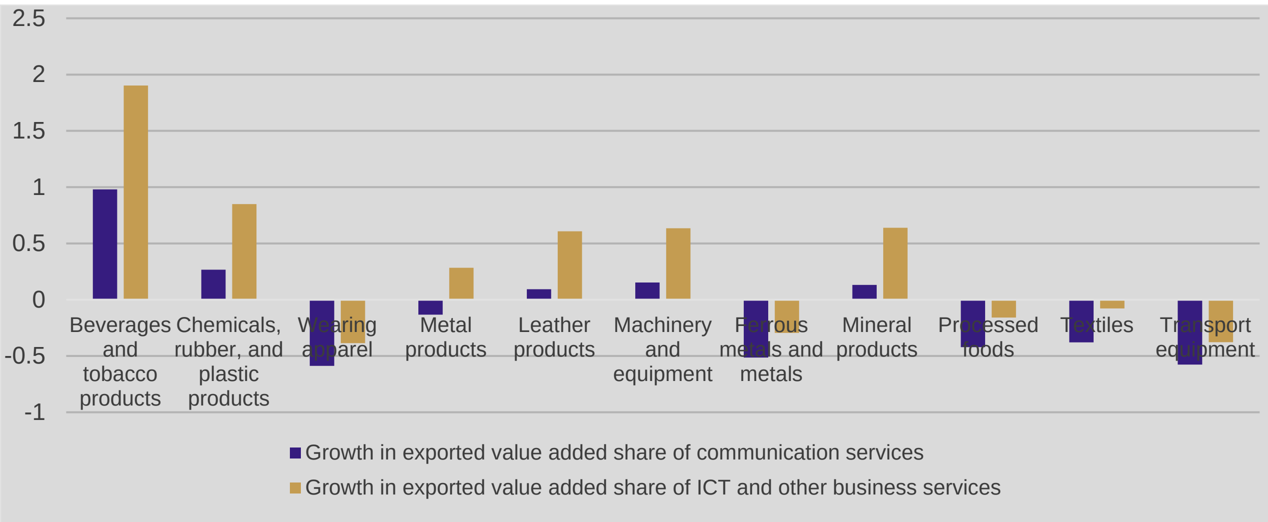
Figure 36: DVA share of digital services in Kenyan manufacturing (%)



Source: Export in value-added database (WITS).
Note: Data is for the year 2011. VA share of domestic digital services is the average share of communications, ICT and other business services.

Figure 37 examines the trends in VA share of domestic digital services in Kenyan manufacturing exports and finds that there was positive growth in the period 2004–2011 for the following industries: beverages and tobacco, chemicals, rubber and plastics, leather products, machinery and equipment and mineral products. Over time the use of domestic digital services has gone down in wearing apparel, ferrous metals, processed foods, textiles, and transport equipment, which may be indicative of decreasing competitiveness of Kenyan digital services in exports of these industries or an overall decline in the use of services in these industries in Kenya.

Figure 37: Growth in VA by domestic digital services in manufacturing exports (2004–2011)

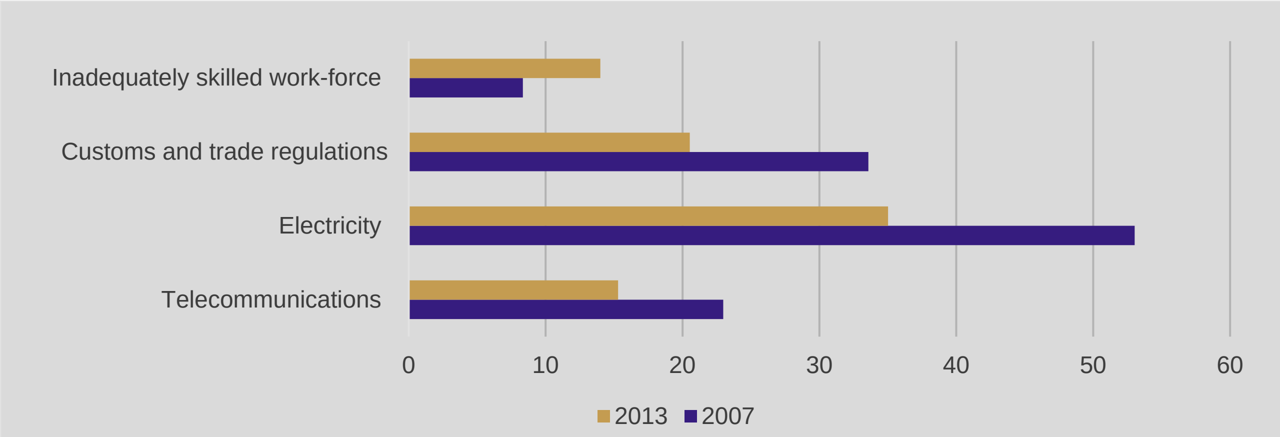


Source: Export in value-added database.
Notes: The vertical axis represent annual growth rate in percentages.

7.4 Digitalisation across Kenyan manufacturing firms

The growing digitalisation in Kenya (as seen in Section 7.2) has coincided with improvements in infrastructure, customs and trade regulations in Kenya. Figure 38 shows that compared to 34% of firms in 2007, only 20.5% of firms in 2013 listed customs and trade regulations as a major to severe obstacle in firm operations. Similarly, the percentages of firms regarding electricity (53% in 2007 and 35% in 2013) and telecommunications (23% in 2007 and 15.3% in 2013) as major constraints have also declined. However, it is important to note that the percentage of firms listing inadequately skilled workforce as a major to severe obstacle has increased from 8.3% in 2007 to 14% in 2013. Rising digitalisation with an increasingly inadequate labour force may be suggestive of an increasing skill mismatch occurring in Kenya.

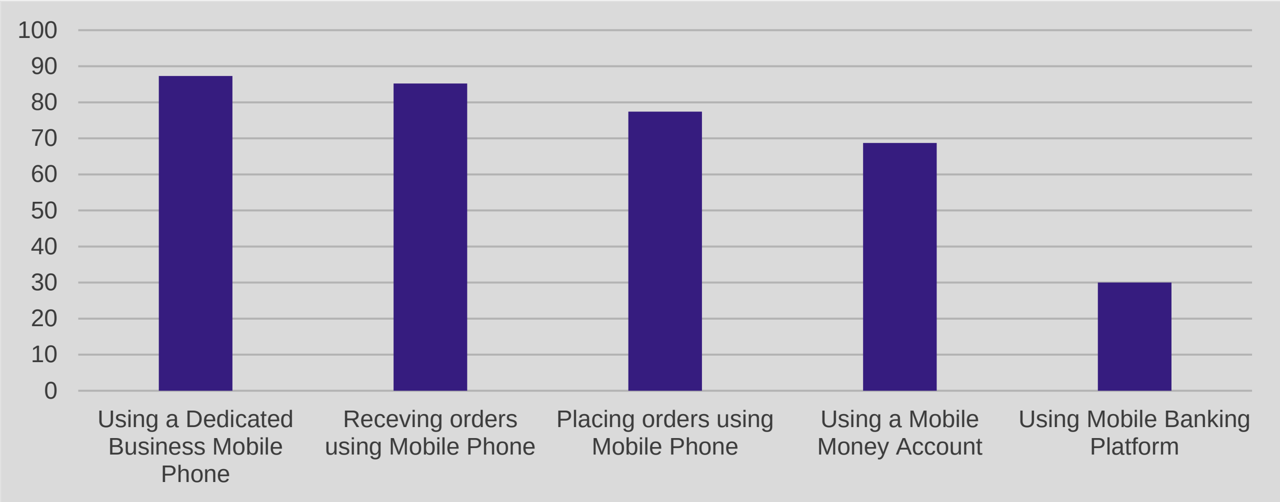
Figure 38: Major-to-severe constraints in firm operations (% of firms)



Source: WBES – Kenya, 2007 and 2013.
Notes: The horizontal axis represents % of firms.

While indicators such as ICT use and IPR indicate that overall Kenyan manufacturing is digitalising, a closer look using the 2016 Kenyan ICT survey tells us that there is a significant difference between firms having access to ICT goods and services, such as mobile phone and internet, and those firms actually engaging with it. While roughly 87% of the manufacturing firms have a dedicated business phone and 81% on average are using the mobile phone to buy or sell goods, only 68% are using a mobile phone account, with an even lower 30% using mobile banking (see Figure 39).

