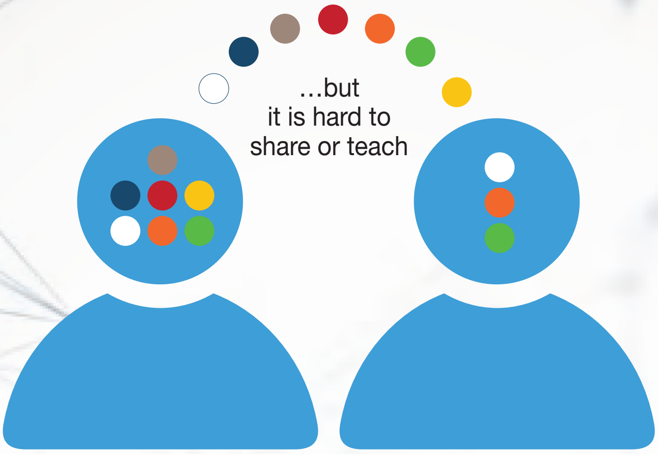
CHAPTER 4

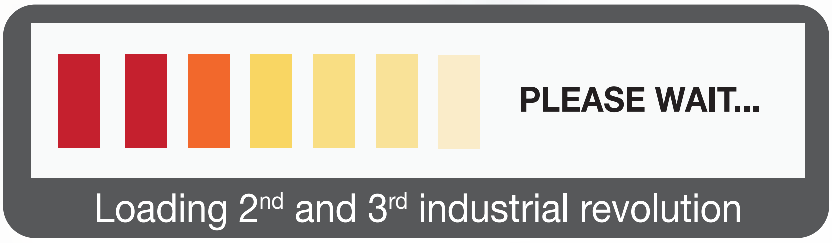
Transition to the digital economy: technological capabilities as drivers of productivity

Tacit knowledge
is a critical component of
technological capabilities

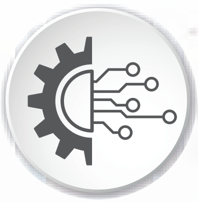


It resides in firms' employees

With limited industrialization,
LDCs struggle to leverage
the digital 4th industrial revolution



Technological capabilities
acquisition by firms
is not automatic



PROMOTE UPGRADING

INCENTIVES

- Scale in operations
- High value segments in supply chains
- Past accumulation of production capabilities and tacit knowledge

FOSTER INERTIA

DISINCENTIVES

- Low value segments in supply chain
- Lack of investment capital
- Need for specialized and matching human and capital assets
- Poor trade facilitation infrastructure

CHAPTER 4

Transition to the digital economy: technological capabilities as drivers of productivity

A. Introduction

Technological capabilities are an indispensable component of the productive capacities needed by economies to climb up the economic development ladder. This chapter examines the technological capabilities that LDC firms need to engage with, in particular the digital technologies of the Fourth Industrial Revolution (4IR technologies), and the digital connectivity at the heart of these technologies. It also covers the role of public policies in helping firms to acquire the technological capabilities for their effective participation in the global digital economy.

The Sustainable Development Goals committed the international community to strive for universal and affordable access to the Internet in LDCs by 2020, as well as ensure gender parity in access to basic services, including technology, by 2030. This places the interdependence between the goals of closing the digital divide and fostering the technological capabilities for the Fourth Industrial Revolution (4IR) squarely on the international and national development agenda of LDCs.

Digital technologies underpin ever greater swathes of transactions and the digital economy is increasingly inseparable from the functioning of the economy as a whole (UNCTAD, 2019a). LDCs have enhanced their investments in core traditional and ICT infrastructure to strengthen the industrial base of their economies. Some have chosen areas where there may be quick wins to be realized from digitalization – e-commerce can be considered as low-hanging fruit for LDCs to benefit from digitalization (UNCTAD, 2019a). However, because e-commerce mainly covers the trade and market exchange aspects of the economy, it constitutes an inadequate basis to capture the policy implications of the diverse changes that a digital economy implies for productive activity and the behaviour of economic actors. Therefore, it is essential to address the broader attributes and aptitudes which firms must have to build and maintain their competitiveness in the digital economy. Technological capabilities are at the heart of these attributes and aptitudes and assume prerequisite status for building and maintaining long-term competitiveness.

It is critical that development policies take account of national and regional strategies which support and incentivize investment in the acquisition of tangible and intangible technological capabilities. Some estimates suggest that firms with traditional business models and technologies in LDCs may still have a shelf life of two to three decades (Akileswaran and Hutchinson, 2019) if they don't adopt new technologies; however, policymakers need to act sooner rather than later. This is evidenced by the already apparent trend of a widening digital divide between and within countries. UNCTAD research on the changing digital landscape since the great financial crisis of 2008–2009 reveals that, while the COVID-19 crisis has accelerated the uptake of digital solutions and gave a solid boost to the global transition to a digital economy, it has nonetheless also exposed the existing chasm between the connected and the unconnected (UNCTAD, 2020d), and facilitated the entrenchment of the market power of already dominant players, especially digital frontrunners, across various industries in global markets. The literature also highlights a widening performance divide between more and less productive firms that might be driven by digitalization (OECD, 2019).

Digital economy policy implications surpass promoting e-commerce

The findings of Rapid eTrade Readiness Assessments undertaken by UNCTAD in 24 LDCs show that in addition to deficiencies in infrastructure and related access problems, LDC firms face significant gaps in relevant skills and capabilities. The assessments also reveal that traditional programmes of support to small and medium-sized enterprises (SMEs), e.g. through loan programmes and trade shows, are unlikely to be effective in addressing these issues.

Compelling claims about the unprecedented opportunities digital technologies represent currently dominate the normative discourse on sustainable development. These claims possess intuitive appeal and are fuelling technological optimism[1] across a variety of economic and social sectors, and also extending into the sphere of development cooperation. The optimism hinges on two central predictions about the impact of 4IR in contexts of LDCs: (i) the predicted ability of these new technologies to induce the creation of new business models and value propositions that stimulate inclusive growth; and (ii) the potential of latecomer countries, such as LDCs, to leapfrog development. Through a review of the current state of knowledge on the process of technological capabilities acquisition and evolution, and selected case studies on 4IR technology adoption in LDCs, this chapter sets out to critically assess how these two predictions fare in reality, and

[1] https://www.weforum.org/agenda/2019/09/why-the-4ir-is-a-fast-track-to-african-prosperity/ accessed 4 June 2020.

the lessons that can be learnt. The chapter builds a picture of some of the technological capabilities needed by firms to adopt and effectively utilize these technologies by specifically focussing on capabilities of relevance to the agriculture, manufacturing and services sectors.

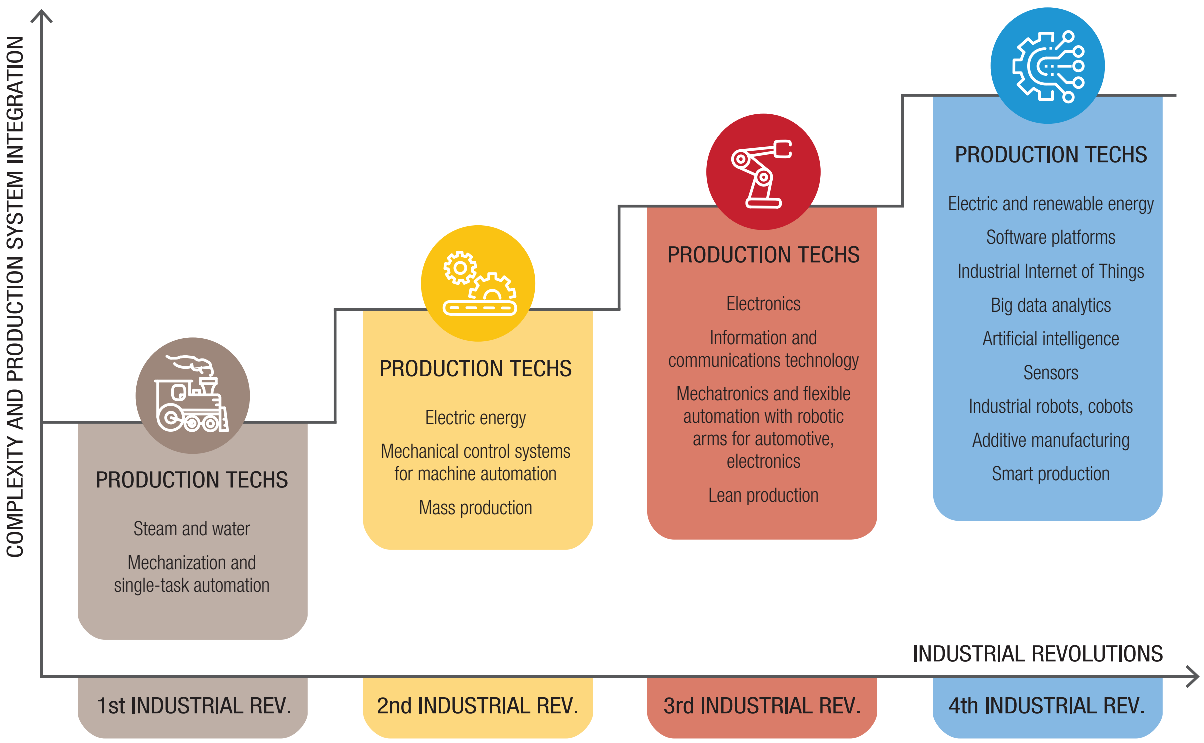
1. Legacy and digital technologies: interdependencies and critical links

The emergence of advanced and interdependent technologies underpinning the digital economy is a source of disruptive change to the functioning of the world economy and has impacted the landscape of international trade. LDCs are admittedly not at the epicentre of this evolution and remain far from the technological frontier but their economies are inextricably linked to these developments because globalization has cemented interdependencies between economies. The deployment of advanced technologies across the world will shape LDCs' prospects for structural transformation, be it directly through their own choice to develop productive capacities, or indirectly through the impact on them of the actions of their competitors and/or trade partners. In international markets driven by global value chains (GVCs), these trends are typically mediated by lead firms and influence the relative competitiveness of participating LDCs. In domestic markets, these trends have the potential to reconfigure the complex network of intra- and intersectoral linkages underpinning the creation of value and the appropriation and retention of value along supply chains.

Development trajectories are also path-dependant, and entailing successive industrial revolutions built on technology adoptions introduced in preceding revolutions. According to UNIDO, the majority of low- and middle-income countries, including LDCs, are clustered in the first and second industrial revolutions. Their economies are characterized by limited production bases and low technological adoption. Most LDCs struggle with the application of second and third industrial revolution technologies. These economies potentially face the most severe challenges in absorbing 4IR technologies (UNIDO, 2019a), and remain encumbered with the challenges of facilitating the emergence of inclusive digital economies and struggling to assure the preconditions for the application of second and third revolution technologies. They are consequently at risk of being excluded from the current industrial revolution and its potential benefits of wage or productivity growth (Van Reenen, 2019).

Figure 4.1

Production technologies: From the first industrial revolution to the fourth



Source: Andreoni and Anzolin (2019); UNIDO (2019a).

There is also an interdependence between traditional and new technologies. Digital technologies offer opportunities for productivity improvements and leapfrogging; their economic and developmental impact is largely dependent on the broader status of technological upgrading and infrastructural provision in the economy. For example, many digital technologies rely on the adequate provision of hard and soft infrastructure to fully unleash their economic potential. Accordingly, access to the Internet represents a dimension of connectivity that is reliant on pre-existing technologies, such as electricity or transport infrastructure. In 2018 barely 52 per cent of the LDC population had access to electricity, imposing severe constraints on the scope for e-commerce growth. Likewise, and as underscored by various UNCTAD eTrade Readiness Assessments, inadequate regulatory frameworks and weak postal systems pose additional challenges. Moreover, leveraging 4IR technologies is often contingent on the availability of complementary end-use machinery, digital data and achieving sufficient scale to justify the fixed costs of physical and other related investments.

The advent of the digital economy has blurred the traditional distinction across economic sectors and enabled some services to assume features traditionally ascribed to manufacturing, for example enabling productivity spillovers and scale and network economies (UNCTAD, 2016; Rodrik, 2016; Nayyar et al., 2018; Hallward-Driemeier and Nayyar, 2017). Advanced digital technologies have facilitated and complemented a deepening specialization in, and expansion of, the range of tradeable services that fuels the so-called trade in tasks and the ascendance of the services sector as a source of value addition (Baldwin and Robert-Nicoud, 2014; Beverelli et al., 2017). In particular, the "servicification" of manufacturing has manifested in the increased reliance on services as inputs acquired, as activities undertaken within firms, and sold bundled with goods, or as stand-alone outputs. Manufacturing firms increasingly derive value-added from the inclusion of digital-intense services in their production processes, including through developing customer-centric business models in which value is co-created with consumers. They also progressively undertake wholesale, retail and transport services (Miroudot, 2017). A similar, albeit more incipient, process of servicification is occurring in agriculture with digital platforms (e.g. farming apps) with smart logistics and distribution services also beginning to drive productivity and diversification (Krishnan et al., 2020: 10). Patterns of structural change in LDCs (chapter 2) suggest that services segments offer limited scope for intersectoral productivity spillovers, being instead more readily associated with under-employment (UNCTAD, 2018). Such services segments fail to generate the productivity increases needed to stimulate sufficient demand for productive labour and trigger structural transformation. Against this backdrop, it is important to qualify the optimism that may be expressed for a shift to services as an alternative pathway to structural transformation for LDCs.

