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IZA DP No. 12678

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ISSN: 2365-9793

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ABSTRACT

Three Varieties of Africa's Industrial Future

This paper shows that African economies have generally not de-industrialized, that manufacturing growth is very possible, and moreover that the contribution of manufacturing in Africa has been underestimated. As far as the future is concerned, African countries will in differing degrees experience three varieties of industrialization, all influenced by new and emerging technologies. In one variety, labelled "acquiring traditional manufacturing capabilities" technological change is too fast and complex for some countries to immediately benefit, requiring an estimated 15-year window to put the complementary investments and business ecosystems in place, while promoting old-fashioned labor-intensive manufacturing. In a second variety, technological innovation is changing the nature of manufacturing and is turning services into the main sector for structural transformation. This variety is labelled "fostering sectors with the characteristics of manufacturing" to denote that services now perform functions previously expected from manufacturing. A third variety of future industrialization is labelled "resurgent entrepreneurship-lead industrialization" denoting that some African countries will take part in new and advanced types of manufacturing, through indigenous entrepreneurs starting high-technology firms. This third variety is elaborated with reference to recent examples. The paper concludes with broad suggestions for industrial policies that are consistent with these varieties of industrialization.

JEL Classification: O47, O33, J24, E21, E25

Keywords: technology, entrepreneurship, manufacturing, industrial policy, Africa

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1 Introduction

Economic activities are classified according to the sector from which it originate: from the "primary sector" (agriculture, mining), the "secondary sector" (manufacturing, energy, construction) or the "tertiary sector" (services). As a country's economy develops, the contribution of the primary sector in terms of its shares of GDP and employment will decline. In fact, the reallocation of production factors, from sectors characterized by low productivity and low productivity growth, to sectors where productivity levels and growth are higher, is a *sine qua non* of development (Gries and Naudé, 2010; Naudé, 2016). This reallocation is known as "industrialization" when it entails the rise in the share of *manufacturing*[1] output and employment in the total output and employment of a country.

The reason for labelling a growing share of manufacturing as industrialization is because ever since the take-off of the West (the "Great Divergence") manufacturing has been associated with development. This has not only been the case for the first countries to industrialize, such as the UK, Germany and the USA, but also for the emerging economies in East Asia after the Second World War (Szirmai et al., 2013). The *Commission on Growth and Development* for instance found that "In countries that in the last 50 years sustained episodes of 7 percent growth or more over 25 years or longer, manufacturing and services led the way" (Commission on Growth and Development, 2008, p.60). And manufacturing was more important than services. The only country among this group of fast-growers over a period of 25 years where manufacturing growth did not outstrip services growth was Botswana[2] .

As the third decade of the 21st century approaches, there is a growing concern that most countries in Sub-Saharan Africa (henceforth "Africa") have not yet experienced the kind of industrialization that will contribute sufficiently to development. There are many who are concerned that Africa is de-industrializing, e.g. Rodrik (2015a) and Timmer et al. (2014). The lack of industrialization, and even de-industrialization, is seen as a serious constraint for African countries to catch-up in terms of income and wealth, in particular given the continent's need for job creation[3] (Fox et al., 2013).

Africa has the world's fastest growing, youngest, and most rural population. Its rapid urbanization[4] driven by young people, is a huge opportunity, but comes however with substantial challenges. The need for more manufacturing is one of these. The creation of urban-based jobs, without neglecting the important rural/food-producing sector, requires the development of sectors such as manufacturing, where productivity-enhancing advantages such as scale economies, learning-by-doing and higher capital and technology intensity can be enjoyed. Taking on this challenge requires answering the question: *how can African countries industrialize?*

While this is an old question it is appropriate to ask it anew in light of possible existential changes to the nature of manufacturing. Some describe these changes, driven by new technologies such as Artificial Intelligence (AI), the Internet of Things (IoT) and Synthetic Biology, as the signs of a new industrial revolution or "new machine age" (Brynjolfsson and McAfee, 2016; Marsh, 2012). The relevant question now is: *how can African countries industrialize given these disruptive technologies?*

[1] Manufacturing is the main "industrial sector" (see Szirmai (2012)) and therefore the focus here.
[2] See figure 7, page 61 of the Commission on Growth and Development.
[3] Between 2010 and 2020 an estimated 170 million job-seekers will enter into African labor markets (Fox et al., 2013).
[4] The population of Africa's cities is expected to grow by 300 percent over the next 30 years (Freire et al., 2014).

To answer this question this paper argues that African countries will experience a variety of industrial futures. Thus, dogmatic approaches towards industrial policy will be counter-productive. Instead, rather pragmatic, pluralistic and entrepreneurial-based approaches, wherein new business model development based on new technologies, are best. Prerequisites for these are a sound understanding of (i) the current state of industrialization, (ii) the possibilities for further industrialization, and (iii) the nature and potential impact of new technologies in opening up or allowing multiple varieties of industrial futures to co-exist.