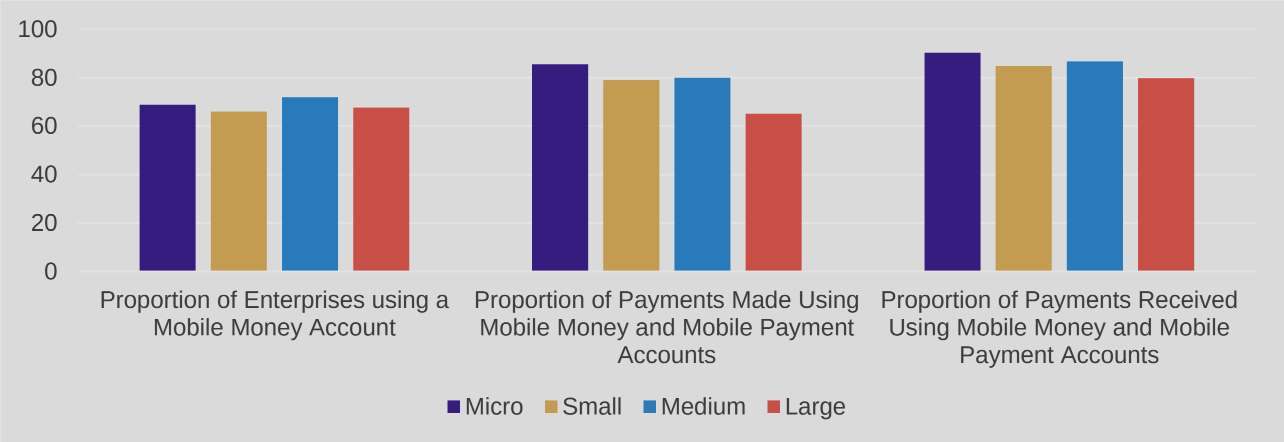
Figure 39: Use of mobile money by Kenyan manufacturing firms



Source: Kenya ICT survey (2016).
Notes: The vertical axis represents % of firms.

So, why is there a gap between firms having a mobile phone and using Mobile Money (MM)? The WBES[16] reveals the majority of the firms in Kenya started using MM to reduce the time spent in financial transactions (43%), to satisfy customer demand (22%) and to reduce the costs and risks associated with financial transactions (26%). Using the Kenyan World Bank Survey (for the year 2013), we find that amongst the firms not using MM, 10% were not aware of it or were aware of it but did not find it easy to use, around 9% of the firms thought that the fee was too high, 60.45% stated that payments of the firm were too large to be conducted via MM and 48% said that their customers or suppliers do not use MM. Interestingly, size does not matter for the use of MM; roughly the same proportion of micro, small, medium and large firms use MM in Kenya (see Figure 40). The use of MM is, in fact, on average, higher in small firms, indicating the potential of MM transfer services for SME development. This has been particularly highlighted in the successful and widespread adoption of M-Pesa in Kenya. Exploiting the economies of scale from automation, M-Pesa has led to considerable financial sector innovation and reduced the cost of sending remittances by almost 90% (Donovan, 2012).

Figure 40: Proportion of manufacturing firms using mobile money (%), by size

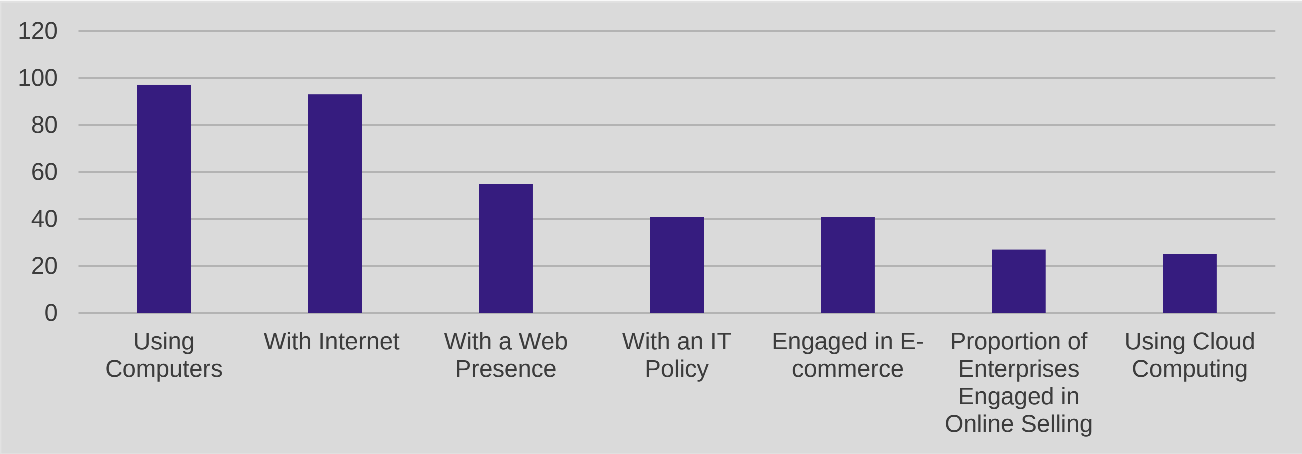


Source: Kenyan ICT survey (2016).
Notes: The vertical axis represents % of firms.

Similar to the gap between firms having a mobile phone and using MM, there is a 40% to 50% difference between the percentage of firms having access to computers and internet and firms actually utilising it (having a web presence, engaging in e-commerce etc.). While 97% of the firms in the manufacturing sector are using computers and 93% have internet, only 54% have a web presence and 40% are engaged in e-commerce (see Figure 41). Amongst the firms engaged in e-commerce, a higher percentage of firms are engaged in online buying (36.5%) compared to selling (27%). Only 25% of Kenyan manufacturing firms are using cloud computing, an important indicator of digitalisation.

[16] WBES (2013) with 134 manufacturing firms using MM.

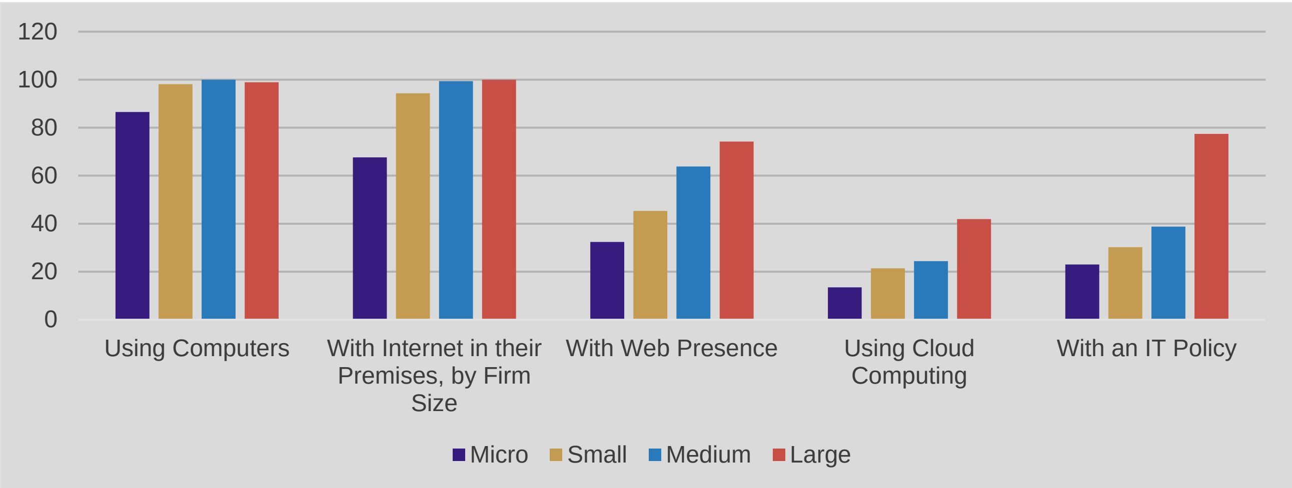
Figure 41: Internet use by Kenyan manufacturing firms



Source: Kenya ICT survey (2016).
Notes: The vertical axis represents % of firms.

Unlike in the case of MM, the gap between access to and actual use of computer and internet can be explained by firm size to some extent. Figure 42 shows that medium to large Kenyan firms are more likely to have a computer and an IT policy, use cloud computing and have a web presence.

