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Propelling LDCs in the Digital Age: A 4IR Perspective for Sustainable Development

UNIDO'S 9TH MINISTERIAL CONFERENCE OF THE LEAST DEVELOPED COUNTRIES www.unido.org

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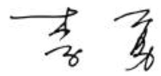
FOREWORD
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

It gives me great pleasure to introduce this background paper “Propelling LDCs in the Digital Age: A 4IR Perspective for Sustainable Development”. Least Developed Countries (LDCs) are a key priority for UNIDO, given that they make up approximately 13 per cent of the world’s population, yet account for just 1.2 per cent of global GDP. This situation strikes at the heart of UNIDO’s mission to promote inclusive and sustainable industrial development (ISID), and particularly at the overarching goal of the 2030 Agenda for Sustainable Development: poverty eradication and its agenda to leave no one behind. This goal will be unattainable without a robust strategic and policy focus, addressing the unique needs, capacities and priorities of LDCs.

Global megatrends are accelerating the need for solutions amidst a rapidly changing backdrop for industrial development, as well as the impending deadline for implementation of the 2030 Agenda. The imperative of addressing development challenges as a result of the Fourth Industrial Revolution, climate change and the COVID-19 pandemic demand urgent and bespoke solutions. It necessitates interventions to significantly increase capacities. This is critical in view of the growing digitalization process that has also drawn attention to a growing digital divide. UNIDO research estimates that just ten economies account for over 90 per cent of global patents and 70 per cent of exports linked to advanced digital production technologies. LDCs are especially vulnerable to being left behind, given their dependence on labour-intensive manufacturing. Innovative approaches to regulation, such as agile regulation and regulatory sandboxes, are often driven by actors in very different 4IR contexts.

UNIDO is mobilizing its resources to support its LDC Member States to mainstream 4IR in their national development. The upcoming United Nations Fifth Conference on the Least Developed Countries, which aims to elaborate a successor framework to the Istanbul Plan of Action (IPOA) will play an important role. UNIDO sees opportunities to leverage the power of science, technology and innovation to support the achievement of the Sustainable Development Goals, and stands ready to support the implementation of the Doha Programme of Action for LDCs for 2022-2031. To this end, the LDC Ministerial Conference will provide our Organization with a consultative platform to enhance our understanding of how we can make 4IR work for all. The Ministerial Conference will supplement our recently concluded 4IR Regional Development Dialogues to determine UNIDO’s 4IR Strategic Framework “Making the 4IR work for all”.

This document provides a number of important recommendations on the way forward. Collaborative approaches are a necessity as we seek to make progress in this area. We are thus appreciative of the cooperation of our colleagues at the Enhanced Integrated Framework (EIF) and the United Nations Technology Bank in the preparation of this document. We look forward to strengthening our cooperation, including with other relevant partners as we look towards the realization of the 2030 Agenda through the achievement of ISID.



LI Yong

FOREWORD
ENHANCED INTEGRATED FRAMEWORK

Although some least developed countries (LDCs) are on a positive developmental path towards meeting the threshold for graduation, many more remain extremely fragile. This paper presents a timely consolidation of the most important priorities that the LDCs need to take into consideration to harness the power of the 4IR. It consolidates the existing impediments and challenges in the LDCs and presents the possible routes for addressing them.

Innovation-based development will undoubtedly be critical for the LDCs over the coming decade and beyond, but a clear understanding of these rapidly evolving concepts is an important starting point for eventual development and take-off. This paper presents a much-needed overview of these increasingly conflated concepts. Equally important is a thorough appreciation of the divide between the LDCs and the rest of the world in terms of access to, affordability and application of technology, and more importantly within the LDCs. For example, when it comes to digital technology, the gender and rural-urban divides are clearly visible in the LDCs.

The LDCs are most likely to face the gravest impacts of climate change, with destructive patterns ranging from rising sea levels to desertification and extreme weather events becoming increasingly obvious. Aid for Trade (AfT) programmes, such as the EIF, must play an important role in the solution, and this paper provides us with valuable insights. The deployment of 4IR technologies can help address this urgent challenge. The paper highlights how the Paris Agreement commitments for USD 100 billion annually in climate finance, which could support this technology transformation, are falling behind. AfT can leverage and complement climate finance in this endeavour.

A few sectors in the LDCs have already attempted to harness the potential of 4IR technologies. Examples include blockchain application for enhancing the traceability of coffee in Ethiopia; the provision of back-end services by a company in Nepal that power artificial intelligence and machine learning; and the use of drones to deliver blood to remote areas in Rwanda.

The 4IR offers growth opportunities for small and medium sized enterprises and transformative effects across sectors such as agribusiness, construction, finance, energy, tourism, and healthcare. The EIF's experience, in supporting IT infrastructure in Ethiopia or digitalizing trade through e-commerce platforms in Cambodia and Senegal, shows us that these areas are all critically important as the foundational ingredients for the LDCs to adopt 4IR technologies.

The upcoming Doha Programme of Action for LDCs for 2022 to 2031 will be crucial for the LDCs on their journey to achieving the Sustainable Development Goals. In this regard, this paper has provided actionable recommendations and aligned them with existing strategic frameworks. Concerted efforts by the governments, development partners and the private sector would be required to implement them and achieve the desired outcomes.

Ratnakar Adhikari

FOREWORD
UNITED NATIONS TECHNOLOGY BANK FOR THE LEAST DEVELOPED COUNTRIES

The role of science, technology and innovation in the recent decades has contributed significantly to the development of many countries. However, the least developed countries (LDCs) have not been able to fully benefit from the technological advancement. The fourth industrial revolution driven by technologies such as artificial intelligence (AI), robotics, and the Internet of Things (IoT) can provide rapid development but also can increase level of inequalities within and amongst countries.

The 4IR technologies have socio-economic and transformative economic impact affecting the global economic systems of labour production that require digital skills and capabilities. LDCs should exploit the opportunities of building synergies across policies, trade, industry, education and other sector, that align with the requirements of the 4IR. Increasing investments from research and development, education, digital skill development to enhancing institutional capacities are critical to supporting the LDCs to transform into new digitally driven economies.

Connectivity and bridging the digital divide between developed, developing and least developed countries plays a critical role in enabling the LDCs to access, adopt and adapt technologies that respond to their local needs. The LDCs are the least connected to the internet at about 20% of the population. The COVID-19 pandemic had both a public health risk and social and economic impact that further highlighted the importance of connectivity and the relative cost of being unconnected.

Emerging technologies together with high-speed broadband connectivity also play a critical role in responding to global challenges across many interrelated fields such as education, employment, health, agriculture, inequalities, climate change, and governance. Addressing the multifaceted sectors, a multistakeholder coordination and partnerships presents an opportunity for supporting developing countries and LDCs to leverage technologies during the decade of action. The 5th Conference for the Least Developed Countries (LDCs) presents an opportunity for transformative impact on the LDCs to utilize technologies to generate new higher productivity in the LDCs as well as structurally transforming their economies.

Joshua Phoho Setipa

EXECUTIVE SUMMARY

The least developed countries (LDCs) have followed a fragile and erratic development trajectory since the United Nations created the category 50 years ago. While the rest of the developed world has achieved a remarkable socio-economic renaissance due to rapid technological advancements, LDCs have lagged behind. Despite LDCs having made some progress, core challenges in making decisive progress on structural economic transformation and inclusive and sustainable development have persisted and become more complex. These challenges stem from demographic developments, rising inequalities impacting particularly women, youth and other vulnerable groups, persistent poverty, and accelerated urbanization, leading to malnutrition, governance issues, poor infrastructure, and a slow capital accumulation rate.

This Background Paper has been designed to make a compelling case that the uptake of new and emerging technology solutions that underpin the Fourth Industrial Revolution (4IR) is critical if LDCs are to achieve rapid economic growth that leaves no one behind and meet the United Nations Sustainable Development Goals (SDGs) while remaining carbon-neutral. In order to foster dialogue amongst the attendees of UNIDO's 9th Ministerial Conference of the LDCs, the Background Paper provides critical recommendations on how LDCs could mainstream the 4IR to achieve SDGs and decarbonization.

The Background Paper asks the main questions that need to be answered for LDCs to harness the power of 4IR technologies to achieve sustainable economic growth, the SDGs, and decarbonization.

The Background Paper asks the main questions that need to be answered for LDCs to harness the power of 4IR technologies to achieve sustainable economic growth, the SDGs, and decarbonization:

- What are the major impediments and challenges LDCs face when trying to deploy 4IR technologies?
- How do we address these challenges and bring opportunities offered by 4IR technologies within reach of LDCs?
- What are the avenues that LDCs can explore to lead the way in decarbonization?
- Which local actors can act as the catalyst for an inclusive and gender-responsive digital transformation in LDCs?
- What interventions are necessary to enable 4IR-led leapfrogging to occur in LDCs?

The Paper's **first chapter** provides the reader with an overview of the problems addressed in subsequent chapters. The chapter has been divided into four sections, i.e.:

- The section titled Innovation-based development concepts in the Digital Era provides the reader with an overview and definitions of the concepts that have emerged from leveraging digital technologies (digitization; digitalization; digital transformation; Science, Technology and Innovation or STI), as many people have started to conflate them.
- A section on The Fourth Industrial Revolution and Society 5.0 introducing the reader to the concept of 4IR and the technologies that fall under its auspices. The section further provides the societal evolutionary process – Society 5.0 – which has emerged as a result of blurring the lines between cyberspace and physical space. Both of these concepts have the potential to tackle significant global challenges, such as poverty, climate change, nature loss, sustainable urbanization, water scarcity, and rising inequalities.
- The Decade of Action, STI, and Digital Transformation section provides an overview of how STI and digital transformation can be critical enablers in achieving the SDGs during the Decade of Action. It focuses on the many multilateral initiatives which have emerged in recent years, which have fostered slow progress amid challenges from the COVID-19 pandemic. However, the effects of the pandemic showed that a digitally accelerated plan is possible for achieving the SDGs and fighting the multidimensional vulnerabilities of LDCs.
- A section on the Multidimensional Challenges for 4IR Deployment provides an in-depth view of the many challenges LDCs will face in deploying novel and emerging technologies. The section identifies that the root cause of LDCs slow growth and the inability to leverage new opportunities offered by 4IR technologies are 'old' developmental issues, such as institutions, infrastructure, and skills.

The **second chapter** presents an overview of the approaches LDCs can take to absorb the emerging and transformative technologies that fall under the auspices of the 4IR, i.e., cluster approach, technology transfer and diffusion, retrofitting, and innovation districts. The chapter provides the reader with the LDCs' two digital divides (access to technology and use of technology) that negatively impact the process of technology absorption. Furthermore, the chapter highlights that the governments of LDCs must increase their direct participation in supporting programs that promote a "knowledge economy" through so-called innovation districts as a means to bridge the digital divide.

The **third chapter** highlights the path LDCs could take in becoming global leaders in the race for climate action by leveraging 4IR technologies. The chapter introduces the reader to the vulnerabilities LDCs face as climate change's looming threat and devastating effects are becoming ever more palpable. To address the negative impacts climate change can have on their population and become global leaders in becoming carbon-neutral, the Paper provides valuable insights into the utilization of 4IR technologies (such as Artificial Intelligence, Robotics, Virtual Reality, Augmented Reality, Blockchain, Drones, the Internet of Things and Big Data, Cloud Computing) and their current applications across the globe.

The Paper's **fourth chapter** introduces the novel value chains, and growth opportunities small- and medium-sized enterprises (SMEs) can potentially seize when leveraging 4IR technologies. This chapter highlights the transformative effects 4IR technologies can have on sectors such as agribusiness, construction, finance, energy, tourism, and healthcare. In addition, it provides real-world use cases of 4IR technologies that are being deployed by SMEs in the developed world and in LDCs.

The **final chapter** of the Paper highlights that the use of 4IR technologies is essential for LDCs as they continue to experience increasingly intense environmental, social and demographic pressures and stagnating industrial production. This chapter provides actionable recommendations for LDCs which are aligned with UNIDO's 4IR Strategic Framework, i.e., skills development and capacity building; digital transformation at firm-level; innovation ecosystems; partnerships, access to finance, investment and infrastructure; and governance, technologies and innovation policies.

CONTENTS

ABBREVIATIONS

4IR	The 4th Industrial Revolution
A4AI	Alliance for Affordable Internet
AAAA	Addis Ababa Action Agenda
ADP	Advanced Digital Production
AI	Artificial Intelligence
AM	Additive Manufacturing
AR	Augmented Reality
ASIC	Australian Securities and Investments Commission
BVLOS	Beyond-Visual-Line-of-Sight
CGAP	Consultive Group to Assist the Poor
COT	Carbon Tracing Platform
CTCN	Climate Technology Centre and Network
CTIS	Cambodia Trade Integration Strategy
DBM	Double Burden of Malnutrition
ECLAC	Economic and Social Commission of Latin America and Caribbean
ECLC-WFP	Early Childhood Learning Centre - Wood Food Programme
EIF	Enhanced Integrated Framework
EIF	Enhanced Integrated Framework
EMR	Electronic Health Record
FAO	Food and Agriculture Organization
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investments
FEAT	Fairness, Ethics, Accountability, and Transparency
FfD3	The Third Conference on Financing for Development
FICO	Fair Isaac Corporation
G2P	Government-to-Person
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gasses
GNI	Gross National Income
GSM	Global System for Mobiles
GVC	Global Value Chain
HVAC	Heating, Ventilation, and Air Conditioning
IBM	International Business Machines
ICT	Information and Communications Technology
IDC	International Data Corporation
IDR	Industrial Development Report
IMF	International Monetary Fund
IoT	Internet of Things
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IPoA	Istanbul Program of Action

IPR	Intellectual Property Rights
ISID	Inclusive and Sustainable Development
ISID	International Society for Infectious Diseases
IT	Information Technology
KOICA	Korea International Cooperation Agency
LDC	Least Developed Countries
LMIC	Low-Income and Middle-Income Countries
ML	Machine Learning
MSMEs	Micro, Small and Medium-Sized Enterprises
NASA	National Aeronautics and Space Administration
NDC	Nationally Determined Contributions
NLP	Natural Language Processing
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
OEM	Original Equipment Manufacturers
OT	Operational Technology
P2P	Person-to-Person
PLC	Programmable Logic Controllers
R&D	Research and Development
RAH	Radical Abdominal Hysterectomy
S&T	Science and Technology
SDG	Sustainable Development Goals
SEPAL	Stern Embarkation Platform and Accommodation Ladder
SMEs	Small and Medium-Sized Enterprises
SBED	Small Business Economic Development
SSA	Sub-Saharan Africa
STEM	Science, Technology, Engineering, and Mathematics
STI	Science, Technology, and Innovation
TA	Technical Assistance
TCDC	Technical Cooperation Between Developing Countries
TFM	Technology Facilitation Mechanism
TVET	Technical and Vocational Education and Training
UAV	Unmanned Aerial Vehicle
UN	United Nations
UNCSTD	UN Center for Science and Technology for Development
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Program
UNFCCC	The United Nations Framework Convention on Climate Change
UNFPA	UN Population Fund
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USD	United States Dollar
VR	Virtual Reality
WB	World Bank
WFP	Wood Food Programme
WTO	World Trade Organization

1

Introduction

LDCs represent an enormous human and natural resource potential for global economic growth, welfare, and prosperity. However, significant gaps persist in them, and the international community must strengthen support from all sources.

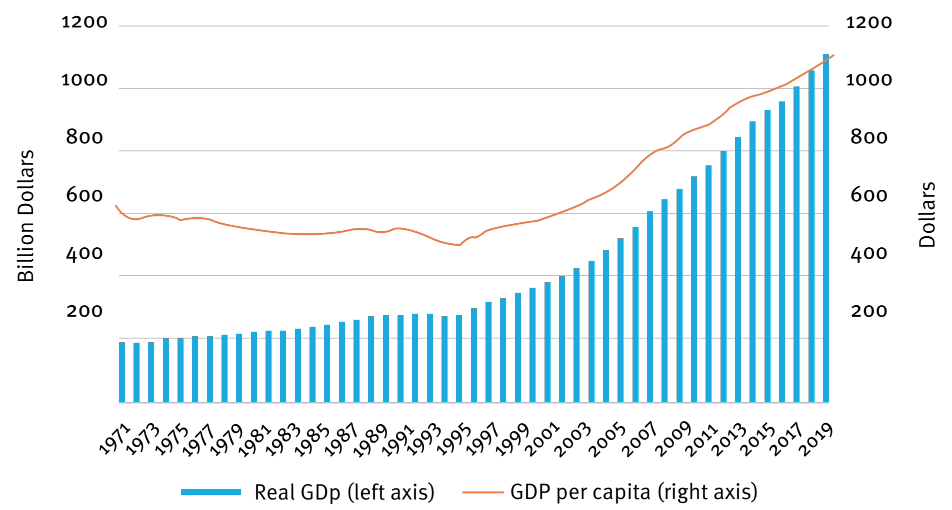
The least developed countries (LDCs) have followed a fragile and erratic development trajectory for 50 years. The term LDCs was coined by a United Nations (UN) General Assembly Resolution 50 years ago.[1] Since then, LDCs have made some development progress. However, core challenges have persisted and become more complex as LDCs have historically grappled and struggled to make decisive progress on structural economic transformation and sustainable development.

LDCs account for over 1 billion people, or 13 percent of the global population, but only for 1.2 percent of the global Gross Domestic Product (GDP).[2] Most LDCs face considerable challenges stemming from demographic developments, rising inequality, and persistent poverty combined with accelerated urbanization. Despite having one of the world's fastest population growth rates and a soaring young population, people living in LDCs suffer from abject poverty. This is mainly due to low levels of education and training contributing to rising inequalities, malnutrition, governance issues, climate change, conflict, poor infrastructure, a generally slow capital accumulation rate as a result of poor access to finance, and, most importantly, low technology adoption.

"The growth performance of LDCs over the course of 50 years has generally been slow and uneven."

LDCs have not been able to share the benefits of the remarkable socio-economic progress felt across the globe. LDCs have recorded some economic growth as real GDP experienced a five-fold increase since the creation of the category, climbing from roughly $200 billion in 1971 to $1,118 billion in 2019. This equates to an average growth rate of 3.7 percent per year, slightly higher than the corresponding world average of 3.1 percent (Figure 1).[3] However, due to LDCs experiencing rapid demographic growth, GDP per capita has experienced a comparatively sluggish annual growth estimated at 1.3 percent, rising from roughly $600 to $1,082 over the same period.[4]

However, the remarkable socio-economic progress achieved across the globe has come at a cost. The impact of the rapid global growth experienced in the previous decade has taken its toll on the planet, accelerating the devastating effects of climate change.



Source: Adapted from *UNCTAD (2021) The Least Developed Countries in the Post-COVID World: Learning from 50 Years of Experience*, at https://unctad.org/system/files/official-document/ldc2021_en.pdf

FIGURE 1: Real GDP and real GDP per capita in LDCs

1) UNCTAD (2021) The Least Developed Countries in the Post-COVID World: Learning from 50 Years of Experience, at https://unctad.org/system/files/official-document/ldc2021_en.pdf
2) UNCTAD (2018) Achieving the Sustainable Development Goals in the Least Developed Countries: A Compendium of Policy Options, at https://unctad.org/system/files/official-document/aldc2018d4_en.pdf
3) UNCTAD (2021) The Least Developed Countries in the Post-COVID World: Learning from 50 Years of Experience, at https://unctad.org/system/files/official-document/ldc2021_en.pdf
4) Ibid

The global economic growth resulting from increased trade expansion has had an obvious direct impact on the environment, increasing pollution and degrading natural resources. Despite insignificant contributions to carbon emissions, the effects of climate change can have a relatively worse impact on LDCs. Climate change will contribute to major decreases in land productivity in LDCs located in sub-Saharan Africa (14-27 percent) and Southeast Asia (18-32 percent), significantly contributing to losses in the genetic diversity of crops by 2080.[5] This will undoubtedly lead to disruptions in the food security of the already malnourished and poor populations of LDCs.

LDCs represent an enormous human and natural resource potential for global economic growth, welfare, and prosperity. Efforts to utilize the vast human and natural resource potential of LDCs have been made. In a bid to reduce LDCs' vulnerabilities and address the omnipresent challenges to their development, the UN created the Istanbul Program of Action (IPoA) 2011-2020, a result-oriented program of action for sustainable development covering eight priority areas, i.e., productive capacity; agriculture, food security, and rural development; trade; commodities; human and social development; multiple crises and other emerging challenges; mobilizing financial resources for development and capacity building; and good governance at all levels.[6] The IPoA had the overarching goal of overcoming the structural challenges LDCs face to eradicate poverty, achieving internationally agreed development goals, and enabling graduation from the LDC category.[7]

However, significant gaps persist in LDCs, and the international community must strengthen support from all sources. For this reason, the Abu Dhabi Declaration[8] aimed at accelerating Inclusive and Sustainable Development (ISID) granted the United Nations Industrial Development Organization (UNIDO) the mandate to become a leader in addressing the needs of LDCs. As a result, UNIDO has been tasked with promoting a global private sector alliance that harnesses the potential of digital transformation and frontier technologies to aid the LDCs graduation process. Through the Abu Dhabi Declaration, UNIDO has recognized that emerging technologies offer great opportunities to advance inclusive economic growth, reduce inequalities and contribute to sustainable development, resilience, and human well-being. It further recognized their transformative potential to address climate change and safeguard the environment in the framework of a circular economy as one of the means to achieve sustainable development.[9]

5) IIED (2015) Impact of Climate Change on Least Developed Countries: Are the SDGs Possible?, at https://pubs.iied.org/sites/default/files/pdfs/migrate/17298IIED.pdf?#:~:text=Climate%20change%20will%20significantly%20hamper%20LDCs'%20ability%20to%20achieve%20the,cities%2C%20marine%20resources%20and%20ecosystems.
6) https://www.un.org/ohrlls/content/istanbul-programme-action
7) UNCTAD (2016), Declaration of the Least Developed Countries Ministerial Meeting to UNCTAD XIV, at https://unctad.org/system/files/official-document/td505_en.pdf
8) UNIDO (2019) Abu Dhabi Declaration, at https://www.unido.org/sites/default/files/files/2019-11/UNIDO_Abu_Dhabi_Declaration.pdf
9) UNIDO (2019) Abu Dhabi Declaration, at https://www.unido.org/sites/default/files/files/2019-11/UNIDO_Abu_Dhabi_Declaration.pdf

Global efforts to achieve sustainable development have become a staple of the decade. The UN has pioneered its 2030 Agenda for Sustainable Development (2030 Agenda) under the motto "leave no one behind." Through this Agenda, the UN has laid out 17 Sustainable Development Goals (SDGs) that promote a holistic approach to achieving sustainable growth for all (see Figure 2). These 17 goals are a tapestry of society's grand challenges and act as a blueprint that aims to address the interlinked crises of climate change, biodiversity loss, and pollution, together with the economic and social fragility they cause.

A mapping of the contribution of the IPoA to the 2030 Agenda reveals that actions undertaken in the Program can, at the same time, contribute to progress in implementing the 2030 Agenda. The Program covers the 17 Sustainable Development Goals of the 2030 Agenda, with particular emphasis on Goal 2 (zero hunger), Goal 8 (decent work and economic growth), Goal 9 (industry, innovation and infrastructure), Goal 16 (peace, justice and strong institutions) and Goal 17 (partnerships for the Goals). The Program and the 2030 Agenda are highly complementary in that the former provides concrete guidance for LDCs about how to achieve the Goals and their associated targets.

FIGURE 2: Negligible progress in structural transformation[10] has led to LDCs' slow progress towards achieving IPoA and SDGs.

Despite achieving the SDGs being imperative, multilateral efforts in providing aid to LDCs have been restrained. Since the creation of the category of LDCs, these countries have received special and differentiated treatment in support of economic growth and escaping the poverty trap.[11] Nevertheless, these efforts have fallen short of fostering inclusive development as the acceleration of the graduation process of LDCs has not borne fruit. Official development assistance (ODA) reached an all-time high in 2014 despite cutbacks in aid budgets after a lingering global recession.[12] However, this trend has begun to reverse, spurring criticism aimed at the selection process for the World Bank and International Monetary Fund (IMF) heads. The generosity of donors has diminished, as the development aid provided by rich countries has stagnated by reallocating or cutting aid. According to the Organization for Economic Cooperation and Development's (OECD) Development Assistance Committee, only five out of 30 countries currently meet their pledges on aid, down from a peak of six.[13] Rising inequality – gender, social, and income inequality – is entrenched in LDCs, and cuts to agencies such as the UN Population Fund (UNFPA) only exacerbated the matter further, affecting women in LDCs and developing countries disproportionally.[14]

The COVID-19 pandemic has highlighted LDCs' institutional, economic and social shortcomings. The pandemic rolled back many years of the hard-won progress LDCs have made, curbing economic activity and increasing the pressure on national health and social support systems. Accelerating the implementation of the 2030 Agenda for Sustainable Development is a priority for the LDCs. The COVID-19 pandemic has made the task even harder, as it has exposed some of these countries' long-standing vulnerabilities. Recovering

10) Structural transformation is understood to mean the transfer of productive resources (particularly labor, capital and land) from activities and sectors of low productivity to those of higher productivity.
11) https://www.oecd.org/dac/financing-sustainable-development/Taking-stock-of-aid-to-least-developed-countries.pdf
12) Ibid
13) Gay, D., Gallagher, K. (2019) For the Least Developed Countries, Revitalising Multilateralism is Life or Death – Op-Ed, at https://www.un.org/sustainabledevelopment/blog/2019/08/least-developed-countries-revitalising-multilateralism-is-life-or-death/
14) Ibid

from the prolonged and deep shock the world economy has experienced is an urgent priority. In the context of the LDCs, the imperative now is to recover from the pandemic, rebuild stronger, and accelerate the SDGs implementation.[15]

Recent moves to redefine and repackage development assistance as a joint public-private endeavor have been criticized in some quarters as attempts by official government donors to escape their obligations. Per the deal, the private money mobilized in LDCs is only a third of the global average. Only eight per cent of blended finance goes to LDCs, with most going to middle-income countries. Of the $52 billion directly mobilized by multilateral development banks in long-term private co-financing during 2017, only $2 billion went to LDCs and other low-income countries.

Source: Gay, D., Gallagher, K. (2019) *For the Least Developed Countries, Revitalising Multilateralism is Life or Death – Op-Ed,* https://www.un.org/sustainabledevelopment/blog/2019/08/least-developed-countries-revitalising-multilateralism-is-life-or-death/

LDCs must take advantage of the emerging technologies that underpin the Fourth Industrial Revolution (4IR) to rebuild after the COVID-19 pandemic, achieve the SDGs, and bridge the digital divide. The 4IR captures the idea of the confluence of new technologies and their cumulative impact on our world. It has the potential to enhance productivity and generate economic growth, ultimately resulting in greater social welfare.[16] However, countries' ability to benefit from its potential will be determined by the capacity to innovate and adapt to new technologies, failing which there is a risk of widening the development gap. The 4IR is being propelled by frontier technologies (such as AI, blockchain, 3D printing, IoT, and virtual and augmented reality, as well as quantum computing and energy-saving and generating technologies) that are better, cheaper, faster, more scalable, and easier to use than ever before. These technologies converge and recombine through digital platforms to accelerate change across multiple sectors. Exciting developments using these emerging technologies have been seen in achieving the SDGs in countries across the globe.

By utilizing 4IR technologies, LDCs can strengthen skills and capabilities to compete and succeed within the new technological paradigm in a post-pandemic world. According to UNIDO's 2020 Industrial Development Report (IDR 2020), advanced digital production (ADP) technologies applied to manufacturing production offer huge potential to advance LDCs' economic growth and human well-being and safeguard the environment, contributing to the 2030 Agenda. While these technologies are already shaping the industrial landscape of the developed world, LDCs have lagged behind due to the fact that they're still using analog technologies in manufacturing production. This is mainly due to the fact that LDCs have a difficult time estimating the benefits of 4IR technologies, coupled with the long time to recover the initial investments of transitioning to a new manufacturing model. Additionally, LDCs lack the awareness, digital culture, human resources, infrastructure, and capital to leverage these new and emerging modes of production. However, in a post-pandemic world, LDCs must utilize 4IR technologies to rebuild their fragile economies. Emerging technologies can provide LDCs with avenues to enhance product-service characteristics and functionalities, boost productivity growth levels, promote knowledge-intensive business services, generate more high-skilled and higher-paying jobs, and promote environmentally friendly solutions.[17]

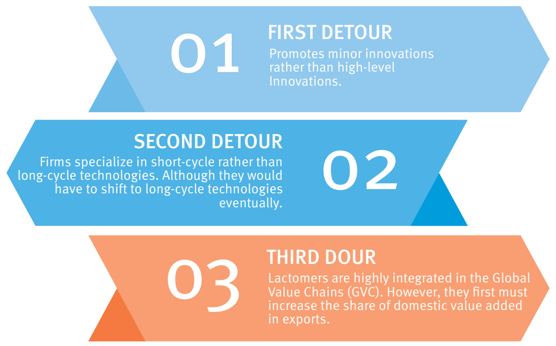
The transformative nature of 4IR can be used to achieve decarbonization, curb climate change, and have profound impacts on all countries, regardless of their economic status. For example, rapid advances in satellites, drones, and advanced sensors – augmented by smart algorithms or AI technology – could provide a real-time flow of data on GHG emissions, which would then be relayed across the Cloud to be tracked by anyone from government officials to schoolchildren. This would significantly improve the transparency of Monitoring, Reporting, and Verification (MRV) data, which is crucial for the accountability and efficacy of global climate agreements. The political implications could be transformative, as could be similar real-time satellite and drone monitoring of industrial GHG emissions for investors, insurers, and regulators. No longer would

15) UNCTAD (2021) The Least Developed Countries in the Post-COVID World: Learning from 50 Years of Experience, at https://unctad.org/system/files/official-document/ldc2021_en.pdf
16) UNIDO (2019) Boosting the dialogue on the Fourth Industrial Revolution at the 11th Africa Energy Indaba, at https://www.unido.org/news/boosting-dialogue-fourth-industrial-revolution-11th-africa-energy-indaba
17) UNIDO (2019) Industrial Development Report 2020. Industrializing in the Digital Age

disclosure regimes rely on companies choosing when and how to report. Instead, the information would be available, possibly in the blockchain, for all to see and act upon. One example of this can be seen in Dynamhex, a US-based company that leverages blockchain solutions to measure the carbon footprint for cities.[18] The company's blockchain solution reduced the time spent on city-wide climate action planning by 81 percent and reduced consumer costs by 50 percent.[19] Therefore, leveraging 4IR technologies could be particularly beneficial for LDCs, as they could allow them to take better advantage of carbon markets and access complex climate finance windows.