In this light this paper presents and discusses in section 2 the current state of African industrialization specifically manufacturing. A case is made that, in general, African countries have not de-industrialized as is often claimed, and that future industrialisation is indeed possible - a case that counters the somewhat pessimistic conclusions elsewhere in the literature. Section 3 explains new and emerging technologies impacting on manufacturing and the implications for job-creating African industrialization. The key message here is that these new and emerging technologies make manufacturing more accessible, viable and less complex under certain conditions, such as availability of skills, supportive entrepreneurial ecosystems and infrastructure. Section 4 contains the main contribution of this paper, which is to describe *three varieties of industrialization* that African countries will experience in the near future, emphasizing the potential for African countries to partake in modern manufacturing through its resurgent entrepreneurship. Section 5 conclude with a summary and recommendations.

2 Industrialization, Deindustrialization, Re-industrialization

2.1 Concepts

Industrialization, de-industrialization and re-industrialization refer to "changes in the share of the manufacturing sector in GDP and/or employment" (Tregenna, 2011, p.5). Industrialization occurs "when the share of manufacturing in GDP and/or employment in manufacturing increases, and de-industrialization when the share of manufacturing in GDP *and* employment declines" (Tregenna, 2011, 2013).

Re-industrialization is "when the share of industrial activity increases in regions (or countries) where it had been higher and declining before" (Wink et al., 2016, p.464). Re-industrialization also includes changes in the structure of manufacturing, for instance when labor-intensive, low-skilled sectors are replaced by sectors requiring higher skills and more capital per labor (Lengyel et al., 2017).

2.2 African Manufacturing in Global Context

Africa is not in any way a world player in manufacturing, contributing less than 2 percent to world manufacturing output. In 2017 manufacturing contributed 10,3 percent on average to Africa's GDP, compared to the world average of 15,6 percent.[5] Rodrik (2015b) pointed out that when Europe and the United States were at similar levels of per capita GDP in the past, manufacturing contributed a much higher share of their GDP.

[5] Source of data: World Development Indicators Online

The services sector and agriculture[6] currently contribute the largest shares to African GDP on average: respectively 50 percent and 22 percent.

2.3 Industrialization or De-Industrialization?

It is often claimed that Africa is de-industrializing, even "prematurely". For instance, Rodrik (2015a) , Timmer et al. (2014) and UNECA (2013) have expressed concerns in this regard. McMillan and Rodrik (2011); de Vries et al. (2013) and McMillan and Harttgen (2014) find that the type of structural change in Africa since the 1990s, amounting to a shift of labor out of manufacturing and agriculture towards services, has reduced productivity growth. According to de Vries et al. (2013) this delivered "static gains but dynamic losses" and according to McMillan and Rodrik (2011) resulted in "productivity-reducing structural change".

Recently however, some scholars have begun to question whether African countries have in fact been de-industrializing. Diao et al. (2018) based on data from the Groningen Growth and Development Centre's Africa Sector Database (ASD), concludes that "it is difficult to make the case that Africa is de-industrializing" (Ibid, p. 39) and finds little basis for pessimism, stating that "the upshot of this analysis is that the majority of the countries in our sample still have potential for industrialization" (Diao et al., 2018, p.42). Signé (2018) concurs, concluding that "across all subsectors and countries, Africa's industrial revolution appears imminent [...] Africa's manufacturing output has the potential to surpass US$ 1 trillion per year by 2025". And more recently Nguimkeu and Zeufack (2019) using panel data on 41 African economies covering the period 1960 to 2016 found that the majority of countries did not experience de-industrialization over this period.

Consistent with this greater optimism, Naudé (2019a) argues that manufacturing has been more robust in Africa, and that the last decade has seen the sector grow faster in Africa than in many other regions. The remainder of this section draws on Naudé (2019a) in arguing the case that Africa is not de-industrializing and suggests that if the new technologies, discussed in section 3 below, can be harnessed, that the momentum of recent years may be sustained.

Naudé (2019a) point out that the narrative of a de-industrializing Africa is based on declining manufacturing shares. In absolute values, the situation is different. Instead of stagnating, the absolute value of manufacturing has grown three-fold since 1980, from (constant-price) US$ 66 billion to US$ 158 billion in 2015. Most of this growth occurred after 2000. Between 1980 and 2000 manufacturing grew, but only slowly at between 1 and 2 percent per year on average; after 2000 a revival occurred, seeing manufacturing growing annually by more than 5 percent per year on average. As shown by Signé (2018, p.4) "manufacturing in Africa has grown 3.5 percent annually from 2005 to 2014 - faster than it has in the rest of the world. Some countries, such as Nigeria and Angola, have experienced an increase in output of over 10 percent per year".

