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

UNIDO'S 9TH MINISTERIAL CONFERENCE
OF THE LEAST DEVELOPED COUNTRIES
Propelling LDCs in the Digital Age: a 4IR Perspective for Sustainable Development

UNIDO’S 9TH MINISTERIAL CONFERENCE OF THE LEAST DEVELOPED COUNTRIES

Vienna, Austria
2021
ACKNOWLEDGEMENTS

This publication was prepared by the United Nations Industrial Development Organization (UNIDO), in cooperation with the Enhanced Integrated Framework (EIF), and the United Nations Technology Bank for the Least Developed Countries (UN Technology Bank).

The publication has been produced under the overall guidance of Mr. Bernardo Calzadilla-Sarmiento. It is based on the work of Mr. Nikola Neftegov, Mr. Samy Kebaish, Ms. Mirjana Stankovic, Ms. Ana Ristovska and Mr. Sanjay Kotha, facilitated by Mr. Ravi Gupta from Tambourine Innovation Ventures. The document benefited from the valuable contributions and support from several members of the UNIDO core team: Mr. Marco Kamiya, Mr. Alejandro Rivera Rojas, Mr. Fernando Santiago Rodriguez, Ms. Freya Gruenberg, Ms. Jessica Neumann and Ms. Rebeca Gallardo Gomez.

UNIDO extends its appreciation to all those who directly contributed and provided feedback, Mr. Bariskov Afshinari and Mr. Peter Donelan (EIF), Mr. Joshua Phoho Setipa and Mr. Moshe Reo (UN Technology Bank).

Coordination support was provided by Ms. Anna Schrenk. Design and layout were developed by Excelcis SARL.

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

PAGE 5
The LDCs are the least connected to the internet at about 44%. 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.
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:

- 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 December 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

| Acknowledgements                              | 4 |
| Foreword. United Nations Industrial Development Organization | 5 |
| Foreword. Enhanced Integrated Framework        | 6 |
| Foreword. United Nations Technology Bank for the Least Developed Countries | 7 |
| Executive Summary                              | 8 |
| Abbreviations                                  | 12 |

## 1 Introduction

1.1 Innovation-based development concepts in the Digital Era | 22 |
1.2 The Fourth Industrial Revolution and Society 5.0 | 26 |
1.3 The Decade of Action, STI and Digital Transformation | 28 |
1.4 Multidimensional Challenges for 4IR Deployment | 33 |

## 2 4IR technology absorption for LDCs

| How LDCs can harness the 4IR in the race for climate action | 48 |
| Leveraging 4IR for SME growth                             | 56 |
| Recommendations                                           | 72 |