Modern technological breakthroughs in 4IR still present themselves as dividers of innovative activity and economic growth, as the historic incumbents of the previous industrial revolutions remain as global leaders and frontrunners in technological creation and diffusion. According to UNIDO's IDR 2020 report, only 10 economies show above-market shares in the global patenting of ADP technologies accounting for 91 percent of global patent families, accounting for almost 70 percent of global exports and 46 percent of global imports.[20] This exclusive club of frontrunners that create new technologies within the ADP technology paradigm comprises the United States, Japan, Germany, China, Taiwan Province of China, France, Switzerland, the United Kingdom, the Republic of Korea, and the Netherlands.[21] The other 40 developed economies, such as Israel, Italy, Sweden, Austria, Canada, Mexico, Thailand, and Turkey that engage in these new technologies act as followers, accounting for 8 percent of global patents and almost half of all imports of goods embodying these technologies. However, many of the remaining economies show low (latecomers) or very low to no activity (laggards) in the field.[22]

While the advent of the 4IR can help LDCs in their quest to leapfrog traditional phases of development, foundational capabilities[23] and production systems must be established. Many of the 46 countries that comprise the LDC category are still stuck in the second industrial revolution and struggle to effectively engage with the third industrial revolution's technological, organizational, and institutional innovations.[24] Deploying 4IR technologies optimally and strategically can create a potent mix of resources and infrastructure that can yield better quality, more sustainable growth. However, LDCs must invest in building foundational capabilities and production systems rather than just trying to leapfrog. In order for LDCs to leapfrog, they go through the three stages of the catching-up progress, i.e., late entry, three detours (Figure 3), leapfrogging.[25] Hence, the leapfrogging process entails the latecomers adopting new technologies ahead of the frontrunners, thus actually leaping over them.[26] Therefore, if LDCs are leapfrog, they must develop sector-specific production and technological capabilities that require a combination of factors and processes that include skills, funding, access to foreign technology that can be adapted to local needs, and exposure to competition not excessive, and government incentives.



Source: Created by the Authors

FIGURE 3: The Three Detours of the Catching-Up Process

Grassroot efforts to help LDCs achieve digital transformation and SDGs have begun to emerge. The United Nations Framework Convention on Climate Change (UNFCCC) has recognized LDCs' need for technology transfer to support climate adaptation, resilience, and mitigation. The UNFCCC recognizes the fundamental importance of technology transfer for LDCs, stressing that developed countries should promote, facilitate, and finance the transfer of environmentally sound technologies to developing countries. This is further supported by Article 4.9 of the UNFCCC, which stipulates that "the Parties shall take full account of the specific needs and special situations of the least developed countries in their actions concerning funding and transfer of technology."[27] However, delivering developed countries' commitments on climate finance, including funding for technology transfer and the flow of funds for LDCs, is a major outstanding issue. Many of the developed countries do not meet the USD 100 billion annual commitments on climate finance. This climate financing gap can be complemented by Aid for Trade, such as the Enhanced Integrated Framework (EIF), if these issues are highlighted in the LDCs' Nationally Determined Contributions (NDCs) on climate change. Following this, several developing countries have supported the creation of a Technology Facilitation Mechanism (TFM) to further supplement the work done by the UN Technology Bank for LDCs and the EIF. The TFM would leverage the capabilities of the UN Technology Bank and EIF in developing capacities for technology assessment and capacities in Science, Technology, and Innovation (STI), particularly in the domains of development and sustainability that are aligned with the SDGs.[28]

18) https://dynmhx.io/
19) Raza, S., Bravante, M., Curry, C. (2021) Understanding and Monitoring our Changing Planet: A Climate Technology White Paper, at https://assets.bbhub.io/professional/sites/24/Monitoring-and-understanding-our-changing-planet.pdf
20 Ibid
21) Ibid
22) Ibid
23) Foundational capavilities are capabilities to learn new technical and organizational solutions, integrate them into production, organize and commit resources over time for the effective deployment of these new solutions. Andreoni, A., Chang, H.-J., Labrunie, M. (2021) Natura Non Facit Saltus: Challenges and Opportunities for Digital Industrialisation Across Developing Countries
24) Andreoni, A., Chang, H.-J., Labrunie, M. (2021) Natura Non Facit Saltus: Challenges and Opportunities for Digital Industrialisation Across Developing Countries
25) Lee, K. (2019) Economics of Technological Leapfrogging
26) Ibid

27) https://unfccc.int/process-and-meetings/bodies/constituted-bodies/least-developed-countries-expert-group-leg/ldc-portal/article-4-paragraph-9-of-the-convention
28) G20 Insights (2019) Leveraging Science, Technology and Innovation for Implementing the 2030 Agenda, at https://www.g20-insights.org/policy_briefs/leveraging-science-technology-and-innovation-for-implementing-the-2030-agenda/

1.1 INNOVATION-BASED DEVELOPMENT CONCEPTS IN THE DIGITAL ERA

Digital technologies have heralded the beginning of the digital era. If businesses, organizations, and governments wish to survive, grow, develop, and flourish, they must embrace the utilization of digital technologies. The digital landscape is constantly evolving and creates with it concepts never thought of previously. These concepts, i.e., digitization, digitalization, and digital transformation, attempt to describe the reality we live in. As many people have begun to conflate these terms, a clear distinction must be made to avoid the creation of confusion.

1.1.1 DIGITIZATION

In its most basic sense, **digitization is the process of changing from analog to digital form, known as digital enablement.**[29] In other words, digitization takes an analog process that augments it to a digital form without any changes to the process itself—for example, converting music from vinyl records or CDs to MP3 or paper documents to digital files saved on a computer.

“Digitization allows the creation of digital versions of physical carriers of information.”

The creation of digital versions of “physical carriers of information” allows businesses, organizations, and governments to extract data that can be processed, transmitted, or used to make processes more efficient and effective. Hence, the concept of digitization does not merely extrapolate information from physical objects that are placed in a digital device; it also includes the automation of existing manual and paper-based processes. In doing so, digitization creates value by cutting costs and laying a solid foundation for data to be leveraged. Through the application of data, governments have almost limitless potential for providing more efficient, effective, and trustworthy public services across sectors.

One of the most common examples of digitization is the conversion of handwritten or typed text into a digital format. Another example is changing bank statements sent via mail into a computer application. Digitization also occurs when hospitals store patient records in computers instead of physical folders, or when a person converts their signature to an electronic format for signing documents online.

1.1.2 DIGITALIZATION

The concept of digitalization refers to enabling or improving processes by leveraging digital technologies and digitized data to provide new revenue and value-producing opportunities. Digitalization cannot occur without digitization. However, digitalization goes beyond turning documents into bits and bytes.[30] By utilizing advanced technologies, digitalization includes the previously converted digital files to the Cloud to transform collaboration and reporting processes, and through the use of analytical tools, it can generate insights and actionable knowledge to mitigate risk and promote efficiency in future endeavors.[31] Hence, digitalization embraces the ability of digital technologies to capture and assess data to make better decisions and enable new business models.

“Digitalization creates value by improving existing processes and business models to increase revenue and decrease costs.”

Digitalization is radically interfering and changing the fundamental assumptions of the way of life and organization of work in a postmodern society that is becoming increasingly globalized and digitalized. Therefore, the notion of digital convergence must be emphasized as it has profound impacts on society and across sectors.[32]

An example of digitalization can be found in cases where organizations migrate their business processes to the Cloud. With a centralized portal via the Cloud, entire workforces, even globally, are able to collaborate effectively as though they were right next to each other in the workplace.

1.1.3 DIGITAL TRANSFORMATION

Digital transformation is the cultural, organizational, and operational change of an organization, industry, or ecosystem through smart integration of digital technologies, processes, and competencies across all levels and functions in a staged and strategic way.[33] Digitalization is an essential step of digital transformation. It has vast impacts on product, service delivery, and people, marking a culture shift within an organization and reshaping how value is created and business is conducted. However, the concept of digital transformation is broader than simply applying technology to existing business models, i.e., it is the capacity to rapidly adapt when required through the intelligent use of technologies and information.[34]

“Digital transformation leverages technologies to create value and new services for various stakeholders, by innovating and acquiring capabilities to adapt to change rapidly.”

The overarching goal of digital transformation is to increase the productivity and creativity of individuals and creations. By leveraging technologies, such as smart devices, Cloud computing, the Internet of Things (IoT) and big data analytics, social media and networking, cognitive computing, AI and machine learning (ML), unprecedented access to pools of knowledge and resources is provided, resulting in greater innovation and outcomes.

One example of this is the convergence of information technology (IT)/operational technology (OT) where the intersection and overlap of IT skills within the OT domain has created the need for a more uniform governance due to cybersecurity concerns, data flow requirements, and skills. Another example of digital transformation is a shift from local control of physical processes to remote monitoring and control of those same processes.

29) Asite (2021) Digitization, Digitalization, and Digital Transformation – What’s the Difference?, at https://www.asite.com/blogs/digitization-digitalization-and-digital-transformation-whats-the-difference
30) Bit and byte are units of measurement for data volume (8 bits = 1 byte). The storage capacity of any medium is given in bytes. Familiar examples include the megabyte and gigabyte storage of hardware such as USB sticks or mobile terminal equipment such as smartphones or tablets.

31) Ibid
32) Gorensek, T., Kohont, A. (2019) Conceptualization of digitalization: Opportunities and Challenges for Organizations in the Euro-Mediterranean Area, at https://emuni.si/wp-content/uploads/2020/01/IJEMS-2-2019_93%E2%80%93115.pdf
33) I-Scoop (n.d.) What is Digital Business Transformation? The Essential Guide to DX, at https://www.i-scoop.eu/digital-transformation/
34) Ibid

1.1.4 SCIENCE, TECHNOLOGY AND INNOVATION (STI)

Science and Technology (S&T) policy is defined as government intervention in the economy to support scientific discoveries and the development of technological solutions.[35] The more recent induction of 'innovation policy' to create Science, Technology, and Innovation (STI) policy reflects the growing recognition that knowledge and innovation are fundamental tools that promote higher national economic performance. Innovation policies incorporate science and technology policies to holistically intervene in the innovation process – from exploration to application of specific technologies, their introduction to the market, and their wide-ranging exploitation.[36] STI also encompasses concepts such as business models and process innovation that do not fall under the classical definitions of S&T. By merging innovation with S&T, minor modifications to technologies are included that broaden the scope of its application. This fosters the commercialization of new ideas through the market by entrepreneurs, thus fueling economic growth.

"Science, Technology, and Innovation have the ability to enhance the sustainability of products and services, optimizing their application and production."

Traditionally, innovation has been understood as something new in absolute terms and not as disseminating something new in a given context. The technology frontier is dominated by economically advanced countries. Nevertheless, considerable opportunities for tapping into global knowledge and technology exist for developing countries. The ability to disseminate these technologies domestically in developing countries will be decisive in improving agriculture and industrial productivity, thus increasing overall welfare. Innovation means technologies or practices new to a given society.[37] This means that they are not necessarily novel in absolute terms, i.e., they are diffused in that economy or society. Dissemination is very significant and requires particular attention in low- and medium-income countries, as structured and planned dissemination can aid them in achieving inclusive growth and innovation, benefiting their many poor and not only a narrow elite.[38]

"Policymakers continue to view STI and digitalization in silos."

STI and digitalization should not be viewed in isolation. The "platform" nature of digital technologies and their ability to be rapidly replicated and deployed makes digitalization closely linked to the innovation agenda. While policymakers continue to view STI and digitalization in silos, there is increased appreciation of the overlap between the two policy areas.

STI has been a core driver of the development process, addressing emerging national, regional, and global developmental challenges across sectors.[39] Investing in STI is essential for economic growth and social progress, as policies and interventions aimed directly at research and development (R&D) capacity building can foster sustainable development. This is particularly significant for LDCs, as they have 100 times fewer researchers per million inhabitants when compared to high-income countries.[40] Efforts in codifying an overall framework for STI have been made, considering the ability innovation and technology have on enhancing the sustainability of products and services, optimizing their application and production. One such effort was establishing the UN Center for Science and Technology for Development (UNCSTD), which proposed a horizontal approach focused on eleven pillars: R&D, technology transfer, innovation, S&T policy, finance, marketing, design, education, networks, and technological cooperation (Figure 4).

35) Chaminade, C., Lundvall, B.-A. (2019) Science, Technology, and Innovation Policy: Old Patterns and New Challenges, at https://oxfordre.com/business/view/10.1093/acrefore/9780190224851.001.0001/acrefore-9780190224851-e-179
36) Ibid
37) World Bank (2010) Innovation Policy: A Guide for Developing Countries, at https://openknowledge.worldbank.org/handle/10986/2460
38) Ibid
39) UNESCAP (2015) A Conceptual Framework for Science, Technology and Innovation Driven Sustainable Development and the Role of ESCAP, at https://www.google.com/search?q=A+Conceptual+Framework+for+Science%2C+Technology+and+Innovation+Driven+Sustainable+Development+and+the+Role+of+ESCAP&oq=A+Conceptual+Framework+for+Science%2C+Technology+and+Innovation+Driven+Sustainable+Development+and+the+Role+of+ESCAP&aqs=chrome..69i57.876j0j7&sourceid=chrome&ie=UTF-8
40) Utoikamanu, F. (2019) Closing the Technology Gap in Least Developed Countries, at https://www.un-ilibrary.org/content/journals/15643913/55/4/10

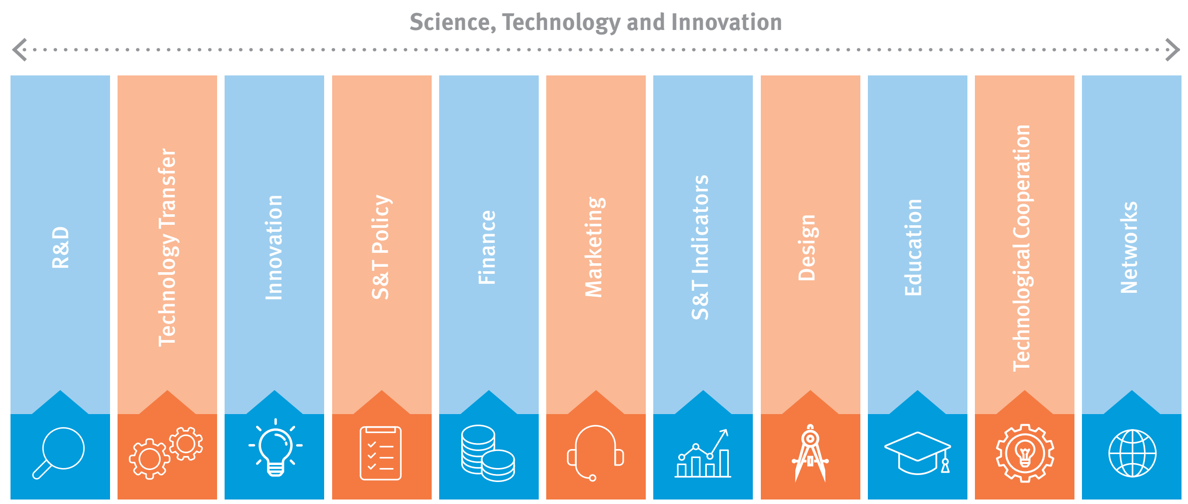


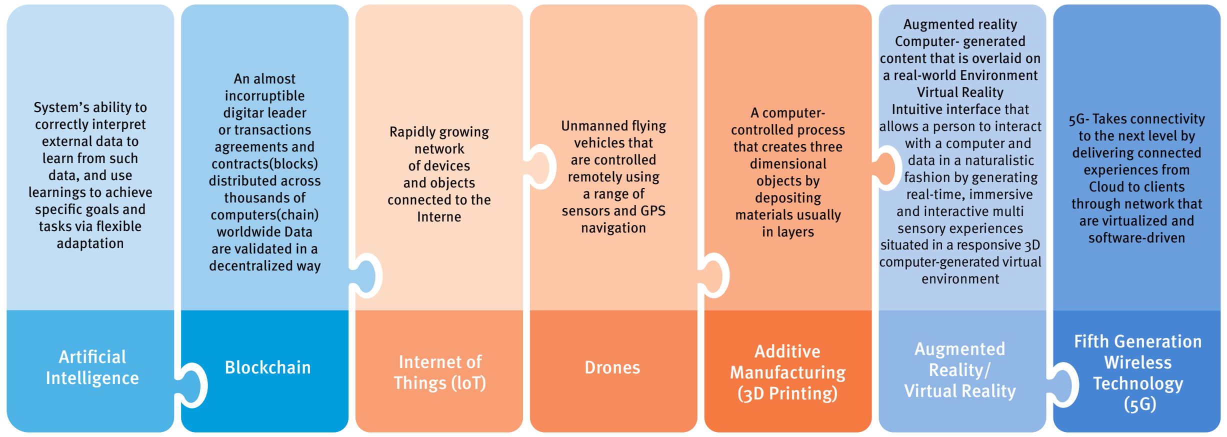
FIGURE 4: Eleven Pillars of STI

1.2 THE FOURTH INDUSTRIAL REVOLUTION AND SOCIETY 5.0

The global industrial landscape is experiencing a dramatic revolution as a result of emerging digital technologies. Over the last two decades, emerging technologies and their integration into complex technology systems have redefined value creation and captured dynamics in production, especially in manufacturing. These changes in global value chains (GVCs) perpetuated by emerging digital technologies have reshaped national and regional industrial systems, augmenting the topography of production and international trade.[41]

The Digital Era powered by emerging technologies that underpin the 4IR has heralded a new paradigm for economic growth. These new and emerging technologies – Artificial Intelligence (AI), blockchain, the Internet of Things (IoT) and Big Data, Unmanned Aerial Vehicles (UAVs/Drones), Additive Manufacturing (3D printing), 5G connectivity, Augmented and Virtual Reality (Figure 5), to name a few – fuse the digital, biological and physical worlds, ushering in a new era of economic growth. By building and extending the impacts of digitization in new and unanticipated ways, the 4IR is rapidly transforming business models and industries across the globe.

“The 4IR is reshaping industries and value chains, scientific discovery, human engagement, and even national economic power at unprecedented speed and scale.”



Source: Created by the Authors

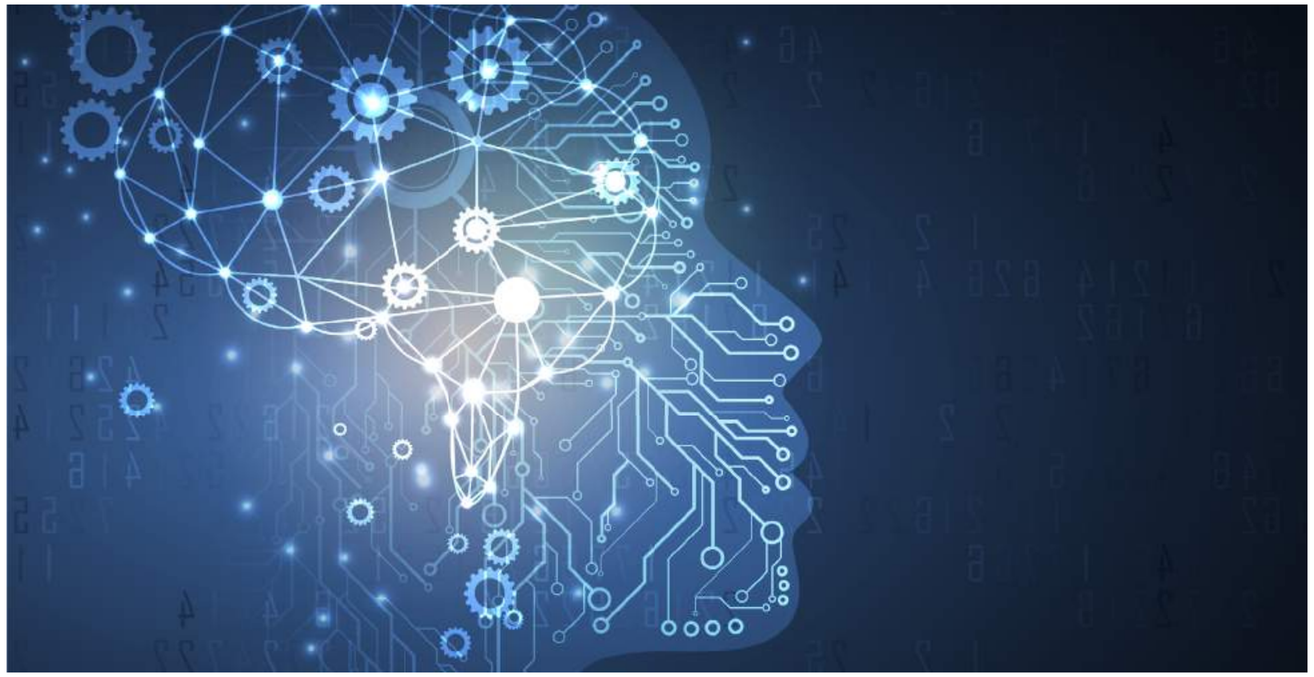
FIGURE 5: 4IR Technologies

The catalyst that is the 4IR and the technologies that fall under its auspices will have a profound impact on economic and social development. Rapid technological advancements can bear fruit for countries at all levels of income. These technologies have become determinants of competitiveness in manufacturing and services, evolving and reimagining outdated concepts of job creation and poverty reduction. By leveraging novel technologies, emerging countries can resolve bottlenecks in industrialization, enable new ways of organizing production, boost productivity and improve rural livelihoods.

“Society 5.0 is a human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space.”

Digital technologies are enabling societies to evolve beyond the cross-sectional sharing of knowledge and information. Humanity is evolving beyond the standard practices of collecting information that is later analyzed by humans. Society 5.0 is emerging as an aspiration to which developed nations are striving towards. The concept can be defined as “a human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space.”[42] Society 5.0 posits that a forward-looking society will be achieved through social reform and innovation that break down the existing sense of stagnation.[43] It aims to achieve this through a high degree of convergence between cyberspace and physical space to address humanity’s most pressing challenges by utilizing 4IR technologies.

The potential of the 4IR technologies to tackle significant global challenges – such as poverty, climate change, nature loss, sustainable urbanization, water scarcity, and rising inequalities – is immense. The transformational power of the 4IR can lead the path to sustainable development, prompting a new economic paradigm that is not prefaced on delivering material wealth at the expense of growing environmental risks, ecological scarcities, and social disparities. The spread of digital technologies can empower the poor and marginalized with access to information, job opportunities, and services to improve their living standards. AI, IoT, and Blockchain can enhance data gathering and analysis opportunities for more targeted and effective poverty reduction strategies.[44] 4IR technologies also have the potential to transform the management of our environmental surroundings radically, mitigate the adverse effects of climate change, and tackle nature loss. By utilizing the power of IoT and big data analytics, governments can better understand air pollution levels, blockchain can be used to help with land rights management, and drones augmented by smart algorithms or AI to provide a real-time flow of greenhouse gas emissions or aid in reforestation efforts in remote areas.



41) Andreoni, A., Chang, H.-J., Labrunie, M. (2021) Natura Non Facit Saltus: Challenges and Opportunities for Digital Industrialisation Across Developing Countries

42) https://www8.cao.go.jp/cstp/english/society5_0/index.html

43) Ibid

44) Brookings (2020) The Fourth Industrial Revolution and Digitization will Transform Africa into a Global Powerhouse, at https://www.brookings.edu/research/the-fourth-industrial-revolution-and-digitization-will-transform-africa-into-a-global-powerhouse/

1.3 THE DECADE OF ACTION, STI AND DIGITAL TRANSFORMATION

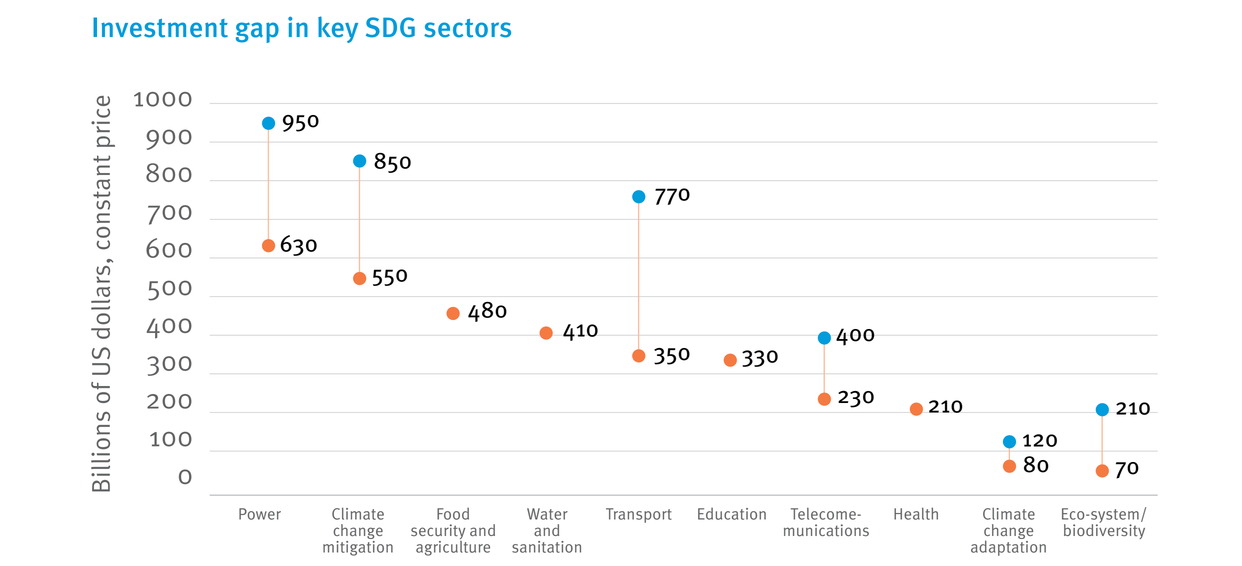
“The Decade of Action calls for accelerating sustainable solutions to all the world’s biggest challenges — ranging from poverty and gender to climate change, inequality, and closing the finance gap.”

The international community embarked on a slow journey to deliver on the SDGs by 2030. The Decade of Action called for accelerating sustainable solutions to all of the world’s biggest challenges. However, as the COVID-19 pandemic swept across the globe, taking hundreds of thousands of lives, affecting the livelihoods of billions, hard-earned progress was halted or reversed. Systemic vulnerabilities and preexisting inequalities were felt more acutely than ever, particularly by the most marginalized. Hence, the Decade of Action for the SDGs demands the mobilization of everyone everywhere and a radical transformation of outdated production systems and governance models.

Delivering the SDGs in the next decade will demand ambition, decisiveness, and a sense of urgency. The Third Conference on Financing for Development (FfD3) in Addis Ababa prioritized STI delivery, underlining the importance and support of addressing STI issues. The FfD3 called for a new global framework for financing sustainable development that aligns financial flows and policies with economic, social, and environmental priorities.[45] The international community, and more importantly LDCs, must take the importance of STI and the availability of innovation-driven solutions to address sustainability challenges seriously. The Decade of Action requires the integration of STI and digitalization to achieve digital transformation for all. This decade fueled by technological advancements will be crucial in developing LDC capabilities to achieve the SDGs and address the multidimensional vulnerabilities that plague them.

The importance of STI and the availability of innovation-driven solutions, particularly to address sustainability challenges, has been a critical theme in many initiatives, including the Rio+20 process that led to the 2030 Agenda for Sustainable Development, the Addis Ababa Action Agenda (AAAA), the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement.[46] While the FfD3 indicated the importance and support of addressing STI issues, challenges in technology cooperation, including the capacity to absorb technologies, poor financial capabilities of governments and private firms in developing countries, and managing intellectual property rights (IPR) regimes persist. With most countries yet to integrate STI policies that aim to achieve the SDGs, concerns regarding the lack of existing models and mechanisms have yielded a slow delivery of the expected results. Present-day efforts facilitating STI cooperation that cater to diverse development and sustainability needs ought to be revamped. This has led to a wide range of interventions to bridge knowledge gaps in technical and scientific domains. One such intervention was the creation of the Global Environmental Facility (GEF), a joint initiative of the United Nations Development Program (UNDP), the United Nations Environment Program (UNEP), and the World Bank, which helps developing countries to obtain new technologies and project financing at a low cost.[47] However, other STI initiatives such as the Paris Agreement’s implementation arm for technology development, transfer, and financing for technology transfer - the Climate Technology Centre and Network (CTCN) – have not been a resounding success. Despite providing implementation support to developing countries, the CTCN has not been supported commensurately with the needs and suffers from a funding shortfall.[48]

Despite ambitious efforts in achieving SDGs, there is a clear SDG financing gap. According to UNCTAD, in order for developing countries to meet the SDGs by 2030, total annual investments in SDG-relevant sectors will need to be between $3.3 trillion and $4.5 trillion. These estimates indicate a clear yearly financing gap of $2.5 trillion between current funding and what is required.[49] Significant investment gaps have been noted in power infrastructure (at $950 billion), climate change mitigation ($850 billion), and transport infrastructure ($770 billion). Furthermore, sizeable investment gaps have been noted in social infrastructure, ranging from $140 billion in health to $250 billion in education (Figure 6).[50]

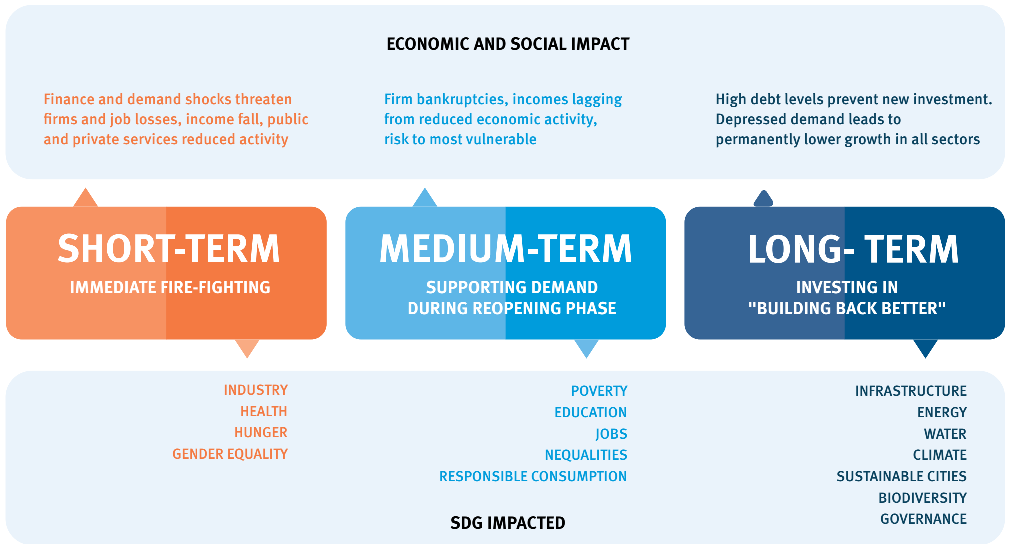


Source: Created by the Authors

FIGURE 6: Investment gap for developing countries

45) https://www.un.org/esa/ffd/ffd3/conference.html
46) G20 Insights (2019) Leveraging Science, Technology and Innovation for Implementing the 2030 Agenda, at https://www.g20-insights.org/policy_briefs/leveraging-science-technology-and-innovation-for-implementing-the-2030-agenda/
47) Ibid
48) Ibid
49) UNCTAD (2014) World Investment Report: Investing in the SDGs: An Action Plan
50) Doumbia, D., Lauridsen M. L. (2019) Closing the Financing Gap – Trends and Data, at https://www.ifc.org/wps/wcm/connect/842b73cc-12b0-4fe2-b058-d3ee75f74d06/EMCompass-Note-73-Closing-SDGs-Fund-Gap.pdf?MOD=AJPERES&CVID=mSHKI4S#:~:text=4%20Looking%20at%20the%20infrastructure,efficiency%20and%20the%20quality%20of

The pandemic indicated the need for more financial aid, as progress towards the SDGs stopped and was reversed in some cases. The pandemic and the economic downturn that it promoted could significantly impact development prospects, as hard-fought development gains face short, medium, and long-term setbacks (Figure 7). The pandemic erased years of progress on poverty reduction, as an additional 100 million people are expected to be pushed into extreme poverty, and job losses are expected to rise to 200 million.[51] Furthermore, rising inequalities are expected to significantly increase in the short term, with Gini coefficients rising on average by 1.5 percent over five years, based on the experience of the previous five major pandemic events.[52] Inequality does not only stem from a lack of income, however, as the digital divide makes it harder to perform tasks from home, regardless of whether they are for work or schooling or simply to access information. The inequality in the digital sphere has been felt even more acutely in LDCs, as challenges of connectivity persist, with only 20 percent of the inhabitants of LDCs having access to the Internet.[53] This had a negative impact on children in LDCs who were unable to attend online schooling during the pandemic due to limited access to the Internet.[54] Uncertainty concerning the interrelated health and economic shocks increased tensions within the multilateral system, compounding pressure on available resources for sustainable development. Hence, the contraction of economies has depressed domestic resources. While financing needs have grown, they are in stark contrast with the decline of available development finance, putting enormous strain on ODA.