Furthermore, even making the case for Africa's de-industrialization based on the relative shares of manufacturing may not be straightforward. As Tregenna (2011) argue, the shares in *both* GDP and employment need to decline before there can be talk of de-industrialization. And while the share of manufacturing in GDP in Africa has declined (from 16,4 percent in 1981 to 9,4 in 2011 - and has since risen), this has not been the case for employment. For instance the

[6] While agriculture contributed 22 percent to GDP in 2015 on average in Africa, this share underestimates the importance of agriculture. Its importance is more appreciated when it is kept in mind that most jobs in Africa are in agriculture (59 percent) and that around 78 percent of the working poor is in agriculture (Christiaensen and Chuhan-Pole, 2015; Naudé, 2016).

share of manufacturing jobs in Africa has not been declining as rapidly elsewhere. Rather, it grew from 5 percent in the 1970s to around 10 percent by 2008 (based on data from the ASD).

Finally, Edjigu and Naudé (2019) use trend analysis to study whether Africa is industrializing or not, using the extended ASD. They show that when the share in manufacturing value added in GDP is used as the only measure of industrialization, that the conclusion can be drawn that many countries are indeed de-industrializing. However, they stress that one should be wary of generalizing this conclusion, because of the 18 countries for which data is available the share of manufacturing value added in GDP has increased in a number of countries: for instance in Ethiopia, Botswana, Uganda, Lesotho, Mozambique and Tanzania.

Using other indicators of industrialization - such as the absolute size of manufacturing value added, the share of manufacturing exports, the absolute size of manufacturing employment, or the share of manufacturing employment, Edjigu and Naudé (2019) find however no evidence of de-industrialization. They furthermore perform Bayesian and System-GMM estimations to identify the determinants of industrialization in Africa - finding total factor productivity (innovation), foreign direct investment, global value chain participation, institutional quality and domestic demand as the main drivers of industrialization. Given progress being made in all these aspects in recent years (see Signé (2018)) this provides further support for the implied optimism about Africa's industrial future of authors such as Diao et al. (2018); Naudé (2019a); Nguimkeu and Zeufack (2019) and Signé (2018).

2.4 Fundamental explanations

While Africa is not de-industrializing and indeed may still have the potential for future industrialization, Diao et al. (2018, p.39) makes valid point that given the extent of industrialization that "most people would be hard pressed to call that kind of industrialization successful". This statement should perhaps be understood by considering the successful export-orientation industrialization that much of East Asia experienced over the past four decades. Industrialization has not lived up to expectations in Africa. There are two broad sets of explanations for this. These are (i) inappropriate policies, institutions and historical legacies; and (ii) the persistence of a technological gap.

As far as policies, institutions and the historical legacies are concerned, the main explanation for Africa's unsatisfactory industrialization ascribe it to wrong policies[7] and the related natural resource "curse" (Frankel, 2010; Lall, 2004; McMillan and Rodrik, 2011; McMillan and Harttgen, 2014). These gave rise to inappropriate import substitution industrialization (ISI) attempts behind protected markets and state-owned enterprises (Lawrence, 2005). Poor institutions with their roots in the colonial legacy[8] (Nunn, 2007, 2008), such as weak property rights, lack of rule of law and low accountability, contributed to a risky business environment wherein conflict, corruption and red tape discouraged productive investment and indigenous entrepreneurship (Eifert et al., 2008).

[7] Lall (2004) argues that industrialization has been difficult due to poor policies such as (i) under- investment in human and physical capital; the (ii) obstruction of entrepreneurial entry and exit; (iii) inappropriate macro-economic policies; and (iv) neglecting the transfer of technology.

[8] Nunn (2008) quantified the strong negative impact the colonial era slave trade continues to exert on African development. He estimated that more than 18 million people were taken into slavery from Africa between 1400 and 1900 and found that countries which had the most people taken are still amongst the poorest on the continent.

A second set of explanations blames the persistence of a technological gap between Africa and the advanced economies. The absorption of new technologies and capital in Africa has been quite slow, despite globalization and the apparent role of multinational enterprises (Comin and Mestieri, 2013). The low level of development of business support infrastructure (Sala-i-Martin et al., 2008) and lack of skills (Lawrence, 2005) reduces incentives for technological innovation, R&D, and technological uptake. Lack of complementary investments, for instance in electricity provision (a 19th century technology) and in broadband infrastructure are further significant causes of the digital gap (Banga and te Velde, 2018).

3 New and Emerging Technologies

Marsh (2012, 2014) argues that the world is now in a "Fifth" Industrial Revolution. The First Industrial Revolution started in 19th century UK and was driven by then radical technologies such as the power loom and steam engine. The Second Industrial Revolution, which saw continental Europe industrializing at the end of the 19th century, was driven by new technologies in transport and communication. The Third Industrial Revolution saw the US catch up to Europe at the start of the 20th century through the application of new technologies including mass production techniques and large-scale electricity provision and declining costs. A "Fourth" Industrial Revolution is said to have been taking place since the 1970s, driven by technological innovations in ICT, such as the personal computer and the Internet. The current, "Fifth" Industrial Revolution is largely driven by technological progress in connectivity, such as the spread of mobile communication and computing, cloud computing and artificial intelligence (AI). These technologies enable the digital transformation of production and consumption, which consists of the digitalization of processes and products and the integration of the physical and online economies.