Figure 42: Engagement in the digital economy differs across size (% of firms)



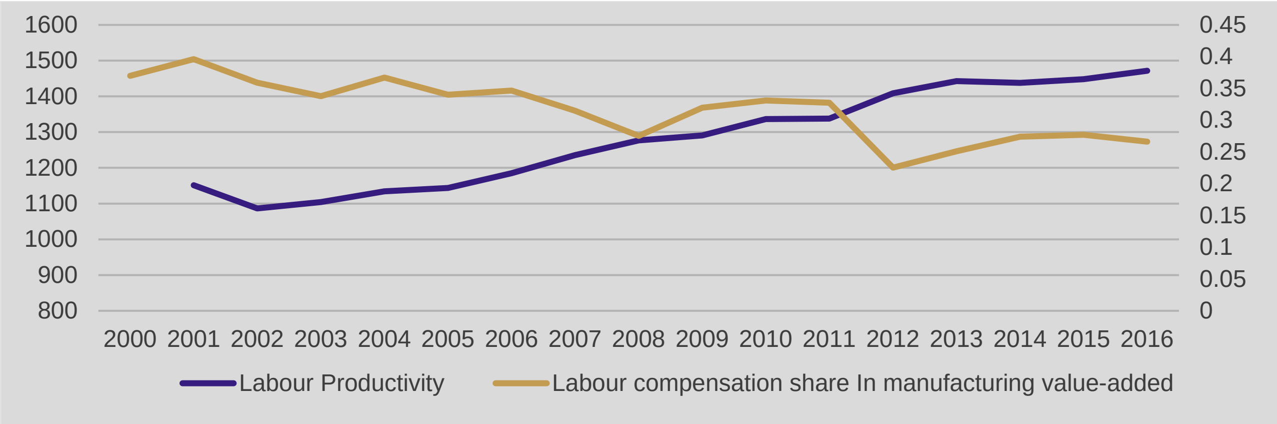
Source: Kenyan ICT survey (2016).
Notes: The vertical axis represents % of firms.

7.5 Digitalisation and the Kenyan labour market

Similar to digitalisation, labour productivity in Kenyan manufacturing increased consistently between 2001 and 2016, but growth has slowed down since 2013. The share of labour compensation in manufacturing value-added in Kenya declined from 40% in 2000 to 27% in 2016 (see Figure 43).

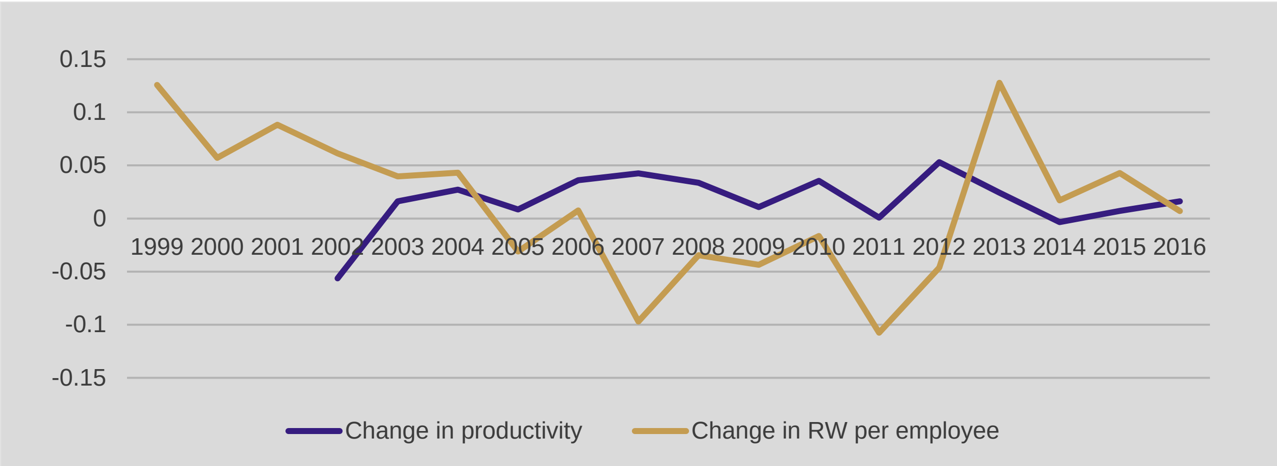
In terms of growth in labour productivity and real wages, we find that since 2001, real wages per employee (in manufacturing) have declined by 0.2% on average per year; whilst real output per employee has increased by 1.7% per year (productivity increases have declined in recent years), which explains the drop in the share of wages (Figure 44). In the last five years, growth in real average earnings was faster than in the years before, whilst productivity growth has declined, and the labour share has increased somewhat (since 2012). Manufacturing formal employment increased from 214,000 in 1997 to 301,000 in 2016 (Figure 45).

Figure 43: Labour market trends in Kenya



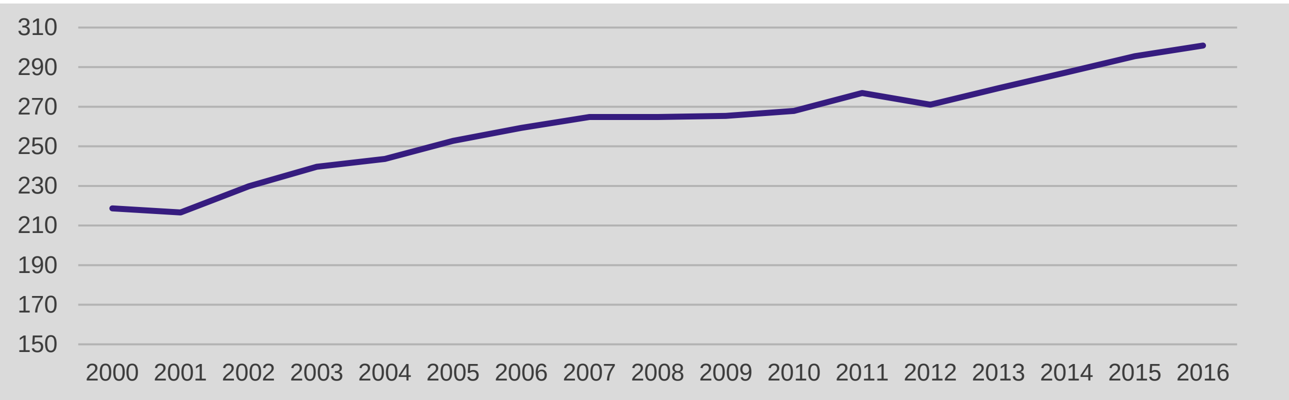
Source: Kenyan Economy Survey (various issues)
Notes: Labour productivity is real value added in manufacturing sectors (in KSh Million)/ number of employees. Data with 2001 and 2009 prices has been spliced.

Figure 44: Change in labour productivity and wages (%)



Source: Kenyan Economy Survey (various issues)
Notes: Data for real wage per employee have been combined from various issues and spliced.

Figure 45: Total employment in Kenyan manufacturing (in 1000 units)



Source: Kenyan Economy Survey (various issues)

Labour productivity in Kenya and its share of ICT exports in total exports (a proxy for digitalisation) has a positive and significant correlation of 70%.[17] Using the WBES of Kenyan manufacturing firms, we classify firms into digitalised and non-digitalised on basis of access to internet, and find that

[17] Scatterplot in Appendix F.

digitalised firms have, on average, higher labour productivity and a higher share of skilled and non-production workers in total employment (see Table 10).

The importance of technology and skills to Kenyan labour productivity has also been confirmed in the existing literature. Heshmati (2016) finds that capital intensity and wages complement labour productivity, but skills are important. Using a sample of manufacturing and service firms in Kenya, Heshmati shows that training of workers, education levels and managerial experience of CEOs can significantly increase labour productivity, while obstacles in accessing and using utilities, such as poor access to electricity and water, negatively affect the efficiency of workers in Kenya. The need for an adequately skilled workforce to make use of digitalisation is also confirmed by World Bank research revealing that inadequate education levels of workers can lower the capacity of firms to transform knowledge into innovative outcomes (Cirera and Sabetti, 2016). Menon (2011) also uses the Kenyan WBES to find that firms' use of technologies such as computers, mobile phones and generators increases the value-added per worker, or labour productivity, especially for firms with female principal owners.

Table 10: Comparing labour market outcomes[18] in Kenyan firms.