## 5 Bibliography

| Annex 1: List of LDCs                                    | 98 |
| List of figures                                          | 100 |
## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4IR</td>
<td>The 4th Industrial Revolution</td>
</tr>
<tr>
<td>A4AI</td>
<td>Alliance for Affordable Internet</td>
</tr>
<tr>
<td>AAAA</td>
<td>Addis Ababa Action Agenda</td>
</tr>
<tr>
<td>ADP</td>
<td>Advanced Digital Production</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>AM</td>
<td>Additive Manufacturing</td>
</tr>
<tr>
<td>AR</td>
<td>Augmented Reality</td>
</tr>
<tr>
<td>ASIC</td>
<td>Australian Securities and Investments Commission</td>
</tr>
<tr>
<td>BVLOS</td>
<td>Beyond-Visual-Line-of-Sight</td>
</tr>
<tr>
<td>CGAP</td>
<td>Consultative Group to Assist the Poor</td>
</tr>
<tr>
<td>COT</td>
<td>Carbon Tracing Platform</td>
</tr>
<tr>
<td>CTCN</td>
<td>Climate Technology Centre and Network</td>
</tr>
<tr>
<td>CTIS</td>
<td>Cambodia Trade Integration Strategy</td>
</tr>
<tr>
<td>DBM</td>
<td>Double Burden of Malnutrition</td>
</tr>
<tr>
<td>ECLAC</td>
<td>Economic and Social Commission of Latin America and Caribbean</td>
</tr>
<tr>
<td>ECLC-WFP</td>
<td>Early Childhood Learning Centre - Wood Food Programme</td>
</tr>
<tr>
<td>EIF</td>
<td>Enhanced Integrated Framework</td>
</tr>
<tr>
<td>EMR</td>
<td>Electronic Health Record</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>FDI</td>
<td>Foreign Direct Investments</td>
</tr>
<tr>
<td>FEAT</td>
<td>Fairness, Ethics, Accountability, and Transparency</td>
</tr>
<tr>
<td>FID3</td>
<td>The Third Conference on Financing for Development</td>
</tr>
<tr>
<td>FICO</td>
<td>Fair Isaac Corporation</td>
</tr>
<tr>
<td>G2P</td>
<td>Government-to-Person</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environmental Facility</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gasses</td>
</tr>
<tr>
<td>GNI</td>
<td>Gross National Income</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobiles</td>
</tr>
<tr>
<td>GVC</td>
<td>Global Value Chain</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation, and Air Conditioning</td>
</tr>
<tr>
<td>IBM</td>
<td>International Business Machines</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
</tr>
<tr>
<td>IDC</td>
<td>International Data Corporation</td>
</tr>
<tr>
<td>IDR</td>
<td>Industrial Development Report</td>
</tr>
<tr>
<td>IMF</td>
<td>International Monetary Fund</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>IP</td>
<td>Intellectual Property</td>
</tr>
<tr>
<td>IPC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>IPoA</td>
<td>Istanbul Program of Action</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>ISID</td>
<td>Inclusive and Sustainable Development</td>
</tr>
<tr>
<td>ISID</td>
<td>International Society for Infectious Diseases</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>KOICA</td>
<td>Korea International Cooperation Agency</td>
</tr>
<tr>
<td>LDC</td>
<td>Least Developed Countries</td>
</tr>
<tr>
<td>LMIC</td>
<td>Low-Income and Middle-Income Countries</td>
</tr>
<tr>
<td>ML</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>MSMEs</td>
<td>Micro, Small and Medium-Sized Enterprises</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NDRC</td>
<td>Nationally Determined Contributions</td>
</tr>
<tr>
<td>NLP</td>
<td>Natural Language Processing</td>
</tr>
<tr>
<td>ODA</td>
<td>Official Development Assistance</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturers</td>
</tr>
<tr>
<td>OT</td>
<td>Operational Technology</td>
</tr>
<tr>
<td>P2P</td>
<td>Person-to-Person</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controllers</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RAH</td>
<td>Radical Abdominal Hysterectomy</td>
</tr>
<tr>
<td>S&amp;T</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>SDG</td>
<td>Sustainable Development Goals</td>
</tr>
<tr>
<td>SEPAL</td>
<td>Stem Embarkation Platform and Accommodation Ladder</td>
</tr>
<tr>
<td>SMEs</td>
<td>Small and Medium-Sized Enterprises</td>
</tr>
<tr>
<td>SBED</td>
<td>Small Business Economic Development</td>
</tr>
<tr>
<td>SSA</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>STEM</td>
<td>Science, Technology, Engineering, and Mathematics</td>
</tr>
<tr>
<td>STI</td>
<td>Science, Technology, and Innovation</td>
</tr>
<tr>
<td>TA</td>
<td>Technical Assistance</td>
</tr>
<tr>
<td>TCDC</td>
<td>Technical Cooperation Between Developing Countries</td>
</tr>
<tr>
<td>TFM</td>
<td>Technology Facilitation Mechanism</td>
</tr>
<tr>
<td>TVET</td>
<td>Technical and Vocational Education and Training</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNCTAD</td>
<td>United Nations Conference on Trade and Development</td>
</tr>
<tr>
<td>UNFCC</td>
<td>The United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>UNFPA</td>
<td>UN Population Fund</td>
</tr>
<tr>
<td>UNIDO</td>
<td>United Nations Industrial Development Organization</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>WB</td>
<td>World Bank</td>
</tr>
<tr>
<td>WFP</td>
<td>Wood Food Programme</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
</tr>
</tbody>
</table>
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. 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 1.2 percent of the global Gross Domestic Product (GDP). 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 human development for 50 years.4

LDCs have made some development progress. 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 decades has taken its toll on the planet, accelerating the devastating effects of climate change.