Here, digital transformation[9] refers to "the process of devising new business applications that integrate digitized data and digitalized applications". Digital transformation is a central element of what has been termed the new industrial revolution, which refers to the merging of digital and physical technologies in production and consumption.

The new industrial revolution builds on the ICT revolution of the 1980s and 1990s which saw the introduction of the personal computer and the internet. This has more recently contributed, by reducing the costs of computing, by providing exponentially more storage of data ("big data") and through improvements in robotics and sensors, to "ubiquitous computing", also referred to as the "third wave of computing" (Manwaring and Clarke, 2015). Three of the manifestations of ubiquitous computing are Artificial Intelligence (AI)[10], the Internet of Things (IoT)[11], and Computational (or Synthetic) Biology (CB)[12]. These three manifestations of digitalization have the potential to disrupt business and impacting on society. A recent critical discussion of the impacts of AI on business and the economy is contained in Naudé (2019b).

Consider first three core areas where businesses face disruption. One is that the IoT is changing

[9] See `https://bit.ly/2ysRmlL` for the difference between digitalization, digitization and digital transformation.

[10] One definition of Artificial Intelligence is "The theory and development of computer systems able to perform tasks that normally require human intelligence" (Deloitte, 2018, p.36).There is no consensus definition yet.

[11] By 2020, around 200 billion objects are expected to be connected as the Internet of Things (IoT): See `https://intel.ly/2t2Ewpe`. The volumes of data collected by machines through the IoT doubles every 18 months (Frey et al., 2016).

[12] According to *Nature* magazine (14 Dec 2018) "Synthetic biology is the design and construction of new biological parts, devices, and systems, and the re-design of existing natural biological systems for useful purposes".

the nature of manufacturing: digital manufacturing is supporting the increasing adoption and development of additive manufacturing (3D-printing), which allows for greater personalization as well as viable small scale production - for a discussion see Kleer and Piller (2019). According to Accenture (2015), the global market for the IoT will be worth in excess of US$ 15 trillion by 2030.

A second area where businesses face disruption is from digital platforms. Digital platforms have become household names virtually across the world. As Naudé (2019c) discusses, "examples include *AirBnB* (a home sharing platform), *Amazon* (a trading platform), *BlaBlaCar* (a carsharing platform), *Deliveroo* (a food-delivery service platform), *eBay* (a second-hand goods platform), *Facebook* (a social networking and trading platform) and *Uber* (an on-demand, lift-hailing platform)". They underpin the on-demand and "gig' economies. The most valued global firms, as measured in terms of their market capitalization at the time of writing, consisted of largely of digital platform firms, such as *Apple*, *Amazon*, *Google*, *Microsoft*, *Facebook*, *Tencent* and *Alibaba*. At the time of writing there were more than 300 unique digital platforms operating across Africa, with around 80 percent of these originating in Africa.[13]

Three, the rise of Artificial Intelligence (AI), due to the availability of big data, better computing power, and advances in machine learning, is increasingly used in predictive maintenance and pattern recognition (e.g. in medical diagnostics), computer vision, voice recognition, automated driving, and the (hyper-) personalization consumption and marketing. *Accenture* estimates the market for AI applications to exceed US$ 72 billion by 2021.

As far as synthetic biology is concerned, it has been called the "dominant technology of the 21st century". Rejeski (2012, p.2) describe the importance of advances in synthetic biology by pointing out that "the ultimate *fabricator* is biology [.....] we could print a chair, but how about growing one by improving the characteristics of cellulose secreted by the gram-negative bacterium Acetobator Xylinum? [....] Many of the capabilities that enabled the last industrial revolution are finding their way into biology". The market for bio-manufactured goods have been estimated to be worth around US$ 584 billion by 2021 (ECLAC, 2018).

The digital transformation effected by AI, the IoT, and SB is also impacting on society. It is expected to affect all aspects of employment, security and human development, as reflected in concerns about the impact of automation, robotics and virtual globalization on jobs and inequality, to hopes for better food security and new medicines; it is reflected in concerns about new forms of conflict, to hopes of better trust-creation mechanisms; and it is reflected in concerns about the rise of remote employment and the gig economy to the hopes for better social security payment systems and increased policy effectiveness, through digital "nudges". Governments are all grappling with the potentially destabilizing effects of the digital transformation, including the potential of new digital technologies to result in a surveillance state, and the difficulty to regulate data.