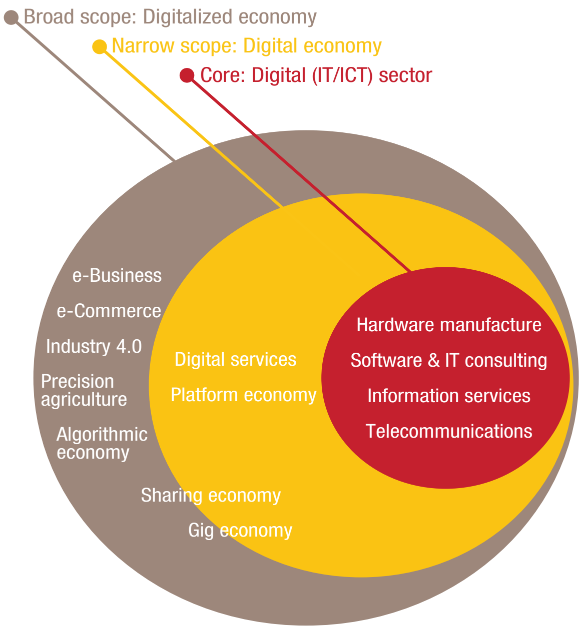
2. What makes digital firms different

The rapidly changing nature of technology creates difficulties in pinning down a definition of the digital economy (Barefoot et al., 2018). UNCTAD (UNCTAD, 2019a, 2017) adopts a broad approach that distinguishes between the core, narrow and broad scopes of the digital economy whereby the digital and information technology sectors are positioned at its core (Figure 4.2). The analysis in this chapter will address firm-level aspects of the digitalized economy encompassing precision agriculture, industry 4.0, and the algorithm-driven economy.

It is important to emphasize that access to information and communication technologies (ICTs) is an indispensable gateway to unlocking the promise of the digital economy. ICTs enable greater leverage of current systems and information; however, they complement rather than compete. Thus, firms that operate in an environment that is increasingly permeated with digital

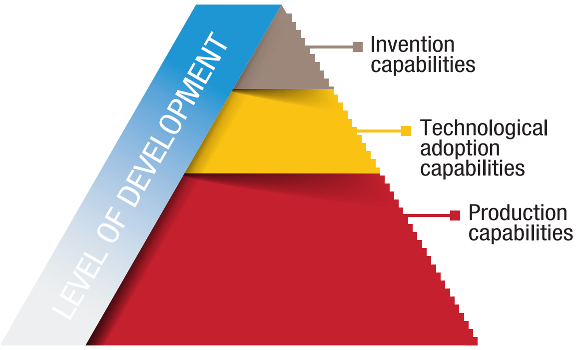
Figure 4.2

A representation of the digital economy



Source: UNCTAD (2019a).

Figure 4.3
The capabilities escalator



Source: Cirera and Maloney (2017).

technology do not automatically transform into digital firms (OECD, 2019). This gives rise to the paradoxical co-existence of rapid technological change and slow productivity growth that has been documented in developed and developing countries (Johnson, 2019; OECD, 2019). Cirera and Maloney (2017) propose a capabilities escalator which depicts the sequential nature in the process of technological capabilities acquisition, and notes the truism that firms do not naturally move by themselves up the escalator, despite proven high returns. This assertion appears to be borne out by a global survey on digital business which found that the vast majority of businesses have yet to undergo successful digital transformation (Palmer et al., 2017, 2018).

Lall (1992) argues that, over the medium-to-long term, economic growth arises from the interplay of incentives and capabilities. Thus, capabilities define the best that can be achieved, while the incentives guide the use of the capabilities and stimulate their expansion, renewal, or disappearance.

This already signals that assertions on the potential for LDCs and other developing countries (ODCs) to leapfrog development ought to be qualified. Discourses around leapfrogging appear to be especially misplaced when the process of acquisition and deployment of technological capabilities is appreciated as an incremental and path-dependant process. The signs that ICTs have added another layer of global inequality offer clear evidence of this fact and underline the need to infuse and maintain a measure of nuance in the global discourse on digital technologies and the challenge of their dormant potential in LDC contexts.

From the perspective of enterprise behaviour and capabilities, it is useful to understand the digital transition of firms as an incremental process of digitization, digitalization, and digital transformation. Digitization addresses the core of the digital economy, whereby physical data is converted into digital data using ICTs. Digitalization is the use of digital technologies and digitized data to impact how work is done (*Bloomberg*, 2018). Digitalization necessarily depends on the availability of digitized data but does not inherently result in a fundamental change to existing production systems. ICTs help firms to deliver short-term improvements, or streamline and optimize existing processes, such as fulfilling procurement needs by undertaking purchases online.

According to Savić (2019), digital transformation assumes an umbrella role, encompassing digitization and digitalization as its constituting components. Dynamic and continuous changes in production systems can be expected to be at the centre of digital transformation and the lagged emergence of productivity impacts (OECD, 2019). Accrued advantages go beyond improving operational performance and reducing costs, although at different intensities across business lines and firms, the use, collection and analysis of data is increasingly an integral part of business models. Thus, digitally transformed firms are better understood as data-driven firms making strategic decisions based on data analytics and interpretation. This data-driven approach enables such firms to develop, identify and exploit new business models and revenue streams using ICTs and digital technologies.

Achieving digital transformation is the most challenging stage of the digital transition. It requires investments in long-term growth drivers for the vast majority of firms that are not born digital. It thus carries the greatest burden of the risk that typically characterizes investments (regardless of whether for short- or long-term gain) made by firms, particularly as complementary investments in skills, organizational changes, process innovation and new systems and business models, involve a high degree of trial and error and take time (OECD, 2019). Moreover, during this time of adjustment and experimentation, productivity growth may be low and can turn negative. A related concern is the limited number of firms in LDCs with surplus investment capital available for innovation (UNCTAD, 2018; UNIDO, 2019b), particularly entrepreneurial ecosystems in these countries are dominated by capital-scarce micro and small enterprises

3. The role of technological capabilities in firms’ digital transformation

a. Defining technological capabilities

Technological capabilities are fundamental elements of productive capacities and are key to increased productivity, competitiveness and profitability for the firm. They play a central role in the integration and participation of firms and economies in industrial revolutions because they turn tangible, physical or intangible assets or resources (e.g. ICTs) into outputs of greater value. Cimoli et al. (2009) emphasize the linkages between micro-learning dynamics, economy-wide accumulation of technological capabilities and industrial development. Technological capabilities comprise that broad range of effort every enterprise undertakes to absorb and build upon knowledge utilized in production, as well as acquiring additional capabilities as an automatic result of that production process, i.e. learning by doing (Biggs et al., 1995; Cirera and Maloney, 2017; UNCTAD, 1999).

Economic literature recognizes the distinction between production capabilities that make use of existing technologies and organizational configurations to operate or maintain existing production systems and technological capabilities that enable firms to improve or develop new technologies and processes needed to realize a change in production systems (Bell and Pavitt, 1993; Cirera and Maloney, 2017; Lall, 1992; UNCTAD, 2020a). Like other technologies, 4IR technologies encompass elements of explicit[2] and tacit knowledge. The two types of knowledge are interdependent (Garcia, 2014) but the greater weight of tacit knowledge in the innovation process often underpins production systems change at the firm level. Tacit knowledge is present in individuals (employees) and firm processes, culture and values (Haldin-Herrgard, 2000). It is an invisible component of the innovation process[3] not easy to aggregate or disseminate and constitutes a source of sustainable competitive advantage (Thum-Thysen et al., 2017; UNCTAD, 1999; UNDP, 2017; Zhu, 2019). The increased reliance on intangibles is one characteristic of digitally transformed firms (OECD, 2018).

The investments of firms in technological capabilities are mediated by the entrepreneurial ecosystem, macroeconomic policy orientation and power dynamics within production chains. For example, an important aspect of firm operations in LDCs is that they have largely been driven by FDI-led integration into GVCs, and as part of national export strategies capitalizing on low cost and relatively low skill labour, as undertaking repetitive tasks requiring little in the way of technological capabilities. Such FDI seldom requires sophisticated technological capabilities; furthermore, productivity in labour-intensive services reliant on mainly low education labour cannot be readily increased through capital accumulation, innovation or economies of scale (Hallward-Driemeier and Nayyar, 2017), as the low education of employees becomes a significant barrier. Under these circumstances, the disincentives these factors can impose on investments in innovation by LDC firms cannot be overlooked.

Supply chain governance influences investment in capabilities

The governance structure of supply chains has an important bearing on decisions on technological adoption and investments in technological capabilities. The benefits from technological investment are typically unevenly distributed between lead and follower partners within GVCs; elevated risks exist when players assuming the cost and risk of investment may not be the ones who can capture the resulting value. Similarly, firms at the same or proximate stage of the chain are rivals/potential rivals. These inherent conflicts of interest between GVC partners will be magnified rather than diminished by 4IR technologies, which have more complex skill requirements and other disincentives for technology transfer (Hallward-Driemeier and Nayyar, 2017; Manyika et al., 2013; UNCTAD, 2018, 2020b). For instance, Baker and Sovacool (2017) review the public policy support for increased solar and wind technology adoption in South Africa and provide evidence that tensions can arise between the commercial priorities of multinationals and the goals of local content regulations. The same case study also highlights the role of international standards in limiting the localization of renewable energy technology capabilities to the lowest skill segment of the industry. The literature highlights the role of investments in specialized assets, such as complementary technologies, distribution channels and logistics networks, in helping firms to bridge the disjuncture between value creation and value capture that typifies GVC regimes (Sako and Zylberberg, 2019).

4. The technological capabilities firms will need

The universe of technological capabilities that will be important for firms' transition to digital status

[2] Explicit knowledge is general, conventional and easy to express and thus possible to share, codify and convert as principles, formulae, data, processes and information.

[3] The development of technological capabilities is not the same as the ability to undertake leading edge innovation. However, innovative capabilities are an important element of technological capabilities (Biggs et al., 1995; Cirera and Maloney, 2017).

Technological capabilities are interdependent

is likely to be as vast as the number of processes, procedures, product lines, business models and strategies that firms might choose to pursue to set themselves apart from their competitors. Capabilities are likely to also vary by: sector; the segment of the production network that firms are active in; and the nature of the interactions they may have with other firms in the production network. They are likely to differ also by orientation, for example, whether a firm pursues an export orientation as its main strategy. They are equally likely to be influenced by internal factors that relate to lack of access to investment capital and low staff complements, particularly in respect of micro and small enterprises that make up the majority of firms in LDCs (UNCTAD, 2018). In LDCs, factors external to the firm can impose severe impediments. It suffices to provide examples of key technological capabilities found in the growing body of literature on the digital economy of broad application to the sectors discussed in this chapter. The interdependencies between the categories of capabilities presented makes it difficult to distinguish between them and they are presented here for illustrative purposes and to enable a discussion, rather than to suggest definitional boundaries.

a. Business and managerial capabilities

Among relevant technological capabilities highlighted in the literature are a variety of organizational and managerial skills that are commonly found across all firms and sectors, namely: goal-setting; problem-solving; decision-making; recruitment; continuous training and/or reskilling of talent; identification of business domains and activities that would most benefit the firm from rapid digitization; sourcing the right technologies and defining digitization targets and identification of best-fit suppliers; tracking and identification of competitors areas of competitive advantage, etc. Cirera and Maloney (2017) identify basic managerial skills as central to the introduction of new processes, technologies, and products, noting the severe scarcity of these capabilities in developing countries. They state that few firms can articulate long-run strategic or innovation project plans. Moreover, few have human resource strategies that could support the latter. They caution policymakers against equating innovation policy to frontier science and technology policy. There is a need for sustained policy interventions to help the learning or relearning process in firms' upgrading (Biggs et al., 1995; UNCTAD, 1999).

b. Data management capabilities

Data management capabilities across all stages of information processing from data capture and data management, data transformation to data delivery can be considered primary operational capabilities and supporting capabilities (Bärenfänger et al., 2015). They include capabilities on information processing, operational business intelligence, analytics and cognitive computing (Knabke and Olbrich, 2018; Mikalef et al., 2018; Pappas et al., 2018).

c. Dynamic marketing capabilities

Dynamic marketing capabilities guide innovation and aim to meet customer needs and include a variety of skills and are impacted by ownership characteristics, entrepreneurial orientation and industry partnerships (Xu et al., 2018). Dynamic marketing capabilities call for adaptability and engagement in vigilant market learning, that enhances deep market insights with an advance warning system to anticipate market changes and unmet needs; also needed is adaptive market experimentation to continuously learns from experiments and open marketing to forges relationships with strategic partners (Day, 2011; Diyamett and Mutambla, 2014; Jiang et al., 2019; Kamasak, 2017; Whitfield et al., 2020; Xu et al., 2018). Dynamic marketing capabilities include sensing capabilities that can anticipate trends; integrating capabilities associated with new operational routines; and learning capabilities needed to revamp and adapt in response to new knowledge (Surmeier, 2020). Dynamic marketing capabilities are key for high-velocity industries and sectors that operate in dynamic international markets, such as tourism. They are relevant to GVCs and rely extensively on combined knowledge derived from global and local contexts.

The remainder of this chapter discusses six case studies of digital technology deployment in the agriculture, manufacturing and services sectors in LDCs. The case studies highlight some of the constraints posed by the lack of technological capabilities and areas where policy support will be critical to unlocking the potential of the digital economy in LDCs.

B. Agriculture[4]

1. The innovation context

Global population trends demand additional efforts to keep food production at levels consistent with population growth and environmental imperatives (FAO, 2017, 2018a, 2009). The Green Revolution yielded a quantum leap in food surplus and led to each farmer feeding about 155 people. It is estimated that for the current revolution and projected population up to 2050, one farmer will need to feed more than 265 people (EY Global, 2017). Other related pressures include more diets of meat and dairy products, and increased global demand for food, land, energy, water and resources, such as phosphate for fertilizers. Agriculture also competes with urbanization if real estate development encroaches on farm land (Abu Hatab et al., 2019; FAO, 2018b, 2017; Streatfield and Karar, 2008).

