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Technological Development, Structural Change and Digital Transformation in Africa

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Berichte aus dem Weltwirtschaftlichen Colloquium der Universität Bremen

Nr. 128

Hrsg. von

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Berichte aus dem Weltwirtschaftlichen Colloquium
der Universität Bremen, Nr. 128, Oktober 2019
ISSN 0948-3829

Bezug: IWIM - Institut für Weltwirtschaft
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Abstract

Digital transformation already changes the ways and means of manufacturing production in Africa. In this study, major issues of Africa's technological efforts and capabilities are discussed in the context of the severe youth employment crisis and the ongoing digital transformation.

Section 1 introduces into the key issues of relevance in the study (measuring technological efforts and capabilities in Africa, assessing structural change and employment of Africa in the new industrial era, and analysing the progress of digital transformation in Africa).

Section 2 gives details on the extent of Africa's technological heterogeneity, on the measurement of technological efforts and progress in digital transformation, and on implications for structural change and employment in times of digital transformation, also looking at country case studies. In this section 2, the extent of Africa's technological heterogeneity is highlighted by using appropriate indexes, indicators and figures, also those related to the progress of digital transformation. The role of technology diffusion and technology development for structural change and employment creation in times of digital transformation is discussed; this is done in the context of the new conditions for the accumulation of technological capabilities in Africa. Technological capabilities are key for manufacturing sector development; in this context country case studies (Tunisia, Nigeria, and South Africa) highlight important aspects of the digital transformation.

In section 3 the impact of Global Techno-economic Changes in times of digital transformation is reviewed, to discuss the available options in Africa of building and accumulating technological capabilities. A wider concept of capabilities is used for digital transformation in the new industrial era, incorporating technological, innovation and ICT capabilities. The technology-related forms of global competition and their impact on Africa are outlined to find the most appropriate ways of responding to the ongoing global technological race. Developing technological capabilities in the context of ICT capabilities and innovation capabilities matters for local and regional domestic firms and for foreign-owned enterprises in Africa. Issues of economic complexity are discussed to consider the new forms of reaching global competitiveness.

As environmental considerations are gaining in importance, green growth and green industrialization patterns are becoming part of the new industrial era also in Africa.

It is good news that even informal manufacturing sectors can contribute to economic complexity and to increasing global competitiveness. Cases of the Nigerian automobile industry show this new trend which is associated with the digital transformation. It is also discussed how employment creation and skills development are relating to this trend of digital transformation. There is a spread of digital skills all over Africa, and digital entrepreneurship ecosystems are developing quickly. All this is a valuable contribution to the development of technological capabilities in Africa. Digital skills impact considerably on employment, skills development and on entrepreneurship development, and are transforming the manufacturing sector in Africa. New entrepreneurship development programmes and technology hubs which are using intensively the digital skills are highly relevant for the building and accumulation of technological capabilities. A new base for manufacturing development is created, also using open innovation platforms.

Section 4 gives the Conclusions for a short summary of the findings. The study brings out the new elements of a digital transformation in Africa and highlights the repercussions on the manufacturing sectors. It is argued that deindustrialization can be better managed when the objectives and the tools of digital transformation are considered. And, reindustrialization can take off under conditions of digital transformation, as examples from Tunisia, Nigeria and South Africa show.

Keywords: digital transformation, technological capabilities; innovation capabilities; ICT capabilities; structural change; economic complexity; country cases from Tunisia, Nigeria and South Africa

JEL Classification: D8, D9, F6, I2, J2, J4, J6, L5, L6, O1, O3, O5

Zusammenfassung

Die digitale Transformation verändert bereits in Afrika die Bedingungen der industriellen Produktion und der Erstellung von Dienstleistungen aller Art. In dieser Studie werden wichtige Fragen der technologischen Leistungsfähigkeit und der Bildung technologischer Kompetenzen in Afrika diskutiert. Fokussiert wird auch auf die krisenhaft hohe Jugendarbeitslosigkeit und auf die Möglichkeiten, dieses Problem durch die digitale Transformation zu entschärfen. Vielfältige Chancen ergeben sich für das rasch anwachsende Arbeitskräftepotential in Afrika durch die beschleunigte Entwicklung der Digitalwirtschaft.

Im Abschnitt 1 wird in einem Überblick zur Relevanz der Studie auf die zentralen Problembereiche der technologischen Entwicklung und der digitalen Transformation in Afrika eingegangen, insbesondere auf die Messung der technologischen Leistungsfähigkeit und auf die neuen Bedingungen der Bildung technologischer Kompetenzen im Rahmen der digitalen Transformation. Bezug wird auch genommen auf die Bedeutung der technologischen Entwicklung und der digitalen Transformation für den Strukturwandel und für die Beschäftigungsschaffung in Afrika. Auch der Fortschritt bei der Entwicklung und Verbreitung digitaler Geschäftsmodelle wird thematisiert.

Im Abschnitt 2 wird die Heterogenität der technologischen Entwicklung in Afrika analysiert, die sowohl zwischen Ländern und Regionen als auch innerhalb von Ländern und zwischen Wirtschaftssektoren sehr ausgeprägt ist. Verschiedene Methoden der Messung technologischer Leistungsfähigkeit werden verglichen und für die Interpretation von technologischen Entwicklungstrends genutzt. Auch auf die Messung der Fortschritte bei der digitalen Transformation wird eingegangen. Ziel dieser Analysen ist es, die Potentiale der technologischen Entwicklung und der sich entwickelnden Digitalwirtschaft für den Strukturwandel und für die Beschäftigungsschaffung abzuschätzen. Die bisher vorliegenden Studien lassen weitgehend einen Fokus auf die digitale Transformation vermissen.

Der Blick auf Länderfälle im Abschnitt 2 soll es ermöglichen, Best Practices im Vergleich von Entwicklungstrends, Potentialen, Handlungsfeldern und Politiken zu erkennen. In diesem Abschnitt werden daher Analysen der technologischen Heterogenität und der Heterogenität in Bezug auf die Entwicklung der Digitalwirtschaft auf der Basis von geeigneten Indizes und Indikatoren vorgenommen, Erfreulicherweise sind

die verfügbaren Daten zu den technologischen und digitalwirtschaftlichen Entwicklungsperspektiven Afrikas in den letzten Jahren erheblich umfassender und aussagefähiger geworden. Die Entwicklung und Verbreitung von Technologien sind für den Strukturwandel und für die digitale Transformation von zentraler Bedeutung, erhöhen aber auch die Chancen für die Beschäftigungsschaffung; zudem sind positive Auswirkungen auf die Armutsbekämpfung, die Reduzierung der Ungleichheit und auf die Entwicklung des Unternehmertums zu erwarten. In den afrikanischen Ländern und in den wichtigen Wirtschaftssektoren (Landwirtschaft, Verarbeitende Industrie, Ressourcenentwicklung, Dienstleistungen) afrikanischer Länder zeigen sich jedoch große Unterschiede bei den technologischen und digitalen Entwicklungsprozessen. Auf die neuen Bedingungen der Akkumulation technologischer Kompetenzen in der digitalen Ära Afrikas wird ebenfalls eingegangen. Technologische Fähigkeiten werden unter neuen Voraussetzungen entwickelt und verbreitet; Fähigkeiten im Bereich der Innovation und der Informations- und Kommunikationstechnologien spielen dabei eine immer größere Rolle. Technologische Fähigkeiten sind für die industrielle Produktion von entscheidender Bedeutung, und es wird daher im Rahmen von drei Länderfällen (Tunesien, Nigeria und Südafrika) auf zentrale Aspekte der technologischen und digitalen Entwicklung Bezug genommen. Es zeigen sich sehr unterschiedliche Facetten der digitalen Transformation.

Im Abschnitt 3 wird der Einfluss globaler techno-ökonomischer Entwicklungen auf die Perspektiven der technologischen und digitalen Entwicklung in Afrika untersucht. Die globalen Veränderungen haben starke Auswirkungen auf die digitale Transformation in Afrika; die Optionen für die Akkumulation und Verbreitung von technologischen Kompetenzen werden beeinflusst und verändert. Ein umfassendes Konzept der „Fähigkeiten“ wird erarbeitet, um den Bedingungen der digitalen Transformation in Afrika zu entsprechen. Neben den technologischen Fähigkeiten im eigentlichen Sinne geht es um Fähigkeiten zur Gestaltung von Innovationsprozessen und um Fähigkeiten, die im Bereich der Anwendung von Informations- und Kommunikationstechnologien (IKT) liegen. Die technologiebezogenen Formen des globalen Wettbewerbs basieren auf diesem Bündel von Fähigkeiten, und afrikanische Unternehmen müssen daher Wege finden, um im globalen technologischen Wettlauf zukünftig mithalten zu können. Die Entwicklung technologischer Fähigkeiten im Kontext der Anwendung von IKT-Fähigkeiten und der Gestaltung von Innovationsprozessen ist für lokal und regi-

onal agierende Unternehmen in Afrika von größter Bedeutung, aber auch die Filialen von ausländischen Unternehmen in Afrika müssen dieses Bündel von Fähigkeiten weiterentwickeln, wenn sie expandieren wollen bzw. eine neue Ansiedlung planen.

Afrika kann durch eine kooperative Industriepolitik durchaus die Perspektiven der ökonomischen Komplexität und Diversität verbessern, also die Diversifikation und technologische Reife bei Produkten, Prozessen und Märkten erhöhen, um die globale Wettbewerbsfähigkeit zu stärken. Da die Umwelt- und Klimaaspekte für die verarbeitende Industrie und für die Ressourcenentwicklung in Afrika immer wichtiger werden, kann eine kooperative Industriepolitik hilfreich sein, wenn sie dieses Bündel von Fähigkeiten gezielt unterstützt. Dieses Bündel von Kompetenzen spielt im Rahmen der Grünen Wachstums- und Industrialisierungsstrategien („green growth strategies“ und „green industrialization patterns“) auch in Afrika eine immer größere Rolle; in der Ära der digitalen Transformation werden Kreislauf- und Nachhaltigkeitsanalysen immer wichtiger. Neue Technologien, Fähigkeiten und Kompetenzen können diesen Prozess unterstützen. Es zeigt sich, dass zunehmend auch kleine Unternehmen des informellen Sektors zur industriellen Diversifikation, zur Integration in globale und regionale Wertschöpfungsketten und zur Marktentwicklung beitragen können; eine Stärkung der technologischen und digitalen Fähigkeiten in diesen Unternehmen ist im Rahmen einer kooperativen Industriepolitik durchaus möglich. Auch diese Unternehmen können von den Chancen des globalen Wettbewerbs profitieren.

Fallstudien für die nigerianische Automobilindustrie, für die südafrikanische Bergbauindustrie und für die tunesische Gesundheitswirtschaft zeigen, dass die digitale Transformation zum Strukturwandel der Industrie erheblich beitragen kann. Es wird in der Studie auch diskutiert, wie durch die Entwicklung von Kompetenzen und Fähigkeiten bei Fachkräften der Trend zur Digitalwirtschaft in Afrika unterstützt werden kann und wie dadurch auch die Jugendarbeitslosigkeit bekämpft werden kann. Es zeigt sich in Afrika eine erstaunlich schnelle Verbreitung von digitalen Kompetenzen und Fähigkeiten, und digitale Unternehmensmodelle und Unternehmerkompetenzen entwickeln sich rasant, wenngleich sehr unterschiedlich in verschiedenen Ländern und Regionen, aber auch Sektoren, Afrikas. Dies sind bedeutende Beiträge für die nachhaltige Entwicklung technologischer Kompetenzen und Fähigkeiten in Afrika, doch sind für diesen Prozess räumlich und sektoral ungleichzeitige Fortschritte prägend. Digitale Fähigkeiten beeinflussen schon jetzt erheblich die Beschäftigungschancen,

die Entwicklung von Kompetenzen der Arbeitskräfte, die Entwicklung des Unternehmertums in Afrika und die Transformation des industriellen Sektors in Afrika. Der Prozess der De-Industrialisierung kann dadurch besser gemanagt und teilweise sogar rückgängig gemacht werden. Neue Förderprogramme zur Entwicklung von Unternehmen, neue Plattformen für Start-Ups, für kleine und mittlere Unternehmen und für die Akkumulation von Venture Capital, und neue Zentren für die Ansiedlung von technologie-basierten Unternehmen spielen eine immer größere Rolle bei der Verbreitung von digitalen und technologischen Kompetenzen und Fähigkeiten. Günstige Voraussetzungen für die industrielle Entwicklung ergeben sich auch durch neue Modelle der Innovation, etwa durch Open Innovation; nicht nur in Südafrika sind solche Plattformen bereits prägend für eine neue Generation von Innovationsprozessen.

Im Abschnitt 4 werden Schlussfolgerungen für Afrikas Perspektiven der industriellen Produktion in der Ära der digitalen Transformation gezogen. Die digitale Transformation hat erkennbar bereits erhebliche Auswirkungen auf Afrika, wenn auch zu bemerken ist, dass die Entwicklungsprozesse ungleichzeitig erfolgen und mit unterschiedlicher Intensität fortschreiten. Besonders wichtig ist, dass die Deindustrialisierung besser gemanagt werden kann und Schritte hin zur Reindustrialisierung möglich werden, wenn die Chancen der digitalen Transformation erkannt, genutzt und umgesetzt werden.

Wichtige Begriffe: Digitale Transformation in Afrika; technologische Fähigkeiten und Kompetenzen; innovationsprozess-bezogene Fähigkeiten und Kompetenzen; IKT-bezogene Fähigkeiten und Kompetenzen; Strukturwandel, Beschäftigung und industrielle Produktion; Deindustrialisierung; Digitalisierung und Unternehmertum; ökonomische Komplexität und Diversität; Länderfälle Tunesien, Nigeria und Südafrika

JEL Klassifikation: D8, D9, F6, I2, J2, J4, J6, L5, L6, O1, O3, O5

Contents

List of Abbreviations and Acronyms

3D	(presentation in) three dimensions
AEO	African Economic Outlook (project)
AERC	African Economic Research Consortium
AfDB	African Development Bank
AISI	Aerospace Industry Support Initiative (South Africa)
ALN	African Leadership Network
AMTS	Advanced Manufacturing Technology Strategy (South Africa)
AOSTI	The African Observatory of Science, Technology and Innovation
ASTII	African Science, Technology and Innovation Indicators (initiative)
AU	African Union
AUC	African Union Commission
BCAs	Blue Carbon Awards
BIDC	Bio-manufacturing Industry Development Centre (launched in South Africa)
BOM	Bill of Materials
BPO	Business Process Outsourcing
CAPDAN	Computer and Allied Products Dealers Association of Nigeria
CAV	Centurion Aerospace Village
CFTA	Continental Free Trade Area (Africa)
CIP Index	Competitive Industrial Performance Index (of UNIDO)
CSD	Committee on Sustainable Development (UNECA, Addis Ababa)
CSIR	Council for Scientific and Industrial Research (South Africa)
DFAM	Design for Additive Manufacturing (system)

DMR	Department of Mineral Resources (Government of South Africa)
DST	Department of Science and Technology (Government of South Africa)
DUP	Deloitte University Press
EBRD	European Bank for Reconstruction and Development (London, UK)
ECI	Economic Complexity Index
EDPs	Entrepreneurship Development Programmes
FOSS	free and open source software
GBL	Global Business Lab
GDP	Gross Domestic Product
GEM	Global Entrepreneurship Monitor
GIST	Global Innovation through Science and Technology (Initiative)
GSMA	Groupe Speciale Mobile Association
GVCs	Global Value Chains
HCI	Human Capital Index (by WEF)
HHI	Herfindal-Hirschman Index
HNCSs	hubs, networks and community spaces
i5F Index	McKinsey's i5F Index (ICT Foundations Index)
ICF	The Investment Climate Facility (for Africa)
ICs	industrial clusters
ICT	Information and Communication Technologies
IGDP Index	McKinsey's IGDP Index (ICTs GDP Contribution Index)
iHub	innovation hubs
III	Innovation Investment Index (for Tunisia)
INSEAD	Institut Européen d'Administration des Affaires