Source: Adapted from OECD (2021), *Global Outlook on Financing for Sustainable Development 2021: A New Way to Invest for People and Planet*

FIGURE 7: The COVID-19 economic and social shock and its consequences for the SDGs

The Decade of Action requires the integration of STI and digitalization to achieve digital transformation for all. The international community, and more importantly LDCs, must take the importance of STI and the availability of innovation-driven solutions to address sustainability challenges seriously. This decade fueled by technological advancements will be crucial in developing LDC capabilities to achieve the SDGs and address the multidimensional vulnerabilities that plague them.

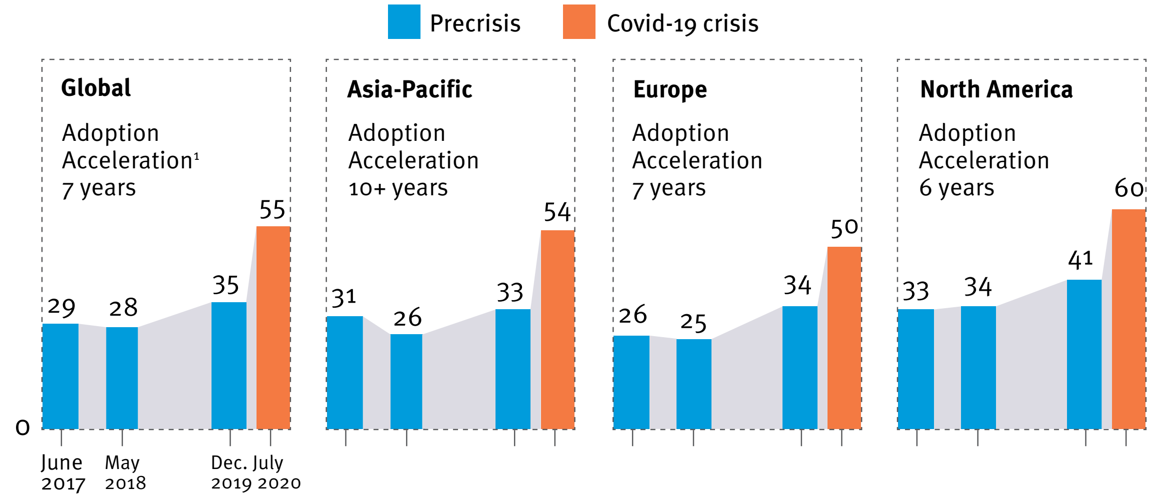
51) OECD (2021) Global Outlook on Financing for Sustainable Development 2021: A New Way to Invest for People and Planet, at https://www.oecd-ilibrary.org/sites/6ea613f4-en/index.html?itemId=/content/component/6ea613f4-en

52) Ibid

53) UN General Assembly (2020) Road Map for digital cooperation: Implementation of the Recommendations of the High-Level Panel on Digital Cooperation Report of the Secretary-General, at https://www.un.org/en/content/digital-cooperation-roadmap/

54) Ibid

The pandemic and the panic it caused was an unexpected catalyst and accelerator for the uptake of digital technologies across sectors. The COVID-19 crisis disrupted widely accepted beliefs about achieving digital transformation goals and brought about years of change in the way companies in different industries and regions do business. Consumers moved drastically toward online channels, companies, industries, and governments across the globe followed suit, speeding up digital or digitally enhanced offerings dramatically. According to a McKinsey survey, the digital uptake across regions experienced a seven-year increase, on average, in the rate at which companies are developing digital or digitally enhanced products and services.[55] The survey states that the recorded technological leap in developed Asia was even more significant – experiencing a ten-year increase (Figure 8).[56]



¹Years ahead of the average rate of adoption from 2019 to 2019

Source: Adapted from McKinsey & Company (2020), *How COVID-19 has Pushed Companies Over the Technology Tipping Point – And Transformed Business Forever*

FIGURE 8: Average share of products and/or services that were partially or fully digitized, percent

The effects of the pandemic showed that a digitally accelerated plan is possible for achieving the SDGs. Before the pandemic, advanced innovations and new manufacturing techniques were primarily driven by business imperatives, such as added value, greater productivity, and comparative advantage. However, the "new normal" in the post-pandemic world has shown that society will increasingly be driven by and reliant on advanced technologies, which can significantly impact inclusive and sustainable development efforts.

While digital technologies have been a game-changer in responding to overcoming the COVID-19 crisis, they have sounded an alarm about the implications of a growing digital divide, exacerbating existing inequalities between the developing and developed world.[57] Historically, each industrial revolution has highlighted a great divergence in the uptake of innovative ways of production between countries that have led them and the rest of the developing world. The pandemic and this current industrial revolution can only amplify those

55) McKinsey & Company (2020) How COVID-19 has Pushed Companies Over the Technology Tipping Point – And Transformed Business Forever, at https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever

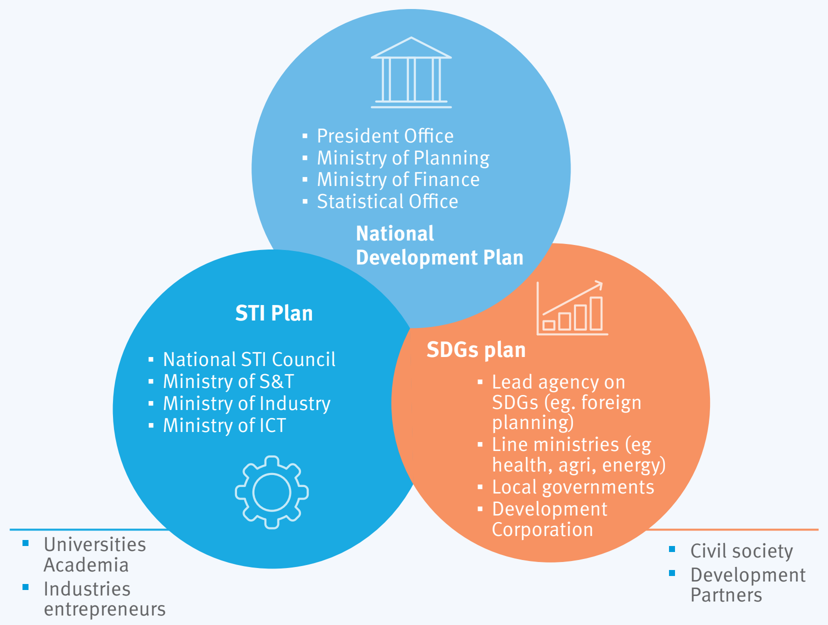
56) Ibid

57) https://www.unido.org/our-focus-building-better-future/digital-transformation-innovation-and-industrial-recovery

unwanted effects. Hence, we have seen that the uptake of digital technologies across the developed world has significantly underlined the existing inequalities and vulnerabilities of LDCs. As a result, UNIDO has identified digital transformation and innovation as one of its focus areas to advance ISID by developing a Strategic Framework for the Fourth Industrial Revolution to curb the negative impacts of a widening digital divide and rising inequalities.

STI capacity building should not only be viewed from one vantage point. STI capacity building should not only be relegated to supporting scientists in laboratories working on theoretical scientific problems. Instead, it should be about building STI capacity to “solve, transform, and impact”[58] the global challenges set forth by the 2030 Agenda. Technology in and of itself has little economic significance; it is its widespread adoption that unlocks productivity gains and growth. Hence, technology transfer and diffusion are economically significant. Economists share a common understanding that the rate at which nations adopted new tools hundreds of years ago strongly affects whether they are rich or poor today.

STI and the recently accelerated digital transformation can aid in fighting the multidimensional vulnerabilities of LDCs. In order to effectively address the multidimensional vulnerabilities of LDCs in the post-pandemic recovery period, as well as throughout the Decade of Action, it is imperative to create STI for SDG roadmaps.[59] These roadmaps are at the intersection of national development plans, STI plans, and SDG plans (Figure 9).[60] This process should be developed at a national level by a central agency or ministry in charge of national development plans, the Ministry of Science and Technology, or other agencies in charge of STI plans; and coordinated at the highest level, i.e., the President’s Office or the Ministries of Planning or Financed.[61]



Source: Adapted from UN (2020), *Implementing the Science, Technology, and Innovation (STI) for SDG Roadmaps at the Country Level: Operational Note*

FIGURE 9: Integration of National, STI, and SDG Plans and Key Actors

58) World Bank (2008) Science, Technology, and Innovation: Capacity Building for Sustainable Growth and Poverty Reduction, at https://openknowledge.worldbank.org/bitstream/handle/10986/6418/439520PUB0Box310only109780821373804.pdf?sequence=1&isAllowed=y

59) The STI for SDGs Guidebook is still being developed and is in its pilot phase. Serbia has currently developed the first Smart Specialization Strategy Action Plan with the help of the European Commission’s Joint Research Centre (EC/JRC). However, there is still much to learn from this process, and efforts for scaling-up of this Action Plan have been made through the Partnership in Action on Science, Technology, and Innovation for SDGs Roadmaps. More information can be found on https://ec.europa.eu/jrc/sites/default/files/summary_-_high-level_dialogue_partnership_in_action_sti_for_sdgs_roadmaps.pdf

60) UN (2020) Implementing the Science, Technology, and Innovation (STI) for SDG Roadmaps at the Country Level: Operational Note, at https://sustainabledevelopment.un.org/content/documents/25818Operation_Note_STI_for_SDG_Roadmaps_final_Feb_28_2020.pdf

61) Ibid

1.4 MULTIDIMENSIONAL CHALLENGES FOR 4IR DEPLOYMENT

The 4IR is predicated on innovation as a critical driver of productivity and value creation. A growing number of emerging economies have begun following in the footsteps of most advanced economies, recognizing the importance of innovation as a core part of their growth agenda. However, many governments across the globe are struggling to understand the nuances of an innovation-based and innovation-driven economy and society, and hence are unable to understand what makes a country innovative.

“The root causes of slow growth and the inability to leverage new opportunities offered by technology in LDCs continue to be the ‘old’ developmental issues – institutions, infrastructure, and skills.”

‘Old’ developmental issues pose barriers to LDCs uptake of 4IR technologies. The root causes of slow growth and the inability to leverage new opportunities offered by technology in LDCs continue to be the ‘old’ developmental issues – institutions, infrastructure, and skills.[62] This is further exacerbated by the myriad of economic, social, and institutional challenges that directly weaken and compromise the potential and capabilities of LDCs to accommodate institutional and economic finetuning for the 4IR.

LDCs have not been able to reap the benefits of ICT as a result of limited Internet access. The development of ICT has supported the creation of new job opportunities. Nevertheless, the spread of ICT in developing countries has remained low. This is particularly true for LDCs, as the proportion of ICT total employment remains low, especially in Sub-Saharan Africa.[63] LDCs grapple with limited access to high-speed Internet, which generally restrains their digital renaissance. By the end of 2017, only 172 million of the slightly more than 1 billion people living in LDCs had access to the Internet. In spite of the efforts to increase ICT utilization and internet penetration rates, LDCs’ investment in ICT infrastructures such as high-speed Internet, ICT research, and ICT education remains extremely low when measured as a percentage GDP or based on public spending.[64] Most people in the LDCs do not have access to affordable Internet connections (Figure 10). Improving connectivity and access to information could help make trade more inclusive and bring more considerable gains to the LDCs, particularly for the most isolated groups—namely women and people living in rural areas.[65]

According to the Alliance for Affordable Internet, 2.3 billion people live in a country where a 1GB mobile broadband plan is unaffordable for individuals earning an average income. Most of these people live in LDCs, where the average cost of 1GB of internet access is 14.8% of Gross National Income (GNI) per capita, with users in countries such as the Democratic Republic of the Congo, the Central African Republic and Haiti obliged to pay almost half of their monthly income.

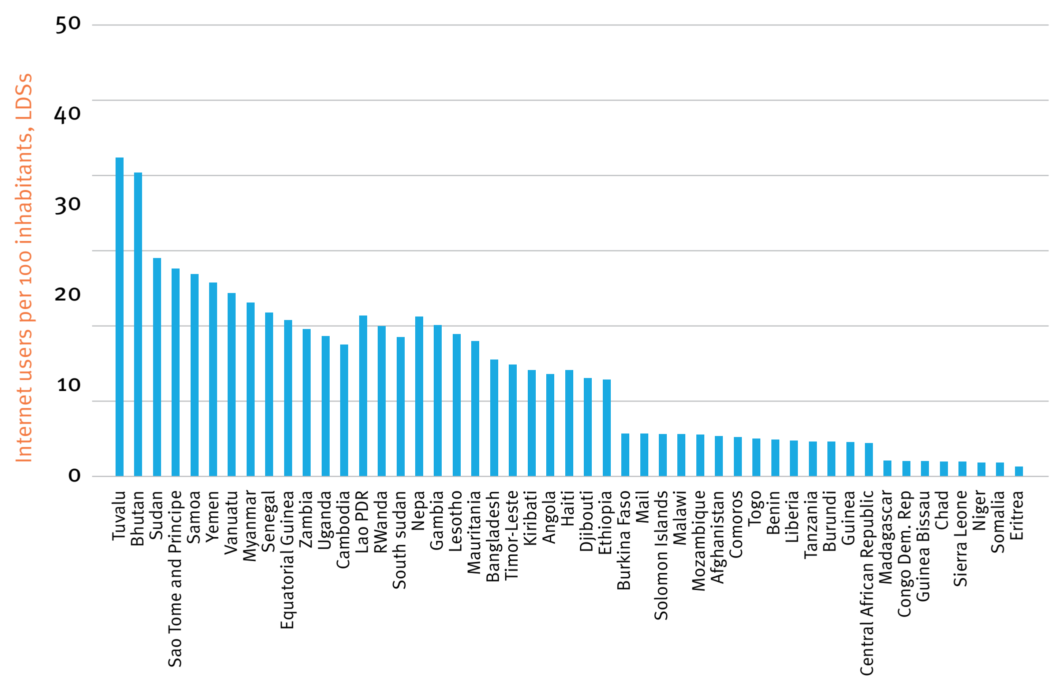
Source: Adhikari, R. (2019), *6 Ways the Least Developed Countries Can Participate in the Fourth Industrial Revolution*, at https://www.weforum.org/agenda/2019/08/6-ways-least-developed-countries-can-participate-in-the-4ir/

62) African Development Bank (2019) Unlocking the Potential of the Fourth Industrial Revolution in Africa

63) Ayentimi, D. T. (2020) The 4IR and the Challenges for Developing Economies, at https://www.researchgate.net/publication/340840065_The_4IR_and_the_challenges_for_developing_economies

64) Ibid

65) OECD, WTO (2017) Aid for Trade at a Glance 2017. Promoting Trade, Inclusiveness and Connectivity for Sustainable Development. Chapter 9. Promoting Trade Inclusion in the Least Developed Countries. Enhanced Integrated Framework



Source: Adapted from OECD, WTO (2017), *Aid for Trade at a Glance 2017. Promoting Trade, Inclusiveness, and Connectivity for Sustainable Development*

FIGURE 10: Internet users per 100 inhabitants in the LDCs

Across the globe, there is a gender gap in the use of the Internet. Worryingly, the gender imbalance in Internet use in LDCs has continued to experience an upward trend since 2013.[66] Internet usage in developed countries in 2019 disaggregated by gender shows that 87.6 percent of men and 86 percent of women had access to the Internet. However, when comparing Internet usage between developed countries and LDCs, a vast gender divide is evident, with only 24.4 percent of men and 13.9 percent of women having access to the Internet (Figure 11).[67] Access to the internet is a prerequisite for pursuing opportunities in digital trade. And most people access the internet via their phones. The data also shows a gap, with women in low- and middle-income countries 10 percent less likely to own a phone than men. That is 197 million fewer women with phones.[68]

Many LDCs are developing national ICT strategies and policies, which guide country ICT development. However, a gender perspective is largely absent from these plans. The relatively young local women's movement has for a long time been preoccupied with other burning priorities, such as domestic violence, trafficking in women, reproductive health and rights, and economic injustice.[69]

In the aftermath of the COVID-19 pandemic, LDCs are at a critical junction for girls' education. At the peak of the COVID-19 pandemic, over 236 million learners across the entire African continent were unable to attend school as a result of partial or full school closures.[70] This disruption to education has the potential to roll back substantial gains made on girls' education in recent decades, with broader immediate and long-term effects on the achievement of the SDGs, including those related

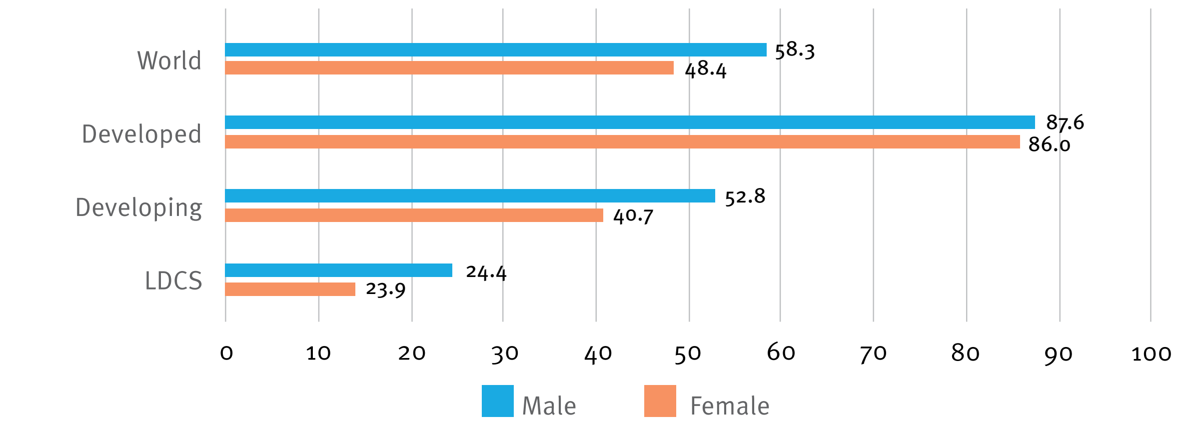
66) Ramsay, D. (2020) Opinion: How to Tackle Least Developed Countries' Gender Gaps in Tech Use and Data, at https://www.devex.com/news/opinion-how-to-tackle-least-developed-countries-gender-gaps-in-tech-use-and-data-96713

67) ITU Publications (2019) Measuring Digital Development Facts and Figures 2019

68) Ramsay, D. (2020) Opinion: How to Tackle Least Developed Countries' Gender Gaps in Tech Use and Data, at https://www.devex.com/news/opinion-how-to-tackle-least-developed-countries-gender-gaps-in-tech-use-and-data-96713

69) https://www.apc.org/en/news/new-report-bridging-gender-digital-divide-challenges-central-and-eastern-europe-and-ex-soviet

70) UNESCO (2020) Girls' Education: Building Back Equal on the African Continent Together, at https://en.unesco.org/news/girls-education-building-back-equal-african-continent-together



Source: Adapted from Adapted from ITU Publications (2019), *Measuring Digital Development Facts and Figures 2019*

FIGURE 11: Internet penetration rates for men and women in 2019

to poverty reduction, health and well-being, inclusive quality education, and gender equality.[71] The pandemic has disproportionally affected girls in Sub-Saharan Africa, as estimates show that 1 million girls from that region may never return to school once they reopen due to policies and practices that ban pregnant girls and young mothers from resuming school.[72]

Worldwide, women's access to finance is disproportionately low. Credit rationing through high-interest rates disproportionately discourages women entrepreneurs from applying for loans, while lacking collateral means they have less access to loans than their male counterparts. Digital financial tools, services, and enabling technologies can help low-income women build economic resilience.

While ag-platforms have the ability to reduce the gender gap in LDCs, a "gendered" digital divide persists. In terms of gender, ag-platforms have the potential to reduce the gender gap in terms of 'access' by improving access to digital skills, finance/credit, and work opportunities, reducing information asymmetries and training gaps, and supporting the creation of a level playing field for women. However, advancing gender inclusion through ag-platforms requires the narrowing of a persistent gendered digital divide in terms of basic access to the Internet and basic ICT skills and challenges related to affordability and cost of running these platforms. As a result, risks of further entrenching existing inequalities do exist when seeking to promote the uptake of new technologies.[73]

A major impediment to LDCs leveraging emerging technologies is their lack of basic and more advanced production capabilities to absorb and effectively deploy them. LDCs have limited production capabilities due to their ineffective deployment of technologies and weak absorption capabilities along supply chains, characterized by a scarce and uneven distribution of digital production technologies.

Digital technologies require adequate infrastructure. Developing countries, and LDCs in particular, face considerable infrastructure challenges in deploying digital technologies. LDCs lack affordable and reliable electricity and decent connectivity – essential requirements for leveraging these technologies. In some cases, these infrastructural bottlenecks have been bypassed by off-grid energy technologies and wireless connectivity systems. While these solutions work in certain areas, they cannot always provide the quality

71) UNESCO (2020) Building Banck Equal: Girls Back to School Guide, at https://unesdoc.unesco.org/ark:/48223/pf0000374094/PDF/374094eng.pdf.multi

72) UNESCO (2020) Girls' Education: Building Back Equal on the African Continent Together, at https://en.unesco.org/news/girls-education-building-back-equal-african-continent-together

73) Krishnan, A., et al. (2020) Ag-Platforms as Disruptors in Value-Chains: Evidence from Uganda, at https://cdn.odi.org/media/documents/odi-jr-eif-agrtechreport4-may20-proof01_final2311.pdf

and reliable services needed to run digital production technologies effectively. As a result, the improvements in productivity and quality provided by digital production technologies are offset by these infrastructural bottlenecks, making technology investments by individual companies too risky and ultimately not profitable.[74]

Digital production technologies are complex and controlled by a limited number of advanced countries and their leading companies. LDCs heavily rely on the import of such technologies from advanced economies. In many cases, even when they can mobilize significant resources to access them, they are tied to their buyers concerning both the hardware and software components. International buyers and original equipment manufacturers (OEMs) control the digital production technologies' source, type, and utilization by setting the parameters of the suppliers' engagement. Those who cannot meet these parameters are marginalized.[75]

Limited technology adoption further highlights the historic challenge in which governments' policies in LDCs have failed to guide the pathways of innovation and technology. Indeed, the deficiencies of prioritizing innovation and technology policy in national development appear to impede the enthusiasm of LDCs for adequately participating in the 4IR, which is dependent on technological development and adoption. Furthermore, the informal sector's deployment of basic general-purpose technologies is likely to be inhibited by the absence of supporting communication and transportation infrastructure, a low entrepreneurial culture within the general business environment, and the lack of human capabilities and limited digital skills. Fundamentally, technological development and the application of general-purpose technologies in the agricultural sector in LDC economies will remain unsuccessful unless there exist downstream and upstream linkages within the agriculture value chain. The advantage of downstream and upstream linkages within the agriculture value chain in LDCs is that it will help create opportunities to integrate gains in agricultural productivity into processing, packaging, and distribution to local and regional markets.

Employment prospects are predominantly concentrated in the agricultural sector, demonstrating limited technology adoption. The informal sector typically dominates LDC economies, mainly characterized by SMEs with limited technology utilization. Essentially, the influence of the 4IR on the informal sector in developing economies will largely be underpinned by the pace of high-tech adoption as an avenue to support increased productivity and efficiency in agro-processing businesses and SMEs in general.

74) UNIDO (2019) A Revolution in the Making? Challenges and Opportunities of Digital Production Technologies for Developing Countries, at https://www.unido.org/api/opentext/documents/download/16423347/unido-file-16423347

75) Ibid

Innovation is limited among entrepreneurs in LDCs, and me-too businesses generally predominate based on imitations of existing activities. On average, only 15 percent of early entrepreneurs in LDCs report introducing a new product or service, compared with 24 percent in other developing countries, and entrepreneurial activity by employees is also more limited.[76]

Entrepreneurial activity in LDCs occurs predominantly in sectors with low entry barriers and limited skill requirements. Entrepreneurs in LDCs provide mainly consumer-oriented services such as those involving retail, motor vehicles, lodging, restaurants, personal services, health, education, and social and recreational services. Limited activity has been noted in more transformative activities, such as construction, manufacturing, transportation, communication, utilities, wholesaling, and business-oriented services; however, it is insignificant. This suggests that the entrepreneurship potential in LDCs translates only to a limited extent into innovative businesses capable of playing a catalytic role in structural transformation.[77]

The use of digital technologies in production and service systems reduces the demand for labor across the globe. LDCs are particularly vulnerable to this trend, as the availability of low-wage workers is no longer considered an imperative international competitive advantage that they have historically relied on. This has resulted in production locations being moved closer to sales markets in industrialized countries. This reshoring[78] of operations that are taking place now is increasing employment in developed, industrialized nations. The original relocation of work processes and production sites to low-wage countries resulted in the loss of jobs for low-skilled workers in developed countries. However, with the emergence of digital technologies, workers in LDCs lack the necessary skill-set to operate these novel production methods.[79] The retention of these industrial plants will require LDCs to act swiftly in re-skilling their already low-skilled and low-wage workforce.

Since the future is digital, it will be critical for LDCs to develop "future-proof" skills. While investing in science, technology, engineering, and mathematics (STEM) is vital, soft skills such as creativity, collaboration, and time management cannot be ignored. However, most LDCs do not have the resources to provide basic education and will only meet this requirement through external assistance or by engaging the private sector. With flexibility and adaptability key to developing skills fit for the future, rigid and inflexible education systems in many LDCs can only be tackled through solid political determination.[80]

76) UNCTAD (2018) The Least Developed Countries Report 2018, Overview, Entrepreneurship for Structural Transformation – Beyond Business as Usual, at https://unctad.org/system/files/official-document/ldcr2018overview_en.pdf

77) Ibid

78) Reshoring is the process of relocation of work operations and even entire industrial plants that were previously relocated from developed industrialized countries to low-wage countries.

79) Petersen, T. (2019) What is the Impact of Reshoring, at https://ged-project.de/trade-and-investment/what-is-the-impact-of-reshoring/

80) Adhikari, R. (2019) 6 Ways the Least Developed Countries Can Participate in the Fourth Industrial Revolution, at https://www.weforum.org/agenda/2019/08/6-ways-least-developed-countries-can-participate-in-the-4ir/

LDCs are at high risk of debt distress as a result of COVID-19. The pandemic worsened the financial situation in LDCs, as foreign direct investments (FDI) and remittances declined. This has led to half of all LDCs to tread very lightly between being at high risk of – or already being in – debt distress.[81]

Each industrial revolution brings with it significant policy issues, and the 4IR is no different. The successful adaptation to new technological achievements is predicated on the ability of governments to respond to policy needs adequately. LDCs must take action to enact appropriate long-term policies so as to not lag behind developed countries. Lagging will have profound negative impacts on LDCs, as inadequate policy interventions will lead to the deterioration of their competitiveness and the reduction of their revenue. Furthermore, the 4IR necessitates policy interventions that will ensure that technological progress works for the benefit of society. Rapid technological advances, coupled with the rapid adoption of these technologies across sectors, can widen the income inequality gap if financial regulation is not imposed.

Overall, the business environment in LDCs is hostile to market-led growth. Private enterprises in LDCs suffer excessive regulatory barriers, and in most respects, regulatory costs are higher than in developed economies. These poor business environments are also more likely to negatively impact women-owned businesses, which are more likely to remain informal. It is recognized that good regulations are necessary to secure benefits, protect workers, consumers, and the environment, promote the rule of law, and for the efficient functioning of market economies.[82]

81) UNIDO (2021) Industrial Production in LDCs and Trade in the COVID Era and Resulting Policy Reactions, at https://www.unido.org/sites/default/files/files/2021-05/Keynote%20-%20LDC%20industrial%20performance%20in%20COVID%20era%20and%20resulting%20policy%20reactions%20%28final%29.pdf

82) https://www.enterprise-development.org/what-works-and-why/evidence-framework/rationale-for-ber/

Unintended Consequences of the Fourth Industrial Revolution

Although many LDCs will benefit from the advances of the Fourth Industrial Revolution, there are unintended consequence which must be considered

For example, Technologies of 4IR share a common thread of connectivity (e.g. WiFi; Bluetooh; Long Range frequencies (LoRa); low-power wide-area network (LPWAN), as evident through the evolution of"Smart devices," ranging from phones to TVs to soil moisture sensors, etc. The ability to proxy these items and promote their intercommunication has generated many benefits, such as increased data collection, remote operation and automation. However, it simultaneously has created newfound liabilities to cybersecurity threats. For example cloud networks in LDCs face challenges in terms of security, breaches, and confidentiality, which reduces the faith of local and international users to engage with such services. Network-wide shutdowns and cyber attacks from bad actors will require continuous monitoring and the involvement of national governments to protect their civilians. Moreover, it is worth considering that there are differences among the capabilities of LDCs themselves, necessitating tailored solutions particular to each country.

4IR has dualistic properties in terms of the cost and benefits to gender equality

For example, in the textile industry, it is estimated that 80 percent of garment worker are female, although many are resigned to such roles due to stereotypes persevered by gender norms. Yet, the garment industry continues to serve a significant component of the economies of least developed countries, due to its accessibility and low barrier to entry. For instance, clothing consists of 85 percent of Bangaldeh's export earnings; in Cambodia, one in five households in Cambodia include garment workers; Myanmar recently joned the garment factory, which has been attributed to its economic revitalization. With this complex backdrop, the introduction of automated process stands to disrupt the industry, via the implementation of more cost-effective, efficient and productive systems driven by AI and robotics. In response, LDCs need to be prepared with a framework and measures which are considerate to gender issues and 4IR technologies. In addition, gender impact assessments should be done prior to the implementation of disruptive technologies to forecast how it will affect disadvantaged groups. Simultaneously, policies must be in place to help reskill women and dissolve normative job roles. Evidence of the benefits that can be provided by gender-sensitive measures have already benefitted particular LDCs. In one success story, the UNDP has collaborated with the Bangladeshi Government towards the development of digital centers that provide paid public services to remote communities, the majority of which are run by rural female entrepreneurs. Complementing these efforts, there is a need for an increased number of initiatives which bridge the skills gap between genders. This may be done through programs similar to UNESCO's EQUALS Digital Skills Hub, UNICEF's Skills4Girls and CloudKettle's Digital Skills for Women.

Coincident with the need for LDCs to gather more data to drive the 4IR ecosystem, such data needs to be well-regulated and comprehensive, with protective measures in place

LDCs must be cognizant of the general complexities of social and technical issues related to data. If governments are to reap the benefits of digitalization, they must introduce adequate checks and balances to ensure data privacy for their citizens. To ensure data privacy compliance, governments must impose data governance policies that ensure the data's availability, usability, integrity, and security. LDCs can look to the work of the European Union's General Data Protection Regulation (GDPR) for inspiration, as it was enacted to give users control over their data, in addition to providing mechanisms which commands compliance by participating websites. These regulations instill greater confidence that data collection is safe, ethical and well-protected in the subject countries.