Afghanistan, Angola, Burundi, Chad, the Democratic Republic of the Congo, Gambia, Malawi, Mali, Niger, Senegal, Somalia, the United Republic of Tanzania, Uganda and Zambia (FAO, 2017) are among the LDCs experiencing the most rapid rates of population growth. Asian and African LDCs are experiencing high rates of urbanization and remain reliant on food imports. Food-insecure countries are considered ill-positioned to guarantee adequate agricultural production to meet the global food challenge (FAO and Collette, 2011; Aminetzah et al., 2020; Schmidhuber and Meyer, 2014; UNCTAD, 2013). There is also increased interest by global business in agriculture as a growth sector, and the World Bank (2008) considers that growth in agriculture is three to four times more effective in reducing poverty than growth in other sectors.

a. The smallholder challenge

The United Nations General Assembly officially declared 2019–2028 the Decade of Family Farming. This makes this segment of farmers a key target of development cooperation efforts aimed at the modernization of agriculture in LDCs and complements the designation of 2020–2030 as the Decade of

The predominance of smallholders is a common feature across LDCs

Action on the Sustainable Development Goals. Eighty percent of the farmland in sub-Saharan Africa and Asia is managed by smallholders; island LDCs and Haiti are likewise dominated by smallholders (Cayeux et al., 2017; UNCTAD, 2018).

The predominance of smallholders is a unifying profile across LDCs, as is their co-existence with usually larger commercial farmers and the predominantly rural nature of agriculture. This underpins differing abilities to use the same assets, including technology and resources in responding to market opportunities. This difference also applies within and across countries. The potential for differences between farms in scale, wealth and resources, including the influence of security of tenure status can be significant. In addition to limited technological capabilities and financial resources, heterogeneity in constraints, capabilities, resources, attitudes, priorities and cultural norms impact adoption decisions. Moreover, extension services in LDCs have been a prime target of downsizing in reforms under development cooperation programmes in the past (FAO, 2005). Smallholders[5] have an extensively documented history of low rates of technology adoption, including dis-adoption (Chandra and McNamara, 2018; Glover et al., 2019; Iiyama et al., 2018; Llewellyn and Brown, 2020; Moser and Barrett, 2003; Mukasa, 2018; Udry, 2010; Vercillo et al., 2020; Yigezu et al., 2018)

New technologies are often closely associated with the youth and strategies addressing youth employment. Such discourses often intersect

[4] Agriculture is broadly defined to include the cultivation of crops, rearing of animals, forestry and fisheries.

[5] The term “smallholder” does not have a widely accepted definition. This chapter adopts the FAO’s definition (FAO, 2012a).

with the fate of smallholders through an implied "fix" that proposes to simultaneously address the productivity challenge in agriculture by substituting (older) subsistence farmers with dynamic young and tech-savvy entrepreneurs.

b. The productivity challenge

Making agriculture more efficient alongside other sectors of the economy is a key motivation for pursuing innovation in agriculture in line with the classical paradigm of structural transformation. Smallholders are widely recognized as being less productive and profitable, and are acutely vulnerable to climate change. Agricultural productivity measured as total factor productivity (TFP) (Figure 4.4), is lower and growing more slowly in LDCs than ODCs (chapter 2). It is the long-standing preoccupation in developing countries to raise the incomes of subsistence farmers and productivity of livelihoods. Eighty percent of production increases in developing countries are projected by the Food and Agriculture Organization of the United Nations (FAO) to come from increases in yields and cropping intensity (FAO, 2009).

Total Factor productivity (TFP) increases if total output grows faster than total inputs. Increasing agricultural TFP is important because it results in better jobs for agricultural workers who remain in the sector while fostering a more rapid transition of workers from agriculture to industry and services, where TFP growth is expected to be higher (UNCTAD, 2015; World Bank, 2011). The reliance on productivity reflects agriculture's dependence on inherently limited natural resources like land and water (Fuglie et al., 2020).

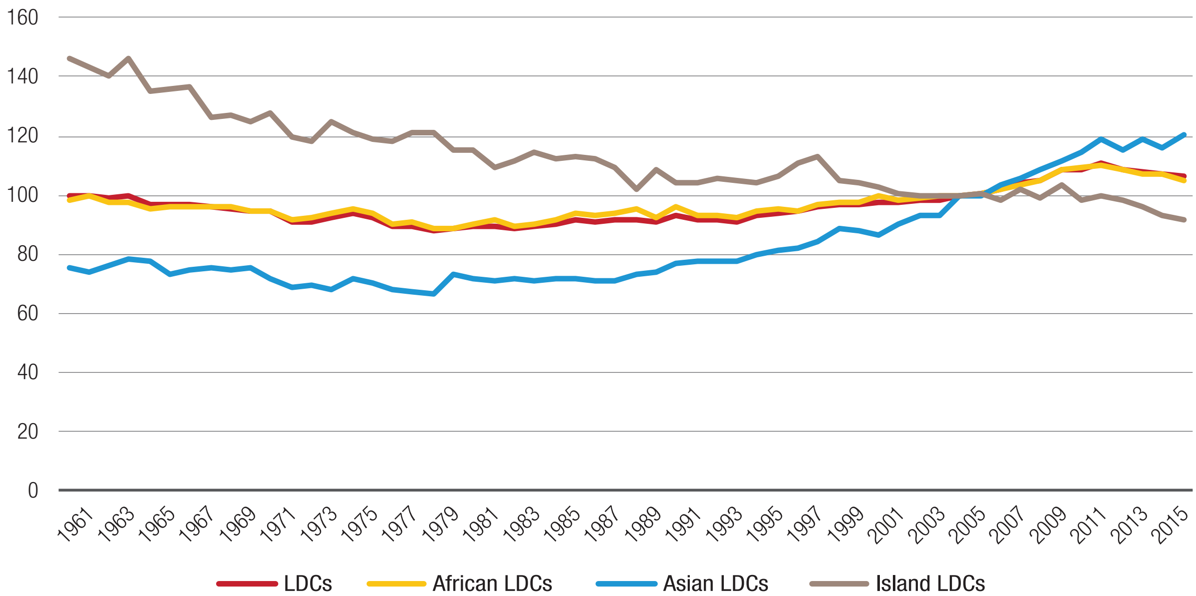
The TFP of Asian LDCs has steadily accelerated, albeit at a slower pace during the early years of the IPoA implementation and surpasses that of other LDCs. African LDCs and Haiti have experienced prolonged periods of stagnation in their TFP, which assumed a downward trend by the start of the implementation of the IPoA. The progress of TFP in island LDCs is volatile and in a general trend of decline; all of which points to LDCs embarking on the digital transformation of their agriculture sectors from different starting points.

In developing countries, women could increase yields on their farms by 20–30 per cent if they had the same access to productive resources as men (UNCTAD, 2015; FAO, 2011). Gender-sensitive deployment of digital technologies represents a double-dividend in terms of closing productivity gaps, while achieving enhanced gender equality (Box 4.1). Studies on land and agriculture in developing countries show that gender inequalities, compounded by an increased feminization of agriculture, affect rural and agricultural development. Increased feminization of agriculture has been linked to a variety of factors, including male rural out-migration, a growing number of women-headed

Figure 4.4

Agriculture Total Factor Productivity index

(2005=100)



Source: UNCTAD secretariat calculations, based on data from United States Department of Agriculture, United States Department of Agriculture database [accessed April 2020].

Box 4.1 **Digital technologies and the gender gap in agricultural productivity**

The gender gap in agriculture productivity has been widely cited and studied in the literature. The difference in agricultural productivity between men and women has been quantified for five African LDCs (Ethiopia, Malawi, Rwanda, Uganda and United Republic of Tanzania) as ranging from 11 per cent in Ethiopia to 28 per cent in Malawi. Gender differentials in the access to machinery and technology explain 8–18 per cent of the gap, driven mainly by lower cash incomes and access to finance (UN WOMEN, 2019). Using national data from the Uganda National Panel Survey for 2009–10 and 2010–11, Ali et al. (2016) estimate a productivity gap of female farming of 20–30 per cent, mainly attributable to greater burdens of childcare. Gender differentials in access to inputs such as labour supply, land, pesticides and equipment, credit, information, skills, and extension services contribute to poorer productivity outcomes in agriculture for women (Huyer, 2016; Oseni et al., 2015; Obisesan, 2014).

Digital technologies cannot solve all constraints faced by women farmers, especially not those influenced by societal norms, their societal status and those specific to the acquisition of technological capabilities. However, they could potentially increase female agricultural productivity by improving operational performance and reducing costs through providing access to digital services (e.g. financial services), market information and enhancing their agricultural knowledge. Studies on gender equality in climate-smart agriculture confirm a positive impact of higher access to ICTs in increasing yields (Mittal, 2016; Huyer, 2016). Murray et al. (2016) argue that failing to incorporate gender equality into climate change adaptation will likely increase global gender inequalities overall. Global System for Mobile Communications (GSMA) estimates that closing the gender digital gap could deliver an additional $700 billion in GDP growth, primarily through benefits from providing necessary information and support in work and education (GSMA, 2020a).

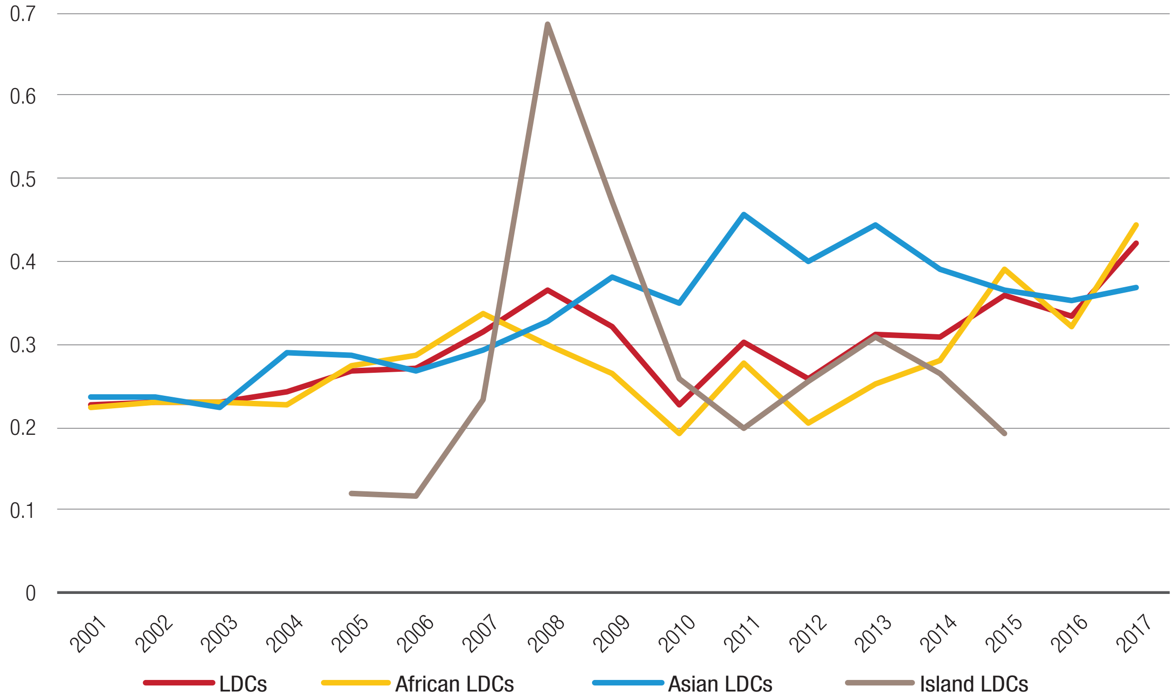
Women are often predicted to benefit more from digital solutions then men, particularly in cultures where, due to social norms, they are more confined to their homes with much less access to farmers' associations and peer information and knowledge (CTA, 2019). Examples of specific initiatives targeting women farmers in LDCs and ODCs are scarce and the availability of gender disaggregated information on agricultural digital solutions is limited. However, with most agricultural digital solutions available through mobile phone applications and the most productivity enhancing solutions often requiring a smartphone (case study 3); before women can use a mobile or smartphone, they have to own one, be able to use it, know how to read, have internet access, and have the electricity to recharge it in the first place. Despite improvements in internet network coverage in most LDCs, barriers to mobile internet services for women persist. Excluding variance due to societal specificities, the literature cites women as disproportionately affected by barriers that limit mobile technology deployment for productive uses, such as low levels of literacy, low mobile ownership and urban-rural divides in access; factors often compounded by unaffordability of technology (mobile phones) and mobile data (case study 3), low digital skills, safety and security concerns. In some contexts, women may need to secure their families' consent to own a mobile phone and in poor families, the use of a single mobile phone may be shared by several family members.

Across developing countries, women generally have lower access to ICT infrastructure, which prevents them from benefitting equally from digitalization. Many digital solutions reach less women than men. Based on country case studies conducted by CTA only 17 and 10 per cent of the registered users of Digitalisation for Agriculture (D4Ag) solutions in Ethiopia and Senegal, respectively, were women. Despite improvements from a low of 27 per cent in 2017, only 54 per cent of women in low- and middle-income countries were connected in 2019. The gap is largest in South Asia, where females are 51 per cent less likely to use mobile internet, followed by Sub-Saharan Africa with 37 per cent (GSMA, 2020a). Large variation exists between rural and urban areas. For example, the gender gap in rural Uganda is four times higher than in urban areas, and in Senegal, women are 32 per cent less likely to use mobile Internet in rural areas, as opposed to only 11 per cent less likely in urban areas. Differentials also exist in the frequency of the use of mobile Internet and in the access to sophisticated services (GSMA, 2020a; Huyer, 2016).