IS	Impact Sourcing
ISI	Institute for Scientific Information
IT	Information Technology
ITES	IT Enabled Services (firms)
ITO	Information Technology Outsourcing
KDES	Kenyan Digital Entrepreneurship Ecosystem
KPMG	Klynveld/ Peat/ Marwick/ Goerdeler (founders of this international group of auditing and consulting companies)
LINUX	free, unix-similar multi-user operating systems
MAR	Microsoft Authorized Refurbishing (Units for Personal Computers)
MDF	Manufacturing Demonstration Facility (of the US Department of Energy)
MEXA	Mauritius Export Association
MIT	Massachusetts Institute of Technology
MVA	manufactured value added
MXs	manufactured exports
MySQL	open source software for data bank administration (company name)
NEPAD	New Partnership for Africa's Development
NIS	National Innovation System
NLC	National Laser Centre (South Africa)
NPCA	NEPAD Planning and Coordinating Agency
NRF	National Research Foundation (South Africa)
NRI	The Networked Readiness Index
NTB	Non-Tariff Barrier
NTBC	National Technology Business Centre (in Zambia)
OECD	Organization for Economic Cooperation and Development

OEM	Original Equipment Manufacturers
OI	Open Innovation
OIRSE	Open Innovation Regional Solution Exchange
ORNL	Oak Ridge National Laboratory
OS	open source
PBIT	Purpose-Built Information Technology (firms)
PCs	Personal Computers
PIN	Paradigm Initiative Nigeria
PNAS	Proceedings of the National Academy of Sciences (USA)
PV	Photovoltaics
RCA	revealed comparative advantage
R&D	Research and Development
RECs	Regional Economic Communities
RIIS	Research Institute for Innovation and Sustainability (in South Africa)
RSA	Republic of South Africa
SAIS	The Southern African Innovation Support (programme)
SAPPI	South African Pulp and Paper Industries (South African Company)
SEZs	special economic zones
SMEs	small and medium enterprises
SSA	Sub-Saharan Africa
STEM	Science, Technology, Engineering, Mathematics (programme)
STI	Science, Technology and Innovation
TCI	Technological Capability Index
TDM	tool-, die- and mould-making industry
TEA	Total Early-stage Entrepreneurial Activity (Index)

TIA	Technology Innovation Agency
Tralac	Trade and Law Center (Stellenbosch, South Africa)
UEM	University Eduardo Mondlane (in Mozambique)
UNAM	University of Namibia
UN DESA	United Nations, Department of Economic and Social Affairs
UNECA	United Nations Economic Commission For Africa
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USD/US$	US Dollar
VC4Africa	Venture Capital for Africa
WEF	World Economic Forum
WIPO	World Intellectual Property Organization

Technological Development, Structural Change and Digital Transformation in Africa[1]

Karl Wohlmuth[2]

1 Introduction

This study deals with options for Africa's policy space and institutional responses to the emerging challenges and opportunities for structural change in the new industrial era of digital transformation. Focusing is on the required technological capabilities, skills and efforts. The concept of capabilities is formulated in a broader sense, incorporating technological capabilities (at the manufacturing production level), innovation capabilities (related to the organization of innovation processes in modern manufacturing) and ICT capabilities (referring to the digital skills which are part of the modern employment system). The key challenge relates to Africa's formidable task to keep pace with the rapidly changing dimensions of technological frontiers which make deep inroads into processing, design and marketing of products. As Africa is part of the global digital transformation, structural transformation in Africa will be more and more linked to digital skills and digital entrepreneurship. The study presents evidence of rather divergent patterns and levels of technological efforts and capabilities of Africa, especially so in areas which are important to reap the benefits of digital technologies. Information and communication technologies (ICT) emerged in Africa as important growth impulses, igniting a new course of development in manufacturing

[1] This research on Africa's digital transformation, structural change and manufacturing development started in December 2014, a revised draft was finished in January 2017, and this is a further revision, updating and extension done in May to July 2019. Various versions of the original paper are published now.

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and related services. Although the trends in Africa differ by region and sector, firms at all sizes are affected by the digital transformation. Despite emerging signs of Africa's determination to modernize its industrial sector – the formal and the informal sectors alike - in the light of new industrial realities and parallel to the ongoing digital transformations, by using ICTs, accumulating technological capabilities and strengthening innovation systems, the continent's technological efforts and capabilities need to be dramatically enhanced to reduce the distance to the frontiers of best technology practices in industrial production and marketing. However, case studies show that Africa has also the capacity to produce own (home-grown) solutions for raising the competitiveness of manufacturing sectors. Examples from various African countries show that such a capacity is available and can be used as a basis for intra-African knowledge transfers. Leapfrogging plays a role in Africa, facilitated by digital technologies, but also the development of indigenous technologies and of key capabilities is increasingly becoming important, supported by ICTs.

In *section 2* of the study Africa's technological heterogeneity is considered and a strategy for structural change based on technological capabilities is presented. Focus is on measuring the extent of technological effort and the progress of digital transformation. Also, the impact of the digital transformation on processes of structural change in Africa is analysed. Case studies (mostly for Tunisia, Nigeria and South Africa) give evidence of significant progress towards structural change and digital transformation. It is shown that practically all manufacturing sectors and the related services suppliers can benefit from the digital transformation. Key for success is the strategy and the political will to take a long-term perspective in the conduct of policies. Digital transformation in Africa is impacting all countries, sectors, regions, firms and workplaces. It is therefore important to spread the understanding of the challenges and opportunities which are related to the digital transformation.

In *section 3* the major global techno-economic changes are analysed to see how Africa is affected by the digital transformation and to derive conclusions on the task of building technological capabilities in Africa. A major focus is on the three key capabilities that matter in modern manufacturing: technological capabilities, innovation

capabilities, and ICT capabilities. It is shown that all industries and all sectors are affected by these capabilities, also the informal sectors in Africa which are so important for employment creation. The digital skills, the related entrepreneurship issues, and the implications for building technological capabilities in Africa are reviewed. Because of the severe youth unemployment crisis these are major challenges and opportunities for the manufacturing sectors in Africa. Global technological trends and local capacities can be matched by new strategies. Local manufacturing can be strengthened, and local demand can be met by open innovation, by networking key stakeholders, and by accumulating digital skills. Because of the increasing role of global digital platforms, also the meaning of competitiveness of African manufacturing and services suppliers and stakeholders in global and regional value chains is newly determined.

Finally, *Section 4* presents Conclusions.

2 Africa's Technological Heterogeneity, Technological Capability and Structural Change - The Limits of Digital Transformation

2. 1 Africa's technological and manufacturing heterogeneity – Measuring the Level and Formation of Technological Capabilities

In Africa, there is a great heterogeneity with regard of technological capability and manufacturing performance. Technological capabilities are most important for manufacturing progress. The global performance of manufacturing is regularly reviewed and shows the divergent global and regional trends (UNIDO 2013a). De-industrialization in Africa, with a much lower share of manufacturing in GDP than in other developing countries, very low per capita manufactured exports in Africa, and a very small share of Africa in global manufactured exports are facts which request urgent action towards structural change, re-industrialization and the building of technological capabilities (Page 2012, Yildirim 2014).

There are various definitions of "technological capability" which are circulating. Lall's Matrix of technological capabilities (Lall 1992) with three functional areas (investment capabilities, production capabilities, and linkage/network capabilities) and three levels of development (Simple/Routine, Adaptive/Duplicative and Innovative /Risky) is still relevant for policy action. Extensions to include the actors in the process of building technological capabilities are however useful. Meyer-Stamer[3] (Meyer-Stamer 2014) identifies four pillars which need to be seen in the context of building technological capabilities: strengthening the skills of the producers to imitate and to innovate; providing incentives by the economic, political, administrative and legal framework conditions, providing direct support by technology-oriented state institutions and by specific service companies; and providing indirect support by the educational system at all education and training levels. This is a view of the role of actors in the process of building technological capabilities based on a National Innovation System (NIS) approach. More far-reaching is the operational definition of "productive capabilities" by UNIDO (UNIDO 2012, p. 12): "Productive capabilities have been defined as personal and collective skills, productive knowledge and experiences embedded in physical agents and organizations needed for firms to perform different productive tasks as well as to adapt and conduct in-house improvements across different technological and organizational functions". A new set of productive capability indicators was developed (UNIDO 2012, p. 48), with indicators for "capability determinants", "capability enablers", "capability outcomes" and "production outputs". In order to understand the heterogeneity of African countries in view of all these definitions and indicators, six indexes are discussed.

Africa's technological capability and manufacturing development base is quite heterogeneous. The heterogeneity is great between and within the African Regional Economic Communities (RECs), but also it is observed at the country, firm size and industry levels. Six indexes as presented below reveal the various dimensions of capability, by considering categories such as: capability accumulation levels, capability

[3] On the definitions of technological capability see: http://www.meyer-stamer.de/pillars.html

functions, capability development constraints, capability determinants, capability enablers, capability outcomes, capability clusters, and others (see Box 2.1 on the six indexes to measure the level of technological capabilities and the progress of digital transformation). However, these six indexes measure the technological capability not only directly, but also indirectly, so that case studies and reports on firm-level and industry-level experiences also matter to get more insights in this regard. Three of these six indexes relate to economic complexity, to human capital and to production performance, and three others give a view of the state of digital transformation. But, by these indexes a wealth of information is brought in for African countries and can be used to compare the situation among them and in relation to other developing countries.

Box 2.1: Indexes to Measure Technological Capability of African Countries in the Era of Digital Transformation

Economic Complexity Index (ECI)

Human Capital Index (HCI)

Competitive Industrial Performance Index (CIP Index)

The Networked Readiness Index (NRI)

McKinsey's i5F Index (Internet Five Foundations Index), and

McKinsey's IGDP Index (Internet's GDP Contribution Index)

These indexes have a different focus, but all of them are of relevance for industry and technology policies in the era of digital transformation. Countries with above African average rankings of Technological Capability are the following: Mauritius, South Africa, and Tunisia, but Namibia, Egypt, Kenya, Botswana, Morocco, Ghana, Seychelles, Rwanda, and Senegal are also mentioned favourably in some of these indexes. Some countries have reached respectable levels, others are catching up from low scores.

Source: Section 2.1 of this study for explaining the various indexes; the relevant indexes were compiled and compared by the author.

The *Economic Complexity Index (ECI)* measures the level and structure of capabilities in an economy by the number of products produced and exported successfully (diversity) and by the number of countries being able to produce similar products (exclusiveness). Sophisticated economies will produce and export many products with a high degree of exclusiveness so that not many other countries can produce them. Such strengths (based on trade data for products) are related to the extent of accumulated knowledge in the economy and can be assessed by trade data. Countries with "diversity" and "exclusiveness" have accumulated technological knowledge and have developed manufacturing capabilities. On this basis income, employment, skills, and further manufacturing possibilities will grow so that also projections about structural change in a country can be made (see WEF/World Economic Forum 2012; Hidalgo/Hausmann 2009; and Hidalgo, Hausmann et al., 2011). In Sub-Saharan Africa (SSA) the most complex economies (for 2008 data) are South Africa (55), Namibia (72), Kenya (73), Senegal (74) and Mauritius (77), while the worst performers are Guinea (123), the Republic of Congo (125), Sudan (126), Angola (127), and Mauritania (128). Out of 128 countries in the sample[4], only few Sub-Saharan countries have a middle or lower middle position. In North Africa, the best performers are Tunisia (47) and Egypt (53), while the worst performer is Libya (119), because of the limited technological capabilities usually acquired in an oil-based African economy (Hidalgo, Hausmann et al., 2011, pp. 63). The changes of the ECI in the period 1964-2008 were calculated for 101 countries (Hidalgo, Hausmann et al., 2011, pp. 80ff): Mauritius has improved its position (in terms of ranks) the most in this long period. In North Africa, Libya (by 11 ranks) and Tunisia (by 20 ranks) were the countries that increased their ECI the most, while the laggards in this process of change were Morocco (90) and Algeria (98), which had ECI ranks of 83 and 114 at the start of the period. In SSA, beside of Mauritius, the countries Uganda, Tanzania, Kenya, Ghana and Madagascar

[4] However, not all African countries are ranked because of data problems.

have seen substantial improvements (Hidalgo, Hausmann et al., 2011, pp. 82). Changes towards some sophisticated product may lead to significant improvements of the ECI.

While the ECI is a measure of the capabilities accumulated over the years, the *Human Capital Index (HCI)* analyses the major components in the form of 4 pillars (education; health and wellness; workforce and employment; and enabling environment). The HCI (see WEF 2013b) considers the capabilities through pillar 1 on education under the headings of access, quality and attainment, through pillar 2 on health and wellness under the headings of survival, health, well-being and services. In the pillar 3 on workforce and employment the headings are participation, talent and training, while pillar 4 on the enabling environment has the headings of infrastructure, collaboration, legal framework and social mobility. Only Mauritius has a relatively high ranking (47), followed in Africa by Tunisia (67), Botswana (79), Kenya (81), Morocco (82), South Africa (86), Ghana (87) and Namibia (97). The sub-indexes are useful for finding out constraints in capability formation. South Africa is much weaker on education, health and wellness, and workforce and employment, and only has this overall rank because of the rank for the enabling environment (42). Other major African countries like Egypt (111), Nigeria (114), and Algeria (115) are at the bottom out of the 122 countries which are included in the HCI.

The *Competitive Industrial Performance Index (CIP Index)* has three dimensions and eight sub-indexes (see UNIDO 2013a). The CIP index has some similarities with the ECI index because as well successes of manufacturing and the building up of capabilities matter. In dimension 1 “capacity to produce & export manufactures” the indicators “manufacturing value added per capita” and “manufacturing export per capita” play a role. In dimension 2 “technological deepening and upgrading” there are 4 sub-indicators. These are the “degree of industrialization”, with the proxy “Medium- and High-tech Manufacturing Value Added as a share in Total Manufacturing Value Added” and the proxy “Manufacturing Value Added as a share in total GDP”, and “export quality” as measured by the indicators “Medium- and high-tech Manufactured Exports as a share in Total Manufactured Exports” and “Manufactured Exports as a

share in Total Exports". The dimension 3 is "World Impact" and is measured by the two indicators "Impact of the country on World Manufacturing" and "Impact of a country on World Manufactures Trade", covering the share of the country in World Manufacturing Value Added and in World Manufactures Trade. The results for the CIP index 2010 (for 133 countries) show that South Africa (41), Tunisia (58), Egypt (62), and Morocco (66) are well placed in upper and central middle ranks, while Mauritius (79), Algeria (82), Swaziland (85), Botswana (86), Cote d'Ivoire (89), Nigeria (95), Cameroon (97), and Congo (100) are in the lower middle and lower ranks.

The *Networked Readiness Index (NRI)* from the *Global Information Technology Report 2014* (INSEAD/WEF 2014) is based on 10 pillars and 4 sub-indexes. Two (2) pillars are in the Environment sub-index with pillar 1 on the Political and regulatory environment and with pillar 2 on the Business and innovation environment; Three (3) pillars are in the Readiness sub-index with pillar 3 on Infrastructure and digital content, pillar 4 on Affordability, and pillar 5 on Skills; there are Three (3) pillars in the Usage sub-index with pillar 6 on Individual usage, pillar 7 on Business usage, and pillar 8 on Government usage; and there are Two (2) pillars in the Impact sub-index with the pillar 9 on Economic impacts and pillar 10 on Social impacts. There are 148 countries in the ranking and the values for the scores are in the range of 1-7. Concerning the overall ranking, Mauritius is number 48 with a value of 4.31 and has improved since last year 2013 from rank 55, followed by Seychelles (rank 66, improved from rank 79), South Africa (rank 70, unchanged in rank), Rwanda (rank 85, improved from rank 88), Tunisia (rank 87, no data for 2013), Cape Verde (rank 89, deteriorated from rank 81), then followed in Africa by Egypt (91), Kenya (92), Ghana (96), Morocco (99), Botswana (103), and Namibia (105). Rwanda is strong in the Environment sub-index and weaker in Readiness and Usage sub-indexes. South Africa is rather strong in the Environment sub-index, much weaker in the Impact sub-index and weaker in the Usage sub-index. Pillar 2 (Business and innovation environment) and pillar 7 (Business usage) show how capabilities of firms can develop through innovation capacity factors and through specific business usage of ICT. The accumulation of capabilities through innovation and digitalization is recorded. This index is useful to

measure the speed of digital transformation in Africa.[5]

McKinsey (McKinsey 2013) has developed two ICT development indexes to inform the public about country and cluster developments. First, the *Five Foundations of the Internet Index (i5F Index)* measures the foundations of an internet-enabling ecosystem in African countries by capturing such indicators as the ICT skills base in education and research; the Finance capital for Internet and ICT companies; the Internet-enabling infrastructure; the Business environment for ICT; and the emphasis on a National ICT strategy. Quantity and quality drivers are important in the first two indicator groups. These five foundations matter for all strategies to advance digital transformation.