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 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 (16–32 percent), significantly contributing to losses in the genetic diversity of crops by 2080.4 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. 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.

However, significant gaps persist in LDCs, and the international community must strengthen support from all sources. For this reason, the Abu Dhabi Declaration 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.

![Real GDP and GDP per capita in LDCs](https://www.un.org/ohrlls/content/istanbul-programme-action)

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

---

4. Ibid
5. Ibid
6. Ibid
7. Ibid
8. Ibid

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.

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. Nevertheless, these efforts have often left behind vulnerable LDCs’ long-standing vulnerabilities. Recovering and rebuilding their fragile economies. Emerging technologies offer huge potential to advance LDCs’ economic productivity, and help them escape their obligations. Per the deal, the private money mobilized in LDCs is only a third of the global average. The COVID-19 pandemic has highlighted LDCs’ lack of 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 help 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.

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 help 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.

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
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 DynamoX, a US-based company that leverages blockchain solutions to measure the carbon footprint for cities. 21 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. 22 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. 23 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. 24 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. 25

While the advent of the 4IR can help LDCs in their quest to leapfrog traditional phases of development, foundational capabilities 26 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. 27 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. 28 Hence, the leapfrogging process entails the latecomers adopting new technologies ahead of the frontrunners, thus actually leapfrogging them. 29 Therefore, if LDCs are leapfrogging, 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.

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.” 30 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. 31

---

21 https://unido.org/
23 Ibid
24 Ibid
25 Ibid
26 Ibid
27 Ibid
28 Ibid
29 Ibid
30 Ibid
31 Ibid

---

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 annual commitments on climate finance.
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.20 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 typewritten 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.21 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.22 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.

1.1.3 DIGITAL TRANSFORMATION

Digital transformation is the cultural, organizational, and operational change of an organization, industry, or ecosystem through the intelligent use of technologies and information.23 It has vast impacts on product, processes, and competencies across all levels and functions in a staged and strategic way.24 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.25

“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 shifts. Another example of digital transformation is a shift from local control of physical processes to remote monitoring and control of those same processes.
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. 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. 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. 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.19

“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. 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.20 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).
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 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. The catalyst that is the 4IR and the technologies that underpin it 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.”

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.” 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. 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. 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.

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 4IR 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.”

Source: Created by the Authors

FIGURE 5: 4IR Technologies


42) https://www.brookings.edu/research/the-fourth-industrial-revolution-and-digitization-will-transform-africa-into-a-global-powerhouse/

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

44) Ibid
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. 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. 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 Environment Program (UNEP), and the World Bank, which helps developing countries to obtain new technologies and project financing at a low cost. 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.

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. 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).

![Investment gap for developing countries](source: Created by the Authors)

**FIGURE 6: Investment gap for developing countries**
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. Inequality in the short term, with Gini coefficients rising on average by 2.5 percent over five years, based on the experience of the previous five major pandemic events, 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. 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. 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.

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. 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. The survey states that the recorded technological leap in developed Asia was even more significant – experiencing a ten-year increase (Figure 8).

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

Agenda. Technology in and of itself has little economic value. Instead, it should be a way to solve, transform, and add value. STI capacity building should not only be about building STI capacity to "solve, transform, and add value" but also about considering the vantage point of the people who are affected by the innovations. The STI capacity building 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.

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 (PASSTIC).

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 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." The root causes of slow growth are the inability to leverage new opportunities offered by technology in LDCs to be the 'old' developmental issues – institutions, infrastructure, and skills.