Rwanda provides a stark reminder of why notions of access should be nuanced as, 4G LTE coverage reached 90 per cent of the population but Internet usage remains at 8 per cent (AfterAccess, 2018). Reasons for lagging uptake vary across countries, but the majority of women polled by an AfterAccess survey stated "no access device" (10 to 77 per cent of respondents) and "do not know what Internet is" (0 to 45 per cent), rather than "no mobile coverage" (0 to 4.2 per cent). The gender gap goes beyond telecommunications coverage and the development of digital agricultural applications. Moreover, many agricultural solutions using ICTs are under way in LDCs but their full potential for closing the gender gap is yet to be realized because digital businesses often view male farmers as the "lowest-hanging fruit" (CTA, 2019). A recent study in Malawi found no gender gap in learning but suggested a gendered-gap in the perception of transmitted information (BenYishay et al., 2020). Studies also emphasize that technology itself is not sufficient, "it needs to be understood in the context of local knowledge, culture, gender relations, capacities, and ecosystems" (Huyer, 2016: 122) underlining the need for nuanced responses to the gender problems in digitalisation. This will require, as a first step, enhancing the availability of gender disaggregated data and information on literacy, access and usage of digital agricultural solutions by farmers in order to deploy tailored support to enable greater possibilities to leverage digital technologies for agricultural development. In addition, technological empowerment requires to be backed by social empowerment (Singh et al., 2019).

Figure 4.5

Agriculture orientation index on government expenditure in agriculture



Source: UNCTAD secretariat calculations, based on data from FAO, FAOstat database, URL: http://www.fao.org/faostat/en/#data/IG [accessed April 2020].

households, and the development labour-intensive cash crops (e.g. horticulture).[6]

c. Public research and development

Agriculture's dependence on inherently limited natural resources (land and water) makes it heavily dependent on productivity for growth, which in turn places a premium on agricultural research and development (R&D). The private sector typically under-invests in this area, especially for indigenous crops. In the presence of this market failure – climate change, which is a threat multiplier – public investment is assigned a specific indicator under Goal 2 (Indicator 2.a.1) and is monitored globally through the Agriculture Orientation Index. The Agriculture Orientation Index is defined as the ratio between the agriculture share of government expenditure and the agriculture value added as share of GDP.

Expenditure across all LDCs (Figure 4.5) shows vulnerability to shocks, with African LDCs and Haiti as a group showing the greatest improvement, albeit from a lower base than Asian LDCs, during the IPoA implementation. However, the index for all LDCs remains low and well below 1, which reflects the low agriculture orientation of public expenditures.

d. Farm size

Recent research suggests that there is no economically optimal agrarian structure, although some farm sizes may face productivity disadvantages depending on their country's level of economic development and circumstances (Fuglie et al., 2020). This means incentives rather than size are the main obstacles to adoption. Factors such as modern supply chains increasingly erode the productivity advantages of small farmers by creating economies of size. Size economies may also be significant in acquiring information and accessing services for farm, financial, risk, and marketing management.

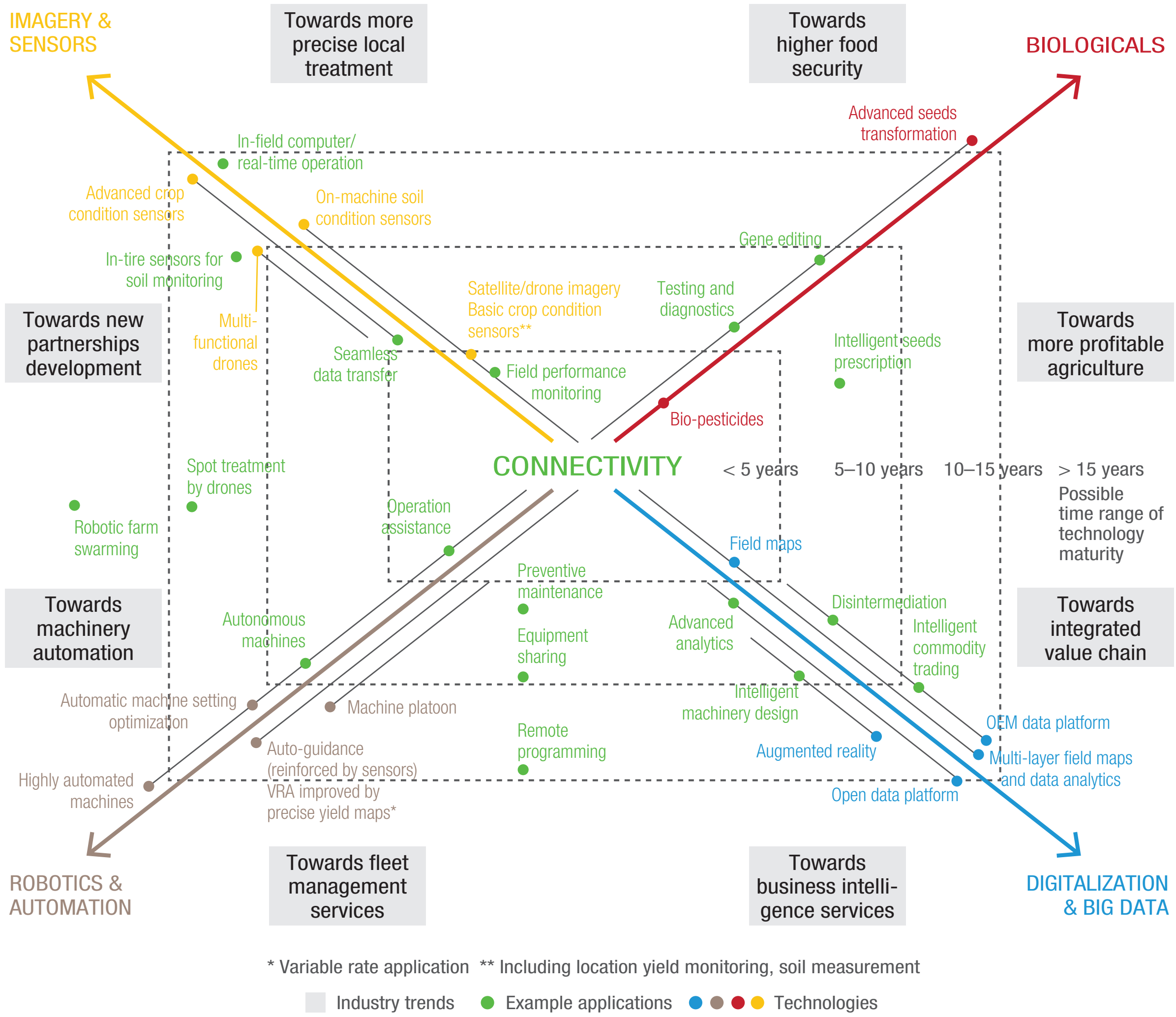
e. Introduction to agriculture 4.0 technologies

Agriculture 4.0 (Figure 4.6) technologies comprise, among others, biologicals, digitalization and big data, imagery and sensors, and robotics and automation, and have myriad applicability and interconnectivity that impacts the entire agricultural value chain from input supply to the end customer. Agriculture 4.0 has an enhanced focus on farm management tools, the internet of things (IoT) and the use of big data to drive greater business efficiencies in the face of rising populations and climate change. IoT is deployed through agricultural machinery and

[6] See for example: Behrman et al., (2011); UN WOMEN (2019); Ali et al., (2016); Akter et al., (2017); Uzoamaka et al., (2019); Murray et al., (2016); Huyer, (2016); Oseni et al., (2015); Donald et al., (2020).

Figure 4.6

Agriculture 4.0 technology map



Source: Roland Berger (2019).

gadgets, such as drones that provide imagery of field conditions, connected tractors and robots, etc. (De Clercq et al., 2018; Agricultural Transformation Consultation Team, 2019; Talavera et al., 2017; National Research Council, 1997; Chandran, 2019; Tantalaki et al., 2019). They are frequently employed as part of precision agriculture[7] (Jones et al., 2017; Mulla and Khosla, 2015; Allen, 2019; European Commission, 2017; Klerkx et al., 2019; Saiz-Rubio and Rovira-Más, 2020; Tantalaki et al., 2019; Wolfert et al., 2017). However, challenges remain given the need for local adaptation (Tantalaki et al., 2019).

[7] Precision agriculture is also known as precision farming. This farm management approach uses ICTs and a wide array of items such as GPS guidance, control systems, sensors, robotics, drones, autonomous vehicles, variable rate technology, GPS-based soil sampling, automated hardware, telematics, and software (Roland Berger, 2019).

2. Agriculture case studies

The case studies address the two central predictions concerning the impact of digital technologies outlined. This section covers three case studies. The Myanmar case study helps us to assess how far the diffusion of core ICTs have induced a significant uptake of digital technologies by farmers. Two subsequent case studies focus on specific manifestations of digitalization through the rise of mobile app- and drones-based agritech services.

a. *Case study 1: expanding access to mobile telecommunications to boost agricultural development in Myanmar*

Myanmar has gone from minimal mobile connectivity to one of the world's fastest growing mobile market. The government's 2012–2015 Framework for Economic and Social Reform set a target of

Figure 4.7

Digital agriculture use cases in Myanmar

Examples of digital tools	Digital procurement	E-Commerce	Smart farming	Information services	Weather and climate services	Digital Finance
Farmtrek	◆	◇	◇	◇	◇	◆
Golden Paddy	◆	◇	◆	◆	◆	◇
Greenway	◆	◆	◇	◆	◆	◇
Htwet Toe	◇	◇	◇	◆	◇	◆
Site Pyo	◇	◇	◇	◆	◆	◇
Tun Yat	◇	◇	◆	◇	◇	◇

Source: GSMA (2020b).

reaching 80 per cent mobile phone penetration by 2015, with a view to broadening access to rural areas, lowering transaction costs and to establish the foundations for eGovernment (Arnaudo, 2019).[8] By 2016, smartphone penetration reached 83 percent in urban areas and 75 percent in rural areas,[9] including 32 million farmers. However, Internet penetration stood at 41 per cent[10] in January 2020, notwithstanding a mobile broadband market driven by increasingly faster speeds as 4G and eventually 5G networks are rolled out (BuddeComm, 2020)

Agriculture is the logical focus of mobile value-added services for the private sector, including mobile telecommunications providers as the sector provides a livelihood to about 70 per cent of Myanmar's population, and dominated by small-scale farmers. Growth in the sector is vulnerable to climate change and extreme weather events. The ratio of extension staff to farm family is nearly 1 to 585, where an extension worker covers 5,081 acres of cropland. Productivity is low due to, among others, inadequate supply of public research and extension services; poor value chain facilities and services; low supply of certified and improved seeds; low input (fertilizer and chemicals) quality; and poor knowledge among farmers about proper fertilizer usage.[11] While the Government of Myanmar strongly encourages organic farming, farmers prefer chemical fertilizers for faster and higher yields.

8 One of the least virtually accessible points on earth after North Korea, Timor-Leste and Eritrea (Arnaudo, 2019).

9 https://www.statista.com/statistics/1063852/myanmar-smartphone-penetration-by-region/ accessed 6 July 2020. According to (GSMA, 2020b), mobile broadband connections reached 44 million or 75 per cent of total mobile connections in 2018.

10 https://datareportal.com/reports/digital-2020-myanmar accessed 6 July 2020.

11 Farmers often underapply or over apply fertilizers.

From the perspective of consumer access to Internet services, the country is considered to have leapfrogged fixed access. Fixed broadband penetration lags due to a limited number of fixed lines and the dominance of the mobile platform. Unwillingness by operators to invest in fixed broadband infrastructure (BuddeComm, 2020) means that the basis for data analytics remains low, despite the apparent exponential uptake of mobile connections. In addition, demand for electricity outpaces supply. A disparity between smartphone and digital finance penetration is apparent (Roest and Konijnendijk, 2018).

Agritech solutions are at the forefront of Myanmar's emerging digital economy. Digital agriculture solutions are predominantly smartphone apps marketed directly to farmers. Most focus on the access to services, specifically advisory services, crop price data, and weather information – relatively low complexity solutions. One start-up enables users to hire agri-machinery, however, infrastructure remains a challenge. For example, (Figure 4.7) shows the use cases of the country's most established digital value-added services in agriculture.

In terms of gender, data show that women in Myanmar are 10 percentage points less likely than men to report mobile phone or internet usage (Htun and Bock, 2017; World Bank, 2020).

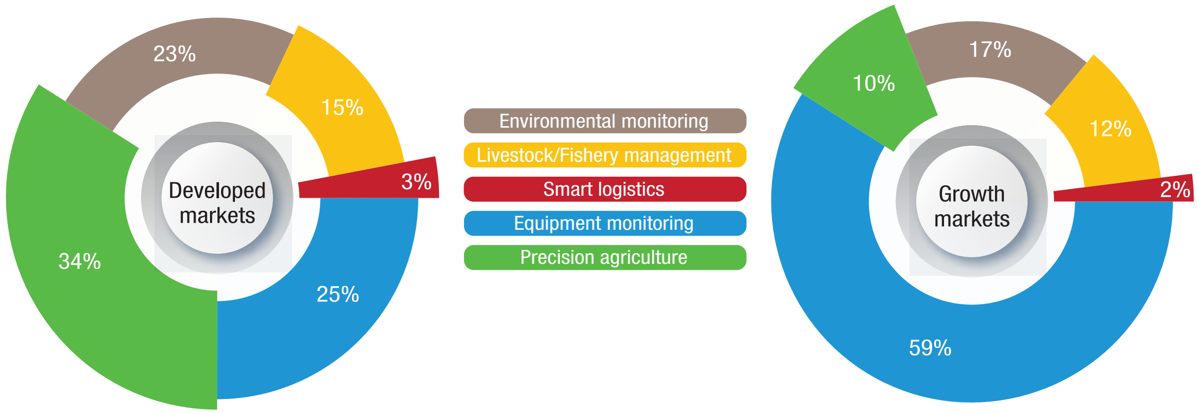
Anecdotal evidence suggests farmers limit mobile phone use to voice calls, Internet access to social networks and sending messages. Farmers also repurpose existing social media platforms to stay rather than gravitating to apps.[12]

12 Apart from the in-text references, this case study is also based on Arnaudo, (2019); Aye, (2018); BuddeComm, (2020); Devanesan, (2020); Htun and Bock, (2017); GSMA, (2020b); Roest and Konijnendijk, (2018); Sparling, (2018); USAID, (2015); World Bank, (2020).