2

4IR technology absorption for LDCs

Technology transfer and technology diffusion can assist LDCs towards the absorption of new technologies. Fostering trade and global and local partnerships can enable LDCs to use 4IR technologies effectively, with collective benefit.

The absorptive capacity of LDCs regarding 4IR technologies is predicated among multiple factors, chief among which include regulations, human capital development, infrastructure, and innovation ecosystems. A country or organization's technological absorptive capacity has been defined as its "ability to search, acquire and exploit external technology, as demonstrated by its characteristics."[83] Currently, technology absorption for many LDCs is quite low. However, there are multiple means of achieving technology absorption, including technology transfer from developed countries to developing countries, applying the cluster approach to assemble organizations towards a common goal, fostering domestic skill development and infrastructural improvements.

Technology transfer and technology diffusion can assist LDCs towards the absorption of new technologies. As the name suggests, technology transfer is the process of transferring technology from one entity to another. There are four key modes of technology transfer, including: "i) physical objects or equipment; (ii) skills and human aspects of technology management and learning; (iii) designs and blueprints which constitute the document-embodied knowledge on information and technology; and (iv) production arrangement linkages within which technology is operated."[84]

Cluster Approach

The cluster approach can help LDCs to integrate innovation in a manner tailored to their unique national needs.

The cluster approach describes the phenomena of linking interdependent firms to one another in a value-adding production chain, at times involving strategic alliances among universities, brokers, research institutes, knowledge-based business services and customers.

Compared to a sectoral approach, cluster-based approach homes in on potential synergies amongst various groups, which can be leveraged towards the development and implementation of new technologies. These clusters can improve the quality of strategic documents derived from the idiosyncratic knowledge of the cluster participants.

Moreover, clusters allow each member to benefit as if it had greater scale or as if it had joined with others without sacrificing its flexibility (Porter, 1998). For example, from 2015-2019, the Korea International Cooperation Agency (KOICA), under the auspices of UNIDO, led a project to enhance the competitiveness and market access of SMEs in Valle del Cauca, Colombia. The project involved three components: (1). formation of an export consortia; (2) providing TA to consortia member enterprises; and (3). Institutional know-how-transfer. The result was market expansion for 21 companies, employment increase of 14 during the project duration, and cumulative exports of nearly US$1 million dollars' worth of material s to 10 markets, including the United States, UK, France, Spain and Hong Kong. In a historical example, Costa Rica's eco-tourism cluster demonstrates how the cooperation of various industries and sectors led to an increase of tourist arrivals from 155,000 to 1.1 million and revenues of $US21 million to 1.15 billion from 1970-2000 (Jones and Spadafora, 2016).

The cluster approach has been mainly utilized in developed countries, but could benefit LDCs – particularly small businesses. By agglomerating reserouces, size limitations are overcome, conferring higher specialization, innovation potential and knowledge transfer (Karaev et al. 2007). Clusters which incorporate donor funding should also be considered, as it adds financial resources, idiosyncratic knowledge, expertise and political attention which can boost economic development.

83) Aldrich, T.J. (1977), Managing the Flow of Technology: Technology Transfer and Dissemination of Technological Information within the R&D Organization, MIT Press, Cambridge, MA.

84) Moon, S. (2008). Does TRIPS Art. 66.2 Encourage Technology Transfer to LDCs? An Analysis of Country Submissions to the TRIPS council (1999-2007). *UNCTAD*.

In contrast, technology diffusion involves the dissemination of innovative technical information and know-how that is already in use in other firms, industries, or countries. Diffused technologies can be incorporated in products and processes. This includes "hard technologies" such as computer-controlled machine tools and "soft technologies" such as improved manufacturing, quality control, or training methods. Technology is also diffused through competition among firms, the mobility of skilled labor, the activities of professional societies, scientific journals, various forms of informal knowledge trading, and such practices as reverse engineering.

Examples of technological diffusion include:

- Providing information on opportunities for improvement in existing technologies, best practices, international trends, relevant regulations, business networks, etc.
- Benchmarking companies in their industries at national and international levels to identify areas for improvement.
- Technical assistance and consulting in quality management and certification, environmental impacts and energy use management, human resource development, strategic management, etc.

LDCs can transition into the Fourth Industrial Revolution by 'retrofitting' their current technologies into existing 3IR developments. Although leapfrogging solutions are certainly possible for LDCs, it may be most pragmatic to pursue gradual improvements to existing infrastructure. Through a meta-analysis of 20 papers, Zambetti et al.[85] identified three significant ways that Original Equipment Manufacturers can retrofit their facilities to accommodate 4IR technologies (Table 1). For example, in the autonomous driving space, as opposed to buying a brand-new vehicle with autonomous driving capabilities, some companies are developing solutions to retrofit older, more affordable vehicles with such technology. Comma.ai is one such company that takes entry-level vehicles, such as a 2016 Honda Civic, and provides self-driving capabilities by installing computer-vision hardware and software.[86] In the manufacturing space, Fan and Chang in 2018 designed a smart box for legacy machines to detect the machine's operating status, providing real-time monitoring of higher fidelity than manual human inspection.[87] In addition, Garcia-Garza et al. (2019) describe the integration of an information processing kit featuring a mini-computer, integrated with cloud computing and data analytics, towards monitoring a manufacturing inspection system.[88]

TABLE 1: Retrofitting Approaches

Addition of smart sensory and/or edge gateways	These IoT sensory and smart gateways can be used to gather data from programmable logic controllers (PLCs) or other data sources.
Retrofit Kits	Deployed by a third party as a complete package of sensors, connectivity, control, and data analytics.
Video Camera	Utilizing industrial cameras to monitor manufacturing operations and capture data from the workforce and equipment.

Adapted from Zambetti et al. 2020

85) Zambetti, M. et al. (2020). Enabling servitization by retrofitting legacy equipment for Industry 4.0 applications: benefits and barriers for OEMs. *Procedia Manufacturing*. 48. 1047-1053

86) https://comma.ai/

87) Fan, Y. and Chang, J. (2018). Embedded smart box for legacy machines to approach to I4.0 in smart manufacturing.

88) García-Garza, M. A., Ahuett-Garza, H., Lopez, M. G., Orta-Castañón, P., Kurfess, T. R., Urbina Coronado, P. D., Güemes-Castorena, D., Villa, S. G., & Salinas, S. (2019). A Case about the Upgrade of Manufacturing Equipment for Insertion into an Industry 4.0 Environment. *Sensors (Basel, Switzerland)*, *19*(15), 3304. https://doi.org/10.3390/s19153304

However, despite many LDCs having advertised their willingness to implement 4IR technologies towards curbing climate change and sustainable development, the reality paints a picture of continued lag, inadequate infrastructure, and deficient or lacking policy. At the most recent Ministerial Meeting of the Least Developed Countries,[89] multiple LDCs expressed their concern about being further marginalized, mainly due to the impact of COVID-19. The keynote documents stressed the urge for LDCs to develop their productive capacities, indicating that "the transfer of productive resources to sectors and activities with higher labor productivity and value-added has been extremely slow, hindering progress towards sustainable development." Implicitly, this suggests poor absorption and implementation and novel technologies, which rendered developed nations more resilient to the impacts of the pandemic. However, for LDCs to absorb technologies, there must be a fertile ground of legislative and infrastructural spearheaded by their national government. For example, many LDCs fail to have a digital technology policy, which provides a framework for 4IR technologies to be implemented. Those who do have made great strides towards graduation to developing status (Table 2). Bangladesh is a strong example of how government involvement can spur the usage and benefits yielded from 4IR technologies. Since Digital Bangladesh was founded in 2008, the country brought its internet users, from 3 percent of the population to 70 percent.[90] In a similar vein, Nepal has released its own technology absorption framework – Digital Nepal – to enact digital initiatives towards diversifying Nepal's economy. Complementing Digital Nepal invoked the country's National ICT Policy in 2015, National Broadband Policy, and invocation of the Electronic Transaction Act. All these measures point towards Nepal's transformation into a knowledge- and information-based society.

TABLE 2: Necessary Components for Digital Technology Policy
Technology Absorption The provision of manufacturing and digital extension services (e.g., organizational and operational systems), demonstration projects, factors, access to data and infratechnology, and access to additive manufacturing.
Standards Development and Dissemination Provision of standardization of services and data, Infratechologies, testing and certification facilities (akin to the promotion of National Quality Infrastructure.
System Integration Retrofitting services and legacy system integration into digital platforms, rapid prototyping facilities, and virtual design.
Technology Scaling Codification and dissemination of successful technology solutions and implementation of scaling up facilities (e.g., venture capital accelerators; start-up incubators; SMEs).

Adapted from Andreoni et al. 2021[91]

89) UNCTAD. (2021). Declaration of ministers of the least developed countries at the fifiteenth session of the United Nations Conference on Trade and Development. *United Nations Conference on Trade and Development*. https://unctad.org/system/files/official-document/td525_en.pdf

90) UN. (2021). Digital Connectivity Essential for Least Developed Countries to Reap Benefits of Fourth Industrial Revolution, Experts Tell Preparory Committee. *United Nations. Meetings Coverage and Press Releases. LDC Prepatory Committee, First Session*. https://www.un.org/press/en/2021/dev3439.doc.htm

91) Adreoni, A., Modliwa, P. & Roberts, S. (2021). Structural Transformation in South Africa: The Challenges of Inclusive Industrial Development in a Middle Income Country. *Oxford University Press*. 1-416

Fostering trade and global and local partnerships can enable LDCs to use 4IR technologies effectively, with collective benefit. Although the world population contributed by LDCs is nearly 12 percent, the share of world trade by LDCs is marginally above 1 percent.[92] However, programs such as the Enhanced Integrated Framework (EIF) have empowered LDCs through various trade and sustainable development initiatives. Many 4IR technologies depend on supporting services such as telecommunications, 5G, and satellite services. Trading systems are integral to the cultivation of such technologies as promoting market access negotiations and e-commerce initiatives towards a competitive and well-regulated market.[93] The EIF has enabled multiple LDCs in this regard. In Ethiopia, the EIF provided IT infrastructure and facilitated virtual meetings towards its resumption of the WTO accession process.[94] Moreover, over 74 technologies have been introduced to LDCs for the optimization of select value chains. In Cambodia, the EIF assisted in developing the Cambodia Trade Integration Strategy (CTIS) and digitalizing trade using e-commerce platforms, providing a larger potential of trading partners.[95] This foundation provides the necessary ingredients to incorporate 4IR technologies later on – the data collected can inform forecasts driven by machine learning; blockchain technologies can be used to track the status of a product throughout its lifecycle; cloud computing can be leveraged to provide a common repository to review shipping records, etc.

Education and R&D are essential to the absorption of 4IR technologies. It has been suggested that half of the differences in 'income levels and growth among countries are due to differences in total productivity' where R&D may explain "up to 75 percent of the differences in total factor productive rates, once externalities are taken into consideration."[96] Compared to developed countries, the governments of least developed countries spend far less than developed countries on education, research, and development. LDC's spend approximately 3 percent of their GDP on education, whereas developed countries such as Sweden (7.5 percent), the United Kingdom (5.2 percent), Germany (5 percent) spend nearly twice more on education.[97]

Two digital divides impact technology absorption in LDCs. As Paul Attewell described in 2001:[98] the first digital divide is in the access to the technology itself, and the second refers to a gap in the usage of the technology. As echoed by James (2021), two broad policy proposals would be of the most substantial impact to LDCs, "The first is to improve learning and raise proficiency in numeracy and literacy in schools; the second policy option is to provide basic digital skills even those lacking full proficiency in numeracy and literacy."[99] Moreover, those who lack digital skills will be subject to compounding exclusion (Figure 12).[100] Regarding the first digital divide, network coverage of LDCs scores at 54 compared with 83 in the rest of the world, while data usage is more expensive – 30 for LDCs compared with 63 in terms of mobile data affordability.[101] The UN Technology Bank has been working with organizations to improve the infrastructural inadequacies of LDCs. As a new member of the Alliance for Affordable Internet (A4AI), the partnership has the opportunity to improve connectivity and foster digital cooperation by spreading access to quality internet. Yet, even though mobile penetration in developing countries is expanding, many lack the awareness to take advantage of the internet provided by such devices and instead use them purely as a communication device. That is, the most advanced technological application of many mobile users in these LDCs is limited to money transfer, but not for their smart-device applications. As James (2020) writes, 80 percent of phone users in LDCs lack the skills or contextual knowledge to operate internet-based operations on phones, such as managing files, e-mail, searching or filling online forms.[102] Moreover, many of the "smart" phones, such as KaiOS, are stripped down to include "essential features" but this, in effect, blunts the learning potential of the population. There is an evident need for increased access to smart devices, yet with the full gamut

92) Bruckner, M. (2012). Limited progress in market access for LDCs. *United Nations. LDC Portal*, *at* https://www.un.org/ldcportal/limited-progress-in-market-access-for-ldcs/

93) WTO. (2019). Fourth industrial revolution - the next servicification frontier. *WTO Public Forum 2019 (report by Session Organizer)*. https://www.wto.org/english/forums_e/public_forum19_e/pf19_82_rpt_e.pdf

94) https://enhancedif.org/en/country-profile/ethiopia

95) Kim, S. & Duval, Y. (2020). In the world's poorest countries, the move to digitalize trade procedures in needed now more than ever. *Trade for Development News by EIF*, *at* https://trade4devnews.enhancedif.org/en/op-ed/worlds-poorest-countries-move-digitalize-trade-procedures-needed-now-more-ever

96) Griliches, Z. (1979). Issues in assessing the contribution of Research and Development to Productivity Growth. *Bell Journal of Economics*. *10(1) 92-116.*

97) https://data.worldbank.org/indicator/SE.XPD.TOTL.GD.ZS?locations=XL

98) Atwell, P. (2001). The First and Second Digital Divides. *Sociology of Education* 74(3). 252-259

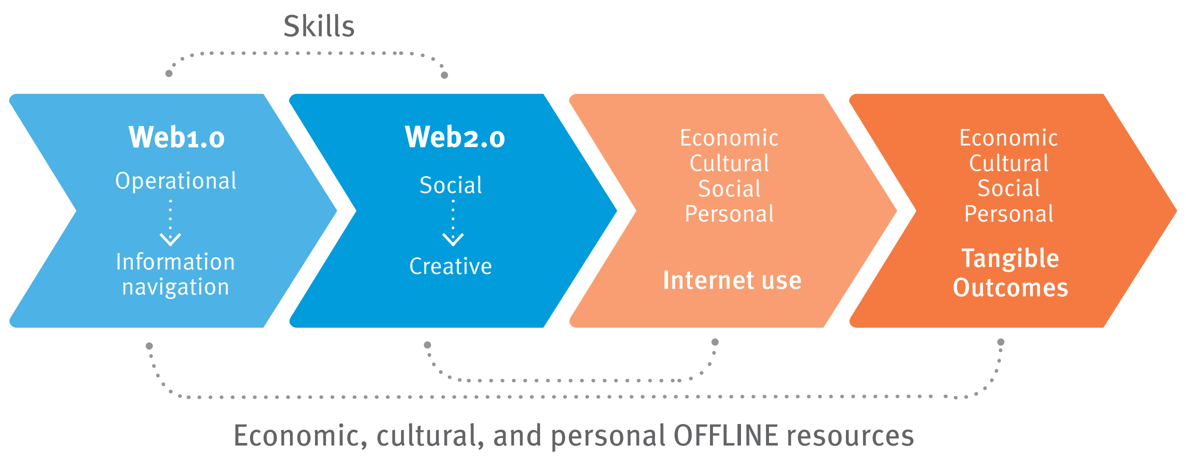
99) James, J. (2021). Confronting the scarcity of digital skills among the poor in developing countries. *Development Policy Review*. *39*(2). 324-320.

100) Van Deursen, A., Helsper, E., Eynon, R. & Van Dijk, J. (2017). The compoundness and sequentiality of digital inequality.

101) GSMA. (2020). The State of Mobile Internet Connectivity 2020. *GSMA*. https://www.gsma.com/r/wp-content/uploads/2020/09/GSMA-State-of-Mobile-Internet-Connectivity-Report-2020.pdf

102) James, J. (2020). The smart feature phone revolution in developing countries: Bringing the internet to the bottom of the pyramid. *The Information Society*. 36(4).

of features. Compounding matters, there is little digital skill promotion by the government, so many individuals remain in limbo with little to zero digital skill knowledge. For example, although the number of mobile cellular subscribers in Zimbabwe was 12.9 million, there was only a 21% of internet penetration rate in Zimbabwe, prohibiting access to remote education during the pandemic.[103]



Source: Adapted from Van Deursen et al. 2017.

FIGURE 12: Model of compound and sequential digital exclusion

To bridge the digital divide, the governments of LDCs must increase their direct participation in supporting programs towards skills development. In a 2020 World Bank report on Digital Skills Frameworks and Programs[104], numerous programs were listed, including Anudip, Microsoft's 4Africa Academy, Digital House, STEP Computer Academy, and Tunapanda. However, a notable trend is that most of these initiatives were private endeavors, run by Microsoft, Cisco, IBM, and Intel, instead of government-driven. Yet, the need for digital skills is particularly imperative in LDCs, which continue to be driven by informal economies. It is estimated that 2 billion of the world's employed population – or 62 percent of the global workforce - does so informally, with over 93 percent in emerging and developing countries.[105] However, as evidenced by COVID-19, workers in the informal economy were hardest hit. It is estimated that 95 million people - mainly informal workers – fell below the extreme poverty threshold due to the pandemic in 2020.[106]

Another component of 4IR Technology Absorption is the embodiment of a "knowledge economy" featuring a strong presence of academic center involvement, spreading a culture of learning. With universities in the vicinity of urban centers, such an environment fosters a feed-forward mechanism of improvements. In contrast, when there is a lack of intellectual opportunity and poor technological progress, this often leads to a phenomenon of brain drain – the emigration of highly skilled and intelligent people. This generates a significant lack of

103) https://harris.uchicago.edu/news-events/news/commentary-many-students-developing-countries-cannot-access-education-remotely

104) World Bank. (2020). Digital Skills: Frameworks and Programs. *World Bank*. https://openknowledge.worldbank.org/bitstream/handle/10986/35080/Digital-Skills-Frameworks-and-Programs.pdf?sequence=1&isAllowed=y

105) ILO. (2018). Women and men in the informal economy: A statistical picture – Third Edition. *International Labour Office*. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_626831.pdf

106) IMF. (2021). IIMF Country Focus: Five Things to Know about the Informal Economy. *International Monetary Fund – IMF News*. https://www.imf.org/en/News/Articles/2021/07/28/na-072821-five-things-to-know-about-the-informal-economy

financial and educational incentives for individuals to return to such areas later on, often causing downward financial pressures in the vacuum left behind.[107]

Another example of localized advancements is that of Innovation Districts, which involves a combination of "…entrepreneurs and educational institutions, start-ups and schools, mixed-use development and medical innovations, bike-sharing and bankable investments—all connected by transit, powered by clean energy, wired for digital technology."[108]

There are multiple participants in determining the economic composition of such districts, including incubators, research institutions, anchor companies (e.g., Facebook and Google in the Silicon Valley area), real estate developers, and means of exploring creativity (e.g., museums, theaters, etc.). Other populated cities, yet in less wealthy regions of the world, have picked up on this trend. In Rio de Janeiro, a partnership with IBM led to the generation of a central command office. The office's monitoring capabilities are vast, with the ability to track traffic, invoke automatic processes in response to floods, distribute warnings to its citizens, etc.[109] Nearby city Bogota, Colombia, executed a similar initiative, winning the Sustainable Transport Award for their work on the transit system in a mixed-land use approach. Their design strategy - 'ciclorutas' - is the most extensive bicycle path network in Latin America, connecting public transport and other major cities.[110]

107) Artz, G. (2003). Rural Area Brain Drain: Is it a Reality? *Iowa State University: Digital Repository. Extension and Outreach Publications*. 90. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1090&context=extension_pubs

108) Katz, B. & Wagner, J. (2014). The Rise of Innovation Districts: A New Geography of Innovation in America. *Brookings. Metropolitan Policy Program*. https://www.brookings.edu/wp-content/uploads/2016/07/InnovationDistricts1.pdf

109) Hawley, K. (2014). Transforming cities for sustainability: Facts and Figures. *SciDev.Net.* https://www.scidev.net/global/features/transforming-cities-sustainability-facts-figures/

110) Torres, A., Sarmiento, O. L., Stauber, C., & Zarama, R. (2013). The Ciclovia and Cicloruta programs: promising interventions to promote physical activity and social capital in Bogotá, Colombia. *American journal of public health, 103*(2), e23–e30. https://doi.org/10.2105/AJPH.2012.301142

3

How LDCs can harness the 4IR in the Race for Climate Action

The financial and humanitarian challenges of LDCs are intertwined with their vulnerability to natural disasters, which is anticipated to increase with the mounting concerns of climate change.

Considering the world's mounting environmental crisis, LDCs can reverse warming trends by implementing 4IR technologies. Current models developed by the Intergovernmental Panel on Climate Change (IPCC) project temperature increases greater than 1.5 – 2 degrees by 2100.[111] The anticipated effects of such climate change are substantial, ranging from disrupting local habitats of endangered species, wiping coral reefs, jeopardizing food security, and the displacement of millions of people. Unfortunately, the evidence of climate change is already quite clear, with the Earth's oceans estimated to have absorbed as much heat from 1997 to 2015 as they did in the previous 130 years.[112] More palpable evidence has come in the form of an increased level of extreme events, sea-level rise of 20 centimeters in the last century (double the rate of the century prior), shrinking ice sheets, and glacial retreat.[113] Although humanity is to blame at large, with the advent of the combustion engine and vast manufacturing releasing greenhouse gases (GHGs), LDCs have contributed the least but will be hurt the most.

The financial and humanitarian challenges of LDCs are intertwined with their vulnerability to natural disasters, which is anticipated to increase with the mounting concerns of climate change. Largely agrarian in nature, the economies of LDCs feature an estimated 72 percent employment in agriculture-related industries, which are also set to be affected as climate change consequences escalate.[114] A World Bank Group Paper in 2020 estimates that 32 to 132 million additional people are liable to extreme poverty by 2030 due to the short-term impacts of climate change.[115] This is in addition to the estimated 71 to 100 million people afflicted due to the implications of COVID-19. The following statistics capture the disproportionate risk to adverse consequences:[116]

"While only 18 percent of climate-related disasters occurred in LDCs in the last 50 years, 69 percent of worldwide deaths caused by such disasters during that period were in LDCs, even though only 13 percent of the world's population live there."

Compounding matters, it has been estimated that the incidence of natural disasters has increased approximately 2 percent a year globally over the past 15-20 years. This is echoed in another startling finding. From 1991-2005, it was estimated that 90 percent of disaster-related deaths and 98 percent of persons affected by such disasters were in developing countries, with a quarter of the deaths in LDCs. Highlighted in the Istanbul Program, LDCs continue to struggle with the effects of climate change. As advocated by the program, achieving SDGs, such as Zero Hunger, can be optimized by strengthening institutions, such as cooperatives, to enhance small-holder farmer food production and make rural markets work better for the poor. As is elucidated below, 4IR technologies can streamline processes and improve efficiency and accountability.

111) IPCC. (2018). Summary for Policymakers of IPCC Special report on Global Warming of 1.5 degrees Celsius approved by governments at https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

112) Gleckler, P., Durack, P., Stouffer, R. et al. (2016). Industrial-era global ocean heat uptake doubles in recent decades.

113) https://climate.nasa.gov/evidence/

114) ILO, UN (2013) Shared Harvests: Agriculture, Trade, and Employment, at https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/genericdocument/wcms_212868.pdf

115) Jafino, B. A., Walsh, B., Rozenberg, J., Hallegatte, S., (2020) Revised Estimates of the Impact of Climate Change on Extreme Poverty by 2030, at https://documents1.worldbank.org/curated/en/706751601388457990/pdf/Revised-Estimates-of-the-Impact-of-Climate-Change-on-Extreme-Poverty-by-2030.pdf

116) IIED (2019) Time to redress the hlobally unjust cost of climate change, at https://pubs.iied.org/sites/default/files/pdfs/migrate/17726IIED.pdf

The downstream effects of climate change pose an additional risk to the multidimensional vulnerabilities of LDCs, including food insecurity and hunger. The UN's Sustainable Development Goal 2 is to achieve Zero Hunger with approximately 700 million people globally – nearly one in ten persons – suffering from extreme hunger.[117] This number has only increased with the impacts of COVID-19. The UN's World Food Program has anticipated an additional 130 million people being forced into a state of starvation due to the impacts of the pandemic.[118] The population of LDCs was estimated at nearly 1 billion persons in 2017 and is anticipated to increase to 1.7 billion by 2050 at the current rate of population growth. An additional concern that has been elevated has been that of the "double burden of malnutrition" (DBM). The DBM is defined as, "simultaneous manifestation of both undernutrition and overweight and obesity, [and] affects most low-income and middle-income countries (LMICs)." The manifold impacts of DBM extend beyond nutrition and hunger. For example, a model by the Economic and Social Commission of Latin America and Caribbean (ECLAC) and Wood Food Programme (WFP) has measured the lifetime effects of childhood nutrition in various facets. The ECLC-WFP model has estimated GDP costs of 0.2 percent in Chile (US$ 500 million), 2.3 percent in Mexico ($28.8 billion), and 4.3 percent in Ecuador (4.3 billion US), for example.[119]

Multiple LDCs have signaled their commitment to decarbonization, which can be assisted by the implementation of 4IR technologies. In December of 2020, multiple leaders of LDCs mean in Bhutan for the Thimpu Ambition Summit.[120] Through uniting the LDCs together, the consortium signaled their intentions to fight climate collectively and propose solutions towards environmental and green economic recovery. As part of the Summit, multiple LDCs released their ambition statements, which included a common theme of achieving carbon neutrality by 2030 through measures such as increasing the usage of renewables, reducing the rate of deforestation, and creating new jobs using clean technology.[121]

AI AND ROBOTICS TOWARDS CLIMATE ACTION

The use of AI can improve the availability and efficiency of basic needs for utilities in LDCs, including electricity, water, and sanitation. Many of the current processes in agriculture require the use of manual labor and vocational skills. The reliance on traditional methods is largely due to economic strife and limited skill capital, which has created a bottleneck of agricultural processes. Compared to developed countries, LDCs have a low degree of food waste at the consumption level. Still, there is substantial waste at the processing level due to LDCs' technological limitations, indicating inefficiencies even during the initial stages of the agriculture lifecycle. Hence, it is evident that the dynamics of food loss differ vastly when comparing developing and developed countries. According to the Food and Agriculture Organization (FAO), more than 40 percent of food loss in developing occurs during the post-harvest and processing levels, compared to 40 percent of food losses in retail and consumer levels in their developed counterparts. Compounding matters, food loss, and waste also have associated environmental impacts. It is estimated that wasting food consumes 173-250 km3 of water consumption per year[122] and approximately 8 percent of the global greenhouse gas emissions. The FAO estimates that the carbon footprint of food waste amounts to 3.3 billion tonnes of CO_2 equivalent through the exploitation of nearly 24 percent of all croplands, freshwater, and fertilizers for total food production.[123]

117) https://www.un.org/sustainabledevelopment

118) Anthem, P. (2020) Risk of hunger pandemic as coronavirus set to almost double acute hunger by end of 2020, at https://www.wfp.org/stories/risk-hunger-pandemic-coronavirus-set-almost-double-acute-hunger-end-2020

119) UN (2017) The cost of the couble burden of malnutrition, at https://docs.wfp.org/api/documents/WFP-0000110372/download/#:~:text=The%20economic%20impact%20of%20malnutrition's,%2428.8%20billion%20per%20year%2C%20respectively.

120) LDC (2020) Welcome the the Thimphu Ambition Summit, at https://ldcambition.world-television.com/home/english

121) https://ldcambition.world-television.com/ondemand/english

122) Mekonnen, M. M., and Hoekstra, A. Y. (2010). The green, blue and grey water footprint of crops and derived crop products. Value of Water Research Report Series No. 48. Delft: UNESCO-IHE.

123) M. Kummu, H. de Moel, M. Porkka, S. Siebert, O. Varis, P.J. Ward Lost food, wasted resources: global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use Sci. Total Environ., 438 (2012), pp. 477-489,

Use cases

Precision Agriculture can streamline the fidelity of agricultural processes using AI and Robotics through automation and remote sensing. A novel solution through Gujarat Technological University is implementing an autonomous mobile robot towards disease and pest control, spraying toxic pesticides from a distance under a farmer's control. Another example is Blue River Technology, a farm-robotics startup, estimates that its robots can reduce agrochemical use by 90 percent.[124]

AI can unlock the potential of agriculture through "agritech" solutions, improving the profitability and efficiency of agribusiness SMEs. For example, the agricultural tech startup PEAT developed Plantix,[125] a deep-learning application that identifies potential defects and nutrient deficiencies in the soil. Software algorithms analyze the data and correlate foliage patterns with certain soil defects, plant pests, and diseases.

VIRTUAL REALITY, AUGMENTED REALITY AND CLIMATE ACTION

Virtual and augmented reality can be used to increase awareness of climate change and promote the experience of rich yet environmentally friendly experiences from the comfort of one's home. Through its diverse uses, virtual reality provides novel means to engage in digital experiences. In the context of climate change, virtual reality can provide a way for individuals to experience unexplored areas without the carbon burden inherent with physical travel while having a potentially psychologically meaningful experience in terms of climate action. As Gifford writes in a 2011 article,[126] psychological barriers limit an individual's willingness to engage in actions towards climate change mitigation and adaptation. Some of the factors he includes are listed below.