It is therefore unavoidable that the new industrial revolution will disrupt manufacturing. In the most advanced manufacturing countries, governments and industry are struggling with the changes that is being wrought. For instance, the EU drafted a strategy (European Commission, 2014)for the re-industrialization of Europe by 2020. Herein the EU states explicitly that it wants to increase the share of manufacturing in EU GDP from its current average 15 percent to at least 20 percent by 2020 (Lengyel et al., 2017). As Naudé et al. (2019) discusses, European countries have been fine-tuning their industrial policies in reaction. They include Germany

[13] see https://bit.ly/2lUBx3W

(*Platform Industrie 4.0*)[14] , France (*Alliance pour L'Industrie du Future*), Italy (*Industria 4.0*), Sweden (*Produktion 2030*), Spain (*Industria Conectada 4.0*) and the UK (*Catapult High Value Manufacturing*) (see Naudé et al. (2019)).

China has in its 13th 5-year plan (2016-2020) and its **Made in China 2025** strategy ambitious aims for the country's manufacturing sector to obtain advanced technologies and to lead as a provider of manufacturing technology, including in the fields of robotics and AI. The country has been investing heavily in foreign buy-outs to acquire new technologies - spending in excess of US$ 11 billion in recent years to acquire German firms producing robots, semi-conductors and other leading new manufacturing technologies[15] .

African countries need therefore to formulate their own industrial policy responses to avoid marginalization and loss of manufacturing competitiveness. Given the scientific complexities that underlies much of the research and development that underpins the technologies mentioned, it may seem on the face of it that the task is too daunting. However, paradoxically, the more complex science underpinning of AI, the IoT and Synthetic Biology makes manufacturing actually simpler. Rejeski (2012, p.2) describe it as follows: "with 3D-printing, *complexity is free* [...] this advance means the barriers to entry posed by old fashioned machine tools and production techniques drop exponentially".

Friedman (2016) summarises the "complexity is free" effect by noting that new technologies make things better, cheaper and more accessible. Hence, small businesses, artisans and even informal sector entrepreneurs can now more than ever before, become producers. An example is the *Maker Movement* (Anderson, 2012) and the emergence of *Fab Labs*[16]. The Maker Movement is characterized by small businesses using 3D-printing and digital platforms (for example *Etsy* and *Amazon Web Services* (AWS)) to design and sell personalized manufactured products (Anderson, 2012; Graham, 2018). Because these technologies are making manufacturing more accessible and easier, small businesses and artisans can become manufacturers and in a way that is more locally embedded, more sustainable(Naudé, 2017a) and that has been shown to raise consumer welfare (Kleer and Piller, 2019).

The upshot is that the three strands of digital transformation discussed above presents a game-changer as far as manufacturing in Africa is concerned. In section 4.3 examples of how these technologies have already been adopted in Africa are given.

4 Three Varieties of Africa's Industrial Future

Despite the difficulties of industrialization in Africa, and the possibility that the new industrial revolution will by-pass Africa, there continues to be optimism that industrialization, and more specifically structural change, is still possible (UNECA, 2015).

There are three main views in the recent literature on how Africa's future industrial development is most likely to proceed. Importantly to note, technological change plays a central role in each three of these views.

[14] According to *The Economist* (2015) Germany's some of leading manufacturing firms such as *Trumpf* and *Klckner* are aiming to become digital manufacturing platform firms (Economist, 2015).
[15] See `https://bloom.bg/2ZyH7aH`
[16] See `https://www.fabfoundation.org`

In one view (Banga and te Velde, 2018) the technology is too fast and complex for African economies to immediately benefit from it, requiring at least a 15-year window to put the complementary investments and business ecosystems in place.

In another view (Newfarmer et al., 2018) technological innovation is changing the very nature of manufacturing and services and making services the most likely sector through which structural adjustment will take place.

In a third view (Naudé, 2019a) the new and emerging technological changes enable a resurgent in indigenous manufacturing through new high-tech start-up firms.

Before discussing these three views in more detail, it has to be pointed out that earlier views on how Africa's industrialization would or should proceed, has fallen by the wayside, being superseded by the technologies mentioned. For instance, the old scenario's for African manufacturing were that Africa should industrialize by integrating into global value chains (GVCs) and/or by establishing assembly-type operations aimed at exporting (e.g. Page (2013)); or by adding more value by beneficiation of minerals and commodities[17] (mining) (UNECA, 2015); or by optimizing the opportunities that China's growing infrastructure investment in and expanding trade with Africa has for industrialization on the continent (Corkin et al., 2008).

Neither current GVCs, nor mineral beneficiation, nor hoping on China, are anymore likely to drive industrialization. Why are GVCs, mineral beneficiation, and China not good options for future manufacturing? These options are unlikely to work because as far as GVCs are concerned they do not take into account the complexity and heterogeneity of Africa's position in GVCs. For instance some scholars have claimed that Africa is generally already very well integrated into global value chains (even on some scores more than the USA[18]) (Foster-McGregor et al., 2015; Taylor, 2016) while others have concluded the opposite[19]. The argument for mineral beneficiation often does not take into account that Africa is in fact generally not as "magnificently" endowed with minerals and metals[20] (Simons, 2012), and the hope that China might spur on industrialization falls apart given that the evidence point rather to the fact that China has not been helping African industrialization (even on the contrary) (Kaplinsky and Morris, 2009; Burgis, 2016; van Biesebroeck and Mensah, 2019), nor that China's domestic expansion in terms of manufacturing into backward-global supply chains linkages are slowing down global fragmentation of production (Frey et al., 2016). Moreover, neither of these old approaches adequately take into account the disruptive changes that technology is causing in manufacturing.