Figure 4.8

Key M2M applications

(Percentage share in number of deployments)



Source: PwC (2017).

b. *Case study 2: LDC experience in the use of drones in agriculture*

Agriculture is a leading sector for the application of unmanned aerial vehicles (UAVs) or drones. According to FAO (2018c), agri-business is the pre-eminent sector for the civilian use of drones, thanks to innovation in areas of miniaturization, batteries, imagery and remote communications. The literature on the use of UAVs to study crops in LDC smallholder systems is still limited (Chew et al., 2020), and mostly focused on the potential of the technology or donor project achievements. Concerns linger that the technology will remain out of reach for the majority of farmers for some time to come (Chandran, 2019; European Commission, 2018a). Compared to other precision agriculture digital technologies, drones are a more recent and less mature tool. Drone data is highly contextual; satellites orbiting much farther cannot compete (Yonah et al., 2018). Globally, motivations and use cases vary considerably.

In agriculture, drones are not a stand-alone technology. To create decision-level actionable agricultural intelligence, data from drones is most useful when complemented by data from other digital technology which draws on a variety of digitized location-specific agricultural information – making the total cost of technology (including maintenance) a critical factor in farmer adoption decisions and requiring public investments in digitized agricultural information (e.g. land and soil registries).

Among more advanced developing countries where an already existing stock of farm machinery and equipment is larger, machine to machine (M2M)[13] adoption is outpacing precision agriculture (Figure 4.8).

The technical base for fully locally operated drone systems may be sufficient in certain LDCs, for example Togo[14] has a drone factory and pilot school[15] and Malawi's University of Science and Technology is implementing drone training. However, there are still a limited number of local businesses active in drones services (Knoblauch et al., 2019).

To serve as an optimized decision tool, data from drones typically requires contributions and collaborations across several technical disciplines, including agronomists, farmers, GIS experts, surveyors, aviation experts, engineers (including software engineers) (FAO, 2018c). Specialists with digital capabilities are often required to design and interpret the predictive analytics and impact models used to generate actionable intelligence (de Jesus, 2019).

Lack of certainty that a farmer can effectively translate the information into actions that guarantee increased profitability, is a constant.[16] The substantial capital investment and technical expertise to be acquired and properly utilized makes drones acquisition difficult for many small- and medium-sized farms to justify

13 Machine-to-machine communication, or M2M, is two machines "communicating," or exchanging data, without human interfacing or interaction. This includes serial connection or wireless communications in the industrial IoT.

14 https://cio-mag.com/agriculture-de-precision-un-deploiement-de-drones-a-partir-du-togo-annonce/ accessed 13 July 2020.

15 http://www.commodafrica.com/10-09-2019-le-togo-abritera-le-futur-centre-de-formation-des-pilotes-de-drones-agricoles-dafrique-de accessed 10 July 2020.

16 http://m.theindependentbd.com/printversion/details/160688 accessed 10 July 2020.

M-agriculture dominates digital agriculture solutions in LDCs

the cost and less likely to benefit from economies of scale, even in developed country contexts (European Commission, 2018a).

Inadequate infrastructure (Internet connections for real-time output and data platforms facilitating integrated software analytics), lack of regulatory capacity, lagging standards development worldwide remain major bottlenecks in LDCs. Drone regulation, albeit inadequate, exists in Bangladesh, Benin, Burkina Faso, Lao People's Democratic Republic, Madagascar, Malawi, Niger, Rwanda, Senegal, United Republic of Tanzania, Vanuatu and Zambia. Minor references are included in aviation regulations in Chad, Mali, Mauritania, Togo and Uganda. Currently, the literature points to the need for a balance between public safety and reliable commerce with underlying trade-offs between over-regulation and promoting private enterprise.

Identified challenges linked to the application of agricultural drones in LDC-specific contexts include:

- inadequate access to electricity (for charging batteries) and spare parts;
- producing maps, 3D models, and other useful data outputs requires considerable computing power; lack of specialized software and adequate computing power, or Internet and mobile data allowing rapid connectivity to access cloud-computing services hinders timely production of actionable insights;
- presenting actionable insights in a way that can be easily understood by farmers;
- intense intercropping or high diversity of crop types often limit drone capabilities; monoculture systems are easier to assess;
- sustainable in-country operations and maintenance require local capacity building and partnerships with local universities and schools of technology;
- the possession of additional knowledge and analytics tools will not bring benefits on its own because local context and local idiosyncrasies count; drone deployment is "localized-knowledge-intensive", requiring local technological capabilities.[17]

[17] Apart from the in-text references, this case study is also based on Chandran, (2019); Chew et al., (2020); de Jesus, (2019); European Commission, (2018a); FAO, (2018c); Knoblauch et al., (2019); PwC, (2017); Yonah et al., (2018).

c. *Case Study 3: The emergence of agritech entrepreneurs in LDCs*

GSMA (2016) states that mobiles offer a unique opportunity for agricultural value-added services (Agritech or Agri VAS). The market potential has been described as nearly limitless (Manhas, 2019). According to GMSA, the largest potential LDC markets for Agri VAS in 2020 are Ethiopia, Bangladesh, United Republic of Tanzania and Angola.[18] Global investments were estimated at nearly €2 billion in 2017 (Tsan et al., 2019). Investment in Africa-based start-ups remains small representing only 3–6 per cent of all tech start-up investment in 2018 (Tsan et al., 2019).

M-agriculture refers to agricultural services, technology dissemination and communication using mobile devices, such as mobile phones, laptops and other wireless enabled devices. The complexity of M-agriculture varies from low to high. Examples of low, medium and high complexity can be found in LDCs. However, there are indications in sub-Saharan Africa that entrepreneurs, users and governments' readiness for sophisticated solutions cannot match the scale of global innovation, which indicates a lack of managerial and business capabilities. Moreover, there are currently relatively limited M-agriculture employment linkages, although agri-finance is a potentially valuable area for start-ups (Chandran, 2019; GSMA, 2016; Tsan et al., 2019). However, it requires a unique set of capabilities that ICT/tech-oriented entrepreneurs usually lack (GSMA, 2020), and a lack of resources to recruit and retain talent. Unlike tech start-ups, mobile operators can scale up but they are not proficient in agriculture extension and advisory services. Partnership models underpinned by dynamic marketing capabilities between mobile operators, public agriculture organizations and institutions are emerging as a standard. The general and specific barriers linked to business models (Table 4.1) require technological capabilities to overcome. Common features and issues include:

- Digital agriculture solutions across LDCs come mainly in the form of apps (mAgriculture) that are marketed directly to farmers.
- The predominant Agri Vas use case are advisory services and information services.
- Agritech struggles to bring projects to scale, has low numbers of repeat users and most business models remaining unproven; highly

[18] Modelled potential based on the size of the rural and agricultural population and the largest growth of agricultural workers with a mobile phone between 2014 and 2020.

Table 4.1

Business model features and barriers

Business model	Key feature	Specific barriers	General barriers
Direct revenue – B2C	Smallholder farmers pay a fee to use the service	Poor rural smallholder farmers have low disposable income and, consequently, very low ability and willingness to pay High in marketing cost to drive initial uptake and maintenance costs to sustain user interest Commoditisation of information as farmers discovered cheaper information sources Strong tendency of farmers to share information amongst themselves, creating many indirect users	*Poor network coverage in rural areas where most smallholder farmers live* *Cost of ownership of mobile devices is still prohibitive for many poor rural farms* *High cost of acquiring and maintaining content, particularly in markets with underdeveloped agriculture ecosystems* *Forging agreements with critical partners, such as content providers* *Language and literacy barriers, especially in multilingual countries* *Growing involvement of women in farming activities and overall gender gap in rural areas* *Technology barriers, especially among older farmers and women in rural areas, leading to high education costs* *Forming strategic partnerships between mobile operators and third-party Agri VAS providers to ensure sufficient value creation for both parties*
Direct revenue – B2B	Agribusiness pay for farmers to access the service	Limited scope for scale in market having weak agriculture ecosystems Some mobile operators may have limited skills and experience in managing enterprise relationships Market decentralisation if agribusiness develop inhouse systems in attempt to reach farmers directly	
Direct revenue – hybrid	Agri VAS generates revenue from both smallholder farmers and enterprise customers	Creating value for both sets of customers may prove expensive, especially content development and delivery	
Indirect benefits	Mobile operator provides support for the service on expectation of increased subscriber uptake, average revenue per user appreciation from network usage and customer loyalty	Difficulty in quantifying indirect benefits to the mobile operator could negate the business case for continued support	
Subsidized model	Donors/NGOs fund the service, mainly for developmental purposes or private companies fund the service as part of corporate social responsibility effort	Continued support depends on the primary objectives of the main donor A change in the main donor's funding strategy could lead to a scaling back of operations or complete closure	

Source: GSMA (2016).

active sub-Saharan users are estimated to range 15–30 per cent.

- The high cost of mobile data services is a significant barrier to wider usage in LDCs (Figure 4.9).
- Farmers are reluctant to adopt apps for a variety of reasons, e.g. preferadvice from peers or consider variation in crop yields subject to numerous unknowns too costly to concurrently control.
- Agri Vas may appeal more to farmers of high-value horticulture.
- Agritech is heavily dependent on donor funding and has difficulty securing additional private investment funding, especially in Africa; investment in complementary infrastructure (such as farmer registries, digital agronomy data, soil mapping, pest and disease surveillance, and weather data infrastructure etc.) is lacking.
- Uptake by women farmers is low in Africa and addressing equity issues is beyond the technological capabilities of ICT/tech-based entrepreneurs.[19]

C. Manufacturing and services

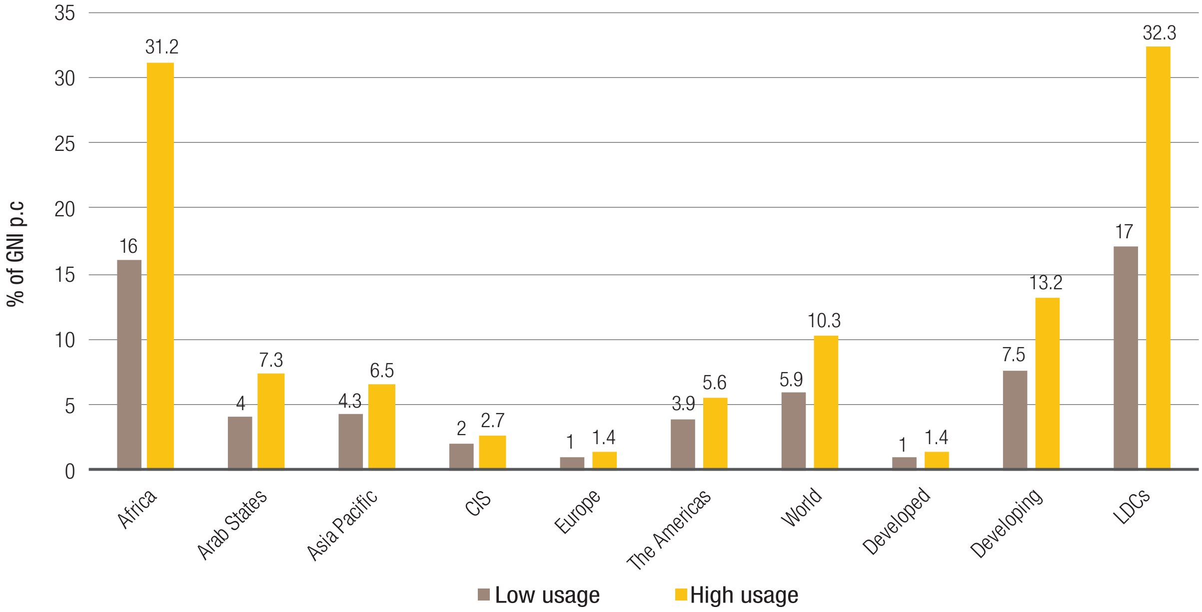
1. The innovation context

Globally the largest traded sector, manufacturing is valued for its labour absorption, higher paying jobs generating capacities and has the highest job multiplier effect on other sectors of the economy. It is also often a driver of innovation. Economic theory emphasizes the main role a robust manufacturing sector plays in sustaining long-term economic growth. Manufacturing is central to achieving Sustainable

[19] Apart from the in-text references, this case study is also based on Chandran, (2019); Baranuick, (2018); *Bloomberg.com*, (2020); Grow Asia, (2019); GSMA, (2020b, 2016); ITU, (2020); Manhas, (2019); Merriott, (2016); Thu, (2020); CTA, (2019b).

Figure 4.9

Mobile-data-and-voice basket in PPP$, 2019



Source: ITU (2020).

Development Goal 9. Target 9.2 of the same Goal aims to “significantly increase” the level of industrialization in developing countries. The ambition of LDCs is to double their share of manufacturing in GDP.