- **Ignorance:** not knowing a problem exists and what to do once aware of the problem. Many individuals in LDCs lack proper education, and it has been evidenced that those with more education are more likely to see climate change as a major threat (Figure 13).[127] Moreover, due to reduced capacities, the amount of available information, Africa has been described as having "a poor understanding and an ineffective regional strategy to tackle the effects of climate change."[128]
- **Judgmental Discounting:** undervaluing distant or future risks. Many individuals have a "temporal distance" from the issue of climate change,[129] to which virtual reality can simulate circumstances into the contemporary. For example, a survey of 3000 respondents in 18 countries displayed that respondents in 15 of the countries thought that environmental conditions were worse in places other than their own homes.[130]
- **Perceived Inequity:** it is well documented that LDCs have contributed less than their developed counterparts to climate change yet receive a disproportionate amount of funding. Moreover, a dearth of resources and minimal impact on the climate change discussion leads to a lack of control in how poor communities cope with climate change.[131]

124) https://www.bluerivertechnology.com/
125) https://plantix.net/en/
126) Gifford, R. (2011). The Dragons of Inaction: Psychological Barriers that Limit Climate Change Mitigation and Adaptation. *American Psychologist*.
127) Fagan, M., Huang, C., (2019) Look at how people around the world view climate change, at https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/
128) https://www.wri.org/
129) Scannell, L., Gifford, R. (2013) Personally Relevant Climate Change: The Role of Place Attachment and Local versus Global Message Framing in Engagement.
130) Gifford, R., Scannell, L., Kormos, C., Smolova, L., Biel, A., Boncu, S., et al. (2009). Temporal pessimism and spatial optimism in environmental assessments: An 18-nation study. Journal of Environmental Psychology, 29, 1-12.
131) Jooste, B. S., Dokken, J. V., van Niekerk, D., & Loubser, R. A. (2018). Challenges to belief systems in the context of climate change adaptation. *Jamba (Potchefstroom, South Africa)*, *10*(1), 508. https://doi.org/10.4102/jamba.v10i1.508

	Less education	More education	Diff
Brazil	62	84	+22
Philippines	53	75	+22
Indonesia	50	68	+18
Mexico	73	91	+18
Argentina	71	88	+17
Australia	54	70	+16
South Africa	52	68	+16
Hungary	64	75	+11
Canada	59	70	+11
Netherlands	67	76	+9
UK	64	73	+9
France	79	87	+8
South Korea	83	89	+6
U.S	56	62	+6

In many countries, people with more education are more likely to see climate change as a major threat

Global climate change is a major threat to our country

Source: Adapted from Pew Research Center (2019)

FIGURE 13: Relationship between Education and Climate Change Perception

Use cases

Virtual reality can also help to educate people living in LDCs on how climate action will alter daily living, from the local level to globally. One virtual reality program developed by UNEP, in connection with Sony, aims to educate people living in LDCs to experience their "carbon footprint." An augmented reality app, "After Ice" helps users see a future scene of one's location with sea level rising. The app-based on three scenarios of climate change: 1. NASA's projections through 2080; 2. A scenario based on the impact of sea-level rise on New York City, and a 3. Total Melt scenario, where the entirety of the polar ice caps will have been eliminated.[132]

132) https://www.3rockar.com/

BLOCKCHAIN AND CLIMATE ACTION

Blockchain technologies have substantial potential to assist LDCs with improving energy efficiency and mitigating against the impacts of climate change. Blockchain can be based in tandem with other technology for synergistic benefit. With concerns over rising sea levels and increased in-land floods, blockchain can help through early detection and intervention. Least-developed countries are particularly vulnerable to the impacts of climate change, with multiple instances of floods savaging livelihoods and local economies. For example, the Blockchain for Climate Foundation[133] has suggested the use of a ledger towards recording the international transfer of emission reductions towards greater transparency and accuracy of GHG emissions.[134] For example, Agri-wallet is a blockchain-based technology operating in Kenya which provides supply chain finance to farmers, buyers, and suppliers. It estimates to reach over 800,000 farmers, 3,000 buyers, and 3,000 input providers by 2024.

Use cases

Blockchain solutions can help track natural resource conservation. Cryptocurency and other blockchain technologies can serve as an important driver in sustainable development, if properly implemented and environmentally sound. Namely, the Crypto Climate Accord intends to decarbonize the cryptocurrency and blockchain industry by 2030.[135] Also, it is to be noted that the traditional means of generating money (e.g., paper notes or coins) causes its own pollution. A recent study by Tufts University implies an annual total environmental cost of 12.9 billion dollars.[136] [137]

In the manufacturing scene, the World Economic Forum's Mining and Metals Industry has the intention to use blockchain solutions towards decarbonization. A proof of concept "Carbon Tracing Platform" (name COT) will provide end-to-end traceability and distributed ledger technology to track CO2 emissions.[138] More generally, blockchain has been proposed to improve the efficiency of freight operations and reduce emissions via smart transportation.[139]

Drones have demonstrated utility in sustainable development and green agricultural uses. In Myanmar, drones from the startup BioCarbon Engineering have been implemented to plant as many as 100,000 trees in a single day.[140] Previously, the country relied on manually planting over 2.7 million trees by hand, after 60 percent of all Mangroves were converted for other uses, including rice, palm oil, rubber, and urbanization.[141] Senegal has also engaged in a similar initiative, albeit manually, having planted 79 million trees due to nearly 25 percent deforestation since the 1970s.[142] The Kruger National Park – at over 7,000 square miles – has been preyed on poaching and deforestation. For monitoring efforts, drones can cover massive terrain in substantially quicker time than human beings. Yet, in combination with IoT devices, they can collect data from remote regions, including monitoring endangered animals, vegetation, and land.[143]

133) https://www.blockchainforclimate.org/
134) Van Wassenaer, L.,Van Hilter, M., et al (2021) Applying blockchain to climate action in agriculture: state of play and outlook, at https://www.fao.org/3/cb3495en/cb3495en.pdf
135) https://cryptoclimate.org/accord/
136) Digital Planet (2021) How green is the Greenback? An Analysis of the Environmental Costs of Cash in the United States, at https://sites.tufts.edu/digitalplanet/how-green-is-the-greenback-an-analysis-of-the-environmental-costs-of-cash-in-the-united-states/?utm_source=rss&utm_medium=rss&utm_campaign=how-green-is-the-greenback-an-analysis-of-the-environmental-costs-of-cash-in-the-united-states
137) Calculated at the average banknote generating 0.26 worth of CO2 annually, with 50 billion US Bank-notes in circulation.
138) Russo, A., (2020) Blockchain Can Trace Carbon Emissions for Mining, Metals Companies, Proof of Concept Released, at https://www.weforum.org/press/2020/12/blockchain-can-trace-carbon-emissions-for-mining-metals-companies-proof-of-concept-released/
139) Wang, M., Wang, B. & Abareshi, A. (2020). Blockchain Technology and Its Role in Enhancing Supply Chain Integration Capability and Reducing Carbon Emisssio: A Conceptual Framework. *Sustainability*. 12. 1-17
140) Peters, A., (2017) These Tree-Planting Drones Are About To Start An Entire Forest From The Sky, at https://www.fastcompany.com/40450262/these-tree-planting-drones-are-about-to-fire-a-million-seeds-to-re-grow-a-forest
141) National University of Singapore (2020) Myanmar lost 60% of mangrove forests in 20 years, at https://www.futurity.org/myanmar-lost-60-of-mangrove-forests-in-20-years/
142) Fleming, S. (2019) Senegal is planting millions of mangrove trees to fight deforestation, at https://www.weforum.org/agenda/2019/09/senegal-is-planting-millions-of-mangrove-trees-to-fight-deforestation/
143) IET (2020) Drones needed for 'critical role' cmbating climage change, at https://eandt.theiet.org/content/articles/2020/02/drones-needed-for-critical-role-combating-climate-change/

Use cases

Drones can provide supplies and materials to vulnerable and isolated individuals in LDCs towards better health and well-being. In Rwanda, the degree and coverage of healthcare are severely limited, with the average district hospital accounting for approximately 195 eds and three operating rooms – with an estimated catchment of 282,769 persons addressed per available facility.[144] In response, drones have been used to facilitate the transportation of medical supplies, which were previously delayed due to transportation barriers. For example, the US Startup Zipline has worked in conjunction with the Rwanda government to deliver blood supplies by drone, in some cases, reducing a 3-hour round-trip to a delivery time of solely 6 minutes.[145] Such drones also managed to dispatch more than 4000 units of blood products to 12 hospitals in the span of six months. In Tanzania, DHL successfully completed a trial of medicine delivery by drone to customers on an island in Lake Victoria – a 60 km flight from the mainland in an average of 40 minutes.[146] One company in particular – RSS Hydro[147] – uses drones, in addition to machine learning models, to assist in flood disaster response efforts and monitoring the effects of climate change.

BIG DATA, IOT, CLOUD COMPUTING

Use cases

Big Data can allow for tracking of the supply chain to streamline processes and identify inefficiencies. For example, palm oil production is prevalent in multiple LDCs. Yet, palm oil production is quite destructive to the environment, often leading to peatland draining and burning, the destruction of woodlands and natural habitats, and greenhouse gas emissions and air pollution through inefficient processing. In response, companies such as Nestle and McDonald's have used big-data analytics in order to track the status of their zero-deforestation and sustainable sourced-palm oil pledges.

Moreover, it is important to also consider the role of agriculture in terms of climate change. It is estimated that deforestation accounts for nearly 11 percent of global carbon emissions, second to only the energy sector.[148] In fact, major tech corporations, including Amazon, have invested in programs promoting sustainable development. Microsoft, for example, has pledged to provide $50 million between 2017-2022 to their AI for Earth Programme, in which they award grants to projects that utilize Microsoft's cloud and AI tools to address climate, agriculture, biodiversity, and water issues.[149]

Further, the International Data Corporation (IDC) estimates that nearly 1 billion metric tons of carbon dioxide emissions could be prevented by the strategic implementation of renewable resources and shifting work locations via cloud computing.[150] [151]SEPAL[152] – a project of the Forestry Department of the United Nations Food and Agriculture Organization (FAO) - is one such endeavor using a cloud-computing based platform for sustainable development. The SEPAL platform can use autonomous land monitoring provided by remotely sensed data to help countries monitor and report on forests and land use.[153]

144) Notrica, M., Evans, F., Knowlton, L. & McQueen. (2011). Rwandan Surgical and Anesthesia Infrastructure: A Survey of District Hospitals. *World Journal of Surgery*. 35. 1770-1780.
145) Baker, A., (2017) The American Drones Saving Lives in Rwanda, at https://time.com/rwanda-drones-zipline/
146) Unmanned Airspace (2018) DHL trials BVLOS medicine delivery flights across Lake Victoria, Tanzania, at https://www.unmannedairspace.info/uncategorized/dhl-trials-bvlos-medicine-delivery-flights-across-lake-victoria-tanzania/
147) https://rss-hydro.lu/
148) https://www.fao.org/redd/en/
149) https://www.microsoft.com/en-us/ai/ai-for-earth?activetab=pivot1:primaryr6
150) Anderson, C., Gantz, J.F., et al (2021) Wordlwide CO2 Emissions Savings from Cloud Computing Forest, 2021-2024: A First-of-Its-Kind Projection, at https://www.idc.com/getdoc.jsp?containerId=US47426420
151) Gedetsis, J. (2021) Tackling Climate Change Challenges with Cloud Computing, at https://www.nutanix.com/theforecastbynutanix/news/tackling-climate-change-challenges-with-cloud-computing
152) https://sepal.io/
153) FAO of the UN, (2021) REDD+ Reducing Emissions from Deforestation and Forest Degradation, at https://www.fao.org/redd/news/detail/en/c/1397036/

4

Leveraging 4IR for SME Growth

UNIDO has adopted a holistic approach that recognizes the current context for pharmaceutical manufacturing in Africa and establishes a realistic technical pathway for manufacturers to upgrade their operations.

The Fourth Industrial Revolution has the potential of providing novel value chains and growth opportunities for small-and-medium-sized enterprises (SMEs). SMEs are a fundamental component of the advancement of LDCs and the global economy. However, SMEs in the Least Developed Countries exhibit a substantial financing gap when compared to their developed counterparts. It is estimated that there is an unmet financing need of $5.2 trillion every year for 65 million firms, with East Asia and Pacific accounting for 46 percent of this gap, the Caribbean accounting for 23 percent, and Europe and Central Asia accounting for 15 percent.[154] Compounding matters, many SMEs in LDCs are unable or unwilling to expand, which impacts their ability to scale.

When combined with technological developments, an environment of accelerated growth and leapfrog opportunities can be fostered for LDCs, conferring the ability to surmount previous obstacles to progress. By implementing emerging technologies, these advances can both be incorporated into existing SMEs and help foster the growth of nascent SMEs. 4IR technologies can also help create novel value chains to improve the export productivity of SMEs, which is currently lagging in developed countries.

Incorporating 4IR in agribusiness can serve as a "Trojan Horse" in spreading 4IR technologies to other sectors. Agribusiness is an important sector of low-income and developing countries, which can help reduce poverty by 75 percent, raise incomes, increase food security, and increase employment.[155] As the World Bank (WG) group notes, as economies continue to develop, agribusiness (e.g., agricultural input and output processing subsectors) tend to increase relative to farming. Agricultural innovation has been a driving factor for the substantial progress of developing countries in Africa, with a regional per capita GDP increase between 2000 and 2015 of nearly 35 percent.[156]

TABLE 3: General Trends of Agricultural Transformation
Labour movement Labor opportunities expand to those out of farming, while farmers that remain in product become more productive and commercialized.
Diversification to Specialization Farms transition from having a gambit of goods driven by self-sustenance, to specializations based on market opportunities, particularly in specific goods, which have demonstrated a regional increase.
Agribusiness to Farm Value Ratio Increases As more economic activity occurs in upstream processes, including manufacturing and supply and downstream trading, processing, and retailing, the agribusiness value increases relative to the farm value-added.
Greater Output by Medium to Larger Farms As farms begin to scale in size, their outputs grow to supply production and marketing, such as restaurants and grocery stores.
Transition to sustainable cultivation There is a feed-forward mechanism as the technologies of farm products track the changes in relative factor prices as a country develops (including labor, land, and capital).
Greater Output by Medium to Larger Farms The expansion of farms and increased production shifts focus to sustainable and management-intensive cultivation of specific fields. The agri-food systems eventually become integrated with the broader economy.

Adapted from Jayne et al. (2018)[157]

154) https://www.worldbank.org/en/topic/smefinance
155) World Bank. (2021). Agriculture and Food: Overview at https://www.worldbank.org/en/topic/agriculture/overview#1
156) World Bank Group. (2013). Jayne, T. et al. (2019). Are medium-scale farms driving agricultural transformation in sub-Saharan Africa? Agricultural Economics. 50(S1). 75-95
157) Jayne, T., Chamberlin, J. & Benfica, R. (2018). Africa's Unfolding Economic Transformation. *The Journal of Development Studies*. *54*(5). 777-787.

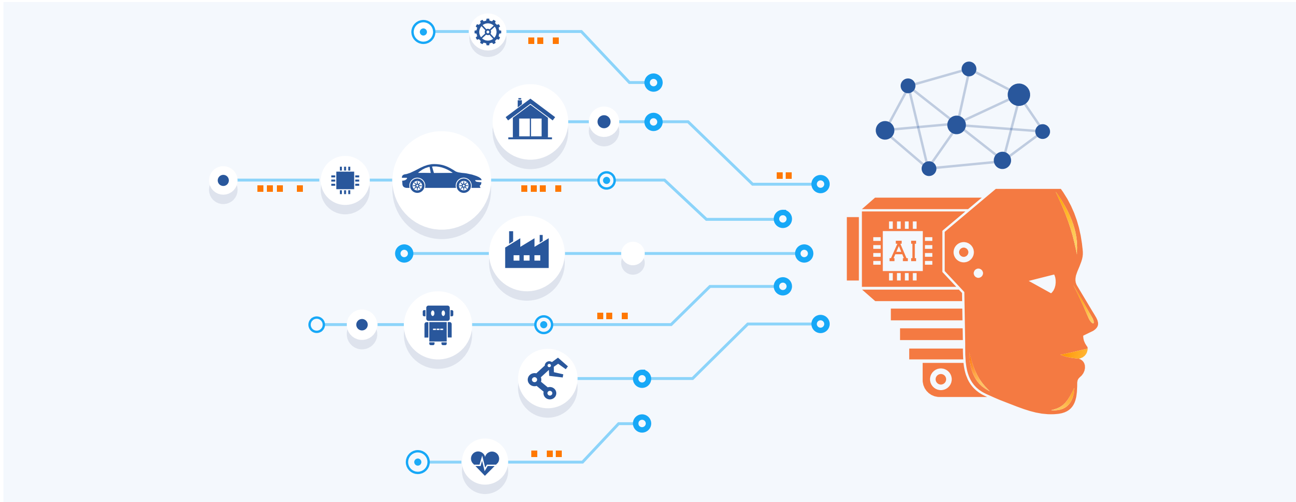
BIG DATA, IOT, CLOUD COMPUTING AND SMEs

Big Data can help SMEs in LDCs become more performant, profitable, and organized and is the bedrock for many 4IR technologies. Big Data can provide SMEs with a greater understanding of their clientele by operationalizing patterns and behaviors in a quantifiable form. When considering the role of Big Data and SMEs, 5 "V's"[158] are often alluded to, which delineate "Big Data" from "Small Data":

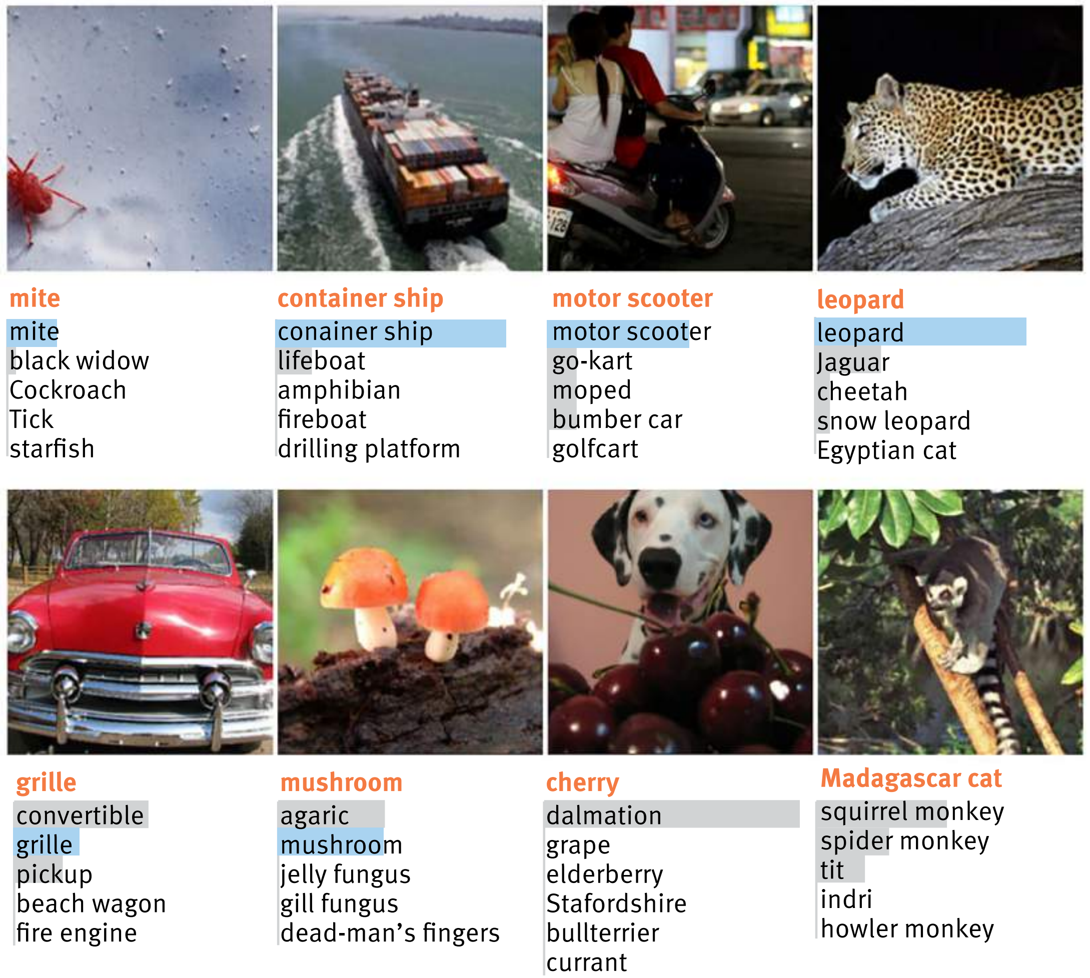
- **Volume:** there is a huge set of data to be stored and processed, seemingly boundless in its limit.
- **Velocity:** The size of the data grows at an exponential rate, which in turn expands the database.
- **Variety:** the assorted types and forms of data, ranging from structured, semi-structured, and unstructured.
- **Veracity:** The quality and accuracy of the data.
- **Value:** The merit and utility of the data.

Big Data is often the prerequisite for other 4IR technologies, including AI, drones, and blockchain. For example, the often-cited training samples for artificial intelligence models require between 10,000 and 100,000 instances, and often this number increases with more complex problems. It is estimated that the combination of big data and AI can assist in automating nearly 80 percent of physical work, 70 percent of data processing work, and 64 percent of data collection tasks.[159] However, many LDCs still do not have adequate data to take advantage of 4Ir technologies, which layer their capabilities on top of a wealth of information.

There is a significant opportunity to create new jobs through Big Data, as many 4IR technologies require human input. For example, ImageNet is one of the most popular image databases organized by the WordNet hierarchy – restricted to nouns in which hundreds to thousands of images represent each node of the hierarchy.[160] The platform represents one of the most robust sources to devise and train object detection and image classification algorithms. However, many images need to be labeled by a human being (Figure 14), which is a laborious process entailing substantial person-hours. In addition, with an increasing onus on data collection, individuals need to collect, process and analyze the data, roles which will require specialists, respectively. Even in the case of autonomous vehicles – including drones – there will be a substantial period when such vehicles will require "operators," creating novel work opportunities which can be done from any part of the world.



158) Iswarappa, A. (2015). A Brief Introduction on Big Data 5Vs Characteristics and Hadoop Technology. *Procedia Computer Science*. *48*. 319-324
159) McKinsey. (2019). Driving Impact at Scale from Automation and AI. *Digital McKinsey at https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Driving%20impact%20at%20scale%20from%20automation%20and%20AI/Driving-impact-at-scale-from-automation-and-AI.ashx*
160) https://www.image-net.org/

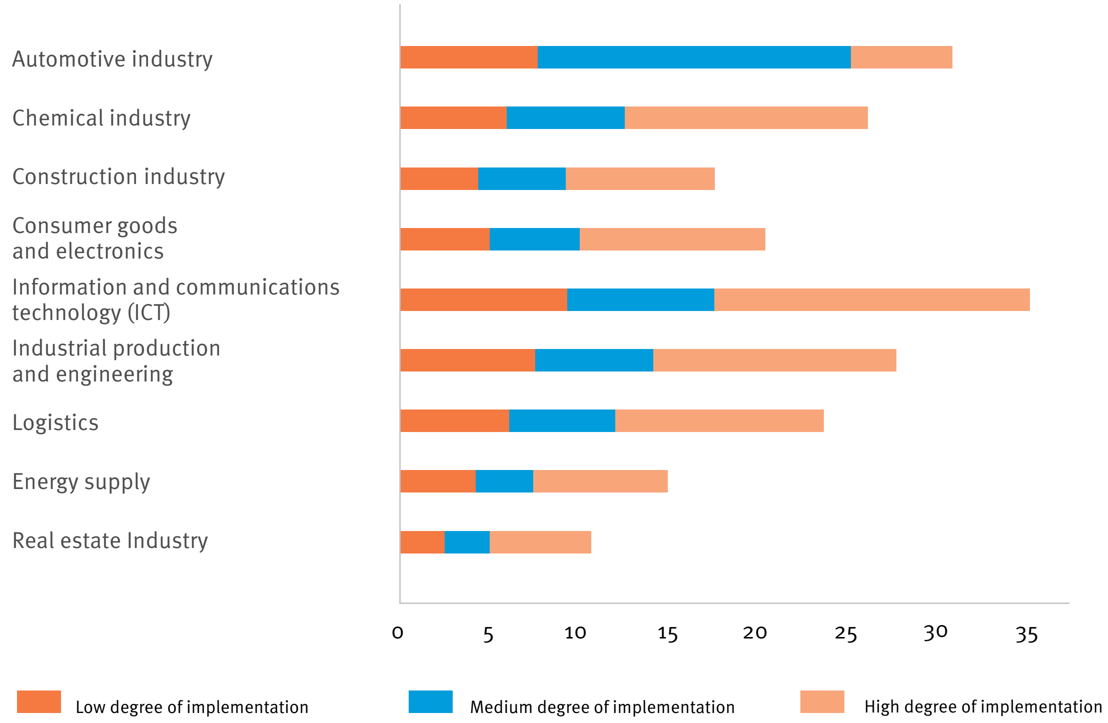


Source: Adapted from http://www.cs.toronto.edu/~fritz/absps/imagenet.pdf

FIGURE 14: ImageNet Classification with Deep Convolutional Neural Networks

BIG DATA, IoT, CLOUD COMPUTING AND SMEs IN DEVELOPED COUNTRIES

Big data has been instrumental to the exponential growth of developed countries, which continue to propel them into the future, building on their wealth of information. The United States has used big data in multiple ways, particularly for research and innovation, in addition to creating new products, processes, and techniques while reducing costs.[161] Moreover, the nexus of big data, IoT, and cloud computing allows for synergistic developments which feed one another. It is anticipated that by 2025, more than 100 billion devices will be connected to the Internet of Things, generating revenues of nearly USD 10 trillion, in addition to an annual growth rate of 26.91% of the sensors market.[162] It is also estimated that profit margins may increase between 11 and 34 percent by 2030 by implementing smart manufacturing in various industries, including chemical, automotive, construction, and logistical arenas.[163] This is reflected in studies on digitalization, such as that by PwC in 2016 surveying over 2,000 companies. Among the findings, investments through 2021 were estimated at $907 billion, with a substantial focus on R&D, as many organizations anticipate paying back Industry 4.0 investments within two years of their implementation.[164] For example, smart-sensing platforms, like the Nirone Scanner,[165] can be used for multiple purposes, from on-site measuring in the petrol industry to assessing milk quality control in farming,[166] all the while being linked to the cloud for fast data collection and analysis. Moreover, the potential of cloud computing renders it possible for organizations situated thousands of miles apart to have the same access to avant-garde technology. For example, Google, NASA, and Lockheed Martin are working with D-wave,[167] a USD 15 million computer that runs 2,000 qubits. Qubits have superior computing power due to their unique "quantum properties" such as superposition, as 500 qubits can represent what would otherwise be impossible with even more than 2500 classical bits.[168]



Source: Adapted from EY (2020) How Smart Sensors are Driving Industry 4.0 Forward[169]

FIGURE 15: Effects on Profit Margins Per Sector: Potential Financial

161) https://www.census.gov/topics/research/big-data.html
162) https://builtin.com/big-data/iot-big-data-analytics-examples

163) https://www.ey.com/en_ch/industrial-products/how-smart-sensors-are-driving-industry-4-0-forward
164) https://www.pwc.com/gx/en/industries/industry-4.0.html
165) https://www.spectralengines.com/products/nirone-scanner
166)
167) https://www.pcworld.com/article/411799/d-waves-quantum-computer-runs-a-staggering-2000-qubits.html
168) https://azure.microsoft.com/en-us/overview/what-is-a-qubit/#introduction
169) Zaugg, D. (2020). How smart sensors are driving Industry 4.0 forward, at https://www.ey.com/en_ch/industrial-products/how-smart-sensors-are-driving-industry-4-0-forward

Use cases

Big data can generate helpful information for agricultural workers, with downstream effects, such as increased access to financing. The Agrilife platform by Kenya is a positive example of the utility of Big Data in developing countries. Agrlife is a cloud-technology platform that collects and processes data from multiple aspects of the supply chain, which can then generate farmer-level recommendations and alerts directly delivered to farmers and service providers.[170] Though Mercicorps, it has been expanded to Uganda, giving further access to rural clients. Its compatibility with mobile phones and financial institutions has created an ecosystem enabling better decision-making in the acquisition, distribution, and storage strategies before and after crop harvest. The information also results in an electronic transaction record that can help such farmers build their credit history, which can be leveraged to procure loans and financing.[171]

Agricloud is a software platform dedicated to the merging of IoT, Big data, and Cloud computing. The service allows for precision harvest estimates, detection of high-risk areas, irrigation planning, harvest segmentation, and more. MTN[172] is one of the largest mobile telecommunication companies which is providing cloud computing for SMEs in Ghana and Nigeria. Moreover, in sub-Saharan Africa, a study on mobile telephony was identified as a novel means to collect information on the aso oke[173] supply chain.[174] The findings were used to reduce the cost of trading by removing intermediaries, increasing communication speed, and improving the quality of communication used for decision making. Other economic benefits were identified, such as connecting weavers with suppliers and customers, allowing for more efficient and targeted transactions. In Nepal, Cloud Himalaya provides Cloud Computing services supporting EMR (Electronic Medical Record), banking, and financial industries.[175] However, these cloud networks – and in other LDCs – face challenges in terms of security, breaches, and confidentiality, which reduces the faith in SMEs to utilize such services.[176]

DRONES AND SMEs

Drones have the potential of providing a novel means of value creation in SMEs of LDCs. In agribusiness, drones can be leveraged for multiple use cases, including radiological, atmospheric, and environmental sensing, agricultural data collection and crop management, natural resource conservation and management, and meteorological monitoring.[177] Moreover, Drones can be used by LDCs to optimize agricultural processes and improve yields (Table 3). In terms of delivery, drones can be used to reach remote areas and/or traverse difficult terrains to deliver products and supplies. In the manufacturing space, drones can provide inspection services, organization packaging, count stocks in warehouses, and conduct 24/7 surveillance of equipment and staff to ensure smooth operations.

170) https://www.f6s.com/agrilifekenya
171) Riecke, J. (2013). New Mobile Platform Empowers Farmers in Uganda. *Center for Financial Inclusion*, *at* https://www.centerforfinancialinclusion.org/new-mobile-platform-empowers-farmers-in-uganda
172) https://www.mtn.com.gh/
173) *Aso oke* fabric is hand-woven cloth creted by the Yoruba people of West Africa
174) Heeks, R. and Whalley, J. (2008). The Impact of Mobile Telephony on Developing Country Microenterprise: a Nigerian Case Study. *Information Technologies and International Development*.
175) https://cloudhimalaya.com/public-cloud
176) Giri, S. (2019). Cloud Computing and Data Security Challenges: A Nepal Case. *International Journal of Computer Trends and Technology*. *67*(3).
177) Sishodia, R., Ray, R. & Singh, S. (2020). Applications of Remote Sensing in Precision Agriculture: A Review. *Remote Sensing*. *12*. 3136

TABLE 4: Use cases for Agricultural Drones

Soil and Field Analysis	Drones can produce precise 3-D maps for early soil analysis which can be used towards planting patterns. After planting, drone-driven soil analysis provides data for irrigation and nitrogen-level management.
Planting	Drones may be used to plant vegetaion at scale, in addition to reaching isolated or obstructed areas.
Crop Spraying	Startups have created drone-planting systems that achieve an uptake rate of 75 percent and decrease planting costs by 85 percent. These systems shoot pods with seeds and plant nutrients into the soil, providing the plant the necessary ingredients to sustain life.
Crop Monitoring	Vast fields, unpredictable weather, and low efficiency in crop monitoring together create farming's largest obstacle, which can be mitigated through crop monitoring.
Irrigation	Drones with hyperspectral, multispectral, or thermal sensors can identify which parts of a field are dry or need improvements. Additionally, once the crop is growing, drones allow the calculation of the vegetation index, which describes the relative density and health of the crop, and show the heat signature, the amount of energy or heat the crop emits.
Health Assessment	By scanning a crop using both visible and near-infrared light, drone-carried devices can identify which plants reflect different amounts of green light and NIR light. This information can produce multispectral images that track changes in plants and indicate their health.