In the remainder of this section, the three most likely varieties of Africa's future industrialization are discussed.

[17] The African Union, in its Agenda 2063 envisages an Africa that is industrializing based on beneficiation and value addition of natural resources.

[18] As concluded by Foster-McGregor et al. (2015, p.1) "Africa as a whole is heavily involved in GVCs being more engaged than many developing countries as well as developed countries such as the USA [...] the possibility of upgrading within GVCs in Africa is likely to be limited therefore".

[19] See for instance van Biesebroeck and Mensah (2019, p.33) who finds that "GVC engagement in most sub-Saharan African economies is not very deep. Most striking is that there are very few signs of a systematic deepening over time'".

[20] Simons (2012) make the point that "of the top 5 metallic minerals [aluminium, iron ore, copper, lead, zinc], which constitute 62 percent of the total value of global production, Africa is a significant producer of only one of them: gold". And most of this is produced by only one country, South Africa.

4.1 Acquiring traditional manufacturing capabilities

The first variety of future industrialization in Africa can be labelled "*acquiring traditional manufacturing capabilities*" following Banga and te Velde (2018)'s argument. They argue that the new industrial revolution is important, but that African countries face two sets of obstacles that prevent it from fully benefitting: one is the "digital divide", in that ICT adoption is lagging; and two, that complementary skills needed for digital transformation is lacking, what they call a "skills mismatch". Thus, for Banga and te Velde (2018) the digital divide and the skills mismatch makes it unlikely that digitally-enabled manufacturing will in the short term transform African manufacturing.

What they see as more likely unfolding, and advocate to African governments, is a two-track approach. Track one is to build capacity and business ecosystems for absorbing and using technology and to improve skills, particularly in the Science, Mathematics, Engineering and Technology (STEM) fields and in Technical Vocational Education and Training (TVET). In track two, countries should "develop those sectors that are less automated, where technology installation has been slow and where Africa can still offer a labour cost advantage"(Banga and te Velde, 2018, p.iii).

These are sectors such as food processing, basic metals, paper products, automotive and garments and textiles. These sectors could be best promoted through developing local markets, infrastructure and regional trade (Signé, 2018) and by reducing the "standard constraints [....] such as electricity costs and management practices" (p. iii). Given that they calculate that robots in the USA will roughly by 2033 be cheaper than labour in Kenyan (furniture) manufacturing, it means that African countries may have roughly 15 years to acquire traditional manufacturing capabilities.

4.2 Building sectors with the characteristics of manufacturing

A second variety of industrialization that Africa will see can be called "*building sectors with the characteristics of manufacturing*" as per the arguments of (Newfarmer et al., 2018, p.2). In short, Newfarmer et al. (2018) does not see the future of African structural change in manufacturing, but rather in services. They characterize this pathway of structural adjustment as "industry without smokestacks"(p.2) and argue that service sectors can take up "the role held by manufacturing in the past" (p.22).

Technology is key for Newfarmer et al. (2018) as it opens up non-manufacturing avenues of value added. Specifically, their book makes the case for a number of key transforming industries in Africa to be the global services trade, tourism, horticulture, business and trade services, and transport.

A view that can be seen as supportive or consistent with that of Newfarmer et al. (2018) is Gollin (2018). He rejects the idea that there is a "causal link between industrialization and development" (Gollin, 2018, p.3). He is not overly pessimistic though that Africa may after all develop its manufacturing - in fact he points out that the share of manufacturing in global employment has been fairly stable over twenty years. He is also not pessimistic that technology will destroy significant numbers of jobs in African manufacturing. Ultimately for Gollin (2018) whether or not manufacturing will develop or not, is not an issue any more, because he sees services as being just as useful for driving growth and development. In his words, "developing

countries should be able to achieve growth without industrialization" (Gollin, 2018, p.17).

This view that services may be just as good for Africa as manufacturing had been in the past for Europe, the USA and East Asia, is shared by UNECA (2015) who advocates that in certain countries (they identify Botswana, Lesotho, Seychelles, Rwanda, Mauritius and Cape Verde) "smart services" including services in business, environmental, tourism and finance may offer a better scope for employment and productivity growth. These smart services may also allow non-manufacturing African countries to provide inputs and support to manufacturing industries located in other countries, and hence contribute to productivity enhancing structural transformation.