Labour market indicators	Digitalised firm	Non-digitalised firm	Difference	p-value	Is this difference statistically significant (at 5%)?[19]
Mean labour productivity	14.76	14.22	0.53**	0.04	Yes
Mean number of permanent full-time employees	111	33	77.8**	0.019	Yes
Mean share of non-production workers in total employment	37.6	8.84	28.7**	0.016	Yes
Mean share of skilled employees in total employment	76	63	13***	0.006	Yes

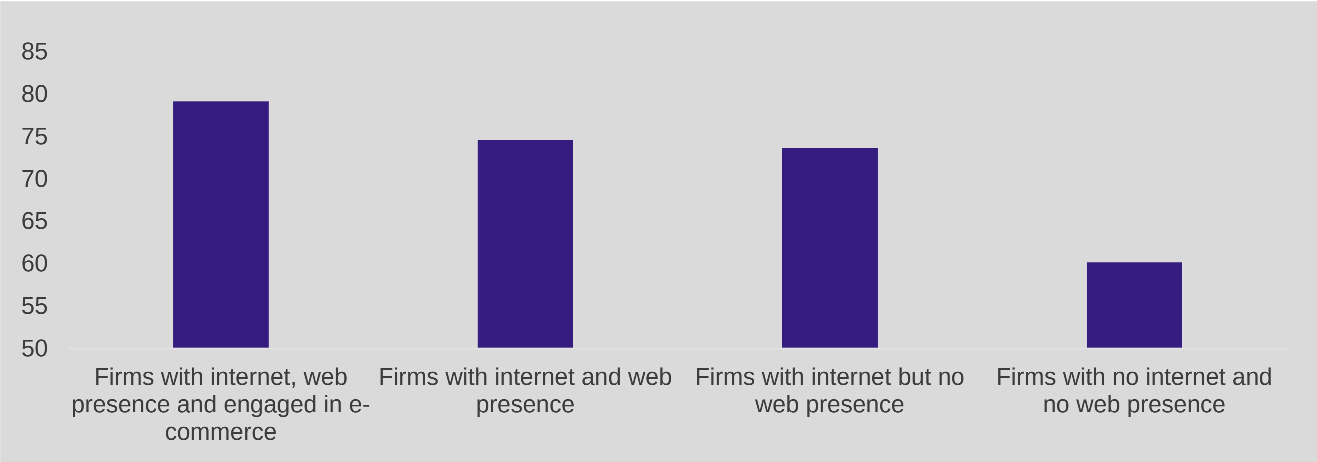
Source: Kenya WBES 2013 of manufacturing firms only
Note: Digitalised firms refers to firms having internet (78%). Labour productivity is calculated by dividing annual sales with labour. Share of skilled employees in total employment = % of full-time workers who have completed high school.

A closer look at the Kenyan WBES data tells us that a higher engagement with the digital economy requires a more skilled workforce. Figure 46 classifies firms according to different categories of digitalisation and finds that the most digitalised firms – i.e. firms which have internet, have a web presence and are actively enagged in e-commerce – have the highest share of skilled labour in their workforce (80%), followed by firms that have internet and a web presence, but are not engaged in e-commerce (74.5%), and then those that have internet but no web presence (73.6%). The share of skilled labour on average is the lowest in firms that have no internet and no web presence, i.e. in the least-digitalised firms.

[18] We also classify digitalised and non-digitalised firms in the year 2007 using different indicators – those that acquired new technological innovations, attempted to hire skilled workers, or have their own websites – and conducted difference in means tests on employment growth in the period 2007–2013. We found that employment growth did not significantly (statistically) differ across digitalised and non-digitalised firms.

[19] This refers to the probability of rejecting the null hypothesis that the difference in indicator between digital and non-digital firm is zero. The difference is significant at 5% is p-value is less than 0.05.

Figure 46: Share of skilled labour in total employment in Kenyan manufacturing firms (%)



Source: WBES, 2013.
Note: Share of skilled labour is captured by the percentage of full time workers who have completed high school.

8. THE FUTURE OF AFRICAN INDUSTRIALISATION

Manufacturing has provided growth and employment opportunities to many Asian countries, but it has not been as successful in African countries, with some exceptions. While Asia has increased its share of total world manufacturing exports significantly (from 36.2% in 2005 to 44.4% in 2014), the relative share in Africa has increased only marginally (from 0.8% to 0.9%), as per Balchin et al. (2016). To realise this untapped potential for driving economic growth, African countries should look towards developing agro-processing and attracting investment in higher-value-added export-based manufacturing. There are a number of promising manufacturing sectors for Africa: garments and textiles, horticulture, automobiles and consumer goods (Balchin et al., 2016).

With the advent and advancement of the digital revolution, there is a growing fear that labour will soon be replaced by robots, and therefore manufacturing will no longer be a major creator of jobs. This then raises the question – should African countries continue to pursue a manufacturing-led development path?

It is important to note that firms will increase investment in automation only when the cost of employing labour is, by some margin, higher than the cost of automation/ operating robots. Our empirical analysis has shown that digitalisation is still low in Africa, indicating that African countries may not yet experience the full impact of the technological surge that we are seeing today. The rate of digitalisation also varies significantly across industries within the manufacturing sector. Growth in the global digital economy is being increasingly associated with the slowdown of international trade, particularly in GVC-intensive sectors such as computers, electronics, transport etc. These sectors are more intensive in the use of intermediate products such as parts and components, and are therefore being automated at a faster rate. In other sectors – such as food, beverage and tobacco products; basic metals; wood and wood products; paper and paper products and other non-metallic minerals – technological change has been slow until now, making them less susceptible to global trends. These sectors can therefore act as a window of opportunity for African countries to undertake local production and regional trade. Whilst several Asian countries are likely to see their preferences weakened (Bangladesh, Cambodia, and Nepal may all graduate out by 2024), African LDCs such as Ethiopia and Tanzania can still use their preferences.

But how long will the window of opportunity last? This will vary across the rate of automation in different sectors. Let us take the case of the furniture sector (includes consoles, desks, cabinets, seats etc.) – a low-skill, labour-intensive tradable sector with a relatively high robot intensity[20] (World Bank, 2017).

Figure 47 compares hourly operation costs of robots with hourly wages for the US and Kenya in the furniture sector. The cost of a ‘generic’ robotics system (e.g. ABB’s[21] industrial robot 2400) – which has a high degree of flexibility and thus can take on many different types of work – was around $28 per hour in 2015.[22] By 2020, this is expected to fall to around $20 per hour, or an annual decline of around 6.5% (consistent with the fall in 3D printer costs at 5.5% a year found above). We project this forward and find that the hourly operation costs of robots will fall below US wages in the furniture sector in 2023. By then, companies may want to switch, although this may still take time. It is also important to note that this sector is well behind others, such as automobiles or electronics, in robot density.

Kenyan operation costs are around 20% higher on the basis that the cost of finance is around 20 percentage points higher (interest rate differential and higher energy costs).[23] We calculate the average furniture wages in Kenya to be around one fifth of those in the US in the same sector in 2015, but they are rising faster in Kenya at around 7.5% a year, whilst lower wage increases are projected in the US. Adjusting for improvements in labour productivity in Kenya (estimated at 1.7% per year, see the previous section), the inflexion point in Kenya is not before 2034, more than a decade later than in the US. The inflexion point is later because wages are lower whilst robot operation costs will be higher in Kenya. This suggests that developing countries such as Kenya have at least a decade longer to adjust if domestic issues are the main determinant. One could argue that the cost of US robots is a better comparator (see below) in which case the inflexion point for Kenya is 2034. For Ethiopia, where manufacturing wages are around two-fifths of the Kenyan wages (based on interviews in the garments sector), the inflexion point would be in 2042 (assuming the same growth rate, or 2038 assuming wages rise 2 percentage point higher in Ethiopia compared to Kenya).