Adapted from Mazur, 2016[178]

DRONES AND SMEs IN DEVELOPED COUNTRIES

Drones transformed delivery services, manufacturing, and supply chain management in developed countries. Drones are playing an important role in construction in the modern day. Construction is currently the fastest-growing sector in the United States, where drones are used for surveillance, managing workflows, operating in dangerous areas, and providing surveying and mapping capacities.[179] Their architectural capacities were on display as early as 2011 in France when four quadcopters built a 20-foot tower model for a futuristic city.[180] In the United Kingdom, Sees.ai has earned approval for a beyond-visual-line-of-sight (BVLOS) flight by the UK Civil Aviation Authority to foster innovation and explorations.[181] The drone startup intends to expand its efforts towards improving infrastructures, such as maintaining road and rail networks, monitoring the electrical grid through remote capture of high-quality data of dangerous components, and inspecting remote or hazardous areas, including inside oil storage tanks and pipelines etc.[182] In the cattle industry, drones are being used to accurately and quick monitor cattle in Kentucky (it is estimated that 2.5 million cows in the US die from health problems, costing over USD 1.5 billion).[183]

178) Mazur, M. (2016). Six Ways Drones Are Revolutionzing Agriculture. *MIT Technology Review*, at https://www.technologyreview.com/2016/07/20/158748/six-ways-drones-are-revolutionizing-agriculture/
179) Calvo, J. (2019). Drones, Drones Everyhere in Business. *Strategy 4.0 Blog*, at http://strategy4.org/my-blog/drones-drones-everywhere-in-business
180) Hornyak, T. (2011). Flying robots build 20-foot tower in France, at https://www.cnet.com/news/flying-robots-build-20-foot-tower-in-france/
181) Lomas, N. ((2021). UK drone startup sees.ai gets go ahead to trial beyond-visual-line-of-sight (BVLOS) flgihts, at https://techcrunch.com/2021/04/20/uk-drone-startup-sees-ai-gets-go-ahead-to-trial-beyond-visual-line-of-sight-bvlos-flights/
182) https://www.sees.ai/
183) Singer, D. (2021). The drones watching over cattle where cowboys cannot reach, at https://www.bbc.com/future/bespoke/follow-the-food/drones-finding-cattle-where-cowboys-cannot-reach.html

Use cases

Drones can help LDCs to deliver products and supplies from a distance in an efficient and expedited manner. For example, in the context of transport delivery, drones can benefit businesses by improving customer reach, flying over congested areas directly to the customer. For example, Huang et al. (2020) have proposed a drone system to be used in conjunction with trains, which are a common form of transportation in LDCs.[184] The train usually operates along its predefined route to transport passengers, but simultaneously, parcels can be delivered to customers by virtue of a delivery drone which is stored on the roof. In Indonesia, the terrain is particularly difficult for standard delivery options, as it is comprised of 17,508 islands, nearly 6000 of which are inhabited.[185] In recognition of these challenges, one of China's largest retailers – JD.com – started a drone delivery program to deliver items ranging from backpacks, books, packages, e-commerce products.[186] These benefits can extend to other LDCs with geographical barriers, such as the archipelagic landscapes found in Kiribati, Samoa, Solomon Islands, Tuvalu, and Vanuatu.[187]

Drones can provide substantial benefits to the agriculture-driven economies of LDCs, with the added benefit of improving sustainability. Many farmers in LDCs are resigned to manually checking on their crops and livestock, taking valuable time and energy from their operations. To this end, drones have the potential to reduce work and improve the quality of operations. Drones can be used in multiple capacities. For example, in 2018, a project in Myanmar implemented drones in remote areas to fire "seed missiles" in areas lacking trees, scout crops, and reduce the work involved in seed planting and fertilization, raising yields.

ARTIFICIAL INTELLIGENCE, ROBOTICS AND SMEs

AI solutions can also help overcome the lack of infrastructure and significant information asymmetries confronted by SMEs in LDCs. Artificial intelligence can benefit LDCs by altering their business environment andevolving business models and practices to improve productivity, communication and efficiency.[188] AI can also drive the development of leapfrogging solutions tailored to serve underserved populations. For example, AI sytems can can be taught to conduct a particular set of tasks and plan schedules in order to accommodate a particular need. Through "self-learning," such AI agents can continuously improve based on the feedback it receives from the environment and manual adjustment by human beings. Robotics, paired with AI, allows for a physical structure to house logic to conduct tasks around the clock, in a reliable and efficient manner. The "super-human" abilities conferred by AI and robotics can generate novel opportunities for LDCs to potentiate the discovery of innovations and undergo work which is otherwise difficult manually.

184) Huang, H., Savkin, A. & Huang, C. (2020). A new parcel delivery system with drones and a public train. *Journal of Intelligent & Robotic Systems*. *100.* 1341-1354.
185) https://www.embassyofindonesia.org/basic-facts/#:~:text=Geography%20of%20Indonesia,which%20about%206000%20are%20inhabited.
186) https://www.unmannedairspace.info/uncategorized/chinese-retailer-jd-com-starts-first-drone-delivery-flights-indonesia/
187) https://apps.who.int/iris/bitstream/handle/10665/136831/ccsbrief_pci_en.pdf?sequence=1&isAllowed=y#:~:text=Kiribati%2C%20Samoa%2C%20Solomon%20Islands%2C,classified%20as%20least%2Ddeveloped%20countries.
188) https://www.oecd-ilibrary.org/sites/01a4ae9d-en/index.html?itemId=/content/component/01a4ae9d-en

ARTIFICIAL INTELLIGENCE, ROBOTICS AND SMEs IN DEVELOPED COUNTRIES

Artificial intelligence has become integral economic success of developed countries. Most of the world's largest companies use Artificial Intelligence as a component of their business and product, e.g. Alphabet (the parent company of Google) and its search engine; Tesla and its autonomous driving; Amazon for its Cloud Computing Services and Product Suggestions; Facebook and its friend suggestion algorithm, etc. In fact, it is estimated that the technology companies on Forbes' Global 2000 represent nearly $17.9 trillion in market value.[189] This has influenced countries such as Taiwan and their National Development Plan (NDP) towards the construction of the "Asian Silicon Valley."[190] Taiwan's NDP has included provisions to upgrade their Smart Machine Industry,[191] incorporating artificial intelligence and smart reports to expand plant output and productivity. Leading this effort, Germany's Electrical and Electronic Manufacturers' Association (ZVEI)[192] developed RAMI 4.0, to offer a service-oriented reference architecture through the entire product life-cycle of smart manufacturing. The concept entails multiple layers, "reflecting that AI is a cross-cutting concern affecting all functionality in IT manufacturing systems… due to its novel forms of data processing and information modeling" which will allow for autonomous and automated business intelligence.[193]

Use cases

AI offers emerging markets an opportunity to lower costs and barriers to entry for businesses and deliver innovative business model. Improved business productivity stemming from automation of core business processes and human capital development can significantly lower production costs for SMEs. AI can also provide "Robo-Advisers" to close the investment advice gap, giving access to SMEs to free financial advice, which is generally cost-prohibitive. AI can be used for anti-laundering and countering fraud, improving the financial reliability of business transactions. Examples include the Australian Securities and Investments Commission (ASIC), which is currently exploring natural language processing (NLP) technology to extract information from documentation.[194] Furthermore, the Monetary Authority of Singapore has produced a document entitled "Principles to Promote Fairness, Ethics, Accountability, and Transparency (FEAT) in the Use of Artificial Intelligence and Data Analytics in Singapore's Financial Sector. Among its technological implementations, AI assists or replaces human decision-making in the delivery of financial products and services. These models are validated to avoid potential bias or the disadvantaging of groups/individuals.[195]

Productivity improvements also stem from more efficient investment in human capital due to automation. AI can spearhead the evolution of education through precisely targeted and individually customized human capital investments. Education companies such as Coursera and Udemy are capturing data on student performance across emerging markets and are poised to leverage this data to deliver upskilling recommendations.[196] In Chile, AIRA is being used to reduce the amount of time human recruiters spend on finding candidates for a job.[197] CVs are automatically read and ranked, in addition to AI monitoring video interviews to assess for attitudes and personality traits. Another service, UpGrad, has enrolled 2,000 students in India's entrepreneurship, digital marketing, data analytics, and product management courses. Other companies combine online education and job platforms data to deliver automatic upskilling recommendations, which can assist in training and hiring efforts.

189) https://www.forbes.com/sites/jonathanponciano/2021/05/13/worlds-largest-tech-companies-2021/?sh=4eb1306d69bc
190) Oztemel, E. & Gursev, S. (2018). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*. *31*. 127-182.
191) National Development Council of Taiwan. (2019). Smart machinery and biomedicine pave way to more competitive Taiwan, at https://www.ndc.gov.tw/en/nc_11024_30668
192) https://www.zvei.org/en/
193) Trakadas, P., Simoens, P., Gkonis, P. et al. (2020). An Artificial Intelligence-Based Collaboration Approach in Industrial IoT Manufacturing: Key Concepts, Architectural Extensions and Potential Applications. *Sensors.* 20(19). 5480
194) Lee, J. (2020). Access to Finance for Artificial Intelligence Regulation in the Financial Services Industry. *European Business Organization Law Review*. 21. 731-747
195) Monetary Authority of Singapore. (2020). Principles to Promote FEAT in the Use of AI and Data Analytics in Singapore's Financial Sector,at https://www.mas.gov.sg/~/media/MAS/News%20and%20Publications/Monographs%20and%20Information%20Papers/FEAT%20Principles%20Final.pdf
196) Strusani, D. & Houngbonon, G. (2019). The Role of Artificial Intelligence in Support Development in Emerging Markets. *International Finance Corporation*. 1-8
197) https://www.airavirtual.com/

3D PRINTING/ADDITIVE MANUFACTURING AND SMEs: BACKGROUND

Additive Manufacturing (AM) encompasses 3D printing technology at the heart of the process and includes the design of the 3D model and the postprocessing of the product. It therefore also benefits from improvements and digitalization in the fields of communication, imaging, and engineering. In 2019, the additive manufacturing market grew to an astonishing $10.4 billion market worldwide.[198] The technology has mainly been applied in conjunction with Rapid Prototyping - the construction of illustrative and functional prototypes. Additive Manufacturing is now being used increasingly in Series Production. It gives Original Equipment Manufacturers (OEMs) in the most varied sectors of industry the opportunity to create a distinctive profile for themselves based on new customer benefits, cost-saving potential, and the ability to meet sustainability goals. AM consists of three phases:

- The design phase, which requires 3D model data and designs and data transfer;
- A building phase, which requires 3D printing techniques and material options; and
- A post-processing phase, in which left-over material and support structures are removed, and the surface of the object is treated to meet the required quality.

3D PRINTING IN DEVELOPED COUNTRIES

3D printing has been used by Developed Countries to standardize the construction of custom-tailored designs at scale, in an efficient and ecologically friendly manner. Many developed countries are resorting to 3D printing in order to manufacture products that are otherwise time and cost-prohibitive when using traditional methods. For example, the Oak Ridge National Laboratory indicates that using additive manufacturing for the creation of aviation designs is normally wasteful, with yields of only 10 percent. However, their work at the Department of Energy's Manufacturing demonstration facility found that " For every 10 pounds of incoming titanium material, 9 pounds are removed, and 1 pound ends up in the final component."[199] The advantages of 3D printing extend to complex designs requiring high precision, such as electronics. Nano design is one such company whose 3D printers can make advanced circuits with functional capacitors, coils and inductors, and even antennas.[200] The number of possibilities is even vaster than manufacturing, such as the creation of 3D printed instruments at Sweden's Lund University, which were used in a concert by musicians from the Malmo Academy of Music, playing on a printed drum, keyboard, and two guitars.[201] Cellink, a biotechnology startup, has used "bioprinters" to culture different cell types, even working on the design of organs, including tissue models consisting of hepatocyte cells combined with arterial, venous, and biliary structures.[202]

198) Nolan, R. (2020). SmarTech Analysis Annual Additive Manufacturing Market Summary Report Says AM Market Grew to Over $10B Worldwide in 2019, at https://www.globenewswire.com/news-release/2020/01/08/1968056/0/en/SmarTech-Analysis-Annual-Additive-Manufacturing-Market-Summary-Report-Says-AM-Market-Grew-to-Over-10B-Worldwide-in-2019.html

199) Oak Ridge National Laboratory (2018). Moving into the future with 3D printing, https://www.ornl.gov/blog/moving-future-3d-printing

200) https://www.nano-di.com/

201) https://www.lunduniversity.lu.se/article/worlds-first-live-concert-3d-printed-band

202) https://www.cellink.com/

Use cases

3D printing can address many of the problems of industrialization encountered by SMEs: isolation, distance from major markets, and low economies of scale. Many agribusinesses and SMEs in LDCs suffer from a lack of accessible and affordable equipment. This was particularly apparent during the COVID-19 pandemic when many countries halted their import and export operations out of concerns for public health. This left LDCs crippled to supplies, such as masks, medical equipment, and other essential commodities. Worse still, LDCs often lack the technology to produce such supplies independently. For example, through the use of 3D printers from formlabsTM, Rihal Digital Designs managed to create personal protective equipment (PPE) out of affordable materials, which were eight times as effective as N95 masks.[203] The potential uses of 3D printing can help to reduce the need for manufacturing using laborious and expensive processes. For example, designing and implementing undercuts, cavities, or internal structures is often bottleneck by ablative or forming processes, including milling, forging, welding, drilling, and soldering.[204]

3D printing has found its niche in industrial purposes, including construction. As evidence of the potential of 3D printing in 2016, Dubai created the "Office of the Future" – a 2,691 square foot space – out of the world's largest 3D printer at the time. Included among its features were responsive LED lighting, an outdoor garden deck, solar shading, and an energy-efficient HVAC system.[205] In China, a 400 m2 two-story house was completed in one and a half months, including plumbing and fixtures, using class C30 concrete – an affordable and durable material.[206] Although the 3D printing technology used to build the house still poses a technological barrier to entry, when surmounted, the costs savings are substantial, from: expedited construction time (down from the expected 6-7 months), use of environmentally friendly materials, and structural integrity, all factors which could greatly benefit LDCs.

BLOCKCHAIN AND SMEs

Blockchain-based systems, in particular, have the potential to boost cross-border trade due to their low-friction qualities and their inherently secure nature. Blockchain shows the potential to enhance transparency and reduce long-standing inefficiencies and costs within multiple sectors by streamlining the current intermediation of services. Blockchain can offer opportunities to cross border trade with a potentially trusted and transparent supply chain. The technology could be used to connect components of the financial trade system, providing a common framework for commerce management. Since corruption and governance issues remain one of the biggest challenges for doing business in the region, having more secure systems could reduce reliance on these countries' bureaucracies and increase total trade, essentially removing the reliance on a third party.

BLOCKCHAIN AND DEVELOPED COUNTRIES

Developed countries are using Blockchain technologies as financial instruments, ledgers and for supply chain management. Many banks are considering the use of blockchain to reduce the chance of fraud to increase the fidelity of transactions. For example, the Bank of England underwent a proof-of-concept investigation[207] to ascertain how a blockchain-linked version of the British Pound could affect the economy. Alluded to as "Central Bank Digital Currencies,"

203) https://formlabs.com/blog/3d-printed-medical-mask/

204) https://www.protiq.com/en/3d-printing/areas-of-application/advantages-3d-printing/

205) https://syska.com/project/office-of-the-future-dubai-arab-emirates/

206) Scott, C. (2016). Chinese Construction Company 3D Prints an entire Two-Story House On-Site in 45 Days, at https://3dprint.com/138664/huashang-tengda-3d-print-house/

207) Bank of England (2020). Central Bank Digital CurrencY: opportunities, challenges and design, at https://www.bankofengland.co.uk/paper/2020/central-bank-digital-currency-opportunities-challenges-and-design-discussion-paper

the discussion paper indicates opportunities to change the financial landscape, such as supporting more resilient payments, added efficiency and innovation, future-proofing towards a digital economy, and its potential eco-friendliness by dissolving paper and metal notes.[208] Blockchain has also been increasingly utilized in supply chain management.[209] Some examples of the use of blockchain for supply chain management include Provenance[210] and Skuchain[211] – the former has been implemented to track the responsible sourcing of tuna in Indonesia, whereas the latter tracks the activity of buyers, sellers, logistic providers, and banks in a global trade finance market estimated at nearly $18 trillion dollars.[212] In terms of music rights, there are multiple services towards transparent remuneration, such as Monegraph,[213] a startup that uses blockchain to monitor the usage and sharing of digital media. Another service, OnChain music[214], uses blockchain technology towards the assurance of royalty payments for musicians, songwriters, bands, and DJs, towards fairer compensation.

Use cases

Blockchain technologies have substantial potential to assist LDCs with improving energy efficiency and mitigating against the impacts of climate change. Blockchain can be based in tandem with other technology for synergistic benefit. With concerns over rising sea levels and increased in-land floods, blockchain can help through early detection and intervention. Least-developed countries are particularly vulnerable to the impacts of climate change, with multiple instances of flood savaging livelihoods and local economies. For example, the Blockchain for Climate Foundation[215] has suggested the use of a ledger towards recording the international transfer of emission reductions towards greater transparency and accuracy of GHG emissions.[216] Agri-wallet is a blockchain-based technology operating in Kenya which provides supply chain finance to farmers, buyers, and suppliers. It estimates to reach over 800,000 farmers, 3,000 buyers, and 3,000 input providers by 2024.

Blockchain technology can provide access to finance to customers without the barriers of traditional banking infrastructure. A key success story in the context of mobile money is M-Pesa. M-Pesa was started in 2007 by Vodaphone and Safricom, the largest mobile network operator in Kenya. In only the span of 2 years (2007-2009), nearly 7 million customers had registered with M-Pesa, and an average of 150 million Ksh (US$ 1.96 million) is transferred through M-PSA per day totaling 130 billion ksh (US$ 1.7 billion)1. Despite its seeming barrier to entry, urban users in Kiberia indicated they chose M-Pesa due to its cost and speed. Many of these urban users actually have persuaded rural recipients to register with the service, leading to a feed-forward phenomenon. According to one study of 75 rural respondents, 54 (77 percent) noted an income increase since adopting M-Pesa. These savings costs were related to decreased transport costs to urban centers. Also, increased saving behavior was observed, with urban migrants remitting more money back home. In a similar example, in Kenya, M-Shwari allows customers to apply for unsecured loans online. Instead of relying on physical branches, the company uses AI to predict the probability of default of loan applicants. By the end of 2017, M-Shwari provided small loans to 21 million Kenyans.

208) Bank of England (2020). Central Bank Digital CurrencY: opportunities, challenges and design, at https://www.bankofengland.co.uk/paper/2020/central-bank-digital-currency-opportunities-challenges-and-design-discussion-paper
209) Deloitte. (2017). Using blockchain to drive supply chain transparency, at https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html
210) https://www.provenance.io/
211) https://www.skuchain.com/
212) Deloitte. (2017). Using blockchain to drive supply chain transparency, at https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html
213) https://monegraph.com/
214) https://www.onchainmusic.com/
215) https://www.blockchainforclimate.org/
216) FAO. (2021). Applying blockchain to climate, at https://www.fao.org/3/cb3495en/cb3495en.pdf

Use cases

Furthermore, during the COVID-19 pandemic, the country has been the continent's leader in digital payment adoption, having one of the highest rates of digital finance adoption globally, with 32 million of its 53 million population being subscribed to mobile money accounts. Furthermore, in an attempt to slow down the coronavirus contagion, Kenya's largest telecommunications company Safaricom has implemented a fee waiver on East Africa's leading mobile-money product M-Pesa as a means to reduce the physical exchange of currency. The company has done this by making all person-to-person (P2P) transactions under 1,000 Kenyan Schillings free for the next three months.

Blockchain can redefine how artisans and small business owners LDCs are remunerated by acting as a platform for Intellectual Property (IP) creators to receive value for their Work. A common complaint lodged by artists is that artists receive smaller revenue cuts as performance-rights organizations and new intermediaries such as Spotify and YouTube increasingly insert themselves into the value chain between artists and their audiences. They have less say over how their creative works are priced, shared, or advertised. For example, Spotify would take between 120 to 170 streams for rights holders to receive their first penny. Blockchain and so-called token economies (tokenization) can enable creative stakeholders, such as artists and inventors, to unlock new financing opportunities without sacrificing their ownership rights and contract rights, including control of future royalties to intermediaries.

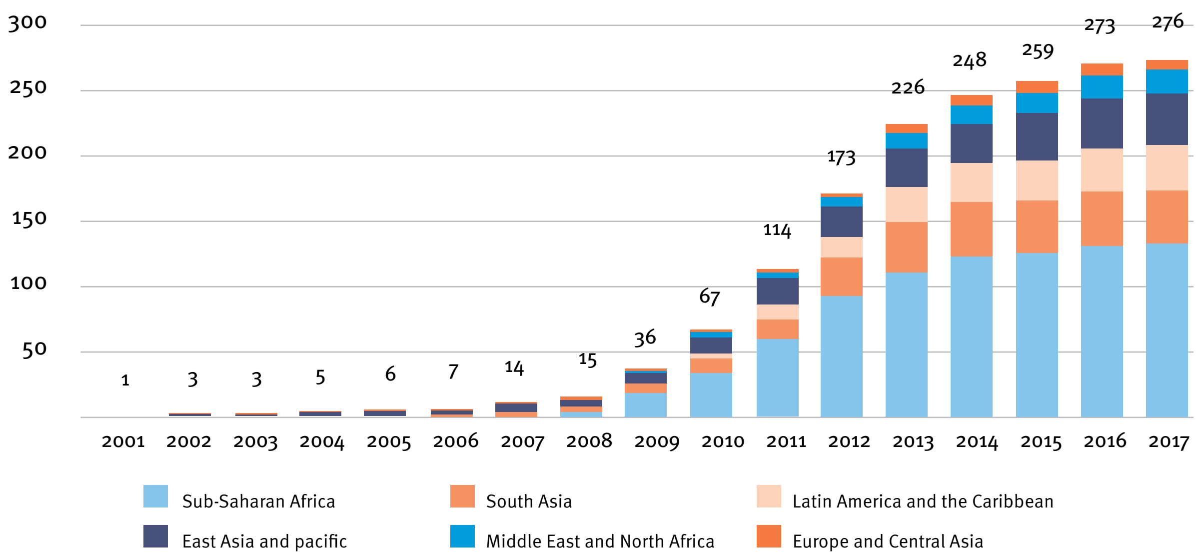
Distributed ledgers can be built on the blockchain, providing greater transparency, auditability, and efficiency of financial transactions for SMEs. At a governmental level, a ledger of electronic transactions will help in tax collection and monitoring. The instant nature of accessing one's mobile money account and the affiliated databases that allow such accounts to be queried generate multiple financial phenomena. For one, applying for credit is easier and more objective, with algorithms driving the back end of credit-score systems to determine one's eligibility. This is how 90% of FICO scores in the United States are determined. For example, the Trade Ministry of Senegal has created an e-commerce platform[217] to allow SMEs to sell essential goods, spurred by its e-trade readiness assessment recommendations. This technology can be improved with the blockchain to enhance the security and efficiency of transactions, generating a larger volume of transactions with greater confidence. Blockchain solutions can also be used for collateral management, providing securitized loans which are underlying smart contracts.

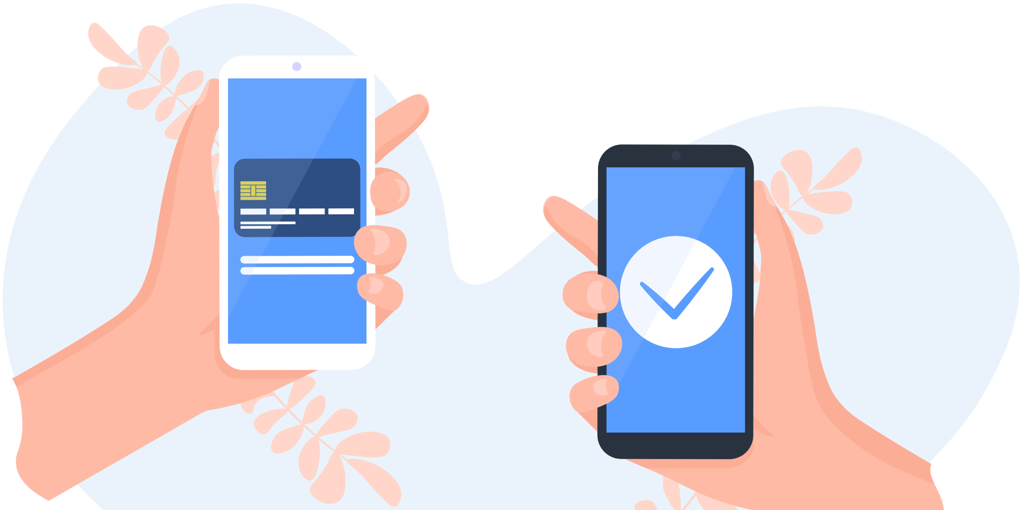
VIRTUAL AND AUGMENTED REALITY

Virtual reality can provide rich sensory experiences that SMEs may leverage for skill development, tourism, and training experiences. Currently, the technology of virtual reality has been substantially improving, giving a truly three-dimensional sensory experience. This has allowed for virtual encounters – such as attending a class provided by a renowned professor or visiting a new city – which was previously unattainable.

Augmented Reality (AR) is another potential avenue for the exploration of tourism. AR embeds computer-generated multimedia content into the real world, with the ability for real-word objects to be tracked with a camera and provide the coordinates to overlay virtual objects and visualize them as if they were part of the real environment."57 This can be either in the form of static tours, in which the location determines the audio recording of the device, or it can be as innovative as providing a tailored tour, with a 'virtual tour guide' watching the experience alongside the tourist (e.g., using Google Glass). Not only can this help produce jobs for the programmers making these technologies, but members of the creative economy, such as art historians, tour guides, and architects, who have a rich, esoteric understanding of their area of expertise.

217) Ecommerce-covid.sn





Mobile money is a technology which may enables people of low-income countries to overcome the poor infrastructure and inaccessibility of institutions in the areas in which they live. Mobile money is defined as digital technology that allows people and organizations to transfer funds between banks or accounts, in addition to depositing or withdrawing funds, paying for goods and services, all through the use of a mobile phone. For example, a 2016 World Bank Group report estimated that nearly 80% of individuals in the developing world own a mobile phone, whereas internet adoption stands at 31% in developing countries (compared to 80% in high-income countries). Moreover, according to a study from Research ICT Africa Access, relative to other means of transferring and/or receiving money, survey participants agreed that mobile money is easier (88%), safer (83%), more trustworthy (78%), more convenient (80% and faster (89%). In a 2014 report by CGAP investigating, Electronic G2P payments in four lower income countries - Haiti, Kenya, the Philippines and Uganda - it was found that G2P payments have the potential to improve efficiency and transparency of cash transfers; reduce costs; and provide value added services.

Source: Adapted from *Number of Live Mobile Money Services for the Unbanked by Region (2001-2017*; Image courtesy of WBG)

FIGURE 16: Mobile Money as an Intermediary to a Digital Ecosystem

Use cases

Virtual tourism has the potential to generate feed-forward mechanisms for LDCs. It is estimated the tourism provided 7% of LDCs total exports of goods in services in 2015, with an average annual growth of 14% for tourist arrivals.[218] The role of SMEs in tourism was highlighted during the COVID-19 pandemic when inbound tourist arrivals declined by 74 percent.[219] However, with virtual reality, tourists will be able to experience a country in a novel sensory experience, which may stoke additional enthusiasm to visit once public health conditions in the country are safe for travel. LDCs, such as Myanmar, have struggled due to a loss of tourism as the country copes with the aftermath of a military coup and ongoing effects of the COVID-19 pandemic. Although there may be obstacles for tourists to visit, virtual reality can still allow individuals to "visit" the country's rich heritage sites such as the Shwedagon Pagoda in Yangon.[220]

Virtual and augmented reality can help affordable skill development by providing immersive training experiences from world experts. For example, a study by PwC revealed that VR learners were four times faster to train than in the classroom; 275% more confident to apply skills learned; 3.75% more emotionally connected, and 400% more focused than their e-learning peers. It is estimated that 80% of individuals with a cancer diagnosis will require surgery at least once during the disease course. Yet less than 5% of low-income countries can provide basic cancer surgery secondary to human resource deficiencies, poor skill development, and infrastructural lack. In response, VR simulators can help surgical novices learn complex surgical oncological procedures in a near-hands-on manner, with real-time guidance. In Zambia, the radical abdominal hysterectomy procedure (RAH) – a complex operation used to remove uterine tumors - was taught by experts at the University of Texas Southwestern Medical Center.[221] Using the $1500.00 multi-use Oculus Rift VR Headset, a near-identical VR reproduction of an operating room on a 1:1 scale allowed for the Zambian medical doctors to participate in a visually and audibly stimulating environment later allowed them to practice themselves. The Zambian training participants substantially improved their movement and time efficiency and their confidence to conduct the operation independently. VR has also been used to develop virtual environments for industrial training.

218) UNWTO. (2017). Tourism for Sustainable Development in Least Developed Countries, at https://.e-unwto.org/doi/pdf/10.18111/9789284418848
219) UNCTAD. (2021). COVID-19 and Tourism, an update: Assessing the economic consequences, at https://unctad.org/system/files/official-document/ditcinf2021d3_en_0.pdf
220) Marcus, L. (2021). Myanmar is planning to reopen to tourism in early 2022. But who will go?, at https://www.cnn.com/travel/article/myanmar-tourism-reopening-coup-cmd-intl-hnk/index.html
221) Bing, E. G., Parham, G. P., Cuevas, A., Fisher, B., Skinner, J., Mwanahamuntu, M., & Sullivan, R. (2019). Using Low-Cost Virtual Reality Simulation to Build Surgical Capacity for Cervical Cancer Treatment. *Journal of global oncology*, *5*, 1–7. https://doi.org/10.1200/JGO.18.00263

5

Recommendations

The 4IR is essential for LDCs as they are experiencing increasingly intense environmental, social and demographic pressures as well as stagnating industrial production. These ever-increasing social inequalities, which have only been amplified in the wake and aftermath of the COVID-19 pandemic, threaten LDCs' potential to bridge the digital divide and to leapfrog as well as the progress made thus far in achieving the SDGs. Hence, LDCs must become authors of their technological revolution, as they have much to lose if they do not seize the opportunities the 4IR provides.

Skills Development and Capacity Building

LDCs need to equip their populations with the requisite digital skills to take advantage of the data economy.

Educational programs that deploy rapid data and AI-skill training are in increasing demand in order to develop data skills and capabilities for the use of data tools by innovators, entrepreneurs, and government agencies. Data literacy is increasingly considered a core skill, with some research suggesting that 90 percent of jobs in advanced economies already require a measure of data skills. At the same time, less than one-third of the population possesses adequate skills. LDCs need to work quickly to close this gap, which is even wider in developing countries. To that end, LDCs need to recognize that digital literacy should be complemented by foundational, language, and non-cognitive skills to help graduates succeed in digital labor markets.[222]

Greater access to tertiary education and vocational training would ensure access to jobs that demand higher skills.

Adaptation of the education curricula to reflect the skills that will be in demand in the future is vital. Greater focus on science, technology, engineering, and math (STEM) education is a requirement for adopting new technologies with early exposure to computer science, entrepreneurship, and interpersonal skills having the ability to help prepare the next generation of workers. Strengthening the educational system to meet the challenges of adopting new technologies will require the hiring and retention of quality educators, proper funding for educational institutions, and high standards for student achievement.

Beyond the acquisition of formal skills, the speed of technological progress requires greater flexibility and the ability to learn quickly from workers.

Policies to support early education and life-long learning skills are therefore critical. According to the OECD, technical and vocational education and training (TVET) institutions can play a fundamental role in providing a "highly skilled labor force, with a range of mid-level trade, technical, professional and management skills alongside those high-level skills associated with university education."[223] Therefore, providing the appropriate skills to current and future workers is an essential area for policy development. The supply of labor at each skill level is affected by the education system and on-the-job training.

TVET plays an essential role in serving individuals whose needs are not met by formal education.

TVET programs provide career pathways for school drop-outs, students who want to complement their education with more practical skills, or older professionals who want to polish their skills or make a lateral career move.[224] High-quality vocational education pathways, particularly in upper secondary education, help those who do not have academic aspirations re-engage with the education system and improve their practical skills, thus responding to the job market needs. Therefore, vocational training can complement formal education, underlining a notion that skills build upon skills.