4.3 Resurgent indigenous entrepreneurship in small-scale manufacturing

Contrary to the view that the new industrial revolution is a challenge for African manufacturing due to the digital gap, skill mismatch, and the equivalence of services as growth engine, some scholars have argued that the new industrial revolution presents an opportunity for Africa[21] (Naudé, 2019a; Signé, 2018; Marsh, 2014). In the words of Marsh (2014) it offers "new forms of manufacturing that would trigger a period of valuable growth".

"New forms of manufacturing" include small-scale and artisan manufacturing based on additive manufacturing (3D-printing). There are a number of reasons why 3D-printing is suitable for small scale and artisan manufacturing (Juma, 2015). One is that 3D-printers are typically more mobile than other machinery. Two, 3D-printers are getting cheaper. Three, 3D-printers tend to use, on average, less energy that traditional machines. In addition, 3D-printing may reduce the need for transportation and keeping large volumes of stock. 3D-printing is still in early stages of development in Africa, but there are positive indications that indigenous entrepreneurs are recognising its potential : for instance a Togolese entrepreneur made a 3D-printer, costing less than US$ 100, from recycled electronic waste back in 2015(Scott, 2015). And at the time of writing, it was claimed that the the world's largest 3D-printer was in Africa, an initiative of South Africa's CSIR.[22]

Other "new forms of manufacturing" include the use of robots in small scale manufacturing. Naudé (2017b) notes the increasing uptake of this technology in Africa, mentioning as examples Ghana's *African Robotics Network*, Uganda's *Fundi Bots*' initiative, and in Egypt *EG Robotics* entrepreneurial initiative. Naudé (2017b) also stresses the potential importance of a branch of robotics for Africa, namely the manufacturing and use of drones. He discusses how drones are used for farming, surveillance, construction site monitoring and wildlife protection. Drones, being imported, implies a potential opportunity for domestic import-substituting manufacturing.

The uptake of 3D-printing and robotics by indigenous, small and medium firms will be greatly boosted by the roll-out of the Internet of Things (IoT) across the continent, which will improve operational efficiency. It will also stimulate the demand for machinery, electrical and electronic equipment, and transportation equipment. Currently, Africa imports around US$ 150 billion worth of these goods annually, suggesting a large potential market available to domestic manufacturers.

[21] This subsection draws on Naudé (2017b, 2019a).
[22] See `https://bit.ly/2O6iT1P`

The technologies described in section 3 can be consistent with green industrialization, and moreover implies an opportunity for entrepreneurs. This is because a potentially large market for clean energy technologies (CETs) such as solar, wind, geothermal and hydro, have been identified[23](UNEP, 2013). African entrepreneurs in clean energy stand to benefit from the significant decline in the prices of CETs. For example since 2010 the costs of solar PV cells have fallen by 85 percent; the price of wind energy by 65 percent and the costs of battery power per kilowatt-hour by 75 percent (Combes et al., 2017, p.7).

The utilization and diffusion of 3D-printing, robotics, the IoT and moreover the utilization of CET in supporting this will require a resurgent tech-entrepreneurship scene in Africa. In this respect too, there are encouraging signs. Naudé (2019a) notes two broad indicators supporting the idea that entrepreneurship is resurgent in Africa: one is that venture capital (VC) to African tech start-ups are increasing rapidly.[24] A second is that tech start-up ecosystems are becoming more commonplace [25]. Improvements in these two indicators are supported by a growing middle class (Bhorat et al., 2017).

A number of global technology giants seem to share the positive outlook on Africa's business prospects, and are investing in Africa's entrepreneurs and technology sectors. At the time of writing *Google* was reported as planning to establish an Artificial Intelligence Lab in Ghana, *Google* and *Facebook* are supporting education in Machine Intelligence in Rwanda, and Silicon Valley's Y-Combinator start-up acceleration program, probably the most famous in the world, has since 2015 been inviting African entrepreneurs to take part. The latter has resulted in at least 19 African high-tech start-ups so far graduate from its program and obtain venture capital seed funding at the time of writing[26].

Obviously, not all African economies will be able to equally benefit from resurgent entrepreneurs in the technology sector starting and growing new modern manufacturing firms utilising 3D-printing, digital platforms, and advanced robotics. And even those who are currently making good strides in this direction and who are currently leading in "smart" manufacturing on the continent, such as Ghana, Kenya, Nigeria, Rwanda and South Africa, still need to go a long way to strengthen the supporting infrastructure, education and entrepreneurial ecosystems that are required to raise satisfactorily the international competitiveness of the new generation of indigenous manufacturers. How this could best be done falls outside the scope of the present paper.

5 Concluding Remarks

What will Africa's industrial future be like?

In this paper it was shown that claims of Africa's de-industrialization is not entirely accurate; the role of manufacturing on the continent has been under-appreciated; and the possibility for

[23] Globally "energy innovation represents a gargantuan US$ 1,4 trillion global business opportunity" (Saha and Muro, 2017).