The second McKinsey index (McKinsey 2013) is the *Internet's Contribution to GDP Index (IGDP Index)* and measures the contribution of Internet to GDP by looking at the increase of the Internet contribution to GDP in relation to the overall GDP growth (so as to see if the Internet contribution to GDP increases faster than the overall GDP growth). The Internet contribution is studied for private consumption, public expenditure, private investment, and the trade balance (exports-imports). In the IGDP index, Senegal (3.3% Internet contribution) and Kenya (2.9% Internet contribution) are leading in Africa, while for the i5F Index South Africa and Morocco are leading in the scores. Looking at both these McKinsey indexes there emerge 4 African clusters, with Senegal and Kenya as "leaders", with Morocco and South Africa as "followers", with Mozambique, Cote d' Ivoire, Tanzania, Cameroon, Ghana and Egypt as "emerging Internet countries", and with Angola, Algeria, Ethiopia and Nigeria as "countries punching below their weight", although Nigeria would jump to the group of "emerging countries" if adjustments for oil volatile revenues are made. Both indexes give a

[5] See on the most up-to-date Global Information Technology Reports: https://www.weforum.org/reports/the-global-information-technology-report-2016; see about the NRI: http://reports.weforum.org/global-information-technology-report-2016/networked-readiness-index/, and: https://tcdata360.worldbank.org/indicators/entrp.network.idx?country=BRA&indicator=3499&viz=line_chart&years=2012,2016

good picture of digital transformation trends in Africa. Employment and growth effects of Internet can be measured by using these data for long periods. Regrettably these indexes are not continually provided; however, the NRI is prepared on a continual basis.

These six indexes give a picture about the role of capability drivers, capability determinants, and about groups of countries, sectors and technologies being of relevance for capability formation in African countries; the prevailing hierarchy of African countries in terms of Technological Capability is becoming visible. These Six (6) indexes also give some signposts for policy action.

2.2 Structural Change, Digital Transformation and the Development of Technological Capabilities in Africa

It is acknowledged that any promotion of structural change in Africa needs a coherent strategy to come forward. It is not enough to improve the investment climate by conventional regulatory reforms towards "ease of doing business" and by related trade and labour market policies (see Page 2012, UNIDO 2009, and UNIDO 2013b). Infrastructure development and skills provision are other important components of policies to improve the investment climate. Again, conventional policies are not enough. In the era of digital transformation relevant infrastructure and skills programmes are needed. Country- and sector-tailored measures are needed. While infrastructure development plans for Africa abound, aiming to link the countries of the Regional Economic Communities (RECs), implementation of these programmes and of national infrastructure policies shows quite diverse results. The same is with skills provision programmes all over Africa. While an expansion of the tertiary education systems takes place, there are still serious mismatches between supply and demand of graduates, especially so in the fields which are of importance for technological capability formation and for deeper industrialization (regrettably, enrolments and graduations in science, engineering, agriculture, management, and ICT are too low). STEM (Science, Technology, Engineering, Mathematics) programmes are of great importance for the

digital transformation, but much more effort is needed in this regard. These deficiencies were not corrected in the last years, despite of so many recommendations to go in this direction (see AfDB et al. 2012). Unemployment of graduates in some subjects and scarcity of graduates for key industrial sectors go hand in hand.

More is needed than looking at conventional steps to improve the investment climate. A *coherent strategy for structural change* requires that three additional components are embedded into a strategy to improve the conditions for private sector development, and specifically for domestic and foreign investment. Such a new strategy for structural change is looking at some of the Asian experiences with technological capability formation, industrial upgrading, and export diversification (UNIDO 2009, Page 2012). In the era of digital transformation, a new strategy for structural change incorporates an increasing role of the Internet for GDP and an increasing role of the five foundations for Internet. Three components matter for such a new approach towards structural change in the era of digital transformation: first, organising for an "export push" as a basis for an offensive market access approach; second, building "industrial clusters" around major cities, capital cities and megacities; and third, strengthening the development of "industrial capabilities". For the development of African agribusiness and agroindustry such a strategy was already presented (UNIDO 2011, Wohlmuth 2011), drawing on Latin American and Asian industrial/agroindustry development experiences. This was done by identifying a strategy for concerted action which is based on seven pillars (see the concept of seven pillars in: Yumkella et al./UNIDO 2011); this is a strategy to develop sustainable agroindustry exports, agroindustry clusters, and related technological capabilities. The concept of an "export push" is related to the task of converting national comparative advantages into competitive advantages of firms by promoting domestic and foreign investments and by strengthening regional and global value chains. The "export push" strategy has to be correlated with strategies to build "industrial clusters" and "industrial capabilities". Internet connectivity is part of this Three Elements Strategy, but "digital infrastructure" and "digital entrepreneurship" are basic requirements for sustainable networking. Both factors, digital infrastructure and digital entrepreneurship, show advances in African countries, although at different speed and scope.

But these three components – integrating Africa's firms much deeper into global and regional value chains, using the advantages of industrial clusters in city agglomerations more fully, and building technological and industrial capabilities for increasing competitiveness - require that the sources of knowledge and the available qualified staff are used fully, enhanced by further training and the recruitment for important new sectors and tasks in the digital age, the new industrial development era. Digital transformation is then the answer to the severe de-industrialization trend in Africa. Experience in Africa shows that most of the countries are weak on all of these three components: only few African countries have experimented with "export push" industrial development strategies; only few African countries have used coherent policies for developing industrial clusters (ICs) and special economic zones (SEZs) for employment generation and the development of technological capabilities; and not many African countries have implemented inclusive, long-term and coherent programmes for the development, exchange and use of skills in African countries. It is not advisable just to wait for the spread of global and regional value chains to firms all over Africa and to expect too much in terms of technological capability building from the integration of African firms into these chains even if it takes place in some cases. At all these levels, pro-active public policies are needed. An "export push" development approach depends on a coherent strategy for structural change and digital transformation which is incorporating the strengthening of industrial clusters and the execution of skills development and upgrading programmes. This strategy has then to become implemented step by step.

How to develop a coherent strategy for structural change which may fit the conditions of African countries? UNIDO (2013b) has outlined such a coherent strategy for structural change by looking carefully at the drivers of structural change (wages, skills, technology, industrial organization, business environment, trade and foreign investment as external drivers, and environment because of resource constraints) and at the policies to promote structural change (industrial policy, education and training policies, and international cooperation). Such a strategy has importance for advancing structural change and structural transformation in Africa as it is made clear that di-

verse drivers and important policy imperatives matter. However, in the meantime the imperatives of digital transformation have become even more important. The drivers of structural change and the policies to promote structural change are now much more linked with digitalization efforts. African institutions (AfDB/African Development Bank, UNECA/UN Economic Commission for Africa, and AUC/African Union Commission) have presented recently annual reports on the theme by emphasizing also specific aspects of structural transformation (natural resources management, green growth development strategies, and policies for unleashing Africa's growth potentials); digital transformation in Africa is increasingly part of these annual reports. These reports make it clear that African countries produce at quite different levels of industrial deepening and digital transformation (also the countries in the key group show this, such as South Africa, Tunisia, Morocco, Mauritius, and countries like Nigeria, Kenya and some smaller Sub-Saharan African countries like Rwanda and Senegal).

In some African countries there are industrial sectors/firms producing sophisticated products but there are also sectors/firms which produce products at intermediate and low levels of sophistication. This heterogeneity in terms of sophistication has implications for a strategy for structural change and digital transformation because the demands for skills and qualifications, for education and training, and for technological learning and upgrading are different (see UNIDO 2013b, table S1, p. 4). The desired extent of industrial deepening impacts on the required levels of technological capability, the demand for skills, education and training, in-firm training, and has also repercussions on the links to other stakeholders. A strategy for structural change and digital transformation has therefore to be fine-tuned to the situation of the country in terms of industrial structure and availability of technological capabilities; it should match the levels of industrial deepening with the major drivers of structural change and the policy imperatives to promote structural change (UNIDO 2013b). An industrial policy based on a consensus model of dialogue between major stakeholders is recommended as a key policy imperative, and this approach requires it to find a balance between the major roles of industrial policy (regulating, financing, promoting, networking; see: UNIDO 2013b, p. 6). It is necessary to involve from the first planning stage onwards the key partners in the dialogue - from the bottom up to the top and from the top down

to the bottom[6].

The issue is to "break into" regional and global markets (UNIDO 2009), while increasing technological capabilities and economic and product complexity (Yildirim 2014). The problems are a) how to get to a product portfolio that fits the productive knowledge of the country and b) how to increase and to change the product portfolio by accumulating productive knowledge. The "product space" defines the products which can be produced with a set of productive knowledge, and the products may be strongly connected or only loosely connected to each other depending on the productive knowledge base which is available. In the era of digital transformation Internet provides more and more connections and more and more transparency in this regard. Industrial policy can learn from these interconnections to derive new export policies and diversification policies. Tunisia is in the process of identifying ways and means to increase economic complexity, product complexity, and the location of the product space (see Zgheib/EBRD/Whiteshield Partners 2014). There is potential to move the product space to the centre of productive knowledge interactions and so to increase connectivity. Identified are the *capabilities* (by measuring the Revealed Comparative Advantage), the *complexity and innovativeness* of products (with regard of the network level in sector value chains), the *opportunities* (with regard of market size and opportunity gain), and the *inclusiveness* of sub-sectors (in terms of employment and distribution of firms over the country). The priority areas for industrial policy can be identified by referring to these four dimensions. The ICT Sector, the Electric and Electronic Industry, and the Pharmaceutical Sector of Tunisia are coming out as priority sectors (high potential sectors) with regard of capabilities for the development of these three sectors, complexity and innovativeness of products in value chain networks of the three sectors, opportunities of the three sectors in terms of market size and growing markets, and inclusiveness of such developments in the three sectors in terms of employment and regional distribution of industries. By using the tool of the Innovation Investment Index (III), the index accounts for these four dimensions (capabilities, complexity and innovativeness, opportunities, and inclusiveness) and so gives policymakers hints for sector targeting and removing barriers to the expansion

[6] Such an approach was proposed for the promotion of agroindustry sectors in Africa (Yumkella et al. 2011).

of these (promising) sectors. Knowledge drivers are thereby identified and the feasibility of such a knowledge development pattern is checked. The product space of Tunisia can move further to the centre of connectivity of productive knowledge what also corresponds to the leading African position of Tunisia in the ECI rank of 47 (Box 2.2).

Box 2.2: The Innovation Investment Index (III) as an instrument to target in Tunisia industrial sectors with higher levels of capability, complexity, opportunity and inclusiveness

Tunisia is in the process of increasing its economic complexity by prioritizing target areas for industrial development. The Innovation Investment Index (III) looks at the chances to move from traditional products and services (in sectors like textiles, fertilizer and agriculture) and products and services at the low end of the knowledge economy value chain networks (electric components, metal and mechanical structures, inorganic chemicals, low-end ICT and offshoring services) to more complex and innovative products in the value chain networks of knowledge economy sectors (medical and scientific electronic equipment, automobile and aircraft electronic components, hardware electronics, mobile solutions, e-payments, and R&D engineering). Integration into knowledge networks and capability building are important drivers of innovation and growth, and therefore need to be strengthened.

Mapping of the type of value chains, and of innovation opportunities and gaps is of importance for adapting to the new industrial era in Tunisia. Innovative and complex products and services will need prioritization from industrial policies. A further step is then the identification of the most important investment areas to strengthen the national innovation system (NIS) of Tunisia. In a quite recent report (see the source of the box) three areas for advancing action towards complexity and innovativeness are proposed: promoting venture capital & technology transfer, establishing dominant players in industry sectors; and supporting platform projects towards inter-firm and cross- border connectivity and networking.

Four dimensions matter for Tunisia's III, and so the following questions have to be answered: first, has the country the capabilities for a product/a service (measured by RCA/revealed comparative advantage); second, is the product/the service complex and innovative (by measuring the sector value chain network level of complexity and the product complexity index); third, is the product/the service an opportunity (as measured by market size and opportunity gain); and fourth, does the product/the service support by size of firms and employment a regionally balanced growth and employment strategy (as measured by the HHI/Herfindahl-Hirschman Index for companies' distribution of size and employment in the sector). The weighted average of all the four dimensions gives the Tunisian III, showing that Scientific, Measuring and Medical electronic equipment, Auto parts, and Hardware and Telecom electronics have the highest scores.

Source: Zgheib/EBRD/Whiteshield Partners 2014

Obviously, new instruments and tools are needed to understand the role of industrial policy in the era of digital transformation.

2.3 African Country Cases of Structural Change, Economic Complexity and Digital Transformation – Role of Formal and Informal Economic Sectors

Most of the African countries are not at this stage of development like Tunisia to work with such tools towards a progressive form of industrial policy for the era of digital transformation. Analyses of global value chains and analyses for identifying the role of African countries in such chains are too often ignoring the complexity issues (this is also the case with AfDB et al. 2014), by concentrating mainly on governance, management and market structure issues. It is not so that the African producers of textiles and agriculture/agroindustry products have a comparative advantage at all

levels of the value chain, and even if there is such an advantage the Innovation Investment Index (III) may reveal that a selection of stages, forms of integration, tasks and activities in the global value chain is requested to build competitive advantages. The example of the textile value chain shows that a cotton producer may not have a comparative advantage in garments as diversification functions along the productive knowledge that exists in a particular location and that can be used for the production of "nearby goods" in terms of productive knowledge, such as developing other and niche agricultural products or specific services and equipment parts for cotton production. A jump-start towards such nearby tasks and activities is required and can be promoted by policy and large conglomerates (see Wohlmuth 2011 on the case of large Kenyan industrial players). Kenya is a case of interest in this context. Kenya is involved in various global value chains of agriculture and agri-processing (horticulture, tea, coffee, leather, textiles, edible oils, etc.) and of manufacturing (automotive, plastics, petrochemicals, etc.), but backward and forward integration levels are very limited and the same is with complexity increase and the accumulation of technological capabilities (AfDB et al. 2014b, Country Note Kenya, pp. 12-13). The long list of barriers to Global Value Chains (GVCs) in Kenya and the severe implementation problems - despite of long-term plans like the Kenya Vision 2030 and the Medium-Term Plans like the one for 2013-2017 – signify a lack of structural transformation. The ECI rank of 73 and an improvement of the ECI through the period 1964-2008 are middle level achievements in Africa, but further progress requires overcoming all these barriers and organizing a jump-start to products with a higher potential for future industrialization in terms of capabilities, complexity and innovativeness, opportunities and inclusiveness. In extractive industries (oil and gas, minerals) there are only few nearby products for using the accumulated knowledge of the sector (see on this issue table 1 in Yildirim 2014), so that organizing a jump-start to something new in terms of complex products is needed. While the productive knowledge of machinery and electrical equipment production can be used for many other products (there is a high connectivity of products via productive knowledge), most of the African countries have loose connectivity of their products to other products because of the specific knowledge accumulated in their (natural resource-based) export sectors.

Structural change is a prerequisite to increase the economic complexity in a country,

but this way to diversification is risky and it is also a long-term venture. Identifying products which enable the country to move up the complexity ladder is only a first step. Then removing the barriers to their production and finding business support for the new production lines is an industry policy task. Structural change requires that new capabilities and forms of productive knowledge are developed being of use for many other industrial activities and tasks (Yildirim 2014, pp. 7-8). By looking at the Product Space one can see which products are near the productive knowledge base for more complex products. So, a country like Tunisia can identify products which are interrelated by capabilities, demand, the production networks and the knowledge base (medical equipment, ICT for health, traditional medicine, and pharma products are examples), whereas countries exporting mainly products based on extractive resources can move forward along the value chain by petroleum refining or minerals beneficiation (but this may not provide the required knowledge spill-overs to other industries and products). Industrial policy can target public resources to identify new products and this can be a successful strategy if the new products are near the productive knowledge base (such as engineering and ICT for health and wellness). Support by governments should be time-bound and limited to key inputs, such as infrastructure, research, regulation, certification, labour training, and the coordination of potential investors (Yildirim 2014, p. 8). All this government action should be available to all industries with potential in order to avoid sector-specific large-scale subsidization. Subsidized energy or water is not the way to encourage production of new products, but publicly supported research, industry parks and labour training can be useful measures when new and more complex products are envisaged. These measures can be of use also to other industries. Thereby, a strategy of diversification can enhance economic complexity by moving to those areas of the product space that are denser and more connected (as ICT hardware and software, or health-related products and services). Business associations and trade unions can support such an identification process; entrepreneurship development and employment generation can be outcomes of this process.