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. 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 of GDP or based on public spending.65 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.66

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), 4 Ways the Least Developed Countries Can Participate in the Fourth Industrial Revolution, at https://www.weforum.org/agenda/2019/08/4-ways-least-developed-countries-can-participate-in-the-4ir/
Across the globe, there is a gender gap in the use of the Internet. Worifyingly, the gender imbalance in Internet use in LDCs has continued to experience an upward trend since 2013. 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. This divide is evident in both developed and developing countries, and LDCs in particular, face considerable infrastructure challenges in deploying digital production technologies. While these solutions work in developed countries, and LDCs in particular, face considerable infrastructure challenges in deploying digital production technologies.

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. 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. 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 to poverty reduction, health and well-being, inclusive quality education, and gender equality. The pandemic has disproportionately 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.

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.

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
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.76

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.77

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.

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.78

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.79

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 reshoring80 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.81 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.82

---

77) Ibid.
79) Ibid.
80) Reshoring is the process of relocating work operations and even entire industrial plants that were previously relocated from developed industrialized countries to low-wage countries.
82) Ibid.
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

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, Bluetooth, Long Range frequencies (LoRa)), low-power wide-area network (LPWAN), as evident through the evolution of "Smart devices," ranging from phones to TVs to 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 assigned 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 86 percent of Bangladesh’s export earnings; in Cambodia, one in five households in Cambodia include garment workers; Myanmar recently joined 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 EQaulS 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.
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.

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: (i) formation of an export consortia; (ii) providing IA to consorita member enterprises; and (iii) 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 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 550,000 to 1.1 million and revenues of $US11 million to $1.5 billion from 1970-2000 (Jones and Spadafora, 2006).

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

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 4IR 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

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

Adapted from Zambetti et al. 2020.
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,\(^9\) multiple LDCs expressed their concern about being further marginalized, mainly due to the impact of COVID-19. The keynotes discussed 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.”\(^9\) 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 79 percent.\(^9\)

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.

**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.\(^9\) 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, G6, 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.\(^3\) 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.\(^4\) 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.\(^3\) 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 makes “up to 75 percent of the differences in total factor productive rates, once externalities are taken into consideration.”\(^9\) 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 (2.5 percent), the United Kingdom (5.2 percent), Germany (5.9 percent) spend nearly twice more on education.\(^\)\(^1\)

Two digital divides impact technology absorption in LDCs. As Paul Attewell described in 2001\(^3\) 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.”\(^\)\(^3\) Moreover, those who lack digital skills will be subject to compounding exclusion (Figure 12).\(^\)\(^3\) 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.\(^\)\(^3\) 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-technological application of many mobile users in these LDCs.

<table>
<thead>
<tr>
<th>TABLE 2: Necessary Components for Digital Technology Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology Absorption</strong></td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td><strong>Standards Development and Dissemination</strong></td>
</tr>
<tr>
<td>Provision of standardization of services and data, Infratechnologies, testing and certification facilities (akin to the promotion of National Quality Infrastructure.</td>
</tr>
<tr>
<td><strong>System Integration</strong></td>
</tr>
<tr>
<td>Retrofitting services and legacy system integration into digital platforms, rapid prototyping facilities, and virtual design.</td>
</tr>
<tr>
<td><strong>Technology Scaling</strong></td>
</tr>
<tr>
<td>Codification and dissemination of successful technology solutions and implementation of scaling up facilities (e.g., venture capital accelerators; start-up incubators; SMEs).</td>
</tr>
</tbody>
</table>

Adapted from Atwehell et al. 2023\(^9\)
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.106

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 Programs104, 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 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 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 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
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 3.5 – 5 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 2019 as they did in the previous 150 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.113 A World Bank Group Paper in 2020 estimates the economies of LDCs feature an estimated 72 percent concerns of climate change. Largely agrarian in nature, the agriculture lifecycle. Hence, it is evident 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. 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.115 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 that 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.116

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.117 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 2050 through measures such as increasing the usage of renewables, reducing the rate of deforestation, and creating new jobs using clean technology.118