[24] The value of VC investment in African tech start-ups rose by a factor of more that 10, from US$ 40 million to US$ 608 million between 2012 and 2016 (Bright, 2016).

[25] It is estimated that there are 314 tech hubs and more than 60 specialized start-up technology accelerators in Africa in 2019. According to Kelly and Firestone (2016) these tech hubs have "bought many new ideas and have provided a rich source of employment and new firm formation" (p.2). Most African technology hubs are led by entrepreneurs and businesses, not governments (Kelly and Firestone, 2016).

[26] see https://digestafrica.com/y-combinator-africa-startup

future industrialization is under-estimated. It was argued that there is a slow and small, but sure, revitalisation of manufacturing under way.

In particular, in this paper it was shown that:

1. Manufacturing value added has grown at 4 percent p.a. in recent years - more the double on average than it had grown since the 1980s.
2. After 2000 manufacturing growth has accelerated, maintaining average annual growth of more than 5 percent.
3. Since 1980 the size of Africa's manufacturing sector has doubled in real terms.
4. The number of jobs in manufacturing in the 18 largest African economies grew by 83 percent between 2004 to 2014.
5. The share of jobs in African manufacturing increased from 5 percent in the 1970s to almost 10 percent by 2008.

New technologies have the potential to change the nature of manufacturing: technologies such as Artificial Intelligence, the Internet-of-Things and Synthetic Biology are manifestations of the digital transformation of society that has been made possible by expanding computing power, the Internet, cloud-based computing, the gathering of big datasets, and the exponential decline in the costs of computing and connectivity.

The technological disruption of manufacturing will stimulate the evolution of three varieties of future industrialization in Africa. In one variety, labelled "*acquiring traditional manufacturing capabilities*", technological change is too fast and complex for some African economies to immediately benefit from it, requiring a 15-year window to put the complementary investments and business ecosystems in place while promoting old-fashioned labor-intensive manufacturing.

In a second variety, technological innovation is changing the nature of manufacturing and is turning services into main sector through which structural adjustment will proceed. This variety is labelled "*fostering sectors with the characteristics of manufacturing*" to denote that service perform a function that was previously due to manufacturing.

A third variety of future industrialization is labelled "*resurgent entrepreneurship-lead industrialization*" and entails that Africa will, to some extent, take part in new advanced in manufacturing and experienced resurgence in indigenous manufacturing driven by new high-tech start-up firms. This third variety was elaborated with reference to recent examples, making the point that the new technology is paradoxically (being based on complex science) making manufacturing easier and more accessible to the many artisans, small businesses and informal entrepreneurs that form the core of most African economies.

What are the policy recommendations, given that African countries will experience one or all of these varieties of industrialization (also simultaneously) in the future?

Obviously, the heterogeneity amongst countries in terms of context and the likelihood that countries will experience all three varieties simultaneously, means that a one-size-fit all approach, even on a country level, will be sub-optimal. Each individual country will benefit though by deliberating on and designing its own response in order to create an environment wherein a multiple of industrial futures can thrive. A broad approach that will be consistent with this, and which ought to find wide support in the business community and the international development community is for African countries to continue to improve their entrepreneurial ecosystems.

Marsh (2012) has described manufacturing as entailing the "combination of materials, energy and ideas". While a lot of past policies were focused on harnessing and governing the continent's materials, minerals, and energy, in future it will be ideas and knowledge and creativity that will be central. These depend on and drive entrepreneurship. Entrepreneurship is not only important for the commercialization and diffusion of ideas but is a "21st century" skill that can benefit all occupations (see e.g. Obschonka et al. (2017)). Historically, African entrepreneurs were neglected in industrial policies. Past industrial policies tended to more concerned about state-owned enterprises, foreign investors and multinationals, and distortive trade policies. In contrast to East Asian countries' industrial policies, African countries rarely promoted indigenous ownership, joint ventures with foreign companies, or established venture capital to provide risk capital for entrepreneurs (Naudé et al., 2013).

Promoting entrepreneurial and innovation-led industrial development, seems a more viable option given that changes in technology are rapid, and the accumulation of data very voluminous. This means that policy makers cannot continue to rely on essentially 20th century top-down and heavily centralized bureaucratic process of industrial policy making any more. Moreover governments need to innovate and evolve, adopting and innovating new technologies to improve the decentralization, efficiency and accountability of government. Application areas include crowd sourcing, facilitating open government, gathering and sharing "big data", offering virtual-citizen schemes and make more use of innovation procurement tools. Low-tech government will be an obstacle to industrialization, given that whatever varieties of industrialization policy makers wish to promote, they cannot avoid having to contend with technology.

Acknowledgements

I am grateful to Emmanuel Lartey and Taye Mengistae of the World Bank and to the participants in Conferences and Seminars at Leiden University (African Studies Centre), RWTH Aachen University (TIME Research Area) and the Partos Innovation Festival (Amsterdam 2018) for their comments and suggestions on earlier versions of this work. The usual disclaimer applies.

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