Some African countries show how the product space can be extended over time. South Africa and Nigeria give examples for formal economic sectors and for informal economic sectors. South Africa is strong in various global value chain (automobile,

mining, finance, and agriculture) and has achieved leading positions in these industries (AfDB et al. 2014a, Country Note South Africa, pp.12--13). Local firms have developed considerable knowledge during their assembly work in the automobile sector to become exporters of automobile parts and components (such as catalytic converters and leather seats). Decades of working experience and building of productive knowledge led to the production of "nearby" products - competences developed during car assembly led to the successful export of own local automobile parts. Mining is traditionally an important sector for exports, employment, for other sectors' growth (steel, timber, rail), and for stimulating finance, consumption, and housing sectors. Most important for capability formation, South Africa became a successful exporter of mining services and mining equipment (see Box 2.3). This shows that even in extractive industries the product space can be extended.

Box 2.3: Promoting Structural Change and Economic Complexity in South Africa through Backward Integration

South Africa's mining sector is important for exports, employment, consumption and poverty reduction, for other industries such as steel, timber, transport and logistics, finance, housing, but also for the development of services and equipment sectors. The mining services and engineering sectors are also important exporters. South Africa has leading firms producing washing spirals, underground locomotives, submersible pumps, hydropower equipment, and mining fans. Also, in various mining services sectors (geological services, prospecting, shaft sinking, turnkey solutions to the mining and mineral processing industries, and operational services) South Africa is an exporter, especially with regard of services for mine safety, tracked mining, shaft sinking and ventilation. Mining equipment makes 8.5% of total exports and 55% of capital equipment exports in 2005-2009. All this activity has a high local content (90%) and generates qualified jobs for a world market. This is backward integration with a high level of complexity and sophistication. When minerals beneficiation prospects are also reviewed, further opportunities become visible. However, there is need in South Africa to maintain this favourable position by investing into knowledge systems and networks for maintaining and upgrading the position in the global value chains. Sector

innovation systems, such as for mining, are important elements of a forward-looking industrial strategy.

Source: AfDB et al. 2014a, African Economic Outlook, Country Note South Africa, p. 13, Web Access: http://www.africaneconomicoutlook.org/fileadmin/uploads/aeo/2014/PDF/CN_Long_EN/Afrique_du_Sud_EN.pdf

This increase of complexity in South Africa's mining sector has occurred through backward integration while forward integration through minerals' beneficiation is limited, although beneficiation strategies have been developed since the 1990s.[7] So, building of technical capabilities and increasing economic complexity are relevant for the major global value chains which are found active in South Africa. However, the danger of erosion of capabilities and competences in South Africa is great – factors such as shortages of skills (engineers and artisans), reduced standards, declining public research, innovation policies which are disregarding the specifics of global value chains, declining links with science councils, research institutes and universities, the relocation of head offices and branches, and outsourcing of tasks, may speed up the erosion. Improving the capabilities along the important South African value chains, also in finance and agriculture[8], is important for South Africa's future competitiveness.

Nigeria is a case of great relevance for Africa in terms of a strategy for structural change (see AfDB et al. 2014c, Country Note Nigeria, pp. 14-15). The informal sector plays a huge role in manufacturing and in the building of technological capabilities. Although Nigeria's manufacturing sector has a minor share of 3.4% in GDP, the share

[7] RSA/Republic of South Africa, 2014, Department of Mineral Resources (DMR), Beneficiation Economics; Web Access: http://www.dmr.gov.za/beneficiation-economics.html

[8] Anti-competitive behaviour of major food producing companies of South Africa when exporting canned fruit and fruit juice purees and concentrates is a severe problem and will affect future export competitiveness, while also leading to anti-dumping and safeguard investigations in destination markets (see Tralac, 15 October 2014, Anti-competitive behaviour in export markets).

of the informal sector in GDP is 57.9%. Formal sector manufacturing is very weak. There are plans for refining crude oil and to develop other sectors in Nigeria which are near the oil and gas production. Fertilizer production can be mentioned. But textile and fertiliser production have very low capacity utilisation rates; also cement production is mentioned. Many of the plans for the formal sector do not lead to concrete implementation steps. Products from agriculture, like shea nuts, have high potentials for developing the subsector of informal manufacturing. Although being the greatest shea nuts producer in Africa, only 10% are exported, as nuts after roasting or as processed traditionally into shea butter. The potentials are great to move up the global value chain by adding value as shea nuts are intermediate inputs for pharmaceuticals, cosmetics companies, and for chocolate factories. Local formal and informal producers could benefit from ongoing automobile assembly plans; local input manufacturers, such as textile for car upholstery, rubber, and tyre manufacturers, could be integrated into the value chain. A more recent industry of importance in Nigeria is waste management, which is relying on formal and informal sector stakeholders (Alabi/Wohlmuth 2019); this industry can create employment, protect environment, save foreign exchange, and promote health. Economic and product complexity could increase by such policy measures for informal and formal industrial sectors. But so far Nigeria has weak positions in the ECI and with regard of changes of the ECI in the period 1964-2008.

The informal ICT sector in Nigeria is extending to formal economic sectors and has a proven capacity to build technological capabilities and to increase the economic complexity at the regional level around Lagos and beyond, up to the national level of Nigeria and to neighbouring West African countries (see Oyelaran-Oyeyinka 2014). The lessons from the Otigba ICT Cluster are of relevance also for other African countries (see Box 2.4).

Box 2.4: Nigeria's Otigba ICT Cluster is Building Capabilities in Formal and Informal Enterprise Sectors

The Otigba Information and Communications Technologies Cluster is presented as an example of self-starting and self-sustaining small enterprises which are in some cases family-owned ones. It originated in the 1990s on two streets, but now occupies eight streets, with Otigba being the largest. The cluster is on a scale ranging between formal and informal. It is informal as it has started in a residential zone which was then turned to a business district. But it is recognized by the state government through an umbrella organization, the Computer and Allied Products Dealers Association of Nigeria (CAPDAN), and the state collects taxes. It is a cluster which had spontaneous been developed. The cluster was stimulated by the large demand from the Lagos area (which produces 60 percent of Nigeria's industrial production) and because of the highest percentage of educated people and educational institutions of Nigeria in this region.

Major activity is the assembly and trade of computer hardware and software. The cluster is also described as the Silicon Valley of West Africa. Activities are many – from the sale of laptops to the cloning of computers, installations, repairs and servicing of desktops and laptops, ICT solutions and applications, cyber coffee services, etc. Associated with the cluster are also larger firms with locally branded products, like Omatek, Zinox, Speedstar and Brian Technology. Finance institutions and cargo firms are also there, as well as banks and SMEs. Indian and Chinese techno-firms are penetrating the cluster. The employees and entrepreneurs are young; 69 percent of the employees are between 21 and 30 years of age. Close to 50 percent of the employees are university graduates; almost 30 percent have technical degrees; and 19 percent have attained a high school certificate; only 3 percent have only attained elementary school level. CAPDAN has about 3,500 registered enterprises with 8,000 to 10,000 employees.

It is argued that the Computer Village is of huge importance to overcome and to avoid unemployment, especially youth unemployment, poverty, and insecurity in the region. Profitability and exports are high and have continually increased over the last years. The cluster has customers in the whole West Africa region and up to Congo and South Africa. Inputs are provided from within the cluster and from international

sources. For imported inputs, the exchange rate fluctuations matter, so that the cluster depends on sustained macroeconomic policies for Nigeria.

Source: Oyelaran-Oyeyinka, Oyebanke, 2014, pp. 16-19

See on the umbrella organization CAPDAN: http://www.balancingact-africa.com/news/telecoms-en/6308/capdan-makes-case-for-local-pcs-in-nigeria

The Otigba Cluster has become a major institution in Nigeria for technological learning, for technological capability formation, and for high technology business activity in Nigeria. The Cluster links informal and formal sector activities and impacts on the economy of the Lagos region but also on other regions of Nigeria and the neighbouring West Africa region. Also, the cluster has a high share of graduates and technicians among its employees and is as well a pool of entrepreneurship development. Diverse ethnical groups demonstrate in the cluster their specific business styles and attitudes. The cluster is also of importance for human development, social protection, employment creation, and poverty reduction. The impact can become even bigger for Nigeria if a strategy for structural change is designed and implemented moving beyond the cluster.

These cases – Tunisia, South Africa, and Nigeria - show that the paths to economic complexity and structural change may be quite different, but in all cases digital transformation will be a great challenge. As the three African cases considered are representing countries with high potential (market size, level of development, history of industrial production and export experience, R&D capacity, skilled labour force, and size of population, the situation of many other African countries may be quite different. But, the opportunities of digital transformation and economic complexity are also relevant for lower developed and smaller African countries. A strategy for structural change in the era of digital transformation can use the experiences from these three African countries (Tunisia, South Africa, and Nigeria) on how to jump-start towards higher complexity and capability.

3 Global Techno-Economic Changes, Digital Transformation and the Task of Building Technological Capabilities in Africa

3.1 Responding to the Global Competitive Race by Developing Technological Capabilities in Local and Foreign-owned Enterprises in Africa

African enterprises can respond to the global competitive race by strengthening their innovation capabilities, their ICT capabilities and their technological capabilities. There is an increasing awareness that innovation capabilities (the ability to organize innovation processes in the firms through provision of external knowledge and creation of internal knowledge) can be created and improved by private and by public measures. Also, ICT capabilities (to organize hardware and software in the firm) are increasingly considered as relevant by policymakers and are created in African countries at the national level and as well in large and small enterprises. Innovation capabilities, ICT capabilities and technological capabilities interact in the digital transformation process. Various dimensions of technological capabilities for manufacturing and of ICT capabilities for manufacturing and services are emphasized: human resources capability, process and management capability, institutional infrastructure capability, technological infrastructure capability, and financial capability (Nissanke 2003). ICT capabilities are of relevance for manufacturing and for diverse tertiary sectors. The ICT sector itself is of increasing importance in African countries. ICT capabilities for the ICT sector have two dimensions: first, manufacturing ICT goods, such as computing hardware and industrial scale software, and these products and services share some characteristics of the secondary sector; and second, ICT applications for running efficiently industries and administrations, such as production control and administration control systems. Technology transfer may have impact on all the constituent capabilities mentioned above, with a strong impact on process and management capability. Lower-level capabilities, such as financial capability, can support higher level capabilities, such as institutional infrastructure capability and technological infrastructure capability (see the figures 2 and 3 in Nissanke 2003). Applied to Af-

rican conditions, some of these core elements of the system of capabilities are weak and need to be strengthened by technology transfers and by institutional and policy measures. But most important is it to understand the full system of capabilities.

To produce ICT goods, four avenues of technology transfer are relevant to strengthen capabilities: R&D alliances, manufacturing alliances, marketing and service alliances, and general-purpose tie-ups (by the way of standards coordination and joint ventures). To produce ICT applications marketing and service alliances are relevant to strengthen relevant capabilities. Some African countries and their enterprises are developing ICT capabilities based on these four forms of technology transfer. ICT capabilities can be best developed in African firms when national industry and ICT policies support such technology transfers; but these policies need to be adapted to both, the ICT base and the manufacturing base of the country. Thereby, governments can support the building of higher-level capabilities, like human resources capability, and technological and institutional infrastructure capabilities. The system of ICT capabilities demonstrates that digital transformation is a complex process, but in some directions African firms and governments are making progress to support them by joint action.

Strategies to build technological capabilities need to consider the fundamental differences which exist between manufacturing sectors (see the classification of industries in McKinsey 2012b, and for job sectors: McKinsey 2012a). Technological capabilities have different roles to play in five distinct segments of manufacturing industries, but also ICT capabilities and innovation capabilities have a quite different and specific importance related to these five groups. The first group of industries – *"Global Innovation for Local Markets"* – comprises sectors such as chemicals and pharmaceuticals, automobiles, other transportation equipment, and machinery, equipment and appliances. This segment has a 34 percent share of the global manufacturing value added. In this segment, there exists a moderately to high R&D intensity, and there is need for a steady stream of innovations and new models to compete. The distribution of production facilities is arranged in a way as close as possible to the consumers, also because of the differing regional impacts of regulatory effects, such as safety standards and trade restrictions and policies. This segment is very important for Africa's

manufacturing sectors, as car assembling, production of auto parts and auto-mechanics enterprises are important for many countries (South Africa, North African countries, Nigeria, and various other countries). This segment is also relevant for informal manufacturing sectors, such as in Nigeria. The second group of industries – *"Regional Processing"* – has a share of 28 % of the global manufacturing value added and comprises food processing and other industries that are located close to demand and to the local sources of raw materials. These products are not heavily traded and are not highly dependent on R&D but are produced under conditions of high degrees of automation. These industries are very important for all African countries, as well in formal and informal establishments. The third group of industries – *"Energy- and Resource-intensive Commodities"*, such as basic metals – make up 22% of the global share of value added. Energy-intensity, transport cost-intensity and capital-intensity determine the production and supply conditions and tie these industries to the markets where the demand derives from. For Africa, there is a huge potential in these sectors, also with regard of backward integration and beneficiation of the raw products. Technological, ICT and innovation capabilities are a constraint in parts of Africa, and dependence on imported technologies is a major problem. The fourth group of industries – *"Global Technology/Innovators Industries"*, and products such as computers and electronics products - is highly dependent on global R&D and on global production and sales networks. The sector has a share in global value added of 9%, and as these are high value products this makes them globally transportable from production sites to customers around the globe. The fifth group of industries – *"Labour-intensive Tradable Products"*, such as apparel manufacturing - has a share of only 7% of the global value added and requires low-cost labour. However, ICT capabilities and innovation capabilities are important as well for this group to be successful in the market, as well as specific technological capabilities are required. These industries are migrating easily to low labour cost areas and to sites with reliable transport/logistics conditions (McKinsey 2012b). However, beside of low cost of labour the digital infrastructure is increasingly important, also for African locations. Although Africa has a role in all of these five groups, the three groups of capabilities (technological, ICT, innovation) have a quite different importance. Policymakers and entrepreneurs need to adapt to these differences.

Technological capabilities, but also innovation and ICT capabilities, need to be adapted to these highly divergent fundamental forces which are affecting these five groups. However, the strategies to build technological, ICT and innovation capabilities need to consider as well other driving factors of manufacturing development (see McKinsey 2012b). First, the distinction between manufacturing and services has blurred; the African manufacturing companies in all these five segments rely heavily on traditional and new service providers, notably transport & logistics and ICT services. Then, second, the role of manufacturing in job creation is changing rapidly, and more flexible work arrangements are requested also in Africa's manufacturing industry; third, demand is shifting and fragmenting as different features and price points are demanded, what is of relevance for Africa because of the middle class being composed of relatively poor and relatively rich segments; fourth, innovations create many new opportunities in terms of sectors, markets and products, as also Africa is exposed to the move from exponential technologies to exponential innovation (Deloitte 2014, DUP/Deloitte University Press 2013).[9] This is the essence of a digital transformation; no country and no firm can miss the cost-performance of the core digital technology building blocks (computing power, storage, and bandwidth).

Technological capabilities need to adapt to complex and uncertain environments. Global shifts lead to the need for new strategies of enterprises to adapt to demand and production changes and to more associated and shared R&D strategies. Technological capabilities need to develop new strengths to grasp the opportunities from ICT and leapfrogging; a move from "copying and pasting" strategies to strategies based on "granularity" strategies is recommended. This move is important for Africa to benefit from the digital transformation and leapfrogging advantages and potentialities. Understanding the dynamics of different segments of markets, regions, customer segments, and looking at total factor performance (not only on labour and energy cost, but also on the core digital technology building blocks) is an imperative for future-oriented corporate strategies. Acting with agility, by making major investment and strategic

[9] See DUP/Deloitte University Press, 2013: The rate of improvement in core digital technologies accelerates, and so we are experiencing rapid advances in the innovations built on top of the core "exponential" technologies. The pace of technological advance is unprecedented in history and shows no signs of stabilizing as other historical technological innovations, such as electricity. The cost-performance of three core digital technology building blocks—computing power, storage, and bandwidth—has been improving at an exponential rate for many years.

commitments and by managing risk and uncertainty at the same time, is a new approach which is recommended for globalized enterprises. To make this possible, developing new operational capabilities and methods, and new data-gathering and analytical tools are crucial tasks (see McKinsey 2011 on all these implications for strengthening technological, ICT and innovation capabilities in the new industrial era). A strengthening of such capabilities requires that globally competitive public/private policies are pursued, that partnerships for competitiveness are enhanced, and that the manufacturing value chains are reorganized dynamically to drive growth (see WEF 2013a). Specific capabilities are needed to cope with global competitive pressures, to partner more effectively around the globe, and to understand and to act on paths towards more dynamic value chains. Large globalized business firms in some African countries follow already such a course of action (Wohlmuth, 2014).