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 stripe 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 173-350 km3 of water consumption per year120 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 CO2 equivalent through the exploitation of nearly 24 percent of all croplands, freshwater, and fertilizers for total food production.121

AI AND ROBOTICS TOWARDS CLIMATE ACTION

<table>
<thead>
<tr>
<th>Propelling LDCs in the Digital Age: A 4IR Perspective for Sustainable Development</th>
<th>AI AND ROBOTICS TOWARDS CLIMATE ACTION</th>
</tr>
</thead>
</table>

115 How LDCs can harness the 4IR in the Race for Climate Action | Chapter 3Propelling LDCs in the Digital Age: A 4IR Perspective for Sustainable Development
118 Thimpu Ambition Summit. 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. 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 2050 through measures such as increasing the usage of renewables, reducing the rate of deforestation, and creating new jobs using clean technology.
119 How LDCs can harness the 4IR in the Race for Climate Action | Chapter 3Propelling LDCs in the Digital Age: A 4IR Perspective for Sustainable Development
122 https://www.fao.org/3/a-i77769r.pdf
123 How LDCs can harness the 4IR in the Race for Climate Action | Chapter 3Propelling LDCs in the Digital Age: A 4IR Perspective for Sustainable Development
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. AI can unlock the potential of agriculture through “agritech” solutions, improving the profitability and efficiency of agriculture businesses and SMEs. For example, the agricultural tech startup PEAT developed Plantix, 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 and augmented reality can be used to increase awareness of climate change and promote the experience of rich yet unexplored environments 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 psychologically meaningful experience in terms of climate action. As Gifford writes in a 2011 article, 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). 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.”

- **Judgmental Discounting**: undervaluing distant or future risks. Many individuals have a “temporal distance” from the issue of climate change, to which virtual reality can simulate temporal 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 circumstances 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

### FIGURE 13: Relationship between Education and Climate Change Perception

<table>
<thead>
<tr>
<th>Less education</th>
<th>More education</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>62</td>
<td>84</td>
</tr>
<tr>
<td>Philippines</td>
<td>53</td>
<td>75</td>
</tr>
<tr>
<td>Indonesia</td>
<td>50</td>
<td>68</td>
</tr>
<tr>
<td>Mexico</td>
<td>73</td>
<td>91</td>
</tr>
<tr>
<td>Argentina</td>
<td>75</td>
<td>88</td>
</tr>
<tr>
<td>Australia</td>
<td>54</td>
<td>70</td>
</tr>
<tr>
<td>South Africa</td>
<td>59</td>
<td>68</td>
</tr>
<tr>
<td>Hungary</td>
<td>64</td>
<td>75</td>
</tr>
<tr>
<td>Canada</td>
<td>59</td>
<td>70</td>
</tr>
<tr>
<td>Netherlands</td>
<td>67</td>
<td>76</td>
</tr>
<tr>
<td>UK</td>
<td>64</td>
<td>73</td>
</tr>
<tr>
<td>France</td>
<td>79</td>
<td>87</td>
</tr>
<tr>
<td>South Korea</td>
<td>83</td>
<td>89</td>
</tr>
<tr>
<td>U.S</td>
<td>56</td>
<td>62</td>
</tr>
</tbody>
</table>

Source: Adapted from Pew Research Center (2019)

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

124 https://www.bluerivertechnology.com/
125 https://plantix.net/en/
126 https://www.bluerivertechnology.com/
128 https://www.wri.org/
132 http://www.howice.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 benefits. With concerns over rising sea levels and increased inland floods, blockchain can help through early detection and intervention. Less-developed countries are particularly vulnerable to the impacts of climate change, with multiple instances of floods saving livelihoods and local economies. For example, the Blockchain for Climate Foundation\(^{1}\) has suggested the use of a ledger towards recording the international transfer of emission reductions towards greater transparency and accuracy of GHG emissions.\(^{1,2}\) 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.\(^{3,4}\)

Blockchain solutions can help track natural resource conservation. Cryptocurrency 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.\(^{5,6}\) 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 2.9 billion dollars.\(^{7,8}\)