222) Blom, A., Nusrat, M., Goldin, N. (2020) 5 Things MENA Countries can do to Design Better Digital Skills Development Programs, at https://blogs.worldbank.org/arabvoices/5-things-MENA-countries-can-do-to-design-better-digital-skills-development-programs

223) OECD (2011) A Skilled Workforce for Strong, Sustainable and Balanced Growth: A G20 Training Strategy, at https://www.oecd.org/g20/summits/toronto/G20-Skills-Strategy.pdf

224) Quintini, G., Manfredi, T. G. (2009) Going Separate Ways? School-to-Work Transitions in the United States and Europe, at https://www.researchgate.net/publication/46457119_Going_Separate_Ways_School-to-Work_Transitions_in_the_United_States_and_Europe

Though LDCs produce many graduates in management and engineering, which are essential for innovation, unemployment is high among the educated youth in the state.

Most economic growth has been in sectors dependent on low labor and commodity costs. For many businesses, the costs of these highly skilled people are too high. Various policy instruments can be used to incentivize the private sector to enter into ventures of a more innovative nature, for example, by subsidizing the wages of these employees to make them more affordable for different priority sectors.

Upgrading education systems and boosting employability must be a priority.

Data on youth and adults with ICT skills show vast inequalities between countries at different levels of development, not least in basic digital skills essential for participation in the information economy. However, there are tremendous possibilities to cater to underserved markets and access knowledge to take advantage of opportunities. Examples include artificial intelligence courses providing scholarships in Nepal and solar-powered projectors being rolled out to teach the fundamentals of literacy and numeracy in Malawi.[225]

The risk of a gender gap expansion is a social issue that requires attention in LDCs.

Governments must address the gender gap by emphasizing female creative thinking and encouraging their active participation in the innovation processes through IT and STEM programs to help them become more competitive in the labor market and promote their social mobility. The protection of women's rights and ensuring equal opportunities for women in all countries, such as their unobstructed access to quality education, are prerequisites for the authorities to effectively deal with the gender gap worldwide.

LDCs must develop inclusive policies that effectively promote useful and meaningful content for women through digital platforms to increase access and essential services.

By promoting these progressive policies, LDCs can nurture technological innovation as a driver for social inclusion and women's economic participation.[226]

225) Adhikari, R., Lehmann, F. (2020) Least Developed Countries Can Become Authors of Their Technological Revolution, at https://oecd-development-matters.org/2020/02/05/least-developed-countries-can-become-authors-of-their-technological-revolution/

226) G20 Insigths (2018) Bridging the Gender Digital Gap, at https://www.g20-insights.org/policy_briefs/bridging-the-gender-digital-gap/

Capacity-building programs that include teaching digital skills for women must be designed.

LDCs must develop and implement programs that will teach women the necessary digital skills and provide individual mentoring that accompanies women through the learning and adoption process on a case-by-case basis. One example of this is EIF's and the International Telecommunication Union's EQUALS Global Partnership which aims to maximize the positive impacts of technology for women. However, impediments to women's economic empowerment such as limited mobility and spousal consent persist across the globe, and in LDCs in particular.[227] Broader social policy interventions will need to be implemented, as skilling initiatives to equip women and other social groups with capabilities for future jobs cannot work in isolation.[228]

LDCs need to create a digitally literate youth.

In order to achieve innovation-led economies, it is essential for LDCs to engage with youth communities, to help them develop entrepreneurial opportunities leveraging emerging technologies through skills development training, linkages with education and research stakeholders, mentoring by private sector stakeholders, and other structured support mechanisms.[229]

Digital Transformation at Firm-Level

The ability of firms and their subsidiaries to absorb digital technologies will be essential to the development of a vibrant SME ecosystem in LDCs.

Businesses and SMEs in LDCs are well poised to reap the benefits of increased technological absorption. In doing so, SMEs will improve their technical know-how and generate new knowledge, which will allow them to increase their productivity, creativity, and developmental process.[230]

Technology absorption should not be viewed in a vacuum.

While technology absorption will undoubtedly affect the generation of new knowledge, LDCs must improve worker education, work experience, invest in R&D, and provide robust training for their SMEs.[231]

Digitalization and digital transformation of SMEs in LDCs will only be possible if transformational entrepreneurship is present.

Fostering transformational entrepreneurship in LDCs will only be possible if entrepreneurship education policies are established. These policies should promote soft skills (such as persistence, networking, and self-confidence) and hard skills (such as business planning, financial literacy, and managerial skills).[232] Transformational entrepreneurship can only be achieved through experimental learning, problem-solving, team building, risk-taking, and critical thinking. Hence, these education policies should focus more on an informal education model.

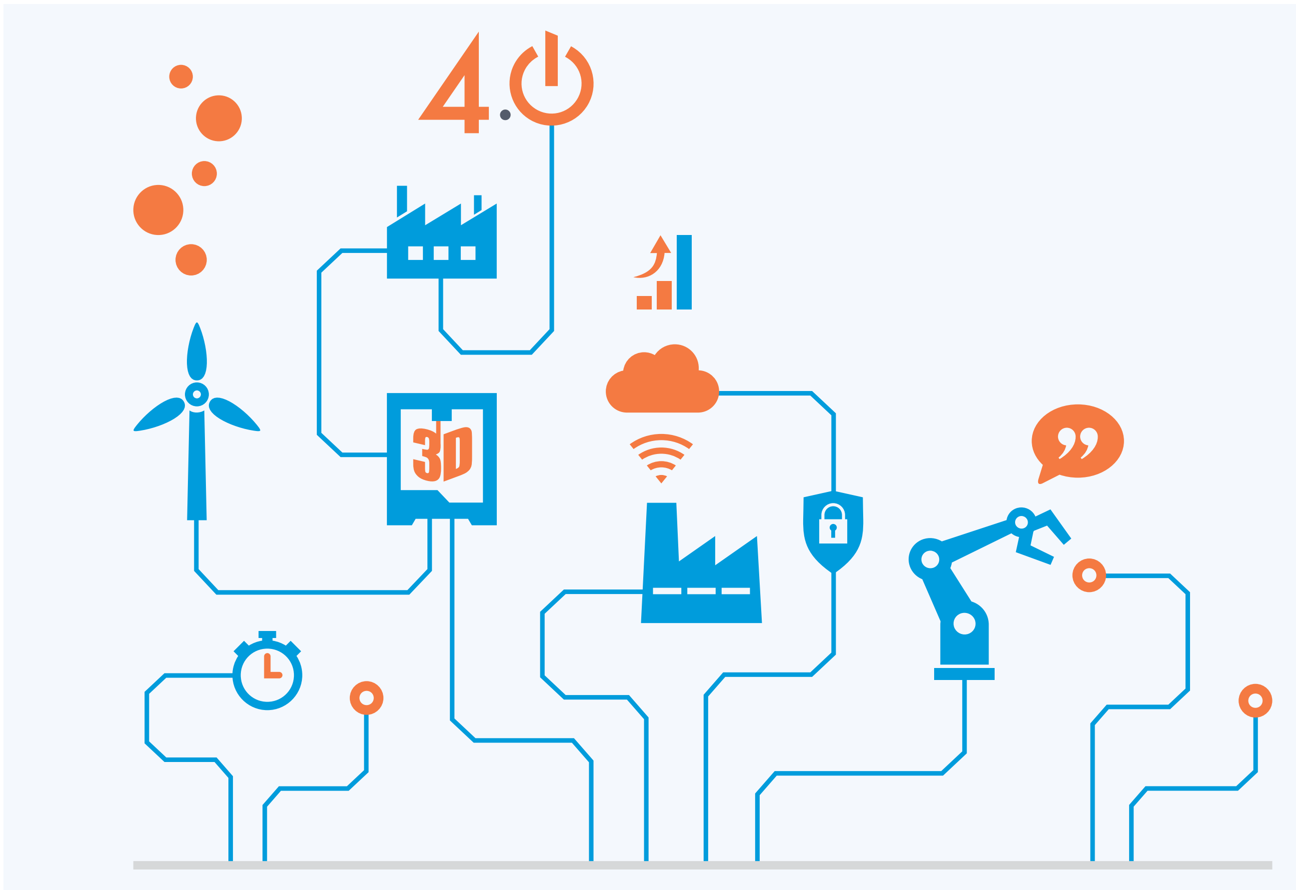
227) Wesely, M. (2017) Economic Empowerment Strategies That are a Win-Win for Women and for Business, at https://womendeliver.org/2017/economic-empowerment-strategies-win-win-women-business/
228) G20 Insigths (2018) Bridging the Gender Digital Gap, at https://www.g20-insights.org/policy_briefs/bridging-the-gender-digital-gap/
229) African Union Commission (2020) Science, Technology and Innovation Strategy for Africa 2024, at https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf
230) Roxas, B. G. (2008). Social capital for knowledge management: The case of small and medium-sized enterprises in the Asia-Pacific region. *Asian Academy of Management Journal*, *13*(2), 57–77
231) Ibid
232) UNCTAD (2018) The Least Developed Countries Report 2018, Overview, Entrepreneurship for Structural Transformation – Beyond Business as Usual, at https://unctad.org/system/files/official-document/ldcr2018overview_en.pdf

E-commerce can provide a growing entrepreneurial and development opportunity in LDCs.

if more producers and consumers in LDCs can link to e-commerce platforms and if policies for building entrepreneurial and productive capacities prove effective. LDCs must address common barriers to the development of a vibrant e-commerce ecosystem which include the insufficient development of telecommunications services, deficits in energy and transport infrastructure, an underdeveloped financial technology industry, a lack of e-commerce skills development, financial constraints on e-commerce ventures and technology start-ups, and a lack of or weakness in an overall national e-commerce strategy.[233]

Industrial policies and enterprise development policies in LDCs need to be more strongly aligned towards structural transformation.

This requires clearly distinguished and effectively articulated entrepreneurship and enterprise development policies tailored to national circumstances and stages of transformation; vertical, horizontal, and functional industrial policies; and supportive policies in many different sectors, with effective coordination to ensure coherence. Enterprise development policies in LDCs should include a monitoring and evaluation framework supported by an alignment between the time frames of different policies.[234]



233) Ibid
234) Ibid

Innovation Ecosystems

Business environment reform will be crucial for LDCs.

Government regulations play a decisive role in creating a predictable and conducive framework for businesses to form, operate, and grow. The reformation of the existing business environment across LDCs will promote the development of markets that encourage competition and enhance effectiveness and sustainability.[235] LDCs must augment their policy, legal, institutional, and regulatory conditions that govern business activities to encourage informal businesses to register as formal businesses. This can be achieved if LDCs improve regulations, reduce administrative costs, foster open and competitive markets, and lower uncertainty for businesses and investors.[236]

Boosting business competition in LDCs will catalyze shared prosperity.

LDCs can enhance the competitiveness of their local firms by integrating them into existing value chains, thus increasing service and product quality standards and participation in public tenders, as well as leveraging digital technologies. This will allow LDCs to improve their business linkages to international markets and investors, increasing their ability to meet service and product quality standards.[237]

LDCs must remove barriers and distortions to sustain private sector-led growth.

Reforms in selected investment areas, competition, and business environment encompassing tax incentives, investment promotion, SME policies, subnational growth, and investment climate policies must be implemented if LDCs wish to attain private sector-led growth.

National strategies for STI and 4IR will be a significant pillar for post-crisis rebuilding and growth in LDCs.

National STI strategies articulate a government's vision regarding the contribution of STI to a country's social and economic development. This vision sets out priorities for public investment in STI, identifying the focus of government reform. Furthermore, these priorities can be used to mobilize actors around specific goals, such as manufacturing, industry, and environmental issues, and may help steer investment by private actors.

STI strategies must be designed to transform LDCs into knowledge-based and innovation-led societies.

LDCs must have a clear set of objectives when creating their own national STI strategies to leverage the 4IR. These objectives must center around enhancing the effectiveness of STI and addressing and implementing priority areas, and improving technical competencies and institutional capacities for STI development. Furthermore, a national STI strategy must promote economic competitiveness through fostering innovation, value addition, industrial development, and entrepreneurship.[238]

235) https://www.enterprise-development.org/what-works-and-why/evidence-framework/rationale-for-ber/
236) World Bank (2020) Improving Business Environment for Prosperity (IBEP), at https://www.worldbank.org/en/topic/investment-climate/brief/improving-business-environment-for-prosperity
237) World Bank (2020) Improving Business Environment for Prosperity (IBEP), at https://www.worldbank.org/en/topic/investment-climate/brief/improving-business-environment-for-prosperity
238) African Union Commission (2020) Science, Technology and Innovation Strategy for Africa 2024, at https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf

LDCs must renew their policy frameworks and capabilities to enable more ambitious STI strategies.

Governments in LDCs must emphasize building resilience in their policies that will enable their STI strategies. This calls for policy agility, highlighting the need for governments to acquire dynamic capabilities to adapt and learn in the face of the rapid changes perpetuated by the 4IR. By engaging stakeholders and citizens in these efforts, policymakers will be exposed to a diverse set of knowledge and values that can contribute to policy resilience.[239] LDCs must invest in evidence about their STI support policies as a means to improve them.

To ensure that STI strategies face long-term challenges, LDCs must link support for 4IR technologies to broader missions that encapsulate responsible innovation principles.

The pandemic acted as a stark reminder that even developed countries are not impervious to crises. This has forced governments to recalibrate their STI policies and strategies to confront long-term challenges of sustainability, inclusivity, and resiliency. It is therefore imperative that LDCs ensure an alignment of 4IR technology development with the objectives of mission-oriented policies. Responsible innovation policies must be included in STI strategies to anticipate problems in the course of innovation and steer technology to best outcomes, emphasizing the inclusion of stakeholders in the innovation process.[240]

239) OECD (2021) OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity, at https://www.oecd-ilibrary.org/sites/75f79015-en/index.html?itemId=/content/publication/75f79015-en
240) Ibid

Partnerships, Access to Finance, Investment and Infrastructure

Support the creation of regional R&D centers and foster linkages with international R&D centers.

and regional and international cooperation as well as exchange programs (preventing the need to reinvent the wheel) where countries can learn from more established players. There should be a focus on demonstration projects of use cases of 4IR technologies in specific sectors and countries with the greatest potential for successful disruption in LDCs. This should focus on specific intervention areas rather than trying to bring the 4IR to the whole continent. Some examples are AI & healthcare, drones & agriculture, Blockchain & FinTech, IoT & smart cities.

Governments can learn from each other to improve the design and administration of innovation support during crises.

Public support for innovation comes in many forms and is not always easy to measure, track overtime or compare to facilitate mutual learning. Governments also need to continue investing, alongside other capabilities, in evidence about their innovation support policies to improve them. This requires breaking down silos and developing capabilities to exploit this information. This is an ongoing priority of the OECD, both in terms of measurement and policy analysis. [241]

Technical cooperation between developing countries (TCDC) will boost regional cooperation and enable emerging technologies.

TCDC can be used as a powerful instrument to promote solidarity and horizontal collaboration while strengthening the institutional capacity of LDCs to meet their digital transformation needs. By sharing experiences, knowledge, and technical capacities, LDCs can contribute to their mutual capacity development, strengthen their relations, and increase the exchange, generation, and dissemination of scientific and technical knowledge pertaining to the 4IR. Leveraging TCDC can add further value for LDCs' digital transformation, as it can result in joint efforts to establish technology mechanisms such as R&D labs, training programs, investment vehicles, and regional conferences.

Global challenges require global solutions that draw on international STI cooperation.

The development of COVID-19 vaccines has benefited from nascent global R&D preparedness measures, including agile technology platforms that can be activated as new pathogens emerge. The pandemic has created momentum to establish effective and sustainable international mechanisms to support the range and scope of R&D necessary to confront a broader range of global challenges. However, governments need to build trust and define shared values to ensure a level playing field for scientific cooperation and equitable distribution of its benefits.[242]

241) OECD (2021) OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity, at https://www.oecd-ilibrary.org/sites/75f79015-en/index.html?itemId=/content/publication/75f79015-en

242) OECD (2021) OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity, at https://www.oecd-ilibrary.org/sites/75f79015-en/index.html?itemId=/content/publication/75f79015-en

Governments will need to balance national STI priorities and goals with the need for internationally coordinated action to address grand challenges and global public goods problems.

Without such collective action, the capacities to deal with them – in the form of scientific knowledge, technology platforms, and international coordinating institutions – will remain underdeveloped, leaving countries more exposed to global shocks. At the same time, governments need to build trust and define common and shared values to ensure a level playing field for scientific cooperation and equitable distribution of benefits.[243]

Since LDCs lack resources, skills, and expertise in digital transformation, they need to harness partnership potential at the international level.

At international levels, mechanisms such as aid for trade, South-South cooperation, and international organizations' support could be instrumental in overcoming the challenges presented by achieving digital transformation and the SDGs. Organizations such as UNIDO, the UN Technology Bank, the Enhanced Integrated Framework, the International Trade Centre, the World Bank Group, the World Trade Organization can support LDCs in this regard.

Financial inclusion plays a major role in overall social inclusion and economic development.

When people lack access to bank accounts or other ways to handle cash virtually, basic everyday tasks such as paying utility bills, transferring money, and receiving their salary require physical transportation of cash, which can be dangerous and time-consuming.[244] Once people have access to some sort of transaction account, they would have easier access to other financial services, such as keeping savings accounts for long-term planning or taking loans to invest in training or even to start a business.[245]

Accelerating and scaling 4IR technologies to realize the SDGs will require public and private capital.

If LDCs wish to leverage the innovative solutions that the 4IR provides, a wide range of financing sources will be needed. Finance mechanisms including private, philanthropic, corporate, and public investment, which rely not only on traditional commercial investment, must be leveraged. LDCs must utilize innovative impact investments that seek a blend of financial, social, and environmental impact investments.[246] An example of impact investments in technology and e-commerce has been noted in Nepal after the establishment of the Dolma Impact Fund.[247] The Dolma Impact fund has invested in hydropower, technology, and e-commerce; however, the sizes of these investments have not been made publicly available.

243) OECD 2021

244) Simon, A. (2017) The Potential and Limits of the Fintech Revolution in Emerging Markets, at https://news.trust.org/item/20170530175958-zdnmt/

245) World Bank (2018) UFA2020 Overview: Universal Financial Access by 2020, at https://www.worldbank.org/en/topic/financialinclusion/brief/achieving-universal-financial-access-by-2020

246) G20 Insights (2017) Enabling a Sustainable Fourth Industrial Revolution: How G20 Countries Can Create the Conditions for Emerging Technologies to Benefit People and the Planet, at https://www.g20-insights.org/policy_briefs/enabling-sustainable-fourth-industrial-revolution-g20-countries-can-create-conditions-emerging-technologies-benefit-people-planet/

247) Adhikari, R. (2021) Repositioning Aid for Trad Discourse in the Context of LDC Graduation, at https://www.sawtee.org/publications/TI_Vol_17_No_1-2.pdf

Offer finance using blended finance and innovative financial instruments.

such as guarantees to help lower the hurdle rates of international investors and increase their participation on the African continent, thus leveraging additional capital. Instruments such as local currency lending are also crucial in reducing exchange rate risks and volatility.

Bridging the gender gap will require gender lens investments.

LDCs must economically empower women by beginning investment to address gender issues and promote gender parity. Investments in women-owned or women-led enterprises, enterprises that encourage an equitable workplace, or enterprises that offer products or services that substantially improve the lives of women and girls must be included to generate and achieve positive impacts on women and girls in LDCs.

Providing a stable investment climate includes actions to improve capital markets and reduce political risk.

(e.g., through currency manipulation or capital controls) and requires strong signaling and demonstrator effects from international financial institutions. Existing pilot projects funded by transnational corporations, global funds, and development banks signal potential opportunities to the private sector. Moreover, it is crucial that finance be channeled to 4IR-ready and 'future-proof' infrastructure such as renewable technologies or ICT-ready road infrastructure to avoid locked-in capital and expensive retrofitting for obsolete infrastructure.

The presence of electricity is the most necessary aspect of achieving digital transformation.

With no access to electricity, there will not be the need to buy a mobile phone and thus resulting in a lack of data access by the general public. Out of 46 LDCs, only 25 have electricity coverage to less than 50 percent population. It is hard to decide whether to push for electrification of these countries or to push for broadband connectivity to countries with more than 50 percent population having access to electricity. For a fast economic push, it is recommended that connectivity and Internet usages for countries where electricity is available be pushed for immediate results. The impact of these countries' development will percolate to the less developed countries with time.

One aspect of digitalization is the growing use of data for businesses and governments to analyze and apply it for their operations.

The need for fixed broadband is critical for supporting LDCs since it can transfer large amounts of data quickly and at a lower per-unit price than mobile broadband. Hence, fixed broadband is essential for LDCs to achieve the structural transformation of their economies and boost productivity. At the same time, COVID-19 has popularized the use of videoconferencing for learning, work, and medical advice. Videoconferencing utilizes large amounts of data and works optimally with a fixed broadband connection (including operating Wi-Fi off the fixed connection).

Because LDCs are largely less populated with no economy of scale, private companies managing telecommunications are not encouraged to set up Internet networks.

Governments must plan programs to encourage private companies by giving them subsidies or avenues to recover their investment. Building infrastructure in remote areas by private companies can be compensated by providing them monetization avenues in urban areas.

A large population in LDCs can access the Internet, but they are not doing so partially because of the cost involved but majorly because of a lack of awareness and digital skills.

Digital Awareness can be triggered if government schemes are planned using telecommunication as the mode of implementation. With this, even if the citizens of LDCs are uneducated, they will start becoming more aware solely because their survival starts depending on it.

There needs to be better coordination among the government, private sector, educational institutions, and development partners to enhance broadband use.

Dialogue among these institutions is essential for understanding skills requirements in order to plan necessary training. LDC governments should also make greater use of the private sector to help develop public broadband applications, including leveraging emerging start-up communities. Micro, small and medium-sized enterprises (MSMEs) should be provided with the necessary assistance to adopt broadband technology for their businesses. This would help accelerate the economic impacts of broadband. Interventions for the development of broadband applications and services should be coordinated between governments and development partners to maximize widespread impact and sustainability.

Data centers are a critical component of the digital economy infrastructure.

They provide the infrastructure required to maintain and securely operate servers where data is stored (including the local hosting of domestic content). Availability of data centers is also a gauge of the digitalization of the economy, reflecting demand not only by the ICT sector but also other industries that have a high demand for digital services, such as finance, transportation, legal, accounting, research and development, advertising and the public sector.

Governance, Technologies, and Innovation Policies

Fast-tracking changes to regulation to enable 4IR uptake will be necessary.

In a world grappling with new technologies, climate change, and a global pandemic, LDCs must leverage novel regulatory practices that a growing number of governments are employing in a bid to manage the opportunities and associated risks of technological change. These practices have been categorized as "agile regulation," which builds on the concept of agile technology development. Implementing agile regulation that focuses on the future by setting clear outcomes for business gives regulators the space to experiment in how they are achieved. By leveraging agile regulators, LDCs can collaborate across institutional, regional, and international boundaries to ensure that rules are interoperable and risks can be tackled jointly.[248]

When applying agile regulation, LDCs must perform a balancing act between seizing economic opportunity and not stifling innovation.

Careful judgment on when to intervene needs to be applied when leveraging agile regulation. If regulators in LDCs act too late, they may fail to seize economic opportunities and address emerging risks. However, if they intervene too soon, regulators may stifle innovation or develop ineffective rules based on an incomplete understanding of the emerging technology. Hence, applying "soft law" mechanisms, such as regulatory guidance, codes of practice, and voluntary standards based on international best practices, can be used to steer technological development. Once 4IR technologies mature, LDCs can codify these soft law mechanisms.[249]

LDCs must develop goal-based regulation that focuses on real-world outcomes for their citizens and environment.

Goal-based approaches are inherently technology-neutral, as they increase flexibility for businesses by enabling them to find the most efficient way to comply and reducing costs for consumers. This encourages innovation since businesses have greater freedoms in trying out new ideas, products, and business models. Additionally, goal-based regulation will enable them to think more carefully about best achieving a regulatory goal rather than mechanically following the rules.[250]

248) World Economic Forum (2020) Agile Regulation for the Fourth Industrial Revolution: A Toolkit for Regulators, at https://www3.weforum.org/docs/WEF_Agile_Regulation_for_the_Fourth_Industrial_Revolution_2020.pdf

249) Ibid

250) World Economic Forum (2020) Agile Regulation for the Fourth Industrial Revolution: A Toolkit for Regulators, at https://www3.weforum.org/docs/WEF_Agile_Regulation_for_the_Fourth_Industrial_Revolution_2020.pdf

Develop collaborative and adaptive regulation.

Besides public-private interplays and other collaborative governance approaches, greater regulatory agility and insight are needed to manage digital exclusion and tensions between the different policy objectives of competing emerging technologies. This will need to be reconciled with safeguarding the public and social value of the Internet through the extension of the Spectrum Commons, unlicensed spectrum, and social use spectrum. In developed and developing countries alike, most spectrum is largely unused outside main metropolitan areas. In the sharing economy, voluntary infrastructure-sharing by operators is already occurring today. These types of collaborative approaches need to be embraced by governments from a critical resource management perspective. Enabling secondary spectrum use would allow for dynamic spectrum sharing, which operates at a fraction of the cost of the GSM (Global System for Mobiles) network and could be deployed in new business models in the largely unused spectrum in rural areas. Such an approach could instantly provide low-cost, high-quality bandwidth.

Seek harmonization of data protection frameworks at regional level (REC).

through compatibility between national legislations, based on a set of core agreed data protection principles, still considering national differences in terms of existing frameworks or advancement in technological innovation. It is recommended that regional organizations focus on unifying internationally compatible initiatives instead of pursuing multiple endeavors.

Governments and policymakers must utilize enabling mechanisms to make the 4IR a sustainable revolution.

If the 4IR is to be successful in becoming the first sustainable industrial revolution, governments and regulators will need to quickly adapt to the rapidly evolving landscape of the 4IR by providing an enabling environment, safeguards, and oversight intended to guide its proper utilization. The governance challenges that stem from leveraging the emerging technologies that underpin the 4IR are more significant than previous industrial revolutions due to their complexity, pace, and global and sectoral breadth of change. Governments and policymakers have to play a balancing act between the positive and environmental impacts that these technologies unlock while at the same time avoiding exacerbating today's most pressing challenges. Foresight, public policies, and technological governance developed by the LDCs' Academies of Sciences will be needed to prevent or minimize unintended consequences and protect public interests.[251]

LDCs should draw on good practices in 4IR governance and public policymaking.

that governments around the globe are deploying. These practices include the establishment of policy labs, regulatory sandboxes, crowdsourced public policymaking, and private-public partnerships.

251) G20 Insights (2017) Enabling a Sustainable Fourth Industrial Revolution: How G20 Countries Can Create the Conditions for Emerging Technologies to Benefit People and the Planet, at https://www.g20-insights.org/policy_briefs/enabling-sustainable-fourth-industrial-revolution-g20-countries-can-create-conditions-emerging-technologies-benefit-people-planet/

Bolster or redesign existing governance institutions to better prepare for challenges posed by data circulation.

New institutions may also need to be created to ensure the safety and security of organizations and individuals. This will include developing frameworks and skills to oversee both the technical management of critical facilities and infrastructure that are increasingly exposed to sophisticated and threatening malware, as well as the processing of the substantial amounts of data being generated to fuel the 4IR.

Policy frameworks tackling potential systemic bias in algorithms will need to be developed.

Crowdsourced raw data typically reflects the biases and prejudices inherent in society, producing results that have been perceived as discriminatory. Hence, policy frameworks that balance the concerns around the unfairness discrimination in publicly sourced big data with technical and ethical challenges (such as monitoring and potential censoring of data) are necessary.[252] Therefore, it is essential to create initiatives supporting academics, technologists, and other stakeholders to inform a concrete and transparent process to hold algorithms and their owners accountable.

To address these 4IR challenges, there is a need for far greater state coordination across different economic and social sectors.

and for public and private sector collaboration to build globally competitive digital economies and societies. Institutional arrangements will need to be reviewed, and the traditional regulation of nationally licensed and regulated players and industries must be aligned with global internet governance systems.

Nurture inclusive institutions favoring and promoting widespread innovation to adopt 4IR technologies in production and service sectors.

Given the cross-cutting nature of 4IR technologies, policy and governance approaches can no longer be designed in a vacuum or in silos by focusing on a particular sector or supply-side issues alone, as has been done in the past. Policy success will be as dependent on demand-side interventions to ensure sufficient absorptive capacity of new technologies. Mechanisms to ensure the affordability of devices and data services for end-users and affordable bandwidth and energy will be a critical input of 4IR technologies. Development of relevant local content and applications in local languages, along with the enhancement of citizens' digital literacy skills and a higher level of engineering, coding, and economic and creative capacity, are all vital to creating an enabling environment necessary to harness the opportunities offered by 4IR. Currently, these conditions are highly uneven between and within regions in Africa. Without active steps to address existing inequalities offline, inequalities will simply be replicated, or even amplified, online.

252) Ibid

Public innovation support policies need to be able to guide private innovation efforts to where they are most needed.

especially where market signals prove to be insufficient and coordination is most challenging. Recent OECD data and analysis show that governments' policy mix is not entirely consistent with that ambition. R&D tax incentives are effective in achieving their generic R&D-raising objectives as long as they are consistently designed and implemented. However, they are insufficient as a means to guide innovation to broader societal needs and represent suboptimal instruments to encourage investment in knowledge at the interface between basic research and actual product or process development.[253]

253) OECD (2021). OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity, at https://www.oecd-ilibrary.org/sites/75f79015-en/index.html?itemId=/content/publication/75f79015-en

BIBLIOGRAPHY

[1] Adhikari, R. (2019) 6 Ways the Least Developed Countries Can Participate in the Fourth Industrial Revolution, at https://www.weforum.org/agenda/2019/08/6-ways-least-developed-countries-can-participate-in-the-4ir/

[2] Adhikari, R., Lehmann, F. (2020) Least Developed Countries Can Become Authors of Their Technological Revolution, at https://oecd-development-matters.org/2020/02/05/least-developed-countries-can-become-authors-of-their-technological-revolution/

[3] African Development Bank (2019) Unlocking the Potential of the Fourth Industrial Revolution in Africa

[4] African Union Commission (2020) Science, Technology and Innovation Strategy for Africa 2024, at https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf

[5] https://www.airavirtual.com/

[6] Aldrich, T.J. (1977), Managing the Flow of Technology: Technology Transfer and Dissemination of Technological Information within the R&D Organization, MIT Press, Cambridge, MA.