Collaboration of firms of all sizes in innovation strategies and in developing capabilities is increasingly important also for Africa, especially towards digital manufacturing (as already based on 3D printing and open source innovation). According to some views (Deloitte 2016), Africa can even skip the second and third industrial revolution based on traditional and computer-aided manufacturing to leapfrog straight into digital manufacturing of the type industry 4.0.[10] Various 3D industrial printing examples and open source innovation platforms give evidence of this potential for Africa; such technologies play already a role in formal and informal sectors. The continent is nowadays even presented as an "awakening manufacturing giant", but beside of using more and more ICT technologies and digital manufacturing competences Africa is impacted by South-South investments, OECD investments and financial investments in traditional manufacturing sectors (see The WorldFolio, November 11, 2014, and The Economist, February 8th, 2014).

Global trends towards higher R&D spending are part of the new global innovation game, but these are based rather on R&D partnerships than on in-house efforts. Inte-

[10] This assessment comes regularly from international consulting firms; see as an example Deloitte, 2016, Industry 4.0, Is Africa ready for digital transformation?, Deloitte Africa, 35 pages; Access: https://www2.deloitte.com/za/en/pages/manufacturing/articles/africa-industry-4-0.html

grating decision-support technologies into the entrepreneurial R&D function is also an important trend (KPMG 2014). These trends require new R&D capabilities. Capabilities to collaborate on R&D, to share views on R&D trends and projects, to install open innovation platforms, and to improve decision-making on R&D issues need to be developed and strengthened. Africa can also benefit from these trends, by sharing views on future trends, by using new tools of decision-making, by recruiting more actively talent, by developing new mind-sets, by investing into organizations and skills, and by developing total factor and life cycle cost for R&D programmes and projects (McKinsey 2012b). All this is part of advanced innovation capability; Africa's large enterprises should become part of such global networks. Innovation capability is complementary to technological capability and ICT capability; and the new trends in innovation capability impact directly on the other two capabilities.

Building of technological, innovation and ICT capabilities is also important for promoting the "green economy" in Africa. Manufacturing along "green economy" imperatives is also more and more affecting Africa and moves in this direction to build specific technological capabilities are requested. But there is good news about all this; there is increasing awareness about "greener industries". Informal sector capabilities for manufacturing, repair and maintenance, recycling, resource-saving, copying, innovating, imitating, networking and organizing are strong and can be used, such as for the greening of supply chains, for increasing resource and energy efficiency, for producing cheap and effective environmental goods and services, and for remanufacturing to extend the lifecycle of products. But also, the formal manufacturing sector can benefit from such initiatives (see Alabi/Wohlmuth 2019 on "greening of the waste management industry" in Nigeria). The spread of ICT to informal sectors allows for enhanced skills acquisition, for use of IT platforms for sourcing of inputs and acquisition of customers, and even for an increasing use of 3D manufacturing tools (see UNEP 2013, Chapter 5). The informal sectors are important for living standards, employment, but also for the knowledge flows and the development of technological capabilities. But also, formal sector enterprises and export associations are increasingly involved in the greening of manufacturing value chains (see Box 3.1).

Box 3.1: Building Technological Capabilities for the Greening of Value Chains in Africa

"Greening of supply chains" within the manufacturing industries is undertaken all over Africa. Also, firms in Africa are ready to develop capabilities to redesign products, processes and organizations so that they can meet environment-related product standards, to reconfigure their processes and organizations to meet environment-related process and organization standards, and to certify that the products and their manufacturing processes are meeting these standards. "Greening opportunities" are available at all stages of the manufacturing supply chain, from the extraction of the raw inputs to the end of product life (UNEP 2013).

African enterprises (producers and traders) are increasingly exploiting trade opportunities in environmental goods which are produced in Africa (such as solar technology, wind turbines, etc.). South Africa, Egypt, and Kenya have the capacity to export environmental goods, such as wind turbines, solar PV, solar water heaters, biofuels, hydraulic turbines, insulation materials, and others, to many other African countries. However, non-tariff barriers, such as subsidies on fossil fuels, technical specifications, local content requirements, and lack of financial, institutional and manufacturing capacities, limit the expansion of exports and imports and so impede the exploitation of the intra-African trade potentials (UNEP 2013, p. 186). The CFTA (Continental Free Trade Area) for Africa may give additional weight to the greening of industries, especially if non-tariff-barriers (NTBs) are removed between African countries.

Remanufacturing in the ICT sector of Nigeria is an important business. There is even an increasing intra-African trade of remanufactured PCs and printer consumables. Nigeria is leading in the remanufacturing business in Africa, as many industrial sectors use some form of refurbishment or remanufacturing. In Nigeria, there are (as of 2009) 11 out of 45 Community Microsoft Authorized Refurbishing (MAR) Units for personal computers in Africa. Also, some of the refurbishing units can partly pre-

install Windows on refurbished PCs. These MAR units can also export their products to the neighbouring countries. Also, refilling and sale of refilled printer and ink cartridges is possible. These refurbishing activities can also lead to other green investments and make use of local technological capabilities which are thereby strengthened. Remanufacturing is expanding in many industrial sectors (motor vehicle components, aircraft parts, compressors, electrical and data communications equipment, office furniture, vending machines, photocopiers, laser toner cartridges, windmills, and agricultural equipment). Local capabilities can be used for upgrading technological, innovation and ICT capabilities, and the significant price reductions of up to 60 % for refurbished products (such as for toners) lead to a considerable widening of markets.

Promoting greener industrial value chains can go as far as introducing - like 2010 in Mauritius by the Mauritius Export Association (MEXA) - Blue Carbon Awards (BCAs) for recognizing companies which are adhering to "green economy principles". Companies in the clothing and textile manufacturing industry and in the eco-building industry have reduced considerably their energy costs and so could increase their export and domestic market competitiveness. Specific energy-saving programmes in Africa's industry show a high potential to increase competitiveness (UNECA 2016). Greening the export-oriented textile and clothing industry was obviously a very successful strategy in terms of raising the international competitiveness. Technological capabilities for the greening of the industrial value chains in Africa are therefore of increasing relevance for competitiveness, environmental protection, mitigating climate change, and modernizing industry structures.

Source: UNEP 2013; UNECA 2016

Technological capabilities in the traditional sense (as formulated by Lall 1992) are not obsolete, but have to be embedded into a wider frame, including innovation and ICT capabilities for the new industrial era. The many studies on technological learning and building of technological capabilities (UNIDO 2002, UNIDO 2005, UNIDO 2009,

UNIDO 2013b, and Yumkella et al. 2011) need an updating for the era of digital transformation.[11] The framework of digital capabilities is needed aside of the traditional frameworks of technological learning as Africa has a wide spectrum of production modes – from highly globalized enterprises near the technology frontier to local microenterprises operating on simple technologies and routine tasks. However, digital capabilities are needed along the whole spectrum of production modes.

The process of building technological capabilities has changed dramatically in the recent years, based on ICT development and the spread of digitalization through production of goods and services, marketing, service delivery, and recycling. The development of technological capabilities is the outcome of a complex interaction of incentive structures with human resources, technological effort and institutional factors (Lall 1992). Referring to Lall, human resources should be treated as the infinite sources of wealth creation; these are the basis for any technological transfer effort becoming efficiently mobilized and for institutional factors being dynamically engineered. Partial explanations of technological efforts and capabilities concentrate exclusively on market-driven incentives on the one hand and the capability-building measures on the other. It is the outcome of the interplay of various factors in a specific country's setting which determines how well producers learn the skills and master the information needed to cope with industrial technologies at the firm level. Such factors also determine how well countries employ and raise endowment factors over time at the national level. These efforts would enable them to grow dynamically in the context of rapidly discovering and changing technological developments, which trigger fundamental changes in processing, design and marketing to thrive in an internationally competitive environment.

Lall (1992) further argues that one set of determinants cannot by itself produce dynamic, broad-based, sustained industrial development. Just getting proper incentives

[11] This is done partly in most recent reports of UNIDO on industrial development: https://www.unido.org/resources/publications/flagship-publications/industrial-development-report-series. The Industrial Development Report 2018 of UNIDO is an example as the demand side of manufacturing development is fully introduced.

in place will be better, *ceteris paribus*, than giving the wrong signals. However, just "getting prices right" as one determinant may lead to specialization in activities with static comparative advantage if other determinants such as skills, technology, or institutions are not present to permit efficient diversification for sustainable development. Similarly, generating skills alone would achieve little if incentives for efficient industrial activity were lacking. Given skills and incentives, performance would still differ, depending on the ability of institutions and government policies to overcome market failures and to protect activities with genuine dynamic potential.

As far as capabilities are concerned, policy interventions to promote physical and human capital development and the transfer of relevant technology are critical determinants (Lall 1992). If education and technology strategies are to be geared to realizing specific forms of dynamic comparative advantage, policy interventions will need to be selective. At the early stage of industrial development basic human capabilities, literacy and numeracy, with some vocational skills would suffice. As a country reaches a higher level of industrialization, more sophisticated and specialized skills would be needed to absorb technological innovations which will enable countries to leapfrog. As development proceeds, more complex and cutting-edge technologies are used and hence, the need for more sophisticated and specialized education and training grows. These issues are more difficult to master with concomitant risk and uncertainty. Accordingly, the development of capabilities is struck with problems of appropriateness, externalities, lumpiness and requirements of very specialized skills. These must be duly dealt with when the late-comers in the sphere of industrialization endeavour to move to a higher level of industrialization in line with the new industrial realities and technological developments which make deep inroads into the productive process and marketing frontiers of the current transformative shift from quantity to quality. Positioning Africa in the above context calls for a systematic assessment of technological efforts and capabilities in Africa.

One of the first systematic attempts to assess technological capabilities of African manufacturing firms, to estimate their technical efficiency levels and to analyse the significance of technological capabilities in determining firm level technical efficien-

cy was a World Bank-initiated Study (World Bank 1995; and World Bank 1996 for the synthesis). The study "broadly defines technological capabilities as the skills and knowledge needed to set up and efficiently operate modern industry. Using firm level data for Ghana, Kenya and Zimbabwe, the study evaluates components of investment capabilities, production capabilities, and learning and linkage capabilities. Four industries provide the focus in each country: textiles and garments, wood working, metal working, and food processing. It is shown that there are important cross-country differences in technological capabilities of firms, as well as across the four sectors of manufacturing activity. At the same time, although significant private efforts are being made by entrepreneurs in each country to upgrade their technological capabilities, the study found out that overall technological capabilities were low in these economies relative to the rest of the world. Econometric analysis using stochastic frontier methods is then undertaken to estimate levels of technical efficiency as a distinguishing aspect of the study, marking the first such comprehensive attempt across sub-Saharan economies. Analysis of technical efficiency shows that technological capabilities are significant determinants of efficiency at the firm, sector and country levels. The study also shows that the traditional learning and linkage mechanisms by which firms enhance their technological competence are weak and, many times, missing in African countries." (See the World Bank Summary, in World Bank 1995) Around 20 years later the picture now looks different as divergences between countries, sectors and firms in Africa have increased and as new industrial sectors play a role as well as new dynamic forces such as ICT and related ICT country policies.

More recent studies on determinants of technological capability for formal and informal enterprises of various sizes in Nigeria are still based on the traditional approach by Lall (see: Oluwale et al. 2013, Sobanke et al. 2012, Sobanke et al. 2014), but around 20 years after the first studies which were inspired by Lall it is becoming obvious that the new framework of ICT capabilities and innovation capabilities can be added and should be added (see Box 3.2 on the informal Nigerian Automobile Sector and Box 3.3 on metal-fabricating firms in South-Western Nigeria).

Box 3.2: Technological Capabilities in the Informal Nigerian Automobile Sector

Informal manufacturing enterprises in Africa have developed technological capabilities, but these are different form formal sector enterprises and from medium to large enterprises. The technological capabilities in the auto-mechanic enterprises in three states of South-Western Nigeria were investigated, by comparing businesses within clusters of auto-mechanics and stand-alone auto-mechanic firms. Four types of capabilities are reviewed for the mostly small firms: investment, marketing, linkage, and minor change capabilities.

Investment capability is limited as only a minority of master mechanics did feasibility and pre-feasibility studies, but they did it at a higher percentage than firms in the footwear informal sector. The ability to recognize and to purchase common tools for equipment is higher than the ability to carry out feasibility studies and the ability to prepare, design and set up modern equipped workshops. The investment capability is higher in clusters in contrast to the stand-alone auto-mechanics, and it is higher in Lagos state relative to Osun and Ogun state, probably because of the cosmopolitan nature of Lagos state and the presence of other clusters in the state (ICT etc.).

Marketing capability is relatively strong, and the contacts to the customers are done by phone and by personal visits, and this is similar the contacts used by the auto spare parts sellers. Cellular phones have a greater weight than visits; contacts by visits are limited because of security problems, and contacts to spare parts sellers are as important as to customers. Marketing capability depends on the frequency of getting information on new models of vehicles from customers, on the frequency of obtaining new ideas from customers, and on the frequency of getting new ideas from spare parts sellers.

The linkage capability is weak with regard of most institutions (linkages with technical schools, polytechnics, universities, research institutions, and linkages to motor

vehicle companies). Strong linkages exist with local mechanics and with national mechanics' associations which are representing the interests of the auto-mechanics. The observed lack of linkages to training, education and research institutions is related to the perceived lack of relevance, the insufficient financial support, and the gaps of training in business management. Such linkages are considered as useful, but structural changes in the partnership with such institutions are recommended.

Minor change capabilities (technical innovation capabilities) play a role in the auto-mechanics sector. As it is the case in other informal sectors, such as footwear, also in this sector incremental innovations play a role – in the form of certain improvements, adaptations and/or modifications of vehicles. Some of the firms even show a high intensity of such modifications over the year. Simple, but highly important technical innovations prevail, such as large transport capacity increases based on used rather small cars. Vocational skills are becoming more important for technical innovation beside of teaching literacy and numeracy abilities.

While investment capability is weak, and marketing capability is strong, the linkage capabilities depend on the relevance of the institutions for the business perspectives of the auto-mechanics firms. The minor change capability is strong. ICT platforms, ICT online training, and ICT capabilities can help to build stronger technological capabilities in the sector. Investment capabilities and linkage capabilities will benefit from an ICT strategy towards the informal manufacturing sectors, but also marketing and minor change capabilities will take advantage when the digital transformation proceeds. Innovation capabilities, ICT capabilities and technological capabilities can be developed in the sector by skills development and ICT strategies for the informal manufacturing sectors. Innovation capabilities could be promoted by initiatives of informal sector producer associations.

Source: Oluwale et al. 2013

In the sphere of informal sector enterprises, the lack of linkage capabilities, but also

the weak investment and production capabilities can be overcome by adapted internet platforms, by specific ICT capacities for these sectors, and by adequate skills, crafts and management training for the informal sector. Mobile operators, mobile service providers, mobile money devices and mobile payments to suppliers of public utilities (water, electricity, communication, information services, etc.) are of increasing relevance for small rural and peri-urban enterprises, and as well for informal sector workers and employers. Technological capability can be enhanced by using such devices. Solar home systems are an example. As in Nigeria 55% of the people are unelectrified but over 85% have mobile coverage, the construction of off-grid solar home systems is an option (see GSMA 2016). Remote control, monitoring, data collection and billing are done via smartphones. Also, other public utilities can be provided on this basis, and will support local business activity and building of capabilities. With the support of mobile phone apps even the smallest informal enterprise can gain from ICT in terms of information. The same is true for small and medium size formal enterprises, and the results show that technological capabilities are weaker the smaller the size of an enterprise is. Strategies to support the growth of enterprises in Africa are therefore also leading to higher levels of technological capability. Innovation capabilities and ICT capabilities can support the growth of firms in informal and formal manufacturing sectors.

Box 3.3: Technological Capabilities in Metal-Fabricating Firms in South-Western Nigeria

The situation is somewhat different in the metal-fabricating sector in South-Western Nigeria as there are many more formal enterprises and as there are beside of many small firms also medium to large enterprises. Investment capability is rated above average in identifying feasible projects, locating and purchasing suitable technologies, designing and engineering the plant, and managing the construction, commission and the start-up of the production facilities. Production capability is different with regard of process, product and industrial engineering functions. Production capability is relatively high for certain functions: debugging and calibration of new equipment, replacing original equipment parts, quality control, reproduction of fixed

specifications and designs, accreditation and certification of product quality, design and introduction of new products in-house, operation of inventory control systems, scheduling production, and monitoring of productivity. Only the accreditation/certification capability was weaker.