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 Tracking Platform” (name COT) will provide end-to-end traceability and distributed ledger technology to track CO2 emissions.\(^{9}\) More generally, blockchain has been proposed to improve the efficiency of freight operations and reduce emissions via smart transportation.\(^{10}\)

Blockchain technologies have substantial potential to assist LDCs with improving energy efficiency and mitigating against the impacts of climate change. Blockchain solutions can help track natural resource conservation. Cryptocurrency 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.\(^{11}\) 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 2.9 billion dollars.\(^{12,13}\)

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 Tracking Platform” (name COT) will provide end-to-end traceability and distributed ledger technology to track CO2 emissions.\(^{14}\) More generally, blockchain has been proposed to improve the efficiency of freight operations and reduce emissions via smart transportation.\(^{15}\)

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.\(^{16}\) 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.\(^{17}\) Senegal also has engaged in a similar initiative, albeit manually, having planted 93 million trees due to nearly 25 percent deforestation since the 1970s.\(^{18}\) 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.\(^{19}\)

---

\(^{1}\) https://www blockadeforclimate.org/

\(^{2}\) https://prospectives.de/

\(^{3}\) Digital Planet (2021) 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-

\(^{4}\) Sustainability

\(^{5}\) https://eandt.theiet.org/content/articles/2020/02/drones-needed-for-critical-role-combating-climate-change/

\(^{6}\) 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-

\(^{7}\) Calculated at the average banknote generating 0.26 worth of CO2 annually, with 50 billion US Bank-notes in circulation.

\(^{8}\) https://cryptoclimate.org/accord/

\(^{9}\) https://www.blockchainforclimate.org/

\(^{10}\) Blockchain solutions can help track natural resource conservation. Cryptocurrency 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. 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 2.9 billion dollars.


\(^{12}\) Blockchain technologies have substantial potential to assist LDCs with improving energy efficiency and mitigating against the impacts of climate change. Blockchain solutions can help track natural resource conservation. Cryptocurrency 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. 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 2.9 billion dollars.

\(^{13}\) https://www.fao.org/redd/en/


---

BIG DATA, IOT, CLOUD COMPUTING

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 beds and three operating rooms – with an estimated catchment of 382,269 persons addressed per available facility.\(^{20}\)

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.\(^{21}\) Such drones also managed to dispatch more than 4,000 units of blood products to 12 hospitals in the span of six months.\(^{22}\)

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.\(^{23}\) One company in particular – RSI Hydro\(^{24}\) – uses drones, in addition to machine learning models, to assist in flood disaster response efforts and monitoring the effects of climate change.

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 1 percent of global carbon emissions, second only to the energy sector.\(^{25}\) 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.\(^{26}\)

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.\(^{27}\) – 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.\(^{28}\)

---


---
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 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. 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. IfR 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. 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.

## TABLE 3: General Trends of Agricultural Transformation

<table>
<thead>
<tr>
<th>Labour movement</th>
<th>Labor opportunities expand to those out of farming, while farmers that remain in product become more productive and commercialized.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversification to Specialization</td>
<td>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.</td>
</tr>
<tr>
<td>Agribusiness to Farm Value Ratio Increases</td>
<td>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.</td>
</tr>
<tr>
<td>Greater Output by Medium to Larger Farms</td>
<td>As farms begin to scale in size, their outputs grow to supply production and marketing, such as restaurants and grocery stores.</td>
</tr>
<tr>
<td>Transition to sustainable cultivation</td>
<td>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).</td>
</tr>
<tr>
<td>Greater Output by Medium to Larger Farms</td>
<td>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.</td>
</tr>
</tbody>
</table>

Adapted from Jayne et al. (2018, 159).