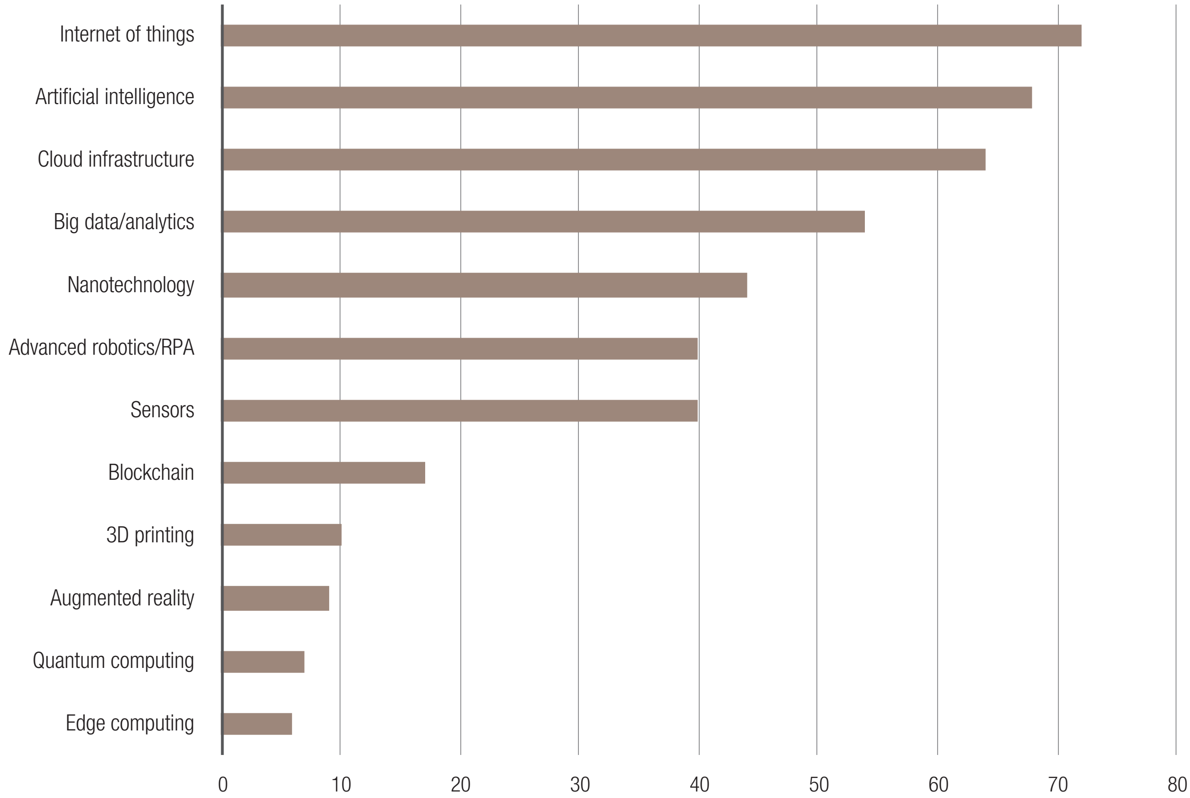
The slow appearance of high-value manufacturing sectors and concerns around premature de-industrialisation in many developing countries, lends urgency to an accelerated reset of LDC manufacturing sectors to foster competitiveness and sustainable development. Manufacturing is key to the achievement of Goal 9 and is traditionally regarded as a critical sector to foster structural transformation.

As documented in chapters 2 and 3, most LDCs have been unable to sustain long periods of industrialization, and achieve a modest integration in global markets; had they done so, they would have registered a slow expansion into higher productivity activities characterized by a re-allocation of labour largely flowing from higher to lower productivity sectors and insignificant technological spillovers across sectors. Manufacturing value added (MVA) is low, and in some cases diverging from other country groupings (UNCTAD, 2019). LDCs experienced a period of deindustrialization in the 1990s when MVA per capita decreased at an annual rate of 2.7 percent. Despite MVA per capita growth of 4.1 percent per year from 2000 to 2016, difficulties in expanding manufacturing sectors has meant that the capacity of LDCs has continued to lag other regions (UNIDO, 2019b). Burundi, Chad and Malawi industrial sectors are falling farther behind on progress towards reaching Target 9.2 (doubling the share of MVA and manufacturing employment as a percentage of total employment) (UNIDO, 2018; UNCTAD, 2020b, 2020a). On current trajectories, LDCs are unlikely to achieve these targets by 2030.

LDCs have predominantly looked to foreign direct investment (FDI) and trade strategies to industrialize and access technology, not least because of the limited size of their domestic markets and low purchasing power of their consumers. This process has been reinforced by the emergence of global value chains, and as industrial processes increasingly embrace modern information technology, traditional manufacturing and production methods are experiencing digital transformation. Digital technologies are driven by a convergence of advancements in sensors, advanced materials and robotics with digital platforms, artificial intelligence and big data analytics. 4IR technologies enable mass customization and hyper-personalization of consumption through additive manufacturing (3D-printing), production-as-a-service through digitization, and new business models (e.g. the shared and on-demand economies). Fifth-generation wireless technology (5G) is expected to revolutionize digital manufacturing as it promises ultra-fast bandwidth speeds and massive connectivity to support a wider range of devices and services and process innovations. According to a survey on business preparedness for a connected era, overall, IoT is expected to have the most profound impact

Figure 4.10

Industry 4.0 technologies by most profound impact



Source: Deloitte (2020); N=2,029.

(Figure 4.10) (Deloitte, 2020).[20] Currently, the three most significant challenges in applying industrial IoT technologies are the lack of interoperability standards, data ownership and security concerns, and under-qualified operators (Deloitte, 2017a).

Table 4.2 summarizes some of the most important pervasive and secondary technologies, including ICT, sensors, advanced materials and robotics in manufacturing. When integrated into future products and networks, these could collectively facilitate fundamental shifts in how products are designed, made, offered and ultimately used by consumers.

Additive manufacturing presents an interesting case because experimentation in LDCs is already taking place (Box 4.2), particularly in 3D printing. However, generally, 3D printing is still underdeveloped at the global level. It currently does not scale well; even as the range of printable materials is expanding. The Atlantic Council cautions that foresights that suggest monumental change is imminent are one of the fallacies surrounding 3D printing (Gadzala, 2018).

[20] For more detailed explanations on each of these technologies see (Ezrachi and Stucke, 2016; UNCTAD, 2017, 2019a; UNIDO, 2019a).

Enabling national economies and industries to take advantage of advanced manufacturing technologies like 3D printing will depend on support from governments and businesses alike to build 3D printing ecosystems by putting key elements of policies, research, education and commercialization together.

2. Manufacturing and services case studies

This section discusses three case studies. The first explores the prospects for Ethiopia's footwear industry in the light of the diffusion of 4IR technologies in the global industry. The second describes Uganda's efforts to use industrial policy to foster domestic solar vehicle manufacturing industry, thereby using renewable energy, an example of frontier technologies. The Uganda case study provides a relevant illustration of how LDCs can use an available window of opportunity to leverage industrial policy to expand their production bases using second and third industrial revolution technologies and business models. The third case study on trade and logistics provides insight on the potential of advances in supply-chain technologies for the manufacturing industry, and how this dovetails with measures to enhance trade facilitation, generally, in LDCs.

Table 4.2

Pervasive technologies and likely future impacts

Pervasive technology	Likely future impacts
ICT	Modelling and simulation integrated into all design processes, together with virtual reality tools allows complex products and processes to be assessed and optimised with analysis of new data streams.
Sensors	Integration of sensors into networks of technology will revolutionise manufacturing. Newly available data streams will: support new services; enable self-checking inventories and products; self-diagnosis of faults before failure; and reduce energy usage.
Advanced and functional materials	New materials will incorporate: reactive nanoparticles; lightweight composites; self-healing materials; carbon nanotubes; and biomaterials and 'intelligent' materials providing user feedback.
Biotechnology	Greater use of biology by industry; new disease treatment strategies; bedside manufacturing of personalised drugs; customised organ fabrication; engineered leather and meat; sustainable production of fuel and chemicals.
Sustainable/green technologies	Reduction of resources used in production; clean energy technologies; improved environmental performance of products; minimized use of hazardous substances.
Secondary technology	
Big data and knowledge-based automation	Enhance on-going automation of tasks; increased volume and detail of information captured; better understanding of customer preferences and possibilities of customised responses.
Internet of things	Business optimization; resource management; energy minimization; remote healthcare; autonomous products with embedded sensors.
Advanced and autonomous robotics	Obsolescence of routine operations in: healthcare and surgery; food preparation and cleaning; autonomous and near-autonomous vehicles; enhanced development of computer vision, sensors and remote-control algorithms; smart 3D measurement and vision to track human gestures.
Additive manufacturing (3D printing)	Essential 'tool' for waste reduction; reduction in weight; reduced inventories; flexibility in manufacturing location; product personalization; and consumer self-manufacture.
Cloud computing	Computerized manufacturing execution systems (MES) in real-time for enhanced productivity; supply chain and customer relationship management, resource and material planning.
Mobile internet	Ubiquitous smartphones for general purpose supply chain, assets, maintenance and production management; directed advertising; remote and personalised healthcare. Linking of battery technology, low energy displays, user interfaces; nano-miniaturization.

Source: UNCTAD compiled from Gadzala (2018); Deloitte (2017); Foresight (2013).

a. Case study 4: Ethiopia's footwear industry under threat from digital transformation

Ethiopia has implemented tax incentives for investment in high priority sectors, including leather and leather goods. Currently, the main investors in Ethiopia's footwear production are Chinese manufacturers. Of the 24 million pairs of shoes produced annually, only 15 percent are exported to international markets. Over 90 per cent of the exports are generated by FDI-originated plants. The bulk of production is destined for higher profitability domestic and regional markets.

Frey and Osborne (2013) estimate that up to 85 per cent of Ethiopian manufacturing may be under threat from automation, and that Ethiopia faced the inflection point between 2038 and 2042 (Banga and te Velde, 2018). The foundational requirements for advanced manufacturing, e.g. low tele- and internet-density, low broadband, etc. are not readily or currently available in Ethiopia. Low teledensity, coupled with low Internet and broadband penetration, with 4G only available in the capital, mean the foundational requirements for advanced manufacturing are absent. Ethiopia currently has the infrastructure potential to use only basic to intermediate cloud computing applications (e.g. email, web browsing and video conferencing) (Banga and te Velde, 2018). Ethiopia's industry is further challenged by unreliable electricity supply,[21] logistical bottlenecks and contraband. Investments in 5G will enable local manufacturers to run precision, high-output, and mostly automated operations but the government has yet to develop the necessary regulations; in addition, the oversupply of 4G mobile Internet, which consumers cannot afford, has left carriers on the continent worried about returns on investment.

21 https://agoa.info/news/article/15316-ethiopian-footwear-on-the-rise-includes-data.html accessed 14 June 2020.

Box 4.2 3D Printing and manufacturing in LDCs

Some LDCs are developing nascent capacity in this technology: in Togo, an inventor realized the first 3D printer created entirely from recycled electronic waste to print small objects like medical prostheses;[22] in Malawi, an entrepreneur printed plastic face masks during the COVID-19 pandemic; in Uganda, Comprehensive Rehabilitation Services Hospital partners and Canadian organizations created prosthetic limbs more efficiently; and lastly Ethiopia launched its SolveIT![23] competition to create 3D printers in 2017.

Adoption of 3D printing technology is also occurring in developing countries neighbouring African LDCs. Algeria and Nigeria acquired skills training programmes in advanced manufacturing technologies and supported innovative local entrepreneurship. The tech garage in Lagos birthed Elephab, a technological start-up initiative to locally prototype and 3D print replacement parts for various industries[24, 25]. Morocco hosts the global centre of expertise for 3D printing for the Thales Group, it has also inaugurated the Industrial Competence Centre to develop and print intricate metal parts for the aerospace sector.[26] Similarly, a public-private partnership (PPP) between Aeroswift and the Council for Scientific and Industrial Research (CSIR) in South Africa is building the world's most extensive and fastest additive manufacturing system to 3D print titanium aircraft parts from powder.[27] South Africa currently hosts 49 businesses to provide 3D printing services, including in jewellery, tooling, and prototyping consulting and design services and supply of 3D printers.[28]

The take-up of 3D printing in South-East Asian LDCs (Myanmar, Lao Democratic People’s Republic, Cambodia) is thought to be low at 1-2 per cent, and far overtaken by their developing country neighbours. Their proximity to more advanced developing countries and the role of South-South cooperation could be a critical advantage for some LDCs. Neighbours in South East Asia – Singapore, Thailand and Malaysia – are lead adopters of 3D printing, accounting for about 80 percent of the market by value. Others in the region are focused on developing related infrastructure and skills.

Sources: Gadzala (2018); AMFG (2019).

The footwear industry faces global headwinds from 3D printing, which currently accounts for 10 percent of global production but is expected to become the largest 3D printed consumer product segment, with a projected growth of $6.3 billion overall revenue opportunity over ten years (Sher, 2019). Several footwear industry leaders now use 3D printing to produce insoles for sandals, moulds and prototyping. Final parts already represent 34 per cent of all revenues associated with 3D-printed footwear parts. Much of the footwear industry’s prototyping and mould-making services are currently undertaken in Asia.

While 3D printers still generally do a poor job of handling soft, flexible materials, the threat from 3D is not trivial considering that American sportswear brand Nike has re-shored manufacturing from China, Indonesia and Viet Nam to the United States. Germany’s sportswear brand Adidas has followed suit. Both brands can access computerized knitting, robotic cutting and additive manufacturing in their home countries using automated computerized processes maintained by highly skilled workers maintained by highly skilled workers (EIU and UNDP, 2018). Should more lead firms accelerate their automation agenda, exporters such as Ethiopia would see their low-wage production undercut by European low-wage robot production (EIU and UNDP, 2018).