There are differences with regard of functions of innovation capability (developing new production methods, introducing new production methods, modifying existing production methods, developing new products, copying/imitating of imported products, and modifying of existing products). Innovation capability is weak in process innovation, but above average in other functions. Concerning linkage capability, there are weak linkages with all actors in the national innovation system (NIS), except with the trade associations. There is ad hoc and systematic cooperation with other fabricating firms, mostly at the same level as with customers and suppliers. Rather poor linkages exist with education, research and finance institutions. Only medium size firms have a comparable (summary) Technological Capability Index (TCI) as firms in developed countries, but the other formal and informal enterprise sizes are far below international standards in their respective TCI.

ICT capabilities play an increasing role in all functions of the enterprises, especially in regard of innovation processes, linkages and production and marketing functions. Links to producer organizations, to research & development organizations and to professional organizations are becoming more important, but are complex because of the heterogeneity of firms in the sector according to size, ownership, proximity to markets, sourcing patterns, key customers, degree of informality/formality, etc. As networking and human capital formation are becoming more relevant for the survival of firms, digital infrastructures and digital competences are increasingly important.

Sources: Sobanke et al. 2012; and Sobanke et al. 2014

African countries, like South Africa, are also contributing to global high technology sectors and are developing related technological, innovation and ICT capabilities.

South Africa is already working on advanced manufacturing strategies, and in cooperation with public Innovation and Technology Support Organizations enterprises in South Africa are translating the advanced manufacturing strategy into business reality, such as in the aerospace and defence cluster "High Tech Advanced Manufacturing, Aero-mechanical and Defence Cluster" at the Centurion Aerospace Village (DefenceWeb, 2012, CAV 2014, De Beer, D. J., 2011, DST/AMTS 2003). In the field of advanced laser manufacturing technologies South Africa is not only building technological capabilities for high tech industries along profitable global value chains but is also using its mineral resources such as titanium for beneficiation towards higher value-added products. However, the Centurion Aerospace Village (CAV)[12] and other high tech-clusters in South Africa[13] should be continuously evaluated so that the main objectives of the national advanced manufacturing technology strategy (AMTS) are compatible with a sector- and region-wide development of technological capabilities to produce more complex and sophisticated products and services in South Africa **(**see on details Box 3.4**).**

Box 3.4: Advanced Laser Manufacturing Technologies in South Africa

A new high speed technique for the manufacturing of titanium components for the aerospace industry was launched by the Department of Science and Technology (DST), the CSIR (Council for Scientific and Industrial Research)'s National Laser Centre (NLC) and Aerosud, a leading aeronautical engineering and manufacturing company in South Africa. South Africa as the second-largest supplier of titanium mineral ore is thereby starting to add value to the ore before export, while at the same time developing on this basis new high-tech products of use in most sophisticated industries (aerospace and defence). CSIR has developed a process whereby titanium metal powder can be produced from the titanium ore much speedier and less

[12] See on recent developments in the CAV: https://www.cav.org.za/

[13] Such clusters exist not only in the Pretoria Witwatersrand region, but also in other regions, such as the Cape Metropolitan region; the Johannesburg software cluster and the South African tool-, die- and mould (TDM)-making industry should be mentioned; more than 20 tech hubs were developed already in the country. All this is developed in the context of a holistic strategy to promote technological, innovation and ICT capabilities.

costly. The process is now commercialized, and a pilot plant was built.

Aerosud is projected to become a world leader in titanium aerospace parts manufacturing. The Project AeroSwift is a collaboration of CSIR National Laser Centre (NLC), the National Research Foundation (NRF) and the Aerospace Industry Support Initiative (AISI). The base is a new 5 kW IPG single-fibre diode laser to be integrated into the manufacturing system, which is transferred to a new Aerosud's Innovation and Training Centre 2 at Centurion Aerospace Village (CAV). This laser system is part of an additive manufacturing process by joining layer upon layer to make complex three-dimensional parts. Producing in this way larger components is critical for the development of the aerospace industry, and waste of expensive materials is also reduced by the new technique. Process qualification will be reached within three years, so that large-scale commercialization can start. South Africa is heading for an important niche based on complex, high-value, low volume parts in materials like titanium.

Centurion Aerospace Village (CAV) will be the home of several advanced manufacturing processes, such as titanium manufacturing processes, thermo-set and thermoplastic manufacturing techniques, digital manufacture, and advanced metrology. The "Hi-Tech Aeromechanical Advanced Manufacturing and Defence Cluster" is an initiative of the Department of Trade and Industry (DTI) and has received a "Special Project Status" from the City of Tshwane. The primary purpose is it to develop a sub-tier supply chain aimed at integrating the local aerospace and defence companies into the global supply chains, to become suppliers of choice to Original Equipment Manufacturers (OEMs) such as Boeing, Airbus, Spirit Aero Systems, Labinat Consulting, etc.

Sources: DefenceWeb, 2012, CAV 2014, and more recently the information on the CAV website since 2018: https://www.cav.org.za/

South Africa and its software industry capital of Johannesburg make spectacular progress in recent years in ICT developments spilling over to other African regions. The African Union (AU) and the Regional Economic Communities (RECs) support many continent-wide and regional ICT initiatives. ICT advancement also provides new frameworks for data collection, data dissemination and Africa-wide information about trends revealed by regularly analysed data. In the 1950s, 1960s and the 1970s, only a limited number of indicators were used for assessing technological efforts in Africa. The conventional indicators included: R&D expenditure and intensity, patent applications, awards and citations. Today, the list encompasses also indicators concerning the digital transformation (capacity and access, storage, bandwidth, cost savings through digital development, trends of digital entrepreneurship, development of digital and technological clusters, etc.), as well as many classical indicators such as: enrolment in higher education, "technological balance of payments", share of medium and high technology products and of sophisticated products in manufactured value added (MVA) and manufactured exports (MXs), functional literacy rates, technical research papers published in Journals as recognized by the Institute for Scientific Information (ISI), Innovation and R&D surveys, scientific output reports, digital plans and related progress reports, productivity growth accounting, and information on incremental and non-R&D routes to innovation. The reporting on science, technology and innovation indicators is progressing at continental, regional and national level in Africa (see on these surveying and reporting developments in Africa: UNECA 2014, NPCA 2014, Johnson/INSEAD/WIPO 2013, AOSTI 2014, and AOSTI 2013; and there are many related reports up to the year 2019, such as the most recent Global Innovation Index 2019: https://www.globalinnovationindex.org/Home, and data from the ASTII/African Science Technology and Innovation Indicators Project/Portal: http://www.nepad.org/programme/african-science-technology-and-innovation-indicators-astii). This wave of new publications on STI should now be translated into more pro-active and offensive policies to shape the digital transformation process in Africa.

3.2 Digital Skills, Employment Creation and the Formation of Technological Capabilities - African Entrepreneurship matters

High youth unemployment and graduate unemployment are alarming trends all over Africa (see AfDB et al. 2012, AfDB Group, 2018, Chapter 2, AfDB Group 2019, Chapter 2). Digital jobs can help to alleviate the problem by expanding the number of activities and tasks and the job opportunities. It is therefore urgent to identify the digital job opportunities and their roles for structural change and growth in Africa, to be able to provide skills training in order to prepare youths for digital jobs. It is also necessary to create an enabling environment for digital jobs by coordinating ICT sectors, private sector, public sector, and the civil society. The initiative *Digital Jobs Africa* (by the Rockefeller Foundation) intends to impact thereby on one million lives in six African countries. *Digital Jobs Africa* "aims to impact 1 million lives in six countries in Africa by catalysing sustainable Information Communication Technology-enabled (ICT-enabled) employment opportunities and skills training for high potential but disadvantaged African youth, thereby generating social and economic opportunities for those employed, their families and communities." [14] Digital jobs are relevant in practically all economic sectors and include the application of ICT to existing processes to make them more efficient, the creation of new products, services and communities based on the virtual economy, the harnessing of new and existing information in creative ways, and the establishment of transactional platforms that enhance access to services and trade (Rockefeller Foundation 2013, p. 2). Such jobs are to be found in large and small firms, and in governmental and non-governmental organisations. Also, new businesses/business models are created to harness ICT, including Purpose-Built Information Technology (PBIT) firms and IT Enabled Services (ITES) firms.[15] Various categories of IT firms exist - by functions, by clients, by funding, by purpose, etc.

[14] See on the Digital Jobs Africa Initiative: The Rockefeller Foundation, Digital Jobs Africa, Web Access: http://www.rockefellerfoundation.org/our-work/current-work/digital-jobs-africa , and for the definition and the strategy: Rockefeller Foundation/Innovation for the Next 100 Years, 2013, Digital Jobs, Building Skills for the Future, by Karim Harji et al., The Rockefeller Foundation, Web Access: http://www.rockefellerfoundation.org/uploads/files/9c9e4885-68e6-4670-9d48-11a830f92401-website.pdf

[15] See also on the impact of the Rockefeller Foundation Initiative: http://reports.weforum.org/disrupting-unemployment/digital-jobs-africa/

Digital jobs require ICT infrastructure (internet connectivity, broadband networks, wireless networks, and computers, tablets, and mobile phones); the building of this infrastructure is also creating jobs. For all these ICT-related activities 150 million new jobs could be created by 2020 (Rockefeller Foundation, 2013, p. 3), although other studies come to lower job creation numbers, but also in the region of millions. However, all this to happen would require a high speed of structural change in all sectors of the African economies towards transformation and digitalization (as looked at as a perspective for 2020 in: WEF Regional Agenda 2012). Such dramatic increases of the numbers of digital jobs may however be questioned as the perspectives for the creation of "stable jobs" (employment based on wages and salaries jobs and on business ownership) are rather limited in Africa (McKinsey 2012a). There is reference to the creation of not more than 70 million stable jobs between 2010 and 2020 and this will happen only if pro-active employment policies are pursued and if all countries mobilize their Internet-related GDP and increase systematically their ICT development scores by laying the foundations for the digital economy (McKinsey 2012a, 2013). So, it may be that most of the additional digital jobs in Africa are of the vulnerable type.[16] Such a speed of change as projected by the proponents of the digital jobs creation initiatives for Africa would fundamentally alter Africa's production and consumption structures and would require a radical change of politics towards entrepreneurship in Africa. A new approach to entrepreneurship in Africa could learn from China's experience how to do this in a state-dominated environment. As in China it is possible to improve the enabling environment for firms to absorb technologies and to become imitators and innovators. Innovative entrepreneurs can be supported by venture capital funds and by business angels (see Naude and Szirmai, 2013). Supportive strategies (as practised in other regions) can work also in Africa (see Evans 2014 and ICF 2014). New technologies (job platforms and digital payment systems) can help to widen the labour markets towards new groups of consumers (users) and workers, but

[16] Although there are risks associated with digital jobs (vulnerability and uncertainty), some positive developments may be cited, such as using digital platforms for widening the job market to unserved consumers and using digital payment systems to reach unbanked workers and consumers: https://www.cfr.org/blog/digital-jobs-africa-way-forward. The progress reports on Digital Jobs Africa give more modest numbers of jobs created and training delivered: see: https://www.britishcouncil.org/education/skills-employability/what-we-do/entrepreneurial-africa/news-events/digital-jobs-africa, and:
https://includeplatform.net/.../2c.-Youth-employment-programs-i...

new and digital entrepreneurs will play a role in this direction.

It is interesting to note that Africa has in 2018 not less than 442 active technology hubs (see the figure below, taken from a GSMA source[17]). This means that the base for digital technology jobs is growing rapidly, as well as the number of digital entrepreneurs. Since 2014 the World Bank is mapping the development of technology hubs in Africa, and it can be seen how fast the development did go on since up to 2018.[18] Nigeria and South Africa have a very high intensity of developing such hubs. 47% are qualifying as Accelerators & Incubators. In these hubs digital developments have a great role. But also, in other hubs (co-working spaces and other technology hubs) digital entrepreneurship can flourish. Some towns are leading with the number of hubs (Lagos, Cape Town, Nairobi, Cairo and Accra), but some other countries/areas/regions show a spectacular growth (Democratic Republic of the Congo and Zambia).

Figure: Mapping the Technology Hubs in Africa (Data from GSMA)

[17] See on GSMA: https://www.gsma.com/mobilefordevelopment/programme/ecosystem-accelerator/africa-a-look-at-the-442-active-tech-hubs-of-the-continent/

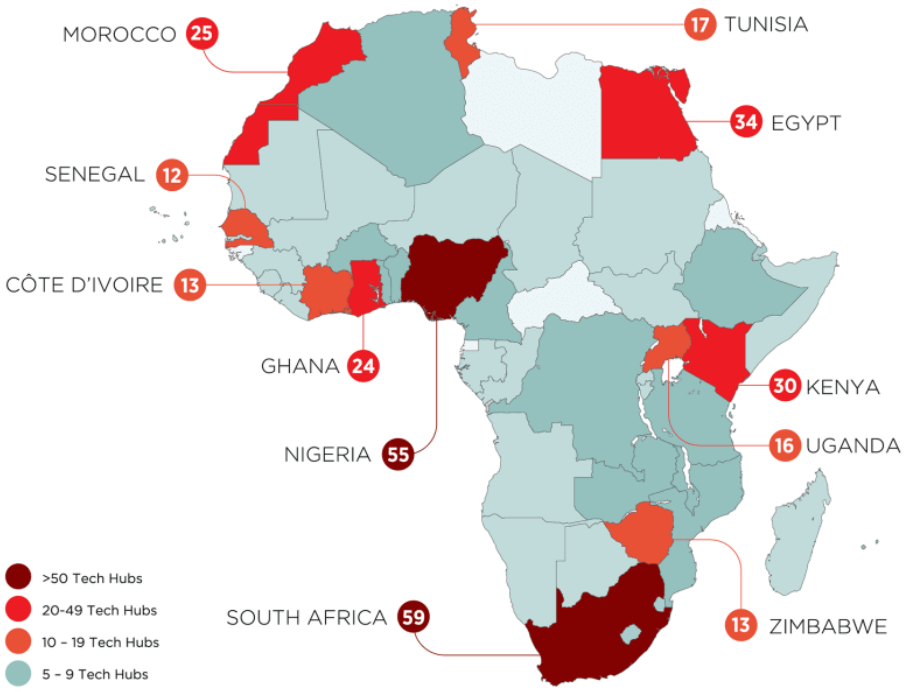
[18] See on the World Bank mapping of technology hubs: http://blogs.worldbank.org/digital-development/importance-mapping-tech-hubs-africa-and-beyond

Ecosystem Accelerator

AFRICA

Tech Hubs Landscape 2018

442 ACTIVE TECH HUBS*



47%	26%	27%
Incubators & Accelerators	Coworking Spaces	Other Tech Hubs

Fastest growing ecosystems
(2016-2018)

- Democratic Republic of the Congo +200%
- Zambia +200%
- Cote d'Ivoire +160%
- Togo +150%
- Nigeria +139%

Top 5 Ecosystem Cities
by number of Active Tech Hubs

- Lagos – 31 Hubs
- Cape Town - 26 Hubs
- Nairobi – 25 Hubs
- Cairo – 23 Hubs
- Accra – 16 Hubs

13% of the hubs are partnering with mobile operators.
MTN,Orange, and Vodacom are among the most represented.

5 Countries

45%

South Africa, Nigeria, Egypt, Kenya, Morocco totalise over 45% of all hubs.

5 y/o Hubs Maturity

Average age of active tech hubs is 5 years – launched in 2013.

Social Media Reach

1.4 Million Followers

4 Million Likes

Main tech hub alliances

AfriLabs · IMPACT HUB · THE indigo TRUST · FABLAB · jokkolabs

*Tech Hubs are defined as physical spaces designed to foster and support tech start-ups. These include incubators, accelerators, co-working spaces, fab labs, makerspaces, hackerspaces, and other innovation centres. Active tech hubs are defined as hubs that have shown active digital presence (website, news, social media) since October 2017.