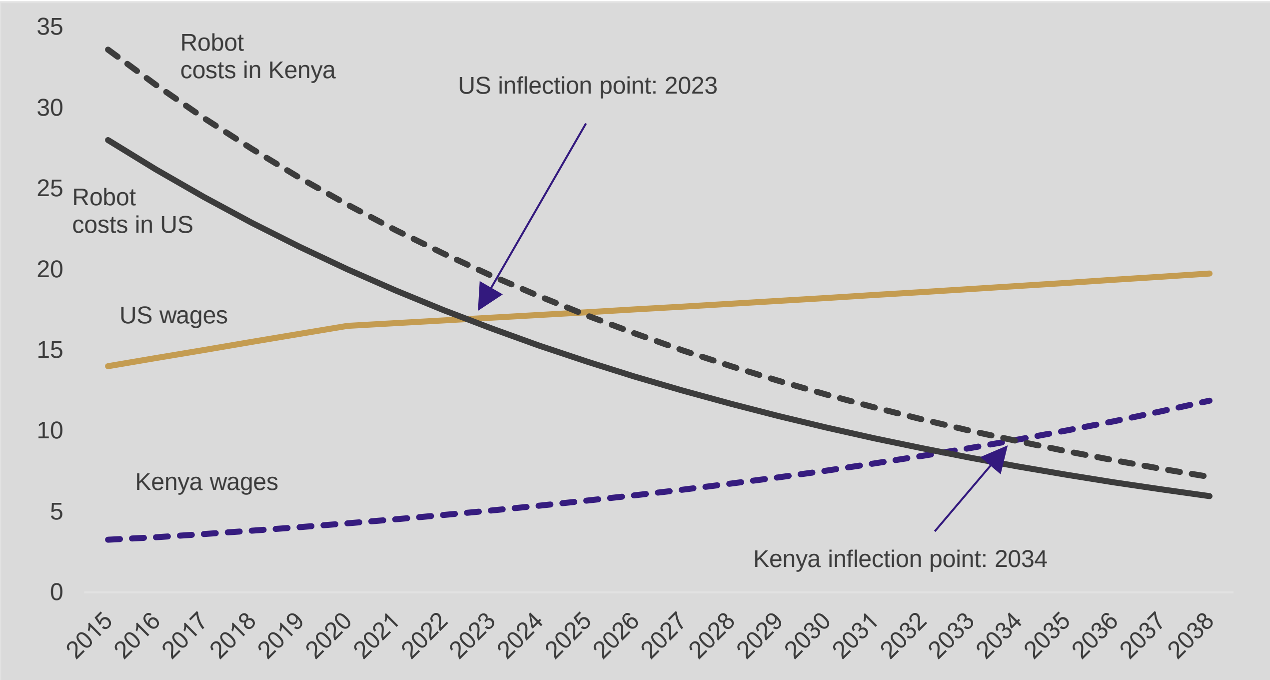
[20] Measured as ratio of robots deployed to labour employed in the sector.

[21] ABB is one of the world’s leading suppliers of industrial robots and robot software.

[22] This cost for robots has been calculated by Boston Consulting Group (BCG) for 21 industries by aggregating all of the production tasks and the types of robots required in these industries. The cost of owning and operating a robot includes installation, maintenance, and the operating costs of all hardware, software and peripherals (sensors, safety barriers etc.) and is adjusted for expected improvements in price and performance (a rate of 8% was assumed). The costs are then projected and finally amortised over a five-year depreciation period, to arrive at the cost per hour of operating a robot in US dollars.

[23] In reality, access to capital is constrained by availability in banks. Also, Kenyan operation costs might be higher (if depreciation rates are higher) or lower (if costs of specific robots are lower) than in the US. Furthermore, included in the costs of capital are higher operation costs (energy costs are around 20 cents per KWH and 12 cents in the US).

Figure 47: Window of opportunity for developing countries – the case of furniture manufacturing



Notes: Data for US furniture wages and operation costs of robots come from https://www.bcgperspectives.com/content/articles/lean-manufacturing-innovation-robots-redefine-competitiveness/ . Kenyan wages are hourly US$ calculated as total annual compensation per employee in the furniture sector (from Kenya Economic Survey 2016), divided by 2000 hours; annual nominal wage growth in the furniture sector over 2012–2016 was 7.5% a year. Kenyan operation costs of robots assumed to be 20% higher due to an approximately 10–15 percentage point difference in interest rates and higher operating (e.g. energy) costs. We estimate labour productivity increases in Kenya (real VA per employee) to be 1.7% a year. Comparing Kenyan wages with costs of Kenyan robots applies to a closed economy model, while comparing Kenyan wages with cost of US robots applies to an open economy model with low transport costs.

It is important to note that it is not the case that digital technologies do not exist in Kenyan manufacturing already – see Box 6 for a case study on the Kenyan furniture firm Funkidz – but that these will take some to diffuse.

Although the inflexion point in Kenya is not before 2034, its global competitiveness may be affected through the international pathways of digitalisation described in Box 3. One such international impact pathway, discussed above, is through re-shoring of manufacturing tasks from labour-intensive to capital-intensive regions, altering the criteria for being a ‘manufacturing hub’. Figure 47 shows that robots in the US, in the furniture industry, will become cheaper than Kenyan labour in the year 2033. Although there are other factors to account for, such as transportation costs, the estimate suggests that re-shoring of furniture manufacturing is a real challenge that African countries will face in the near future. Here again, it is important to differentiate between ‘tasks’ re-shored versus ‘jobs’. See Box 7 on the inflexion point for Levis Strauss’s task of finishing jeans.

Further, the changing competitiveness of countries in the digital economy can lead to changes in the organisation of global value chains. As manufacturing becomes increasingly based on a ‘digital thread’, i.e. continuous flow of data between the different stages of production, it is likely that goods will become concentrated in developed countries, which can provide good infrastructure, R&D capabilities and skilled labour at all points along the value chain.

Therefore, not being left behind in the digital revolution remains an important challenge for African countries. One way of achieving this is by focusing on and boosting traditional manufacturing. This can still be an important first – if perhaps only temporary – step in acquiring traditional manufacturing capabilities that can help countries to jump more easily to more complex, digitised manufacturing activities (Hausmann et al., 2011). The question of development has always been a dynamic not a static question: How can countries use what they have now to upgrade further?

Box 6: Funkidz – building an 'IKEA' in the Kenyan furniture manufacturing sector

Founded by a female entrepreneur, Wanjiru Waweru-Waithaka, Funkidz is a one-of-a-kind SME in Kenya that locally manufactures furniture for children. What makes Funkidz different from other furniture firms in Kenya is that it has invested heavily in technology. As a result, the beds, desks, cots etc. manufactured here are more similar to what you would find at Ikea—flat-packable, made with computer-controlled cutting machines and printers.

Leveraging technology has allowed Funkidz to lower its cost of production, undertake mass-production with exact specifications, and take advantage of economies of scale. Since its incorporation in the year 2010, the company has gone from employing 2 people to 23 people in 2015, and now serves not only the domestic market of Kenya but also regional markets of Uganda and Rwanda.

The main technology that has led to this impressive growth for the firm is Computer Numerical Control or CNC, which is the automation of machine tools by means of computers. In modern CNC systems, there are two technologies at play: first, the mechanical dimensions of the furniture parts are defined using computer aided design (CAD) software and, second, they are translated into manufacturing instructions using computer aided manufacturing (CAM). CNC technology, along with large printers, allows furniture design to be multiplicated, with exact specifications and quality.

According to Wanjiru, the main challenges that she faced in growing her company were: (a) a shortage of skills; (b) financial access; and (c) market access. There is a dearth of technicians in Kenya, and in Africa, who are needed to operate computer-controlled machines, leading to Funkidz hiring more expensive engineers to do the job. There is thus a need for retraining workers in new skills and upgrading education.

Source: Kuo (2016)

Box 7: 'Finishing' of Levi's jeans: inflexion point at 2020

Another example illustrating the threat of automation for developing countries is Levi Strauss. The denim-making company is turning to laser-wielding robots to produce and style its jeans, the production of which was offshored to countries with cheaper labour in the 1990s. With the goal to remain competitive, cut waste and costs, adapt to fast-changing consumer demands and shorten the design and manufacturing process, Levi's expects its laser rollout to replace almost all of its workers by 2020.

This is how the new manufacturing works at Levi's. One pair of basic denims (for example plain blue jeans) is photographed and uploaded to the computers, the design to be implemented on the jeans – ripped effects, design patterns etc. – is then illustrated using the CAD software and the final item is produced using lasers. What takes a finisher 8–12 minutes to produce can be produced in under 90 seconds or so by this laser technology. It also cuts down the number of steps in the finishing process from 18–20 to just 3.