Assuming the 3D soft materials challenge will eventually be overcome, this may offer only temporary respite to Ethiopian and other LDC producers, e.g. Cambodia (Gadzala, 2018). In addition, for African LDCs, the future success of continental initiatives such as the African Continental Free Trade Area, (AfCFTA), Boosting Intra-African Trade and the Single African Air Transport Market. A significant regional market for Ethiopia’s low-wage footwear products will be contingent on the impact of regional competition, other African countries have begun footwear production and the global industry might continue to relocate production to countries that proactively invest in capabilities to adopt and apply 4IR technologies.

22 https://globalvoices.org/2013/12/18/made-in-togo-a-3d-printer-made-from-recycled-e-waste/.
23 http://addisstandard.com/news-local-3d-printer-solveit-2019-top-prize-winner/.
24 http://www.3ders.org/articles/20161123-ge-opens-lagos-garage-new-home-for-nigerian-3d-printing-innovation.html.
25 https://www.3ders.org/articles/20171004-nigerian-startup-elephab-aims-to-increase-local-manufacturing-with-3d-printing.html.
26 http://www.mcinet.gov.ma/en/content/thales-launches-global-centre-expertise-morocco-specializing-metal-additive-manufacturing.
27 https://3dprint.com/166672/south-africa-aeroswift-project/.
28 http://www.rapdasa.org/members/ accessed 19 July 2020.

Prepare and incentivize industry for digital transformation

A 2014 survey of 79 firms in the fashion industry (51 per cent of whom were leather and leather goods manufacturers) found that only 25 per cent possessed ISO certification, and the level of adoption of hard[29] and soft[30] process and product technologies was limited (Mekasha, 2015). Many local factories did not have a systematic approach to managing the production process and developing human capacity to ensure that machinery performs efficiently and effectively. Although some local tanneries and footwear factories in Addis Ababa have similar or identical equipment to those used in Italy, Turkey and India, deficiencies in process management, information handling, work task and workplace design and motivation has meant quality is an issue for many factories. Interactions with buyers, suppliers and other producers play a bigger role as channels through which Ethiopian firms acquire knowledge (Gebreeyesus and Mohnen, 2011), with inter-firm interactions locally still weak, despite the government's policy goal of promoting clusters.

The Ethiopian footwear industry faces near-term decisions to make on how it should prepare and incentivize its industries for digital transformation. Active engagement will require work to build robust technological capabilities. Ethiopia's education policy already focuses on digital literacy. However, while its ICT-focus supports students to be effective users of technology more needs to be done to transition students from being technology consumers to being creators. This requires the development of knowledge, skills and understandings of the underlying concepts of information systems, data and computer science that underpins the digital economy. In 2018 the University of Addis Ababa launched courses and workshops on data science and machine learning in 2018 but the focus is not on manufacturing. The prospects of Chinese investors accelerating digital transformation in the industry are uncertain. For example, while 72 per cent surveyed in China have adopted industrial IoT applications, only 46 per cent had clear-cut industrial IoT strategies and plans (Deloitte, 2017). Given the significant weight of FDI, Ethiopia could also consider reforming its investment regime to favour tax incentives for manufacturers to introduce apprenticeships and on-the-job training, including in more advanced production locations.[31] The country could also benefit from modernizing its industrial policy and developing job-creating service sectors linked to servicification (Akileswaran and Hutchinson, 2019).[32]

b. Case study 5: Uganda's Kayoola Bus initiative

Uganda's capital city is the backbone of the economy, generating over 60 per cent of its GDP. Most people in the capital, Kampala, commute by foot or low capacity transportation modes, including private vehicles. The estimated resident population is 1.5 million, with a daytime population of over 4.5 million people, leading to extreme traffic jams, massive losses in productivity and air pollution. In the past decade, at 162(µg/m3) pollution is up to six times higher than World Health Organization Air Quality Guidelines (25 µg/m3).[33] The Uganda National Environment Management Authority (NEMA), estimates that about 140,000 litres of fuel is burnt daily by idling cars, which is equivalent to almost US$134 000 worth in fuel consumption.[34]

In response, the government put in place strategies to ramp up domestic research and development established the Ministry of Science, Technology and Innovation in 2016, and tasked it with creating an enabling policy environment for STI and national development. It enacted the National Science, Technology and Innovation Policy (2009), the National Development Plan II and Vision 2040. Uganda's 2016/2017 Budget committed 30 billion Uganda Shillings (about $9 million) to support innovations and technology research. An additional $4 million was allocated to finance talented youth in the ICT sector. The government has initiated other measures to fund and support innovation and collaborative research and development, especially with the private sector. It has also leveraged the Kyoto Protocol's Clean Development Mechanism (CDM) to launch the Kiira Electric Vehicle Project.

The project evolved from staff and students' extracurricular activities at the Makerere University

29 Hard technologies are those relating to facilities, equipment, robotics and computer aided manufacturing.

30 Soft technologies are those related to management and information system such as total quality management (TQM), just in time (JIT), enterprise resource planning (ERP).

31 For example, Switzerland has concluded agreements with 13 countries outside of the EU to help develop job and language skills [https://www.swissinfo.ch/eng/apprenticeship-agreements/29274220, accessed July 2020].

32 Apart from the in-text references, this case study is also based on (Gadzala, 2018; Akileswaran and Hutchinson, 2019; Banga and te Velde, 2018; Deloitte, 2017; Frey and Osborne, 2013; Gebreeyesus and Mohnen, 2011; SmarTech, 2019; Mekasha, 2015; EIU and UNDP, 2018).

33 Exposure to contaminated air may narrow or block blood vessels. It could lead to a heart attack, chest pain, stroke, or other respiratory diseases such as asthma, chronic bronchitis, lung cancer, and pneumonia.

34 https://www.kcca.go.ug/news/316/#.XuT8Si17HOR.

College of Engineering, Design, Art and Technology (CEDAT). It grew into a national programme championing value addition in the domestic automotive industry. Kiira Motors is fully owned by the government and is funded through the Presidential Initiative on Science and Technology.[35] The project has designed and manufactured a prototype 35-seater electric bus, which relies on two lithium-ion batteries and 2-speed pneumatic shift transmission.[36] Power is supplemented by solar panels on the roof to increase the bus's range of distance up to 80 kilometres without refuelling. The Kayoola solar bus prototype cost $140,000 to produce but is projected to cost $45,000 once mass production is under way.

Kiira Motors Corporation (KMC) partnered with CHTC Motors of China to acquire technological capabilities. The partnership agreement explicitly includes requirements for technology transfer, capacity development for Ugandan engineers and practical training on bus manufacturing with a view to establishing a modernized local industry; under the agreement, CHTC is also required to supply parts that are not readily available in Uganda. These collaborative efforts are expected to foster broader development of high-tech firms, and other spin-off industries in the economy.

The floor of the bus is made of bamboo, the interior is mainly plastics and aluminium with a steel superstructure and body panels; mostly sourced locally and providing opportunities for supply chain localization. KMC is developing a comprehensive local content policy to support local participation in the automotive industry. Just over 100 local firms have been identified as potential component suppliers through the Uganda Manufacturers Association (UMA). Truck and bus manufacturing lines and a regional facility for contract assembly planned to be developed along. Strategies targeting the youth are also in place. It is envisaged that locally manufactured components and items could include automotive batteries, paints, brakes, various metal components, seats, plastic mouldings for the interior panels and fibreglass rooftops, although until local capabilities have been sufficiently developed, all components are expected to be imported.[37]

35 The initiative works through various bodies including the Uganda Industrial Research Institute (UIRI), the Uganda National Council of Science and Technology (UNCST), Makerere University Institute of Science and Technology/ Food Science, and the various research stations across the country. http://www.statehouse.go.ug/presidential-initiatives/science-and-technology

36 Kayoola Solar bus: http://kiiramotors.com/edvehicles/kayoola-solar-bus/.

37 https://www.256businessnews.com/kiira-motors-identifies-a-century-for-local-content-in-automotive-value-chain/

Forward-looking public policy has catalytic impact

It has yet to be established if the initiative has any potential or whether it can achieve scale and profitability. However, the case highlights the potential of strategic forward-looking public policy to have catalytic impact, and illustrates how systems thinking and collaborative public investments can lower risk and facilitate systemic diffusion of technological capabilities. It also establishes that innovation is present in LDC contexts and the benefits that can still be reaped by LDCs at each stage of the technology escalator.

c. Case study 6: Trade and logistics services

Effective supply chain management is a critical element in the manufacturing industry and has increasingly been elevated as an independent function. It ensures that raw materials arrive at production sites on time and that finished products are efficiently delivered to markets and consumers. Industry 4.0 induces firms and industries to rethink the design of their supply chains. Firms nowadays increasingly need to take account of trends, such as growth in trade with rural areas, pressures to reduce carbon emissions, consumer preferences for online purchases and availability of digitally skilled labour that add to the challenges that logistics face. A significant proportion of supply functions involve services activities in trade and logistics. Digital technologies can be a source of innovation in all these sectors by contributing to increased efficiency and competitiveness of supply and trade processes. Like manufacturing production processes, supply-chain management applies digital innovations (e.g. IoT, advanced robotics, analytics, and big data) to jump-start performance and customer satisfaction. According to McKinsey & Company (Bradley et al., 2020; Bughin et al., 2017; Gezgin et al., 2017), the implications for revenues, profits, and opportunities from the deployment of digital technologies in supply chain management are potentially dramatic for firms. Business and trade models driven by e-commerce also have the potential to reduce transaction costs, enhance remote goods and services delivery, and contribute to market integration. According to ITC,[38] emerging success

38 ITC (2018). What sells in e-commerce: New evidence from Asian LDCs. International Trade Center. Geneva. Online at https://www.intracen.org/publication/What-sells-in-e-commerce/.

stories in cross-border e-commerce by LDCs, including Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar and Nepal, engaging in merchandise transactions in agricultural products, food and beverages, textiles and crafts on Alibaba's B2B platform. B2C trade dominates e-commerce in other LDCs, such as Rwanda, where it is mainly dedicated to the airline, hospitality, health, banking, food delivery and courier services sectors. Similarly, in Uganda, customer-facing mobile app-enabled platforms connect customers to service providers (such as motorbike taxis) and boost the sales of many small Ugandan traders.[39]

The potential application of digital technologies to trade facilitation ranges from establishing paperless trading to enhancing the efficiency of transportation infrastructure and transportation flows, including postal services in the case of e-commerce.[40] For example, the COVID-19 pandemic has increased business to consumer (B2C) and business to business (B2B) e-commerce – it is expected that this trend will endure. At the firm level, business and trade models driven by e-commerce have the potential of reducing transaction costs, enhancing remote goods and services delivery, and contributing to market integration. The global value of e-commerce sales (B2B and B2C) reached nearly $26 trillion in 2018, accounting for 30 percent of world GDP; an annual increase of 8 per cent (UNCTAD, 2020c). The bulk of these dividends were, however, realized in developed and ODCs, not LDCs. Of economies that benefitted the least, LDCs accounted for 90 per cent.[41]

Enhancements to optimize supply chain management increasingly explain the widening disparity in profits and degrees of operational excellence in the global corporate-performance race. Digital supply chain require in-firm technological capabilities, and also at the level of the environment in which industries operate. For business, paperless trade provides a unique opportunity to reduce trade costs by streamlining information flow, and simplifying the exchange of required documents or contractual arrangements for cross-border trade in goods and services, thereby curbing cumbersome regulatory procedures. In LDCs, the private sector often battles physical infrastructure bottlenecks and lengthy custom procedures. For example, digital trade facilitation measures are estimated to reduce trade costs for businesses by up to 40 per cent in LDCs in Asia and the Pacific (Duval et al., 2018) The trade and logistic transparency and performance of LDCs will increasingly be contingent on if digitalization is effectively mainstreamed in trade facilitation reforms with the aim of enabling the efficiency of logistics systems, especially in LDCs that are, or seek to position themselves, as transit hubs.

Advanced technologies have the potential to boost trade facilitation

Advanced technologies, including drones, mobile applications and blockchain have the potential to boost cross-border trade facilitation and supply chain management.[42] For example, drones have been used for underwater inspection and port infrastructure maintenance, inspecting bridges and tunnels, and monitoring traffic. Blockchain has the potential to revolutionize the tracing of goods, their content and original source unlocking dividends in terms of customs clearance and settlement, cross-border cooperation, tax compliance and a variety of payment transactions (UNECE, 2020).

Raising the efficiency of logistics and distribution channels at the level of the economy, a key factor for economic competitiveness and integration into global and regional value chains, is critical for landlocked and coastal LDCs and is a vital complement to the internal efforts undertaken by firms to enhance their individual performance.

The digitalization of border procedures has yielded tangible outcomes across LDCs. In Senegal, automated and digitalized custom clearances, the implementation of the e-trade data platform and paperless administration system for cargo-preclearance have all contributed to significant reductions in time and costs. Registration time for custom declaration decreased from 2 days to 15 minutes, customs pre-clearance process dropped from 2 days to 7 hours, and clearance for exports and imports decreased from 14 days and

39 UNCTAD (2020. Ugandan e-commerce platforms power recovery from COVID-19 crisis. Online at https://unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2442.