UKaid from the British people

gsma.com/ecosystemaccelerator

Australian Aid

Source: https://www.gsma.com/mobilefordevelopment/programme/ecosystem-accelerator/africa-a-look-at-the-442-active-tech-hubs-of-the-continent/

Digital jobs can be entered by combining base level skills with technical training and soft skills training in the job areas data management, human resources & customer service, technical specialists, and digital entrepreneurs (Rockefeller Foundation 2013, p. 5; see also the case studies for digital jobs in these four areas in Africa and related training and capacity-building, pp. 6-9). Employment niches through IT can be used widely also in Africa. BPO (Business Process Outsourcing), ITO (Information Technology Outsourcing) and IS (Impact Sourcing) play a role in employment creation for the youths in Africa as the global market is expanding rapidly. Outsourcing of global corporations to Africa can lead to manufacturing jobs and to digital jobs, and it may be that the creation of digital jobs may be faster than that of manufacturing jobs. Impact Sourcing (IS)[19] is important for disadvantaged youth in disadvantaged regions. Not less than 11 per cent of the global BPO and ITO markets (US$ 574 billion by 2015) could be in IS (US $ 65 billion), and Africa could get a fair share in it (Rockefeller Foundation 2013, pp. 6-7). Global corporations will increasingly also look to Africa to "win the war for talent" (McKinsey 2012b, p. 14); policymakers in Africa can respond to this trend by creating enabling environments for outsourcing, instead of risking further waves of brain drain. The employment effects can be huge if such measures are taken. Also, development cooperation will need to change programmes and attitudes towards the digital age. Samasource is an example of a social business being active in Africa - by breaking down large-scale digital projects from corporate contracts into small tasks for workers in disadvantaged countries and regions, who are trained in basic computer skills and are paid in accordance with the Fair Wage Guide.[20]

The role of digital entrepreneurs for employment creation and growth in Africa should

[19] IS relies on providing employment in the context of BPO and ITO businesses for disadvantaged groups of the society and in disadvantaged regions. IT gives the opportunity to do so, if proper support is organized. Some global companies organize their supply chains around this objective (see: http://gisc.bsr.org/).

[20] See the social business model SAMASOURCE; Web Access: http://samasource.org/.

not be underestimated. They are crucial for employment creation in a direct way (the digital sub-sectors) and in an indirect way (for all the economic sectors and sub-sectors). Kenya's digital entrepreneurship ecosystem is increasing rapidly and is already diversified (see GSMA 2014, and box 3.5); and in other African countries digital entrepreneurship is also growing rapidly (see the figure above). There is a considerable capacity to increase the number of digital jobs if the whole ecosystem system is strengthened. It is obvious that all over Africa millions of jobs can be created if the digital employees get the appropriate technical training and soft skills training (Rockefeller Foundation 2013) and if the digital entrepreneurship ecosystem in Africa is further developed to increase the number of digital employees. Technological capabilities are growing in the digital sector and will spill-over to the other economic sectors. Important is it that the organisations and actors in the digital entrepreneurship ecosystem are cooperating fully among each other and that they are advancing in parallel. The digital entrepreneurship ecosystem of Kenya consists of the mobile operators, the incubators and accelerators, the private equity, commercial lending, commercial venture capital, and impact venture capital financing institutions, the hubs, networks & community spaces, the research & training institutions, as well as government, professional services, events & media, development organisations, and ICT corporates (GSMA 2014, p. 22). Kenya is rich in successful cases, such as Wananchi Online[21], a leading Kenyan Internet service provider valued at more than US $ 100 million, and Craft Silicon, a Kenyan software firm providing core banking, microfinance, mobile, switch solutions software and electronic payments services for over 200 institutional clients in 40 countries and valued at US $ 50 million. The Kenyan Digital Entrepreneurship Ecosystem is already diversified (see Box 3.5) and is considered as a model of balanced digital entrepreneurship development.

Box 3.5: Kenya's Digital Entrepreneurship Ecosystem and Strengthening the Economy's International Competitiveness

[21] See about the mission of the fully vertically integrated media and telecoms company Wananchi Group; Web Access: http://wananchi.com/

The Kenyan Digital Entrepreneurship Ecosystem (KDES) comprises mobile operators, incubators and accelerators, funding agencies (private equity funds, commercial banks, commercial venture capital funds, impact venture capital funds), hubs, networks and community spaces (HNCSs), research and training institutions, government agencies, professional services, events and media agencies, development organizations being active in this field, and (mostly large) ICT corporations. There are opportunities to deepen and to broaden the ecosystem and so to increase the role of the digital entrepreneurs for all economic sectors and for structural transformation in Kenya. This may lead to more innovation and to the spread of new digital and services-offering enterprises; technological capabilities are increased country-wide. The employment creation potential of digital entrepreneurship is therefore considered as huge.

However, only few start-ups in the ICT sector have in Kenya managed to secure stable partnerships with mobile operators, although the mobile operators cooperate with digital entrepreneurs through mobile application (app) stores, toolkits and other support mechanisms. Start-ups need more professionalization and more advanced skills. There is a lack of trust on the side of small digital entrepreneurs towards the mobile operators; they are hesitant to share with them ideas freely. Mobile operators and digital entrepreneurs can cooperate on a mutually beneficial basis; new combinations of mobile technology and digital services are of advantage for both partners. Digital entrepreneurs can also help mobile operators to scale digital services to impact all sectors of Kenya – from supply chains to small businesses and school-age children.

Venture capital funds are not active at early stages of start-ups, and so capital is available only at later stages of the start-ups. Lack of capital is mentioned as a main barrier of growth. Lack of venture capital at early stages of a start-up and lack of confidence in the teams of digital enterprises at later stages require new forms of support. The mentorship by business angels and angel networks is important to help in financing at early and later stages of digital enterprises. There are however gaps in Kenya with regard of technology-focused business angels and angel networks. Competitions and grants lead to a type of "compepreneurs" who are competing for the prize money,

but they are too often not interested in offering scalable business ideas but are presenting "cool and trendy" mobile applications. Thereby a distracting environment is created and affects the mass of digital entrepreneurs. Cooperation in the whole digital entrepreneurship ecosystem needs to be strengthened, and it needs to be built around coherent ICT, STI, digital transformation and development strategies.

Source: GSMA 2014; see also the collection of essays on Digital Kenya: https://www.researchgate.net/publication/299469062_Digital_Kenya_An_Entrepreneurial_Revolution_in_the_Making

Although this is an impressive achievement, a myriad of financial, commercial and technical challenges prevents most of the digital entrepreneurs from scaling and realising the full potential of their business ventures (GSMA 2014, p. 2). Recommendations refer to the major groups of organisations and to various functional areas in the Kenyan digital entrepreneurship ecosystem. It is necessary to look at entrepreneurship development programmes more broadly to strengthen technological, ICT and innovation capabilities in Africa (see box 3.6).

Box 3.6: Entrepreneurship Development Programmes and Building of Technological Capabilities in Africa

Entrepreneurship Development Programmes (EDPs) play a role in stimulating the growth of African start-ups and the growth of African enterprises, but these programmes can also have an impact on structural transformation and the building of technological capabilities in various sectors. Such programmes range from the support of innovation hubs to education, training and skills development programmes, management and leadership academies, specific action programmes, and prize award competitions.

Innovation hubs in Africa are of different provenience; they are either publicly or privately or jointly managed. They range from small, privately run entities to university-sponsored incubators and to large, government-sponsored research clusters, such as the Smart Village Cairo. The *Global Innovation through Science and Technology (GIST) Initiative*, a collaborative effort between the US Department of State and CRDF Global intends to facilitate the building of entrepreneurial ecosystems in 54 countries across the Middle East, Turkey, Asia, and Africa. Each year GIST holds the *Tech-I Competition* and finalists are invited to attend the *Global Entrepreneurship Summit* where they receive skills training, mentorship, and networking opportunities as well as competing for USD 70,000 in funding. The *Entrepreneurship and Innovation Programme (EIP)*, established by the American University of Cairo, includes elements such as training, boot camps, mentorship, and business plan competitions, and has so far graduated more than 4,000 people from across Egypt, and in December 2013 the programme will officially launch an incubator space. The *African Leadership Academy (ALA)* was started in 2004 in South Africa by a Ghanaian biotech entrepreneur to improve the quality of leaders in Africa through training and networking. In 2010 the *African Leadership Network (ALN)* was established, based partly on the TED (Technology, Entertainment, and Design) lecture series. The *Omidyar Network*, an international philanthropic investment firm, has also provided funding for ALN. The *Omidyar Network* launched the *Accelerating Entrepreneurship in Africa Initiative* in 2012, a project in collaboration with the Monitor Group, which was founded in 1983 by six entrepreneurs with ties to the Harvard Business School, including Michael Porter, Mark Fuller, and others. It is the purpose of the *Accelerating Entrepreneurship in Africa Initiative* to better understand the state of entrepreneurship in Africa. *VC4Africa* is a network dedicated to helping African entrepreneurs to access more tangible resources through their online platform. They focus on both connecting entrepreneurs with mentors and helping start-ups to access funding through crowdfunding. The *MIT Africa Business Conference* is the flagship event of the *Africa Business Club at MIT Sloan School of Management* that attracts over 400 participants annually. The conference focusses on entrepreneurship and innovation in Africa and organizes panels on entrepreneurship, agriculture, finance, infrastructure, mobile and telecommunications along with talks by Africa-focused entrepreneurs and business leaders, and there is also a business plan competition. The *Global Business Labs*

(GBL) initiative, run by the Stockholm School of Economics, has developed partnerships with universities in Botswana, Namibia and Uganda and has several partnerships in other countries in the making. Based on a successful model which was developed, the *GBL initiative* establishes incubators on or near the business facilities of a university.

Such entrepreneurship development programmes however need to become more home-grown in Africa, and there is some progress recorded in this regard. However, the whole issue is under-researched; case studies are still missing.

Sources: Information on these programmes was taken from the respective websites; and see also for more homegrown entrepreneurship development programmes: https://www.researchgate.net/publication/270576617_Entrepreneurship_development_in_Africa_an_overview

As Africa continues to develop through its digital transformation in these important areas which are discussed above, several positive spill-over effects will emerge. First, the burgeoning ICT development scene is not only breeding entrepreneurs, but it is also attracting considerable attention from abroad, leading to a growth in international networks. The World Bank Report (The World Bank, 2010) with the title "Global Opportunity in IT-Based Services" suggested early that innovation hubs, with their pre-prepared spaces, internet connections and other amenities, are also places where international firms are likely to establish their subsidiaries.[22] Already in 2010 the market volume was around 500 billion US dollars, but only 30% were utilized at that time. The situation has changed since; developing countries have benefitted from global integration into IT markets. Even major multinational organizations are being attracted to invest and to establish operations in such areas. A case in point is the *Smart Village Cairo*[23]. Secondly, innovation hubs are becoming centres of training

[22] See the blog on this book: https://blogs.worldbank.org/digital-development/the-global-opportunity-in-it-based-services; The book presents the "Location Readiness Index", a diagnostic tool that may help to analyze the strengths and weaknesses in the industry. One of the main findings is that, given the right business enabling environment is there, the quality of the labor pool matters the most.

[23] Smart Village Cairo, Web Access: http://www.smart-villages.com/ and

and development, leading to increased employment as well as to increased interest in science and technology through outreach programmes with local schools.

3.3 Digital Skills, Open Innovation and Development of Local Manufacturing

One significant potential positive spill-over effect in the longer term is the rise of local manufacturing to meet local demands. An example in the USA from which to gain inspiration is *Local Motors*.[24] *Local Motors* is a collaborative, open source-based endeavour that brings together a global community of more than 30,000 car designers, engineers, fabricators and enthusiasts to design, manufacture and market their own solutions locally. Cars are designed by the global community and produced locally on demand in local factories using 3D fabrication tools and local materials and solutions. Today, *Local Motors* claims to build cars five times faster and at one hundred times less the capital costs of conventional auto manufacturers through its local micro-factories.[25] The relevance for Africa is demonstrated already, and the advantages of locating micro-factories near the African innovation hubs and internet platforms are obvious[26]. About 100 micro-factories will be built around the globe in the coming years (see Box 3.7).

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http://www.ecgsa.com/smartvillagecairo1

[24] See: https://localmotors.com/; and also: https://en.wikipedia.org/wiki/Local_Motors

[25] Greenwise Weekly, 22 May 2013, Green innovation: how Local Motors is revolutionising the way cars and bikes are designed, manufactured and sold, Web Access: http://www.greenwisebusiness.co.uk/news/green-innovation-how-local-motors-is-revolutionalising-the-way-cars-and-bikes-are-designed-manufactured-and-sold-3947.aspx, and: Autodesk, Newsroom, September 15, 2014, Autodesk and Local Motors Collaborate on First Spark 3D Platform Implementation, Web Access: https://adsknews.autodesk.com/pressrelease/autodesk-and-local-motors-collaborate-on-first-spark-3d-platform-implementation, and: https://adsknews.autodesk.com/search-results

[26] Local Motors is revolutionizing the production of cars and bikes; see from Local Motors: Honda Africa Twin by Jakusa Design, Web Access: https://localmotors.com/Jakusa/honda-africa-twin-by-jakusa-design/, and Local Motors, Micro-factory, Web Access: https://localmotors.com/microfactory/; these are new product developments, but there is already some history of "Made in Africa" cars; see: https://www.brandsouthafrica.com/investments-immigration/africa-gateway/8-african-cars-270116

Box 3.7: Local Motors, Open Source Innovation and Manufacturing Capabilities in Africa

Local Motors is the first open source car company to reach production. It is a platform combining global co-creation and local micro-manufacturing to bring hardware innovation to market at unprecedented speed. It is stated that *Local Motors* is five times faster in making cars and needs 100 times less capital than mass manufactured cars. *Local Motors* produces some designs and components themselves (chassis design), but leaves other designs and components to other manufacturers, and for details prospective customers are involved as co-creators. *Local Motors* is combining the specialist expertise of manufacturers with the motivation of prospective customers to feedback, to encourage and to vote in their favourites.

Autodesk plans to introduce Spark, a new open platform for 3D printing - to make it simpler and more reliable to print 3D models and easier to control how the model is printed. *Autodesk* cooperates with *Local Motors*, the leader in open-source hardware innovation; *Local Motors* utilizes the Spark platform to continue to develop the *Strati, the world's first 3D printed car*. The Spark platform will speed up manufacturing innovation considerably. Digital models can be more quickly turned into physical production. Spark will allow for a better transformation of ideas guided through the Design for Additive Manufacturing (DFAM) system.

The *Strati* is developed by the Local Motors team at the Department of Energy's Manufacturing Demonstration Facility (MDF) at the Oak Ridge National Laboratory (ORNL), a leading innovation centre around additive manufacturing. The *Strati* was developed jointly from entries by *Local Motor*s' global co-creation community. The *Strati* will then become the first large-scale industrial application of Spark. The *Strati* simplifies the automotive assembly and leverages the contribution of the co-creative community, of advanced manufacturing tools and of software, like the Spark platform. One of the advantages is the reduction of the number of parts in a vehicle's Bill of Materials (BOM), down from 25,000 components to less than 50. Details of

design can be continuously changed because of the on-demand nature of 3D printing.

Local Motors operates a growing global network of micro-factories around the world, from USA to Singapore to South Africa, each one operating as nexus of next generation product development. Building cars locally, as in Africa, will lead to vehicles adapted to the local climatic and physical conditions and energy sources; the production will create employment, is not capital-intensive and can use the growing ICT, entrepreneurship and skills base of the African countries. The *Local Motors* principle "harnesses a distributed knowledge network which is both hyper-local and super-global and makes a clear point of being green and sustainable."

Sources: Local Motors 2014; Greenwise Weekly, 22 May 2013; and: Autodesk, Newsroom, September 15, 2014; Web Access: https://adsknews.autodesk.com/pressrelease/autodesk-and-local-motors-collaborate-on-first-spark-3d-platform-implementation

Furthermore, one significant question that has been raised by researchers across the globe is how the 'mobility' of labour through freelancing and open source communities, together with the 'mobility' of physical goods due to 3D printing and open design, will impact the competitiveness of regions and nations.[27] These activities can be performed practically exclusively via the internet; entrepreneurs located in remote parts of Africa such as in the mountains of Namibia may develop successful international operations. Combined with the empowering influence of online collaboration across time zones and an increasing emphasis on open source and shared development among both software and hardware developers, the building blocks for impressive shared growth for African entrepreneurs in just about any industry can be put in place. To put this perspective into reality there is need for a facilitating environment in Namibia or in any other country benefitting from this type of mobility. *Local Motors* and similar micro-factory initiatives may be quite relevant for Africa, to make use of Afri-

[27] See on the impact of this 3D printing "revolution" on Africa: https://infomineo.com/additive-manufacturing-africa-middle-east/

ca's innovation and technology hubs and of the growing ICT networks and communities for technological innovation, for the building of technological capability, and for localized small-scale manufacturing. Digital transformation includes important technological trends, such as 3D printing, Open Innovation, and Industry 4.0, but also key institutional trends, such as developing digital entrepreneurship ecosystems and new generations of technology hubs; both types of trends matter also for Africa.