One of the first laser-finishing lines in Levi's operates in a distribution centre in Nevada. Designers in San Francisco send digital files to the depot, where lasers can start mass-producing customised jeans within minutes, which can then be delivered to nearby customers within hours. This implies that even if automation of finishing tasks does not directly take away jobs from developing countries – since higher-value-added activities such as designing have remained with lead firms – the subsequent increase in cost-competitiveness and the growing demand for mass customisable production may lead to Levi's bringing its other manufacturing tasks that have been offshored closer to home. Also, if this goes on, then the whole manufacturing supply chain can be automated, which would inevitably threaten millions of workers in developing countries that are involved in labour-intensive manufacturing.

Source: Donnan (2018)

9. CONCLUSIONS AND IMPLICATIONS

9.1 Conclusions

This paper examined the future of manufacturing in developing countries in the context of growing digitalisation. Digitalisation is defined in this paper as the interaction of digital technologies with physical infrastructure that leads to the creation of smart machines, smart platforms and digital products, and is supported by a digitally enabling environment, comprising a digitally skilled workforce, policies and regulations and other digital accelerators.

Using different measures for inputs and outputs in the digital economy, the paper compares digitalisation across countries. We find that while the global digital economy is growing fast, there is a persistent digital divide between the developed and developing countries. We also find that compared to Asian countries, African countries are lagging in internet use, e-commerce, deployment of robots, ICT development etc. The paper then examines key factors in the digital divide: the higher cost of capital and the low digital readiness – in terms of skills, connectedness, infrastructure, logistics and customs – in African countries.

Reducing this digital divide can have important implications for developing countries. The paper maps out national pathways through which digitalisation can impact growth and the labour market in the manufacturing sector. These pathways include increases in productivity because of capital–labour complementarity, higher output and exports, job creation in the manufacturing sectors and possible spillover onto other sectors. However, it is also possible that a substitution effect takes place; automation may displace domestic labour and lead to more precarious work.

If nothing is done to close the digital divide, and developed economies digitalise faster, African countries run the risk of being left behind, unable to 'catch up'. The paper highlights international pathways through which digitalisation can indirectly impact African economies: re-shoring of manufacturing, a fall in wages in African countries to remain competitive, a falling share of labour, exclusion from GVCs, and further concentration of production in industry 4.0 in developed countries.

To examine whether African countries will be able to leverage digitalisation to achieve industrial growth, we then empirically analyse the impact of digitalisation on labour productivity using a cross-country panel spanning the period 1990–2013. Our findings suggest that: (a) technological progress can boost labour productivity, more so in the LICs, supporting the hypothesis of unconditional convergence; (b) digitalisation can boost labour productivity by 10% on average for all developing countries, but its impact is 8% lower in LICs compared to lower-middle- and upper-middle-income countries, indicating that convergence is not guaranteed or automatic; (c) as the economy becomes more digital, the impact of technological progress on labour productivity increases, but again less so in LICs, indicating the lower ability of LICs to absorb and utilise digitalisation; (d) skill development can increase the impact of technological and digital progress, more so in LICs than other countries for the former.

To gain a better understanding of the challenges and opportunities at the country level, we then take the case of Kenya – a lower-middle-income country at the forefront of technological progress in SSA. Kenya is found to be more digitalised than Ghana, Tanzania, and Uganda. It is also found to rank higher in the ability to finance digitalisation, in connectedness and in skill-development. In the period 2001–2016, internet penetration steadily increased in Kenya. This growing digitalisation is tracked to improvements in infrastructure, customs and trade regulations.

Labour productivity and employment also increased in Kenya in the period 2001–2016, and while the labour share of income has fallen, it has recovered in recent years. This indicates that high-productivity activities are taking place in Kenya. We find that Kenyan firms with access to internet are, on average, more productive and have a higher share of skilled workforce. However, there is still a divide of 40%–50% between firms that have access to the internet and firms that use it, possibly linked to firm size and skills; the most-digitalised firms tend to have a higher share of skilled workers.

In summary, our descriptive and empirical analysis confirms that LICs, particularly in SSA, face a two-pronged problem in the manufacturing-led development path. First, despite impressive growth in digitalisation in some African economies, the actual level of digitalisation is still very low in LIC and SSA countries. Second, even if the low-income countries manage to digitalise their manufacturing, they will not be able to utilise the technology in the same way as the developed economies. A digital divide persists between developed and less-developed countries, but there is also a digital divide between access and use, as seen in empirical results and in the Kenyan case study.

9.2 Scope of further work

While this study focuses on the impact of technological and digital progress on labour productivity, examining the impact on employment remains a key goal for future research. This would involve understanding the overall effect of digital progress on the labour market by examining changes in capital-to-labour ratio and marginal productivity of capital. Moreover, examining spillover effects of technology in the manufacturing sector on other sectors can yield interesting insights into the net impact of technology on employment in developing economies.

Critical issues for further research include within-country digital inequality, labour market effects of the gig economy, implications of digitalisation for sustainable development, and the future of work. Country-level case studies will need to be undertaken in order to address these issues. It may also be important to develop better measures of digitalisation to capture access to – and use of – digital technologies.

9.3 Policy suggestions

Based on the above analysis, we provide the following policy recommendations for those wanting to support African manufacturing.

Boost traditional manufacturing

At the macro level, there is a big digital divide between developed countries and developing countries or least-developed countries, but also between developing countries and LDCs. This suggests that Africa is not yet affected by the global technological surge, creating a window of opportunity for African countries to move into less-automated sectors where technology installation has been slow – such as food and beverages, basic metals, and paper and paper products, among others.

At the same time, African countries need to look towards more export-based and higher-value-added manufacturing. Focus on traditional manufacturing requires traditional constraints to be met; African countries need to first and foremost improve basic infrastructure such as a reliable power supply, improvements in telecommunications, roads etc. This is in line with Juma's (2017) argument that for Africa to move from using mobile phones or mobile money to using communications for broader economic development, investment into infrastructure is a must. Leapfrogging – technology making manufacturing easier – may be possible, if traditional challenges are met first.

It is also important to prepare for the future. Policy plans in the more digitalised African countries, such as Kenya's and Rwanda's Vision 2030, recognise ICT as an important priority sector. To bridge the global and regional digital divide, African countries should look to digitalise manufacturing and reap maximum benefits. Here we describe how this might be done.

Digitalise manufacturing: increase access to ICT technologies

As we saw in Section 4, accessing the internet in African countries is much more expensive than in Asian economies. To make the internet more affordable to populations, policies targeting public-access solutions need to be developed. This includes free or subsidised access to public/open areas such as educational institutions and local and community centres and public Wi-Fi. One country that has significantly improved its internet affordability since 2016 is Botswana. The government introduced new rules that enable technology and service neutrality, without restricting operators from holding several types of licenses, such as a network licence, a services license etc. This has already greatly simplified the existing licensing regime. The government has also used its Universal Service / Universal Access Fund (USAF) to increase the number of public Wi-Fi hotspots in hospitals, bus stops and shopping malls, across seven towns. Botswana is now preparing to increase access to computers and broadband for schools in remote and rural areas. To close the digital urban–rural divide, it can be useful to reduce taxes on ICT services and equipment supplied to rural areas, provide incentives to network operators to expand coverage to marginal areas, and reduce import duties of local content suppliers.

To increase access to ICT, both Kenya and Rwanda, under the East African Community (EAC), consider ICT equipment as capital goods that are zero rated for import duties. In 2015, Rwanda also reduced corporate income tax from 30% to 15% for ICT investors.

Financial support from the government needs to be extended – not only to manufacturing and services start-ups but also to ecosystem enablers such as technological and innovation hubs. There are more than eight established tech hubs in Kenya, with iHub, one of the most established in Africa, having around 150 companies and over 13,000 members. The success story of one such hub in

Box 8: Technology firms in Ghana: The Kumasi Hive and Klaks 3D printing

Incorporated in the year 2016, Kumasi Hive is technological and collaborative hub that provides a multifunctioning platform to innovative entrepreneurs in Africa. The Hive uniquely uses a multi-space approach to a sustainable model. It provides meeting space, co-working and training spaces that lower the shared costs, and maker space for quick-prototyping of ideas. It also provides business development support through organising financial literacy programmes, investment-readiness training, mentorship and co-learning support.

At present, the Kumai Hive has 25 starts-up using co-working spaces, 9 start-ups in incubation and over 100 start-ups as network members who benefit from their business development support. It is also supporting 4 hardware start-ups to prototype their ideas into a minimal valuable product (MVP) to enter the market. One such team is DEXT, with an innovative product called the 'Science Set' – a user-friendly and affordable miniaturised science laboratory fitted into a portable box.