---

**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” 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. 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. 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.
Leveraging 4IR for SME Growth

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

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 petrochemical industry to assessing milk quality control in farming.\(^{166}\) The entire backbone of 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 2,500 classical bits.\(^{168}\)

### 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 petrochemical industry to assessing milk quality control in farming.\(^{166}\) The entire backbone of 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 2,500 classical bits.\(^{168}\)

### Source

4. [https://www.census.gov/topics/research/big-data.html](https://www.census.gov/topics/research/big-data.html)
5. [https://www.ey.com/en_ch/industrial-products/how-smart-sensors-are-driving-industry-4-0-forward](https://www.ey.com/en_ch/industrial-products/how-smart-sensors-are-driving-industry-4-0-forward)
10. [https://www.pwc.com/gx/en/industries/industry-4.0.html](https://www.pwc.com/gx/en/industries/industry-4.0.html)

---

**FIGURE 14**: ImageNet Classification with Deep Convolutional Neural Networks

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

DRONES AND SMEs

Drones have the potential of providing a novel means of value creation in SMEs of LDCs. In agriculture, drones can be leveraged for multiple use cases, including radiological, atmospheric, and environmental sensing, agricultural data collection and crop management, national resource conservation and management, and meteorological monitoring. 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.

TABLE 4: Use cases for Agricultural Drones

<table>
<thead>
<tr>
<th>Use cases</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil and Field Analysis</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Planting</strong></td>
<td>Drones may be used to plant vegetation at scale, in addition to reaching isolated or obstructed areas.</td>
</tr>
<tr>
<td><strong>Crop Spraying</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Crop Monitoring</strong></td>
<td>Vast fields, unpredictable weather, and low efficiency in crop monitoring together create farming’s largest obstacle, which can be mitigated through crop monitoring.</td>
</tr>
<tr>
<td><strong>Irrigation</strong></td>
<td>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 can calculate the algorithm of the vegetation index, which describes the relative density and health of the crop, and show the heat signature, which reduces the need for water or the heat the crop emits.</td>
</tr>
<tr>
<td><strong>Health Assessment</strong></td>
<td>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.</td>
</tr>
</tbody>
</table>

Adapted from Mezor, 2019

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. 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 13,708 islands, nearly 6,000 of which are inhabited. 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. These benefits can extend to other LDCs with geographical barriers, such as the archipelagic landscapes found in Kiribati, Samoa, Solomon Islands, Tuvalu, and Vanuatu.

Drones can provide substantial benefits to the agriculture-driven economies of LDCs, with the added benefit of improving sustainability. Many farmers in LDCs are assigned 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 fertilizing, raising yields.

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 and evolving business models and practices to improve productivity, communication, and efficiency. Al can also drive the development of leapfrogging solutions tailored to serve underserved populations. For example, AI systems 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.

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 $7.9 trillion in market value. This has influenced countries such as Taiwan and their National Development Plan (NDP) towards the construction of the “Asian Silicon Valley.”

Taiwan’s NDP has included provisions to upgrade their Smart Machine Industry, incorporating artificial intelligence and smart reports to expand plant output and productivity. Leading this effort are Taiwan’s Electrical and Electronic Manufacturers’ Association (2VEI) 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.

Use cases

Al 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. Al can also provide “Robo-Advisers” to close the investment advice gap, giving access to SMEs to free financial advice, which is generally cost-prohibitive. Al can be used for anti-laundering and counteracting fraud, improving the financial reliability of business transactions. For example, the American Securities and Investments Commission (ASIC), which is currently exploring natural language processing (NLP) technology to extract information from documentation. 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, Al 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.

Productivity improvements also stem from more efficient investment in human capital due to automation. Al 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. In Chile, AIRA is being used to reduce the amount of time human recruiters spend on finding candidates for a job. CVs are automatically read and ranked, in addition to Al 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.
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 30 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.\(^{202}\)

### 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\(^{203}\) to ascertain how a blockchain-linked version of the British Pound could affect the economy. Alluded to as “Central Bank Digital Currencies,”

---

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. Blockchain has also been increasingly utilized in supply chain management. Some examples of the use of blockchain for supply chain management include Provenance and Skuchain – 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. In terms of music rights, there are multiple services towards transparent remuneration, such as Monograph, a startup that uses blockchain to monitor the usage and sharing of digital media. Another service, Onchain music, uses blockchain technology towards the assurance of royalty payments for musicians, songwriters, bands, and DJs, toward fairer compensation.