It is suggested that the above cases and examples only scratch the surface of the true impact of a new industrial and digital era in Africa. In the new industrial and digital era, basic assumptions are challenged and replaced by new ways of thinking and doing, and herein lies a considerable potential for Africa in the medium to long term. Thus, it is argued that the traditional means with which value creation in society has developed and been organized since the first industrial revolution, i.e., through firms and their global supply chains, may be disrupted and fundamentally changed due to these new communication and production technologies. Adjusting to such emerging changes is critical for Africa to move up the technology ladder. An environment conducive to inclusive entrepreneurship is also critical to leverage the benefits of ICTs. The GEM (Global Entrepreneurship Monitor) report 2012 (GEM 2012) presented at that time nine factors aimed at stimulating and supporting innovation and entrepreneurial activity: availability of entrepreneurial finance; government policy encouraging new and growing firms; government entrepreneurship programs; entrepreneurial education; R&D transfer between national R&D and the private sector; a commercial and legal infrastructure promoting the emergence of new firms; ease of market entry; accessible physical infrastructure both in terms of location and prices; and norms supporting entrepreneurship in society. Such an environment can be created by strengthening the National, Regional and Sectoral Innovation Systems (NISs) in African countries. The GEM reports up to 2018/19 give a lot of insights to understand better the role of entrepreneurs in times of digital transformation; myths about entrepreneurship are replaced by evidence-based knowledge, especially so for entrepreneurship development in low income countries.[28]

[28] See on the GEM reports up to 2018/19: https://www.gemconsortium.org/report

In addition to the complex bureaucracy in Africa, other major challenges for African entrepreneurs which are continuously noted are related to raising funding and conducting financial transactions. Clearly raising funding is a challenge for entrepreneurs irrespective of where they are in the world; however, while the challenge for entrepreneurs outside of Africa has often to do with the ability of convincing investors of their idea, inside Africa there are considerable structural problems that discourage or preclude financing of investment (although there are differences between countries and regions in this regard). In times of digital transformation this is a great handicap. For example, reports by iHub Research (especially iHub Research 2013, and see also iHub Research 2012) found that most of the innovation hubs surveyed faced funding problems, but also suffered from limited space, slow connectivity, and limited skills among members[29]. The list of problem-areas is longer. Also, electricity supply is a problem in some places/countries; and so powering Africa is an issue for the digital transformation.[30] Funding is a problem as venture capitalists were in the past seldom seen in Africa, and therefore getting seed funding is difficult for young start-ups. But, also in this regard the scene is changing quickly. Platforms for venture capital funding, mentoring, supporting and investing are getting stronger.[31] Solutions to the challenge of funding may lie in the rise of crowdfunding and peer-to-peer lending (debt-based crowdfunding).[32] While crowdfunding is still in its infancy in Africa, the phenomenon is gaining acceptance as the number of platforms and individuals pitching their ventures continues to grow.[33] As in the US, in Asia and in Europe, policymakers also within Africa should look over their regulations when it comes to how they may hinder or enable investors making donations to or buying equity in ventures launched on crowdfunding platforms. Also, this issue is part of an agenda to strengthen the national innovation systems (NISs) via innovative finance instruments. However, the role of financing established firms is also relevant when new regulations for crowd-

[29] See iHub Research, 2013, Draft Report On Comparative Study On Innovation Hubs Across Africa, by Duncan Gathege/Hilda Moraa, Nairobi, Kenya: iHub_Research, May 2013, Web Access: http://research.ihub.co.ke/uploads/2013/may/1367840837__923.pdf, and iHub Research, 2012, The Impact Of ICT Hubs On African Entrepreneurs, A Case Study OF IHUB (Nairobi), by Hilda Moraa/Wangechi Mwang, Nairobi, Kenya: iHub_Research 2012, Web Access: http://www.ihub.co.ke/downloads/ihub_entrepreneurs_report.pdf; see also on the collection of ihub resources: https://ihub.co.ke/resources

[30] See: https://edition.cnn.com/2015/06/19/africa/gallery/african-tech-hubs/index.html

[31] See: https://vc4a.com/

[32] See on the African Crowdfunding Association: http://africancrowd.org/about/what-is-crowdfunding/peer-to-peer-lending/

[33] Pitching means that start-ups can fascinate investors about their business ideas.

funding are discussed.

A further area attracting attention across many African countries and elsewhere relates to how women and young entrepreneurs can be trained, supported and encouraged to promote inclusiveness and to fuel economic growth. Studies indicate that despite rising numbers, only 62 percent of women are economically active (compared to 80 percent among men) in Sub-Saharan Africa, a mere 29 percent of women are economically active (compared to 74 percent among men) in Northern Africa[34], and referring to data from the GEM (GEM 2012) less than 20 percent of all entrepreneurs in Egypt are women.[35] An analysis of opportunity and necessity motives among entrepreneurs shows that men in Latin America and Sub-Saharan Africa (SSA) are more likely opportunity-motivated while women have higher necessity motives. This is interesting given that these regions have fewer differences between the sexes in terms of their Total early-stage Entrepreneurial Activity (TEA) Index, "which gauges the level of dynamic entrepreneurial activity in an economy by considering the incidence of start-up businesses (nascent entrepreneurs) and new firms (up to 3.5 years old) in the adult population (i.e. individuals aged 18–64 years)".[36] In other words, although relatively more women participate in entrepreneurship in these regions, they do so out of necessity, which contrasts with Asia where women are more opportunity-driven than men. This has also to do with the role of women entrepreneurs in the emerging African middle class; while women have positions in the lower ranks of Africa's middle class, men are present at higher income levels of Africa's middle class (Akinkugbe/Wohlmuth 2016).

Young entrepreneurs also hold promise for development as they may have fresh ideas, a higher level of risk tolerance, and as they are generally more technology-savvy. Worthy to mention here is the extremely fast-paced population growth of some coun-

[34] UN-DESA/United Nations, Department of Economic and Social Affairs, 2010, The World's Women 2010, Trends and Statistics, New York: United Nations 2010; Web Access: http://unstats.un.org/unsd/demographic/products/Worldswomen/WW_full%20report_BW.pdf

[35] This situation may have changed a bit, as most recent GEM reports up to 2018/2019 reveal, but the progress is limited.

[36] GEM/Global Entrepreneurship Monitor 2012 Global Report, p. 14, Web Access: http://gemconsortium.org/docs/download/2645

tries in Africa. For example, while Tanzania had 34 million people in 2000, in 2013 it now has around 45 million people, and it is predicted to grow to 100 million by 2040 and to 276 million by 2100, reaching the current population figure of the US.[37] In such a situation youth entrepreneurship can only have a quite small direct contribution to solve the unemployment problem in Africa. To solve potential issues of unemployment and resulting societal instability due to such a rapid increase, policymakers need to develop and implement policies encouraging youths to start businesses with high employee growth expectations. The contribution to solve the youth unemployment problem may be very limited, but in the context of the digital transformation there is an effect. Clearly innovation hubs and incubators are one solution to this severe problem; however, they should be combined with mentoring activities in which mentors with more experience, networks and credibility can facilitate the development of young entrepreneurs. One area that is of critical importance is the digitization of goods, as more and more industries go beyond e-commerce of physical goods to digitization of virtual goods (music, movies, books, games, software, etc.). Governments in Africa need to investigate the ramifications of the sale and distribution of virtual goods and 3D printing designs across geographical boundaries. Also, for Africa these trends have favourable employment and entrepreneurship perspectives, especially so for youths. Digital transformation can contribute to solving the unemployment problem, but only in the context of a holistic and inclusive development process and based on coherent and comprehensive social protection and transfer systems.

One of the major issues related to entrepreneurial and other commercial activity through the internet is the control over and the appropriation of returns from one's value-creation efforts. The regulatory system which was developed for the production and trade of physical goods within and across countries with their own national currencies needs to be reconstructed. Issues related to intellectual property and copy-

[37] The Washington Post, July 16, 2013, The amazing, surprising, Africa-driven demographic future of the Earth, in 9 charts, by Max Fisher, Web Access: http://www.washingtonpost.com/blogs/worldviews/wp/2013/07/16/the-amazing-surprising-africa-driven-demographic-future-of-the-earth-in-9-charts/; new evidence confirms these trends: http://worldpopulationreview.com/continents/africa-population/.

rights will need to be revisited as the value of virtual goods and their 3D printed versions in the global economy increases. Value creation through open innovation has increasingly implications for production, trade, investment and intellectual property in Africa. The global taxation issues related to global Internet firms have also relevance for Africa, as a source to finance entrepreneurship programmes.

The widespread global adoption of the Internet has led to the development of numerous open source (OS) communities as collective environments for technology-based entrepreneurship, innovation and knowledge creation. Until recently, open source has primarily been used within the software industry, e.g., FOSS – free and open source software, but with the advent of 3D printing, open design is now gaining momentum as well. OS software communities, such as LINUX and MySQL[38], are often used as examples of how a group of individuals across the globe can self-organize online around a shared interest and common practices to create value through sharing knowledge and information and innovating products and services. Innovation can take many forms, such as idea generation, realization, prototyping, transfer, and diffusion, and the number of open source code repositories is exploding. A code which is stored at repositories is representing not less than ideas, experiments, curiosity, and moments of inspiration. Millions of developers are sharing this knowledge globally.[39] Open innovation is a key development trend for future manufacturing (see Box 3.8). Countries like South Africa are advanced in this field, and support of small and medium enterprises (SMEs) and of start-ups has priority; South Africa has strategies to support advanced manufacturing processes, but preferably in cooperation with global partners. But, also in other African countries, like Senegal, open innovation platforms are established and are growing rapidly; Africa Open Innovation is an example; it is a start-up with a digital platform, with various fields of activities beside of open innovation.[40] Value creation through open innovation is a chance for firms in Africa, and entrepreneurship development for youths is associated with it.[41]

[38] See on the MySQL Community Downloads, Web Access: http://dev.mysql.com/downloads/
[39] See on such open source code repositories: https://github.blog/2018-11-08-100m-repos/
[40] See: https://www.crunchbase.com/organization/africa-open-innovation#section-overview
[41] See: https://blogs.thomsonreuters.com/sustainability/2018/04/17/youth-perspective-open-innovation-for-africas-future-agenda/

Box 3.8: Open Innovation, Building Technological Capabilities and African Entrepreneurship in South Africa

Open innovation (OI) is increasingly entering manufacturing and services sectors in Africa, especially so in South Africa. All these initiatives aim also at promoting SMEs and start-ups, but established firms will also benefit. South Africa-based company GridCars is producing commuter vehicles for a new vision of transportation under open innovation conditions. GridCars seeks to realise its vision by inviting partners for this venture all over the world: part suppliers, but also potential employees (like graphics artists, drafting engineers, electric and mechanical engineers, IT professionals, and production specialists). GridCars intends to produce in most countries of the world. The company is built on the principle of open innovation and applies crowdfunding and open source concepts, inviting inputs at different levels of value addition. A presentation of style variants would allow it interested partners to select among 8 present styles / style variations with each having 3 different detail levels: high**,** medium, and low, for editing the combinations in the template as outlined on the Style Control page. A wide network of sub-assembly and components manufacturers is envisaged. As the cars are built around high tech-platforms, specialist service stations and a multitude of value-added services offer wide business opportunities.

Open Innovation (OI), as defined by GridCars, refers to a set of defined processes and engagement with virtual and physical networks to discover, isolate and implement innovative ideas, technologies, products and capabilities from outside organizations to address identified problems / challenges. The central idea behind open innovation is that in a world of widely distributed knowledge, companies cannot afford to rely entirely on their own research, but should instead buy or license processes or inventions (e.g. patents) from other companies. In addition, internal inventions not being used in a firm's business should be taken outside the company (e.g., through licensing, joint ventures, spin-offs). This type of innovation has many advantages: accelerating the innovation cycle, providing faster access to new ideas, developing

new skill sets and competence, providing a worldwide R&D platform, assisting in finding new suppliers, customers, manufacturing solutions and manufacturers for specialty items, helping to manage risk, and provide technology intelligence to support strategic technology planning and investments.

Open Innovation (OI) platforms are developing rapidly all-over Southern Africa. The Research Institute for Innovation and Sustainability (RIIS), in partnership with Namibia, Zambia and Mozambique, builds an Open Innovation Regional Solution Exchange (OIRSE). This will become the first cross-border Open Innovation Solution Exchange in the region. This Open Innovation project is implemented by a collaborative partnership between The Research Institution for Innovation and Sustainability (RIIS) in South Africa, the University of Namibia (UNAM), the National Technology Business Centre (NTBC) in Zambia, and the University Eduardo Mondlane (UEM) in Mozambique; it was launched in Namibia in September 2013. The pilot project is financially supported by SAIS (the Southern African Innovation Support) programme. In 2012, as reported by RIIS, the institute has successfully implemented a similar web-based platform for The Innovation Hub in Gauteng (www.exchange.theinnovationhub.co.za). The institute as well has conducted various open innovation projects for the Technology Innovation Agency (TIA), in collaboration with Eskom, Transnet and a portfolio of international projects through NineSigma, with partners such as SAPPI and Anglo American South Africa, and has also recently launched the first Mega Challenge for Telkom in South Africa (See on this *open innovation mega challenge*: https://www.dailymaverick.co.za/article/2013-11-04-telkom-innovation-challenge-a-mega-sting-in-the-tail/#.WJ9C4X8e_hc).

The CSIR (Council for Scientific and Industrial Research) in South Africa is also launching an *open innovation platform* for developing and supporting bio-manufacturing in South Africa. A *Bio-manufacturing Industry Development Centre (BIDC)* was launched and will become a hub for open innovation in bio-manufacturing, intended to support SMEs and start-ups in the region for the development of new technologies and products (see details on BIDC: http://biomanufacturing.csir.co.za/?page_id=576). Competency is offered by BIDC

throughout the value chain (see also on recent developments of biomanufacturing through BIDC: https://researchspace.csir.co.za/dspace/handle/10204/9794).

Sources: GridCars.net 2014, Web Access: http://www.gridcars.net/, and: Research Institution for Innovation and Sustainability (RIIS) in South Africa, Web Access: www.riis.co.za, and CSIR (Council for Scientific and Industrial Research), Web Access: http://www.riis.co.za/?p=2116, and CSIR (Council for Scientific and Industrial Research), Web Access: http://www.csir.co.za/; see on NineSigma: https://www.ninesigma.com/?gclid=EAIaIQobChMI7fzJ8IWl4wIVGs13Ch0vvQ-TEAAYASAAEgIea_D_BwE; see on SAPPI's R&D: https://www.sappi.com/de/research-and-development; and see on Anglo American South Africa: https://southafrica.angloamerican.com/.

While the Internet has contributed to services innovation in a dramatic way, its potential direct link to fostering the expansion of the manufacturing sector is yet to be gauged systematically. Africa's participation in the global value creation network could be significantly enhanced by using ICTs as a dynamic force. Open innovation (OI) is feasible in a virtual world, and it is relevant for Africa's manufacturing sector in the new industrial era. It is important to identify viable avenues of dovetailing new ideas and knowledge with the aim of commercializing those ideas to the benefit of Africa. Open Innovation is a further chance to leapfrog in technology. South Africa is advanced in this field of digital transformation and has regional and global networks over the total value chain in manufacturing and services sectors.

4 Conclusions

In this study, Africa's technological heterogeneity is considered and a strategy for structural change as based on technological capabilities is presented. The major global techno-economic changes are analysed to see how Africa is affected, and the purpose is to derive conclusions on the task of building technological capabilities in Africa.

Africa's progress with regard of digital skills, the entrepreneurship base for it, and the implications for building technological capabilities in Africa are reviewed, focussing strongly on the role of digital entrepreneurship for the building of technological capabilities. The study is about the progress of digital transformation in Africa; knowing more about the progress helps to transform the industrial strategies, the industrial policies and ways of strengthening the national innovation systems (NISs). The study proposes new strategies to adapt to the challenges and opportunities of the digital transformation; in this context technological trends and country experiences are evaluated to promote structural change, to strengthen technological capabilities, to increase economic complexity, and to advance manufacturing technologies and policies in Africa. Participating in the global digital transformation process is a formidable task for African countries, and the study shows that there are many avenues to support such strategies. The impacts on labour and skills may be huge, as the digital transformation changes the labour relations and the employment prospects fundamentally. The many examples presented show also that homegrown solutions are important for inclusive development strategies.

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