In the Hive, sustenance of local industry is considered an important target. One of its start-ups that has made a tangible contribution to this front is Klaks 3D, which sells 3D printers and 3D printing services. 3D printers in Klaks are manufactured using electronic waste or e-waste, which includes locally obtained materials from discarded items: computers, electronic equipment, electronic entertainment devices, mobile phones, television sets, refrigerators etc. Also, while earlier some electronic equipment that required moulding was imported by Klaks, mainly from China, it is now 3D printed, leading to some imports being substituted with local content. With a locally manufactured 3D printer now costing about 2000 Cedi, the cost of prototyping products and entering the market is going down for firms, but technical and design skills remain important. While these locally manufactured 3D printers can produce a range of goods, the print area is still limited, implying that relatively big objects (handbags, for example) can be made in steps, but not in one go. Important challenges faced by Klaks 3D in producing and improving the 3D printers include: access to quality electronics, the presence of high shipping costs, and a limited demand for 3D printers due to the lack of education, information and awareness of its potential uses.

While the government and non-governmental organisations (NGOs) are approached for financial assistance, it is not possible to acquire a loan from the banks since financial assistance is directed more towards manufacturing start-ups rather than ecosystem enablers like the Hive. To further its sales, Klaks 3D now relies on TechforTrade, a leading UK based charity, which provides technical and market expertise, along with its network of potential funders.

Source: Authors (2018).

Ghana – the Kumasi Hive – in unlocking the potential of many other manufacturing start-ups is given in Box 8. What separates Kumasi Hive from its competitors, such as Impact Hub Accra, iSpace, and Hapaspace, is that Kumasi Hive is the first one to specialise in hardware. It supports businesses' growth by providing them with: a space for manufacturing; manufacturing equipment; training in hardware engineering, coding, digital fabrication and IoT; and skill development. The curriculum is accordingly centred on the future of the workforce, and training is given in the relevant fields of robotics, AI, 3D printing and blockchains. It also acts as an incubator, offering support along different steps of product formation, conceptualisation of ideas, training and modules to develop appropriate skills, networking with partners, and attracting funding.

Box 9: Rwanda: preparing for the future by closing the digital skills gap

Under the leadership of President Paul Kagame, Rwanda is directing its efforts towards ICT development and transformation of the economy. In partnership with the World Economic Forum's Internet for All Northern Corridor initiative and Digital Opportunity Trust, Rwanda's Ministry of Youth and ICT is pushing to provide internet access, skills trainings and jobs across the country. This is being done through a 'Digital Ambassadors Programme' (DAP), which aims to employ 5,000 young Rwandans (50% participation by young girls and women) as digital-skills trainers. These digital ambassadors (DA) are first trained in ICT and soft skills, and then will provide hands-on training on using the internet, mobile applications and other ICT technologies to around 5 million Rwandans across the country. With the aim to deliver digital literacy to rural communities, DAP is a step towards reducing the digital gap between urban and rural areas and moving towards digital inclusion. It is also an example of innovation and collaboration between government, civil society and other key stakeholders to position Rwanda with the ICT and skills needed to benefit from digital revolution.

The Rwanda Utilities Regulatory Authority (RURA) is also taking steps towards expanding internet access. As compared to other developing countries, internet services are already quite affordable in Rwanda. And now, in collaboration with other stakeholders, RURA is implementing programs towards Universal Access for all Rwandans. This includes setting up of e-learning and e-service centres and subsidising internet in rural areas.

Source: Wong (2017)

Leverage digitalisation for boosting the economy

Our empirical analysis shows that even if African countries gain access to the same level of ICT technologies as, say, Asian countries, they will not be able to utilise the ICT in the same way to transform the economy. This is because African countries have lower-skilled labour and consequently lack the ability to absorb ICT technologies, innovate and digitalise.

Skills development therefore should be a top policy priority for African countries. With technology increasing at a faster rate than skills, it is also important to develop complementary skills to avoid skill mismatch. Attempts have already been made by some African countries to put in place policies boosting ICT skills; there are ICT policies in the education sectors of Botswana, Rwanda, Uganda, and Zambia, and there are national plans on ICT in education in some countries including Kenya, Botswana, Uganda, and South Africa. Rwanda has also recently launched a digital ambassadors programme that aims to reduce the digital skills gap (Box 9). However, the countries of Cameroon, Comoros, Congo, Guinea, Lesotho, and Madagascar do not have any ICT plans or policies in place for education (UNESCO, 2015).

To become future-ready, the curriculum in African educational institutions needs to be revised and reoriented around science, technology, engineering and mathematics (STEM) subjects, with special focus on technical and vocational education and training (TVET) and collaboration between the public and private sectors. African countries also need effective policies in place to alter country-specific conditions that will improve the investment climate, firm capabilities, national innovation and knowledge systems, ICT infrastructure, direct financing opportunities and participation in GVCs.

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APPENDICES

Appendix A: The bias of technological progress towards factors of production

Technological progress can play a key role in influencing economic growth by increasing the output produced per unit employed. It helps in intensifying the utilisation of natural resources, which consequently leads to an increase in output and diversification of output, contributing to growth in national income and economic development. Technological progress also facilitates the discovery and use of potential resources in the economy, leading to increase in domestic production and substitution of imports with domestically produced goods. Diversification of output, as a result of technical advancement, can contribute to export promotion and improvements in terms of trade for developing countries. Other contributions of technical change in economic developments include growth of infrastructure, increase in efficiency of inputs, and agricultural development.
However, technical progress often is not neutral with respect to factors of production. It some cases it can make capital relatively more productive, while in other cases it can make certain types of labour more productive. The different impact pathways through which technical change can affect growth are summarised below:

a) Hick's Neutral: Technology raises marginal product of labour (MPL) and marginal product of capital (MPK) in the same proportion. MPL/MPK remains unchanged at constant K/L.
b) Harrod-Neutral: Technology is labour augmenting. Improves efficiency of labour (MPL increases) and is thus labour saving.
c) Solow-Neutral: Technology is capital augmenting, improves efficiency of capital (MPK increases) and is thus capital saving.

Appendix B: Correlation of internet penetration with other indicators of digitalisation

Other indicators of digitalisation	Correlation with internet penetration (in %)	Number of observations (countries)
Fixed broadband subscriptions per 100 inhabitants - ITU Database	87	196
Active mobile broadband subscriptions per 100 inhabitants - ITU Database	70	183
Used an account to make a transaction through a mobile phone (% aged 15+) [w2] - Global Findex	62	140
Percent of population having mail delivered at home - UPU Database	67	187
Postal reliability index - UPU Database	67	183
LPI international shipments score	72	160
LPI logistics competence score	74	160
B2C internet use - NRI World Economic Forum	77	139
Firms' technology absorption - NRI World Economic Forum	72	139

Source: WITS e-trade indicators
Note: Internet penetration here is measured as internet users (per 100 people) – ITU Database. Data is for several areas: 2013, 2014, 2015.

Appendix C: Data sources

Variable	Construction	Data sources
Dependent variable		
Labour productivity	Real GVA/ employment	SET database, matching UN and ILO data
Digitalisation proxies		
Internet penetration	Individuals using internet/ population	WDI
ICT imports share	ICT goods imports/ total goods imports	WDI
ICT exports share	ICT goods exports/ total goods exports	WDI
Share of high-tech goods	Import of high-tech goods (Lall's classification)/total imports	UN COMTRADE
Controls		
Manufacturers imports	Merchandise imports/total imports	SET database, matching UN and ILO data
Manufacturers exports	Merchandise exports/total exports	SET database, matching UN and ILO data
Real annual wage	1.Nominal monthly wage (LCU) converted into nominal annual wage 2.Divided by Consumer Price Index 3.Converted to US dollars using Official Exchange Rate (OER)	Nom. Wage data collected from ILO global wage database. CPI and OER data collected from WDI.
Total exports	Exports of goods +exports of services (constant 2010 US dollars)	SET database, matching UN and ILO data
Total imports	Imports of goods +imports of services (constant 2010 US dollars)	SET database, matching UN and ILO data
FDI share in GDP	FDI Inward Stock/GDP	SET database, matching UN and ILO data
Import share	Imports/GDP	SET database, matching UN and ILO data
Capital-to-labour ratio	Capital employed/Labour employed	Penn World Tables 9.0
Human Capital Index	Based on years of schooling and returns to education	Penn World Tables 9.0