[7] Andreoni, A., Chang, H.-J., Labrunie, M. (2021) Natura Non-Facit Saltus: Challenges and Opportunities for Digital Industrialisation Across Developing Countries

[8] Adreoni, A., Modliwa, P. & Roberts, S. (2021). Structural Transformation in South Africa: The Challenges of Inclusive Industrial Development in a Middle Income Country. *Oxford University Press*. 1-416

[9] Anderson, C., Gantz, J.F., et al (2021) Wordlwide CO2 Emissions Savings from Cloud Computing Forest, 2021-2024: A First-of-Its-Kind Projection, at https://www.idc.com/getdoc.jsp?containerId=US47426420

[10] Anthem, P. (2020) Risk of hunger pandemic as coronavirus set to almost double acute hunger by the end of 2020, at https://www.wfp.org/stories/risk-hunger-pandemic-coronavirus-set-almost-double-acute-hunger-end-2020

[11] https://www.apc.org/en/news/new-report-bridging-gender-digital-divide-challenges-central-and-eastern-europe-and-ex-soviet

[12] Artz, G. (2003). Rural Area Brain Drain: Is it a Reality? *Iowa State University: Digital Repository. Extension and Outreach Publications*. 90. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1090&context=extension_pubs

[13] Asite (2021) Digitization, Digitalization, and Digital Transformation – What's the Difference?, at https://www.asite.com/blogs/digitization-digitalization-and-digital-transformation-whats-the-difference

[14] Atwell, P. (2001). The First and Second Digital Divides. *Sociology of Education* 74(3). 252-259

[15] Ayentimi, D. T. (2020) The 4IR and the Challenges for Developing Economies, at https://www.researchgate.net/publication/340840065_The_4IR_and_the_challenges_for_developing_economies

[16] https://azure.microsoft.com/en-us/overview/what-is-a-qubit/#introduction

[17] Bank of England (2020). Central Bank Digital CurrencY: opportunities, challenges and design, at https://www.bankofengland.co.uk/paper/2020/central-bank-digital-currency-opportunities-challenges-and-design-discussion-paper

[18] Baker, A., (2017) The American Drones Saving Lives in Rwanda, at https://time.com/rwanda-drones-zipline/

[19] Bing, E. G., Parham, G. P., Cuevas, A., Fisher, B., Skinner, J., Mwanahamuntu, M., & Sullivan, R. (2019). Using Low-Cost Virtual Reality Simulation to Build Surgical Capacity for Cervical Cancer Treatment. *Journal of global oncology, 5*, 1–7. https://doi.org/10.1200/JGO.18.00263

[20] Blom, A., Nusrat, M., Goldin, N. (2020) 5 Things MENA Countries can do to Design Better Digital Skills Development Programs, at https://blogs.worldbank.org/arabvoices/5-things-MENA-countries-can-do-to-design-better-digital-skills-development-programs

[21] https://www.blockchainforclimate.org/

[22] https://www.bluerivertechnology.com/

[23] Brookings (2020) The Fourth Industrial Revolution and Digitization will Transform Africa into a Global Powerhouse, at https://www.brookings.edu/research/the-fourth-industrial-revolution-and-digitization-will-transform-africa-into-a-global-powerhouse/

[24] Bruckner, M. (2012). Limited progress in market access for LDCs. *United Nations. LDC Portal*, at https://www.un.org/ldcportal/limited-progress-in-market-access-for-ldcs/

[25] https://builtin.com/big-data/iot-big-data-analytics-examples

[26] Calvo, J. (2019). Drones, Drones Everywhere in Business. *Strategy 4.0 Blog*, at http://strategy4.org/my-blog/drones-drones-everywhere-in-business

[27] https://www8.cao.go.jp/cstp/english/society5_0/index.html

[28] https://www.cellink.com/

[29] https://www.census.gov/topics/research/big-data.html

[30] Chaminade, C., Lundvall, B.-A. (2019) Science, Technology, and Innovation Policy: Old Patterns and New Challenges, at https://oxfordre.com/business/view/10.1093/acrefore/9780190224851.001.0001/acrefore-9780190224851-e-179

[31] https://climate.nasa.gov/evidence/

[32] https://cloudhimalaya.com/public-cloud

[33] https://comma.ai/

[34] https://cryptoclimate.org/accord/

[35] Deloitte. (2017). Using blockchain to drive supply chain transparency, at https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html

[36] Digital Planet (2021) How green is the Greenback? An Analysis of the Environmental Costs of Cash in the United States, at https://sites.tufts.edu/digitalplanet/how-green-is-the-greenback-an-analysis-of-the-environmental-costs-of-cash-in-the-united-states/?utm_source=rss&utm_medium=rss&utm_campaign=how-green-is-the-greenback-an-analysis-of-the-environmental-costs-of-cash-in-the-united-states

[37] Doumbia, D., Lauridsen M. L. (2019) Closing the Financing Gap – Trends and Data, at https://www.ifc.org/wps/wcm/connect/842b73cc-12b0-4fe2-b058-d3ee75f74d06/EMCompass-Note-73-Closing-SDGs-Fund-Gap.pdf?MOD=AJPERES&CVID=mSHKl4S#:~:text=4%20Looking%20at%20the%20infrastructure,efficiency%20and%20the%20quality%20of

[38] https://dynmhx.io/

[39] Ecommerce-covid.sn

[40] https://enhancedif.org/en/country-profile/ethiopia

[41] https://www.enterprise-development.org/what-works-and-why/evidence-framework/rationale-for-ber/

[42] https://www.ey.com/en_ch/industrial-products/how-smart-sensors-are-driving-industry-4-0-forward

[43] Fagan, M., Huang, C., (2019) Look at how people around the world view climate change, at https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/

[44] Fan, Y. and Chang, J. (2018). Embedded smart box for legacy machines to approach to I4.0 in smart manufacturing.

[45] https://www.fao.org/redd/en

[46] FAO of the UN, (2021) REDD+ Reducing Emissions from Deforestation and Forest Degradation, at https://www.fao.org/redd/news/detail/en/c/1397036/

[47] FAO. (2021). Applying blockchain to climate, at https://www.fao.org/3/cb3495en/cb3495en.pdf

[48] Fleming, S. (2019) Senegal is planting millions of mangrove trees to fight deforestation, at https://www.weforum.org/agenda/2019/09/senegal-is-planting-millions-of-mangrove-trees-to-fight-deforestation/

[49] https://www.forbes.com/sites/jonathanponciano/2021/05/13/worlds-largest-tech-companies-2021/?sh=4eb1306d69bc

[50] https://formlabs.com/blog/3d-printed-medical-mask/

[51] G20 Insights (2017) Enabling a Sustainable Fourth Industrial Revolution: How G20 Countries Can Create the Conditions for Emerging Technologies to Benefit People and the Planet, at https://www.g20-insights.org/policy_briefs/enabling-sustainable-fourth-industrial-revolution-g20-countries-can-create-conditions-emerging-technologies-benefit-people-planet/

[52] G20 Insights (2018) Bridging the Gender Digital Gap, at https://www.g20-insights.org/policy_briefs/bridging-the-gender-digital-gap/

[53] G20 Insights (2019) Leveraging Science, Technology and Innovation for Implementing the 2030 Agenda, at https://www.g20-insights.org/policy_briefs/leveraging-science-technology-and-innovation-for-implementing-the-2030-agenda/

[54] García-Garza, M. A., Ahuett-Garza, H., Lopez, M. G., Orta-Castañón, P., Kurfess, T. R., Urbina Coronado, P. D., Güemes-Castorena, D., Villa, S. G., & Salinas, S. (2019). A Case about the Upgrade of Manufacturing Equipment for Insertion into an Industry 4.0 Environment. *Sensors (Basel, Switzerland), 19*(15), 3304. https://doi.org/10.3390/s19153304

[55] Gay, D., Gallagher, K. (2019) For the Least Developed Countries, Revitalising Multilateralism is Life or Death – Op-Ed, at https://www.un.org/sustainabledevelopment/blog/2019/08/least-developed-countries-revitalising-multilateralism-is-life-or-death/

[56] Gedetsis, J. (2021) Tackling Climate Change Challenges with Cloud Computing, at https://www.nutanix.com/theforecastbynutanix/news/tackling-climate-change-challenges-with-cloud-computing

[57] Gifford, R., Scannell, L., Kormos, C., Smolova, L., Biel, A., Boncu, S., et al. (2009). Temporal pessimism and spatial optimism in environmental assessments: An 18-nation study. Journal of Environmental Psychology, 29, 1-12.

[58] Gifford, R. (2011). The Dragons of Inaction: Psychological Barriers that Limit Climate Change Mitigation and Adaptation. *American Psychologist.*

[59] Giri, S. (2019). Cloud Computing and Data Security Challenges: A Nepal Case. *International Journal of Computer Trends and Technology. 67*(3).

[60] Gleckler, P., Durack, P., Stouffer, R. et al. (2016). Industrial-era global ocean heat uptake doubles in recent decades

[61] Gorensek, T., Kohont, A. (2019) Conceptualization of digitalization: Opportunities and Challenges for Organizations in the Euro-Mediterranean Area, at https://emuni.si/wp-content/uploads/2020/01/IJEMS-2-2019_93%E2%80%93115.pdf

[62] Griliches, Z. (1979). Issues in assessing the contribution of Research and Development to Productivity Growth. *Bell Journal of Economics. 10(1) 92-116*

[63] GSMA. (2020). The State of Mobile Internet Connectivity 2020. *GSMA.* https://www.gsma.com/r/wp-content/uploads/2020/09/GSMA-State-of-Mobile-Internet-Connectivity-Report-2020.pdf

[64] Hawley, K. (2014). Transforming cities for sustainability: Facts and Figures. *SciDev.Net.* https://www.scidev.net/global/features/transforming-cities-sustainability-facts-figures/

[65] Heeks, R. and Whalley, J. (2008). The Impact of Mobile Telephony on Developing Country Microenterprise: a Nigerian Case Study. *Information Technologies and International Development*

[66] Hornyak, T. (2011). Flying robots build 20-foot tower in France, at https://www.cnet.com/news/flying-robots-build-20-foot-tower-in-france/.

[67] Huang, H., Savkin, A. & Huang, C. (2020). A new parcel delivery system with drones and a public train. *Journal of Intelligent & Robotic Systems. 100.* 1341-1354.

[68] IET. (2020). Drones needed for 'critical role' cmbating climage change, at https://eandt.theiet.org/content/articles/2020/02/drones-needed-for-critical-role-combating-climate-change/

[69] IIED (2015) Impact of Climate Change on Least Developed Countries: Are the SDGs Possible?, at https://pubs.iied.org/sites/default/files/pdfs/migrate/17298IIED.pdf?#:~:text=Climate%20change%20will%20significantly%20hamper%20LDCs'%20ability%20to%20achieve%20the,cities%2C%20marine%20resources%20and%20ecosystems.

[70] IIED (2019) Time to redress the globally unjust cost of climate change, at https://pubs.iied.org/sites/default/files/pdfs/migrate/17726IIED.pdf

[71] ILO, UN (2013) Shared Harvests: Agriculture, Trade, and Employment, at https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/genericdocument/wcms_212868.pdf

[72] ILO. (2018). Women and men in the informal economy: A statistical picture – Third Edition. *International Labour Office.* https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_626831.pdf

[73] https://www.image-net.org

[74] IMF. (2021). IMF Country Focus: Five Things to Know about the Informal Economy. *International Monetary Fund – IMF News.* https://www.imf.org/en/News/Articles/2021/07/28/na-072821-five-things-to-know-about-the-informal-economy

[75] IPCC. (2018). Summary for Policymakers of IPCC Special report on Global Warming of 1.5 degrees Celsius approved by governments at https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

[76] I-Scoop (n.d.) What is Digital Business Transformation? The Essential Guide to DX, at https://www.i-scoop.eu/digital-transformation/

[77] Iswarappa, A. (2015). A Brief Introduction on Big Data 5Vs Characteristics and Hadoop Technology. *Procedia Computer Science.* 48. 319-324

[78] ITU Publications (2019) Measuring Digital Development Facts and Figures. 2019

[79] https://harris.uchicago.edu/news-events/news/commentary-many-students-developing-countries-cannot-access-education-remotely

[80] Jafino, B. A., Walsh, B., Rozenberg, J., Hallegatte, S., (2020) Revised Estimates of the Impact of Climate Change on Extreme Poverty by 2030, at https://documents1.worldbank.org/curated/en/706751601388457990/pdf/Revised-Estimates-of-the-Impact-of-Climate-Change-on-Extreme-Poverty-by-2030.pdf

[81] James, J. (2020). The smart feature phone revolution in developing countries: Bringing the internet to the bottom of the pyramid. *The Information Society.* 36(4).

[82] James, J. (2021). Confronting the scarcity of digital skills among the poor in developing countries. *Development Policy Review. 39*(2). 324-320.

[83] Jayne, T., Chamberlin, J. & Benfica, R. (2018). Africa's Unfolding Economic Transformation. *The Journal of Development Studies. 54*(5). *777-787.*

[84] Jayne, T. et al. (2019). Are medium-scale farms driving agricultural transformation in sub-Saharan Africa? Agricultural Economics. 50(S1). 75-95

[85] Jooste, B. S., Dokken, J. V., van Niekerk, D., & Loubser, R. A. (2018). Challenges to belief systems in the context of climate change adaptation. *Jamba (Potchefstroom, South Africa), 10*(1), 508. https://doi.org/10.4102/jamba.v10i1.508

[86] Katz, B. & Wagner, J. (2014). The Rise of Innovation Districts: A New Geography of Innovation in America. *Brookings. Metropolitan Policy Program.* https://www.brookings.edu/wp-content/uploads/2016/07/InnovationDistricts1.pdf

[87] Kim, S. & Duval, Y. (2020). In the world's poorest countries, the move to digitalize trade procedures in needed now more than ever. *Trade for Development News by EIF,* at https://trade4devnews.enhancedif.org/en/op-ed/worlds-poorest-countries-move-digitalize-trade-procedures-needed-now-more-ever

[88] Krishnan, A., et al. (2020) Ag-Platforms as Disruptors in Value-Chains: Evidence from Uganda, at https://cdn.odi.org/media/documents/odi-jr-eif-agrtechreport4-may20-proof01_final2311.pdf

[89] Labrunie, M. (2021) Natura Non Facit Saltus: Challenges and Opportunities for Digital Industrialisation Across Developing Countries

[90] Lee, J. (2020). Access to Finance for Artificial Intelligence Regulation in the Financial Services Industry. *European Business Organization Law Review. 21. 731-747*

[91] Lomas, N. ((2021). UK drone startup sees.ai gets go ahead to trial beyond-visual-line-of-sight (BVLOS) flgihts, at https://techcrunch.com/2021/04/20/uk-drone-startup-sees-ai-gets-go-ahead-to-trial-beyond-visual-line-of-sight-bvlos-flights/

[92] LDC (2020) Welcome the the Thimphu Ambition Summit, at https://ldcambition.world-television.com/home/english

[93] https://ldcambition.world-television.com/ondemand/english

[94] Lee, K. (2019) Economics of Technological Leapfrogging

[95] https://www.lunduniversity.lu.se/article/worlds-first-live-concert-3d-printed-band

[96] Marcus, L. (2021). Myanmar is planning to reopen to tourism in early 2022. But who will go?, at https://www.cnn.com/travel/article/myanmar-tourism-reopening-coup-cmd-intl-hnk/index.html

[97] Mazur, M. (2016). Six Ways Drones Are Revolutionzing Agriculture. *MIT Technology Review*, at https://www.technologyreview.com/2016/07/20/158748/six-ways-drones-are-revolutionizing-agriculture/

[98] McKinsey. (2019). Driving Impact at Scale from Automation and AI. *Digital McKinsey* at https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Driving%20impact%20at%20scale%20from%20automation%20and%20AI/Driving-impact-at-scale-from-automation-and-AI.ashx

[99] McKinsey & Company (2020) How COVID-19 has Pushed Companies Over the Technology Tipping Point – And Transformed Business Forever, at https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever

[100] Mekonnen, M. M., and Hoekstra, A. Y. (2010). The green, blue and grey water footprint of crops and derived crop products. Value of Water Research Report Series No. 48. Delft: UNESCO-IHE.

[101] https://www.microsoft.com/en-us/ai/ai-for-earth?activetab=pivot1:primaryr6

[102] https://monegraph.com/

[103] Monetary Authority of Singapore. (2020). Principles to Promote FEAT in the Use of AI and Data Analytics in Singapore's Financial Sector,at https://www.mas.gov.sg/~/media/MAS/News%20and%20Publications/Monographs%20and%20Information%20Papers/FEAT%20Principles%20Final.pdf

[104] Moon, S. (2008). Does TRIPS Art. 66.2 Encourage Technology Transfer to LDCs? An Analysis of Country Submissions to the TRIPS council (1999-2007). *UNCTAD*.

[105] https://www.mtn.com.gh/

[106] https://www.nano-di.com/

[107] National Development Council of Taiwan. (2019). Smart machinery and biomedicine pave way to more competitive Taiwan, at https://www.ndc.gov.tw/en/nc_11024_30668

[108] National University of Singapore (2020) Myanmar lost 60% of mangrove forests in 20 years, at https://www.futurity.org/myanmar-lost-60-of-mangrove-forests-in-20-years/

[109] Nolan, R. (2020). SmarTech Analysis Annual Additive Manufacturing Market Summary Report Says AM Market Grew to Over $10B Worldwide in 2019, at https://www.globenewswire.com/news-release/2020/01/08/1968056/0/en/SmarTech-Analysis-Annual-Additive-Manufacturing-Market-Summary-Report-Says-AM-Market-Grew-to-Over-10B-Worldwide-in-2019.html

[110] Notrica, M., Evans, F., Knowlton, L. & McQueen. (2011). Rwandan Surgical and Anesthesia Infrastructure: A Survey of District Hospitals. *World Journal of Surgery. 35*. 1770-1780.

[111] Oak Ridge National Laboratory (2018). Moving into the future with 3D printing, https://www.ornl.gov/blog/moving-future-3d-printing

[112] https://www.oecd-ilibrary.org/sites/01a4ae9d-en/index.html?itemId=/content/component/01a4ae9d-en

[113] OECD (2011) A Skilled Workforce for Strong, Sustainable and Balanced Growth: A G20 Training Strategy, at https://www.oecd.org/g20/summits/toronto/G20-Skills-Strategy.pdf

[114] OECD, WTO (2017) Aid for Trade at a Glance 2017. Promoting Trade, Inclusiveness and Connectivity for Sustainable Development. Chapter 9. Promoting Trade Inclusion in the Least Developed Countries. Enhanced Integrated Framework

[115] OECD (2021) OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity, at https://www.oecd-ilibrary.org/sites/75f79015-en/index.html?itemId=/content/publication/75f79015-en

[116] OECD (2021) Global Outlook on Financing for Sustainable Development 2021: A New Way to Invest for People and Planet, at https://www.oecd-ilibrary.org/sites/6ea613f4-en/index.html?itemId=/content/component/6ea613f4-en

[117] https://www.onchainmusic.com/

[118] Oztemel, E. & Gursev, S. (2018). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing. 31*. 127-182.

[119] https://www.pcworld.com/article/411799/d-waves-quantum-computer-runs-a-staggering-2000-qubits.html

[120] Peters, A., (2017) These Tree-Planting Drones Are About To Start An Entire Forest From The Sky, at https://www.fastcompany.com/40450262/these-tree-planting-drones-are-about-to-fire-a-million-seeds-to-re-grow-a-forest

[121] Petersen, T. (2019) What is the Impact of Reshoring, at https://ged-project.de/trade-and-investment/what-is-the-impact-of-reshoring/

[122] https://plantix.net/en/

[123] https://www.protiq.com/en/3d-printing/areas-of-application/advantages-3d-printing/

[124] https://www.provenance.io/

[125] https://www.pwc.com/gx/en/industries/industry-4.0.html

[126] Quintini, G., Manfredi, T. G. (2009) Going Separate Ways? School-to-Work Transitions in the United States and Europe, at https://www.researchgate.net/publication/46457119_Going_Separate_Ways_School-to-Work_Transitions_in_the_United_States_and_Europe

[127] Ramsay, D. (2020) Opinion: How to Tackle Least Developed Countries' Gender Gaps in Tech Use and Data, at https://www.devex.com/news/opinion-how-to-tackle-least-developed-countries-gender-gaps-in-tech-use-and-data-96713

[128] Raza, S., Bravante, M., Curry, C. (2021) Understanding and Monitoring our Changing Planet: A Climate Technology White Paper, at https://assets.bbhub.io/professional/sites/24/Monitoring-and-understanding-our-changing-planet.pdf

[129] Ramsay, D. (2020) Opinion: How to Tackle Least Developed Countries' Gender Gaps in Tech Use and Data, at https://www.devex.com/news/opinion-how-to-tackle-least-developed-countries-gender-gaps-in-tech-use-and-data-96713

[130] Riecke, J. (2013). New Mobile Platform Empowers Farmers in Uganda. *Center for Financial Inclusion*, at https://www.centerforfinancialinclusion.org/new-mobile-platform-empowers-farmers-in-uganda

[131] Roxas, B. G. (2008). Social capital for knowledge management: The case of small and medium-sized enterprises in the Asia-Pacific region. *Asian Academy of Management Journal, 13*(2), 57–77

[132] https://rss-hydro.lu/

[133] Russo, A., (2020) Blockchain Can Trace Carbon Emissions for Mining, Metals Companies, Proof of Concept Released, at https://www.weforum.org/press/2020/12/blockchain-can-trace-carbon-emissions-for-mining-metals-companies-proof-of-concept-released/

[134] Scannell, L., Gifford, R. (2013) Personally Relevant Climate Change: The Role of Place Attachment and Local versus Global Message Framing in Engagement.

[135] Scott, C. (2016). Chinese Construction Company 3D Prints an entire Two-Story House On-Site in 45 Days, at https://3dprint.com/138664/huashang-tengda-3d-print-house/

[136] https://www.sees.ai/

[137] https://www.spectralengines.com/products/nirone-scanner

[138] Singer, D. (2021). The drones watching over cattle where cowboys cannot reach, at https://www.bbc.com/future/bespoke/follow-the-food/drones-finding-cattle-where-cowboys-cannot-reach.html

[139] Sishodia, R., Ray, R. & Singh, S. (2020). Applications of Remote Sensing in Precision Agriculture: A Review. *Remote Sensing. 12.* 3136

[140] https://www.skuchain.com/

[141] Strusani, D. & Houngbonon, G. (2019). The Role of Artificial Intelligence in Support Development in Emerging Markets. *International Finance Corporation.* 1-8

[142] https://syska.com/project/office-of-the-future-dubai-arab-emirates/

[143] Torres, A., Sarmiento, O. L., Stauber, C., & Zarama, R. (2013). The Ciclovia and Cicloruta programs: promising interventions to promote physical activity and social capital in Bogotá, Colombia. *American journal of public health, 103*(2), e23–e30. https://doi.org/10.2105/AJPH.2012.301142

[144] Trakadas, P., Simoens, P., Gkonis, P. et al. (2020). An Artificial Intelligence-Based Collaboration Approach in Industrial IoT Manufacturing: Key Concepts, Architectural Extensions and Potential Applications. *Sensors.* 20(19). 5480

[145] https://www.un.org/esa/ffd/ffd3/conference.html

[146] https://www.un.org/sustainabledevelopment

[147] UN (2017) The cost of the couble burden of malnutrition, at https://docs.wfp.org/api/documents/WFP-0000110372/download/#:~:text=The%20economic%20impact%20of%20malnutrition's,%2428.8%20billion%20per%20year%2C%20respectively.

[148] UN (2020) Implementing the Science, Technology, and Innovation (STI) for SDG Roadmaps at the Country Level: Operational Note, at https://sustainabledevelopment.un.org/content/documents/25818Operation_Note_STI_for_SDG_Roadmaps_final_Feb_28_2020.pdf

[149] UN General Assembly (2020) Road Map for digital cooperation: Implementation of the Recommendations of the High-Level Panel on Digital Cooperation Report of the Secretary-General, at https://www.un.org/en/content/digital-cooperation-roadmap/

[150] UN. (2021). Digital Connectivity Essential for Least Developed Countries to Reap Benefits of Fourth Industrial Revolution, Experts Tell Preparory Committee. *United Nations. Meetings Coverage and Press Releases. LDC Prepatory Committee, First Session.* https://www.un.org/press/en/2021/dev3439.doc.htm

[151] UNCTAD (2014) World Investment Report: Investing in the SDGs: An Action Plan

[152] UNCTAD (2016), Declaration of the Least Developed Countries Ministerial Meeting to UNCTAD XIV, at https://unctad.org/system/files/official-document/td505_en.pdf

[153] UNCTAD (2018) Achieving the Sustainable Development Goals in the Least Developed Countries: A Compendium of Policy Options, at https://unctad.org/system/files/official-document/aldc2018d4_en.pdf

[154] UNESCAP (2015) A Conceptual Framework for Science, Technology and Innovation Driven Sustainable Development and the Role of ESCAP, at https://www.google.com/search?q=A+Conceptual+Framework+for+Science%2C+Technology+and+Innovation+Driven+Sustainable+Development+and+the+Role+of+ESCAP&oq=A+Conceptual+Framework+for+Science%2C+Technology+and+Innovation+Driven+Sustainable+Development+and+the+Role+of+ESCAP&aqs=chrome..69i57.876j0j7&sourceid=chrome&ie=UTF-8

[155] UNESCO (2020) Building Back Equal: Girls Back to School Guide, at https://unesdoc.unesco.org/ark:/48223/pf0000374094/PDF/374094eng.pdf.multi

[156] UNESCO (2020) Girls' Education: Building Back Equal on the African Continent Together, at https://en.unesco.org/news/girls-education-building-back-equal-african-continent-together

[157] https://www.unido.org/our-focus-building-better-future/digital-transformation-innovation-and-industrial-recovery

[158] UNIDO (2019) A Revolution in the Making? Challenges and Opportunities of Digital Production Technologies for Developing Countries, at https://www.unido.org/api/opentext/documents/download/16423347/unido-file-16423347

[159] UNIDO (2019) Abu Dhabi Declaration, at https://www.unido.org/sites/default/files/files/2019-11/UNIDO_Abu_Dhabi_Declaration.pdf

[160] UNIDO (2019) Boosting the dialogue on the Fourth Industrial Revolution at the 11th Africa Energy Indaba, at https://www.unido.org/news/boosting-dialogue-fourth-industrial-revolution-11th-africa-energy-indaba

[161] UNIDO (2019) Industrial Development Report 2020. Industrializing in the Digital Age

[162] UNIDO (2021) Industrial Production in LDCs and Trade in the COVID Era and Resulting Policy Reactions, at https://www.unido.org/sites/default/files/files/2021-05/Keynote%20-%20LDC%20industrial%20performance%20in%20COVID%20era%20and%20resulting%20policy%20reactions%20%28final%29.pdf

[163] UNCTAD (2018) The Least Developed Countries Report 2018, Overview, Entrepreneurship for Structural Transformation – Beyond Business as Usual, at https://unctad.org/system/files/official-document/ldcr2018overview_en.pdf

[164] UNCTAD. (2021). COVID-19 and Tourism, an update: Assessing the economic consequences, at https://unctad.org/system/files/official-document/ditcinf2021d3_en_0.pdf

[165] UNCTAD. (2021). Declaration of ministers of the least developed countries at the fifteenth session of the United Nations Conference on Trade and Development. *United Nations Conference on Trade and Development.* https://unctad.org/system/files/official-document/td525_en.pdf

[166] UNCTAD (2021) The Least Developed Countries in the Post-COVID World: Learning from 50 Years of Experience, at https://unctad.org/system/files/official-document/ldc2021_en.pdf

[167] https://unfccc.int/process-and-meetings/bodies/constituted-bodies/least-developed-countries-expert-group-leg/ldc-portal/article-4-paragraph-9-of-the-convention

[168] Unmanned Airspace (2018) DHL trials BVLOS medicine delivery flights across Lake Victoria, Tanzania, at https://www.unmannedairspace.info/uncategorized/dhl-trials-bvlos-medicine-delivery-flights-across-lake-victoria-tanzania/

[169] Utoikamanu, F. (2019) Closing the Technology Gap in Least Developed Countries, at https://www.un-ilibrary.org/content/journals/15643913/55/4/10

[170] UNWTO. (2017). Tourism for Sustainable Development in Least Developed Countries, at https://.e-unwto.org/doi/pdf/10.18111/9789284418848

[171] Van Deursen, A., Helsper, E., Eynon, R. & Van Dijk, J. (2017). The compoundness and sequentiality of digital inequality.

[172] Van Wassenaer, L.,Van Hilter, M., et al (2021) Applying blockchain to climate action in agriculture: state of play and outlook, at https://www.fao.org/3/cb3495en/cb3495en.pdf

[173] Wang, M., Wang, B. & Abareshi, A. (2020). Blockchain Technology and Its Role in Enhancing Supply Chain Integration Capability and Reducing Carbon Emisssio: A Conceptual Framework. *Sustainability. 12.* 1-17

[174] Wesely, M. (2017) Economic Empowerment Strategies That are a Win-Win for Women and for Business, at https://womendeliver.org/2017/economic-empowerment-strategies-win-win-women-business/

[175] https://data.worldbank.org/indicator/SE.XPD.TOTL.GD.ZS?locations=XL

[176] https://www.worldbank.org/en/topic/smefinance

[177] World Bank (2008) Science, Technology, and Innovation: Capacity Building for Sustainable Growth and Poverty Reduction, at https://openknowledge.worldbank.org/bitstream/handle/10986/6418/439520PUB0Box310only109780821373804.pdf?sequence=1&isAllowed=y

[178] World Bank (2010) Innovation Policy: A Guide for Developing Countries, at https://openknowledge.worldbank.org/handle/10986/2460

[179] World Bank Group. (2013).

[180] World Bank. (2020). Digital Skills: Frameworks and Programs. *World Bank.* https://openknowledge.worldbank.org/bitstream/handle/10986/35080/Digital-Skills-Frameworks-and-Programs.pdf?sequence=1&isAllowed=y

[181] World Bank (2020) Improving Business Environment for Prosperity (IBEP), at https://www.worldbank.org/en/topic/investment-climate/brief/improving-business-environment-for-prosperity

[182] World Bank. (2021). Agriculture and Food: Overview at https://www.worldbank.org/en/topic/agriculture/overview#1

[183] World Economic Forum (2020) Agile Regulation for the Fourth Industrial Revolution: A Toolkit for Regulators, at https://www3.weforum.org/docs/WEF_Agile_Regulation_for_the_Fourth_Industrial_Revolution_2020.pdf

[184] https://www.wri.org/

[185] WTO. (2019). Fourth industrial revolution - the next servicification frontier. *WTO Public Forum 2019 (report by Session Organizer).* https://www.wto.org/english/forums_e/public_forum19_e/pf19_82_rpt_e.pdf

[186] Zambetti, M. et al. (2020). Enabling servitization by retrofitting legacy equipment for Industry 4.0 applications: benefits and barriers for OEMs. *Procedia Manufacturing.* 48. 1047-1053

[187] Zaugg, D. (2020). How smart sensors are driving Industry 4.0 forward, at https://www.ey.com/en_ch/industrial-products/how-smart-sensors-are-driving-industry-4-0-forward

[188] https://www.zvei.org/en/

ANNEX I

List of LDCs

Country	Scheduled for graduation
Afghanistan	
Angola	2024
Bangladesh	2024
Benin	
Bhutan	2023
Burkina Faso	
Burundi	
Cambodia	
The Central African Republic	
Chad	
Comoros	
The Democratic Republic of the Congo	
Djibouti	
Eritrea	
Ethiopia	
The Gambia	
Guinea	
Guinea-Bissau	
Haiti	
Kiribati	
Lao People’s Democratic Republic	
Lesotho	
Liberia	
Madagascar	
Malawi	
Mali	
Mauritania	
Mozambique	
Myanmar	
Nepal	
Niger	
Rwanda	
Sao Tome and Principe	2024
Senegal	
Sierra Leone	
Solomon Islands	2024
Somalia	
South Sudan	
Sudan	
Timor-Leste	
Togo	
Tuvalu	
Uganda	
United Republic of Tanzania	
Yemen	
Zambia	

LIST OF FIGURES

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