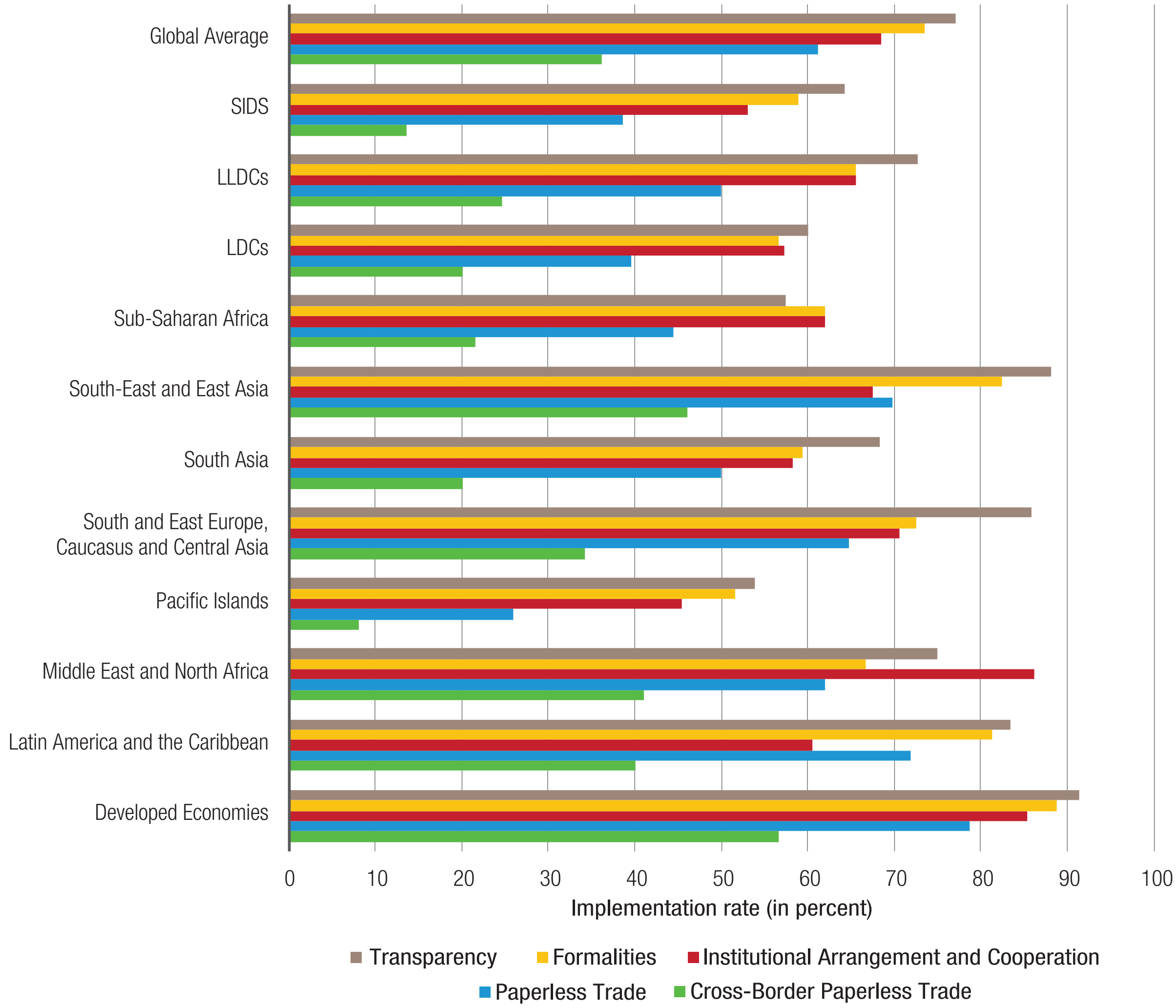
40 WEF (2017). Supply Chain and Transport Briefing. Geneva. World Economic Forum.

41 The Index is calculated as the equally weighted average of four indicators: account ownership at a financial institution or with a mobile-money-service provider (% of population above 15); Individuals using the Internet (% of population); Postal Reliability Index; and, Secure Internet servers (per 1 million people).

42 International Finance (2019). Technology uptake drives African logistics innovation. Logistics Magazine, September-October issue. Online at https://internationalfinance.com/technology-uptake-drives-african-logistics-innovation/.

Figure 4.11

Regional trade facilitation scores by dimension



Source: UNCTAD secretariat compilation, based on data from UN Global Survey on Digital and Sustainable Trade Facilitation, 2019 [accessed August 2020].

18 days to 1 day, respectively; time for removal of goods from ports decreased three to two days (UN-OHRLLS, 2017). In Eastern African Community (EAC) member countries, the implementation of electronic cargo tracking systems contributes to reduced transit time, enhanced cargo safety, and helps traders and customers to better predict the arrival of shipments, while at the same time as boosting revenue collection for customs and other trade-related authorities (Kilonzi and Kanai, 2020)). Nevertheless, the UN Global Survey on Digital and Sustainable Trade Facilitation 2019,[43] shows that LDCs lag global implementation of enhanced trade facilitation measures. LDCs implemented 20.16 per cent and 39.64 per cent of cross-border paperless trade[44] and paperless trade,[45] respectively, of measures foreseen by the WTO Trade Facilitation Agreement that came into force in 2017, compared to respective global averages of 36.15 and 62.76 per cent (Figure 4.11).

43 The UN Global Survey on Digital and Sustainable Trade Facilitation, Online at untfsurvey.org, 2019.

44 *Cross-border paperless* trade measures in the UN Survey accounts for laws and regulations for electronic transactions, paperless collection of payment from a documentary letter of credit, electronic exchange of SPS Certificate, recognized certification authority, electronic exchange of Customs declaration.

45 *Paperless trade* measures account for automated customs systems, electronic application for custom refunds, e-payment of customs duties and fees, electronic application and issuance of preferential certificate of origin, electronic submissions of air cargo manifests, internet connection available to customs and other trade control agencies, electronic single windows systems, electronic submission of customs declarations, electronic application of import and export permit.

Deep understanding of digital technologies is needed for policy decisions

With such notable successes, it might be tempting to assume that digitization is advancing well in LDCs. However, digitalizing trade facilitation is not without its challenges for them. Policymakers will need to have a thorough understanding of digital technologies to make the right investment decisions in infrastructure, technologies and appropriate regulatory frameworks/ capacity, and identify and develop talent to avoid stranded assets (both human and physical).

An UNCTAD assessment (UNCTAD, 2019b) found that the key underlying challenges in LDCs include aspects linked to the lack of technological capabilities and barriers to their acquisition, including:

- Limited awareness by policymakers, businesses and consumers of the relevance of e-commerce to their business transactions.
- Low access to and limited experience of online payments, contributing to the prominence of cash-based transactions.
- Weak institutional, legal and regulatory environments, including for consumer protection.
- Lack of digital business development skilling, especially for MSMEs.
- Pervasive barriers for women and the youth.

Supply-chain transformations at the firm and industry level encompass technology and operations, and call for appropriate and targeted investments underpinned by market intelligence and experience. Strengths in organizational culture and strategic long-term visions (intangible technological capabilities) underpin firm potential in the global corporate-performance race, as do the magnitude and the scope of digital investments, including in developing supporting talent and capabilities to build and reinforce operational agility along multiple dimensions. LDC firms are acutely disadvantaged in all respects. Moreover, with the function often located in multinational lead firms' headquarters, already severe challenges to technological capabilities transfer are further constrained in LDC firms located far from the centre of power of international production networks.

As the characteristic convergence of digital technologies in 4IR deepens and accelerates intersectoral linkages and interdependence, policymakers in LDCs will need to adopt integrated cross-cutting and coherent policy approaches to strengthen and grow the industrial bases of their respective economies.

D. Case study synthesis

Much of the literature on digital technologies in developing countries and LDCs is focused on highlighting the potential benefits and uses of these technologies. All the case studies highlight the signs of the digital economy, such as the process of e-government, roll out of e-agriculture, universal/inclusive access to the Internet and mobile phones do not signify that economic actors will automatically mobilize available technologies for productive purposes. Policy strategies for digital transformation exclusively embedded within or substituted for by ICT strategies do not necessarily offer a window into the process of transition for firms from digitization to digital transformation. They may risk missing the mark. For instance, it could be argued that the returns to the diffusion of broadband in Myanmar might have been more far-reaching if the strategy were driven by a sufficiently balanced approach to consumption and productive sector-facing considerations. Nevertheless, while highlighting the dangers of narrow technology-centric approaches and consideration of firm-level dynamics, the case study confirms that government policies and frameworks can be powerful driving forces behind digitalization. Indeed, high-level political commitment to maximizing economy-wide benefits of ICTs is not always lacking in LDCs.

While instances of farmer acquisition of frontier technologies beyond AgriVas services are hard to find, the case studies show that farmers often lack the resources to move to a higher level in exploiting the technology. Many farmers and agritech entrepreneurs do not, as yet, have the skills, access to energy or affordable broadband to take advantage of digital technologies. Moreover, Agri VAS services (Myanmar, drones and agritech case studies) confirm that in LDC contexts, conditions for profitable agritech entrepreneurship and technological capabilities development are difficult. These are limited by factors that are internal and external to entrepreneurs. Lastly, the studies highlight signs that the balance of power in agriculture supply chains and value chains can be a significant impediment to the profitability of smallholders in LDC contexts.

Agritech entrepreneurs lack the critical range of digital technological capabilities to design and effectively deliver agritech business models that deliver profitability through scale, which requires both an increasing number of farmer adopting their apps and a critical mass of repeat users. LDC agritech entrepreneurs will need to build multidisciplinary teams and find innovative business models to develop increasingly complex products. The agriculture case studies underline requirements for increased partnerships and collaboration at meso and micro level, including across multiple disciplines by, among others, breaking down silos across technical disciplines, as this is a prerequisite for appropriate and viable digital solutions. Pools of digitally skilled talent and business advisory experts and advice on better business models is needed. The current overwhelming presence of donor, private sector and NGO project-type initiatives in agritech might make it difficult to identify and address skills and capabilities gaps in a systematic and targeted way, and potentially complicates coordination and the learning of lessons (UNCTAD, 2019c).

In all of the case studies, it is clear that adequate infrastructure and related services development will be key to driving structural transformation in LDCs. The case study on services and trade facilitation shows that improvements in the enabling environment and investments by firms are interdependent. LDCs with lower transport and communication costs can stimulate and enhance returns to technological capabilities investments made by firms. Leveraging joint investments could offer advantages in this respect. For African LDCs, the advent of the AfCFTA, might offer some impetus to counter technological inertia in forms, and generate opportunities for the uptake of digital technologies, digital transformation, new business models and attract investors.

The case study on Ethiopia's footwear industry provides valuable insights on how gains from traditional industrial and export orientation policies that have served LDCs well in the past are being rendered obsolete by the digital economy. Firms in these countries will increasingly be challenged by these trends. However, the Uganda case study also shows that strategic vision and deployment of traditional industrial policies and systems thinking remains relevant in some industries; it also confirms how such policies could have a catalytic impact by lowering firms' risks through socializing the costs of technological capabilities development. In such cases, the policy initiatives facilitate the movement up the technology escalator and systematizes the impact of technological advancement at meso levels.

E. Conclusions

Innovation is occurring in different LDCs but these initiatives are currently hamstrung by a lack of technological capabilities. Still, the possibility that digital technologies uptake in some industries or sectors (e.g. retail services) might be easier, cannot be discounted. Notable example of successful cases of digital technology deployments provide encouragement but place in sharp relief key structural challenges in LDCs; they also confirm that the discourse on leapfrogging understates the magnitude of the effort in capital and human resources investments individual firms in LDCs need to make to leverage advanced technologies. Furthermore, it conceals the magnified threat of expanding new and further entrenching existing gender inequalities. More nuanced assessments are needed, especially in view of the lagged stages of technological capabilities acquisition and the complexity of 4IR technologies packaged in suites of converged technologies.

The discourse on leapfrogging understates the challenge faced by LDCs

LDCs have three concurrent opportunities to pursue. The first lies in the need to continue to consolidate on gains already achieved in raising productivity and fostering structural transformation. As illustrated by the Uganda case study, this can be achieved by strategic use of industrial policies. Studies suggest that some LDCs have the necessary breathing space for traditional business models to succeed. The second opportunity lies in the use of digital technologies, especially ICTs, to accelerate and strengthen the latter process of consolidation – e-commerce being an obvious example. The third opportunity is to actively pursue the digital transformation of firms in the economy as this process is path-dependent and takes time. The size of investments and the breadth of the public policy reconfigurations needed to support digital transformation are likely to be substantial, and in a climate of habitually constrained LDC budgets, strategic choices with a focus on long-term gains will be crucial.

Digitalization implies investments in institutional and regulatory capacity in LDCs. A successful reset of LDC sectors and economies is contingent on bolstering institutional capacity to incentivize innovation. Policy design is likely to require deep insights and understanding on digital technologies and their application across different sectors. Goals on fostering inclusivity and consumer preferences will require policy responses on technological capabilities development that are calibrated to address socio-economic, geographic, infrastructure provision and technological development at the ecosystem and firm level. The role of public extension service provision in technology adoption by rural producers is another case in point. Maintaining policy coherence will be important.

For example, appropriately calibrated education, tax, and tariff incentives are implicated in fostering firm and industry level dynamic technological capabilities investment. Maximizing the return on investments in infrastructure will require LDC governments to pay closer attention to the impact of market concentration on the affordability of access to critical ICTs services, as digitalization can raise barriers to entry in digital markets and give rise to security and privacy concerns. While consensus has not been reached on the appropriate policy responses, a sentiment that is is gaining traction is that enforcement might need to be bolder, quicker and context-specific (European Commission, 2018b; Gökce Dessemond, 2019; OECD, 2018; Sodano and Verneau, 2014; UNCTAD, 2019d).

Another area that could benefit from greater policy coherence is engagement to reap the youth dividend. Currently, development discourses tend to readily associate youth and technology, and many projects currently target youth specifically in, for instance, agritech. This could inadvertently lead to overlooking the important role of on-the-job experience in fostering tacit capabilities acquisition and raising the quality of entrepreneurship across all sectors, if it lends to a disproportionate emphasis on self-entrepreneurship as an entry point for youth in LDCs (UNCTAD, 2018). The case studies also highlight the need for LDC policymakers not to overlook the manufacturing sector as an attractive area for engagement with the youth on technology adoption.