Source: Authors (2018)
Note: UN – United Nations. ILO – International Labour Organization

Appendix D: Robustness checks using GMM estimations

Dependent variable: Log (labour productivity)

Variables	**(1)** **Model 1**	**(2)** **Model 2**	**(3)** **Model 3**	**(4)** **Model 4**	**(5)** **Model 5**
L. labour productivity.	0.797*** (0.0981)	0.834*** (0.106)	0.789*** (0.0957)	0.837*** (0.0924)	0.843*** (0.116)
IPR*time trend*LIC	**-0.0101**** **(0.00428)**				
IPR*time trend*SSA		**-0.0145**** **(0.00657)**			
Time trend* IPR	0.00544** (0.00268)	0.00543 (0.00397)			
IPR*HCI			**0.0556*** **(0.0319)**	**0.0359*** **(0.0186)**	
Time trend*HCI					**0.0120*** **(0.00686)**
Time trend*LIC	0.0458** (0.0220)				
SSA*time trend		0.0820** (0.0329)			
IPR_SSA		-0.00705 (0.0535)			
L. (Real Wage)	-0.00707 (0.0565)	0.0231 (0.0349)	0.0206 (0.0558)	-0.000803 (0.0424)	0.0206 (0.0660)
IPR	-0.000466 (0.0212)	-0.00874 (0.0255)	-0.110 (0.0684)	-0.0686* (0.0401)	
HCI			-0.000370 (0.0949)	0.0655 (0.0718)	-0.115 (0.271)
K/L ratio	0.0319 (0.131)	-0.0211 (0.104)	0.0879 (0.0864)	0.0331 (0.125)	0.0560 (0.0980)
Import share	-0.00190 (0.00637)	-0.00138 (0.00311)	-0.00122 (0.00351)	0.000875 (0.00251)	-0.00206 (0.00392)
FDI share	0.00710 (0.0507)	0.112** (0.0488)	0.0261 (0.0643)	-0.00261 (0.0740)	-0.0103 (0.0592)
Time trend	-0.0234* (0.0134)	-0.0256 (0.0196)			-0.0256 (0.0168)
IPR*LIC	-0.0291 (0.0447)				
Constant	1.775 (1.601)	1.603 (1.626)	0.821 (0.774)	0.940 (0.607)	1.096 (1.064)
Time fixed effects	No	No	No	Yes	No
Time trend	Yes	Yes	No	No	Yes
Observations	623	623	592	592	599
AR(2)	0.154	0.18	0.15	0.155	0.127
Hansen pval	0.7	0.5	0.5	0.8	0.22
Number of countries	59	59	54	54	54

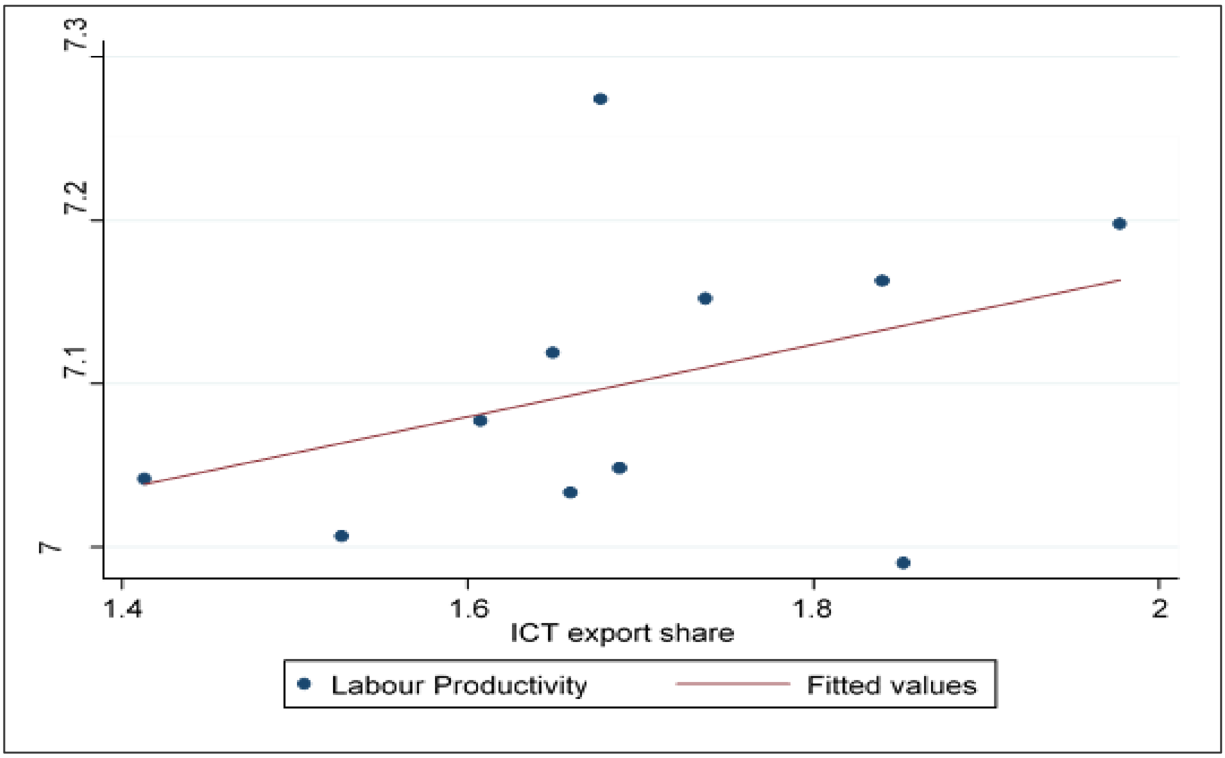
Notes: Columns 1 and 2 have LIC and SSA dummy included. IPR is internet penetration rate. HCI is human capital index. LIC is low-income country. Labour productivity, real wage, internet penetration and FDI are in logs.

Appendix E: Robustness checks using other proxies for digitalisation

Variables	**(1) Model 1**	**(2) Model 2**	**(3) Model 3**	**(4) Model 4**	**(5) Model 5**
L. Real Wage	0.101* (0.0478)	0.0975 (0.0506)	0.168** (0.0472)	0.183* (0.0775)	0.192*** (0.0192)
Time trend	0.0257*** (0.00555)	0.0248*** (0.00554)	0.0340*** (0.00851)	0.0662** (0.0235)	0.00420 (0.00937)
Time trend*Broadband subscriptions	**0.00418* (0.00206)**	0.00452* (0.00217)	0.00306 (0.00178)		
LIC*Broadband subscriptions	**-0.0685*** (0.0153)**	0.0532 (0.0353)	0.0677 (0.0606)		
LIC*Time trend	**0.0341** (0.0103)**	0.00950 (0.00788)	-0.00593 (0.0255)	0.0195 (0.0110)	0.0483 (0.0256)
LIC*Time trend*Broadband subscriptions		**-0.00617* (0.00266)**	-0.00533 (0.00283)		
Broadband subscriptions	-0.0526* (0.0238)	-0.0559* (0.0248)	-0.0352 (0.0250)		
Mobile subscriptions				0.0496 (0.0475)	
Time trend*Mobile subscription				-0.00605 (0.00431)	
LIC* Mobile subscription				**-0.0982* (0.0458)**	
Time trend*secure internet servers					0.00314** (0.00123)
LIC* secure internet servers					0.00641 (0.109)
LIC*Time trend*secure internet servers			(0.135)		**-0.0121** (0.00481)**
FDI			0.0334 (0.0910)		0.0915 (0.107)
Manufacturers exports			0.00249* (0.00109)		0.00187** (0.000750)
Manufacturers imports			-0.000691 (0.00241)		
Secure internet servers					0.0384
Constant	7.965*** (0.169)	8.046*** (0.201)	8.925*** (1.244)	7.243*** (0.480)	7.632*** (0.256)
Observations	546	546	452	737	463
R-squared	0.175	0.176	0.193	0.300	0.248
Number of countries	70	70	55	71	55

Note: Columns 1–3 use broadband subscription per 100 people as a proxy for digitalisation, column 4 uses mobile subscriptions per 100 people and model 5 uses secure internet servers per million people. Data for these variables are in logs and taken from ITU. Real wage and FDI are also in logs.

Appendix F: Scatterplot of Kenyan labour productivity and digitalisation



Source: Authors (2018).
Notes: Spearman's correlation test shows a positive and significant correlation of 70%.