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 has suggested the use of a ledger towards recording the international transfer of emission reductions towards greater transparency and accuracy of GHG emissions. 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 Safaricom, the largest mobile network operator in Kenya. In only the span of 3 years (2007-2009), nearly 7 million customers had registered with M-Pesa, and an average of 50 million Ksh (US$ 1.96 million) is transferred through M-Pesa per day totaling 170 billion Ksh (US$ 1.7 billion). Despite its seeming barrier to entry, urban users in Kisumu 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.

Use cases

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 Safaricom, the largest mobile network operator in Kenya. In only the span of 3 years (2007-2009), nearly 7 million customers had registered with M-Pesa, and an average of 50 million Ksh (US$ 1.96 million) is transferred through M-Pesa per day totaling 170 billion Ksh (US$ 1.7 billion). Despite its seeming barrier to entry, urban users in Kisumu 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.

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 5,000 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 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 underly smart contracts.

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. 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.
Mobile money is a technology which may enable 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 86% 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.

Virtual tourism has the potential to generate feed-forward mechanisms for LDCs. It is estimated that tourism provided 7% of LDCs total exports of goods in services in 2015, with an average annual growth of 14% for tourist arrivals. The role of SMEs in tourism was highlighted during the COVID-19 pandemic when inbound tourist arrivals declined by 74 percent. 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 and 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.

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; 276% 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. 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.

Source: Adapted from Number of Live Mobile Money Services for the Unbanked by Region (2003-2017; Image courtesy of WBIS)

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.

Virtual and augmented reality can help affordable skill development by providing immersive training experiences from world experts.

Virtual tourism has the potential to generate feed-forward mechanisms for LDCs.

Virtual tourism has the potential to generate feed-forward mechanisms for LDCs.
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.\(^{223}\)

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.”\(^{224}\) 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.\(^{225}\) 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, underlying a notion that skills build upon skills.


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.\(^{226}\)

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.\(^{227}\)

\(^{226}\) 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/

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 training initiatives to equip women and other social groups with capabilities for future jobs cannot work in isolation.218

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.

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 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
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 reform 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

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

235 [https://www.oecd-ilibrary.org/sites/75f79015-en/index.html?itemId=/content/publication/75f79015-en]
239 Ibid
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

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.

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.  

**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.  

**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.

**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.

**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.

---


249. Ibid.


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. 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.

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.
Bibliography


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


[188] https://www.zvei.org/en/
## Annex I

### List of LDCs

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

Figure 1 Real GDP and real GDP per capita in LDCs ............................ 16
Figure 2 Negligible progress in structural transformation has led to LDCs’ slow progress towards achieving IPoA and SDGs ............................ 18
Figure 3 The Three Detours of the Catching-Up Process ......................... 20
Figure 4 Eleven Pillars of STI .................................................................. 25
Figure 5 4IR Technologies ...................................................................... 26
Figure 6 Investment gap for developing countries ............................... 29
Figure 7 The COVID-19 economic and social shock and its consequences for the SDGs ................................................................. 30
Figure 8 Average share of products and/or services that were partially or fully digitized, percent ................................................................. 31
Figure 9 Integration of National, STI, and SDG Plans and Key Actors ......... 32
Figure 10 Internet users per 100 inhabitants in the LDCs ...................... 34
Figure 11 Internet penetration rates for men and women in 2019 ............ 35
Figure 12 Model of compound and sequential digital exclusion .......... 46
Figure 13 Relationship between Education and Climate Change Perception ................................................................. 53
Figure 14 ImageNet Classification with Deep Convolutional Neural Networks ................................................................. 60
Figure 15 Effects on Profit Margins Per Sector: Potential Financial ....... 64
Figure 16 Mobile Money as an Intermediary to a Digital Ecosystem ...... 70