UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Technical and statistical report

Data for development

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Abbreviations

AI	Artificial Intelligence
ADB	Asian Development Bank
AMI	Advanced Metering Infrastructure
API	Application Programming Interfaces
BIM	Building Information Modelling
CAR	Central African Republic
CCS	Carbon Capture and Storage
CIRT	Computer Incident Response Team
CIS	Commonwealth of Independent States
CNC	Computer Numerical Control
CSTD	United Nations Commission on Science and Technology for Development
DLT	Distributed Ledger Technology
DTM	Displacement Tracking Matrix
ECOSOC	United Nations Economic and Social Council
EO	Earth Observation
FDI	Foreign Direct Investment
GDC	Global Digital Compact
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GEO	Group on Earth Observations
GHG	Greenhouse Gas
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPL	General Public License
GPS	Global Positioning System
GPT	Generative Pre-trained Transformer
GVC	Global Value Chain
IAEA	International Atomic Energy Agency
ICT	Information and Communication Technology

IEA	International Energy Agency
IGF	Internet Governance Forum
IoT	Internet of Things
IP	Intellectual Property
ITU	International Telecommunication Union
LDCs	Least Developed Countries
LLDCs	Landlocked Developing Countries
LLM	Large Language Model
MEDC	More Economically Developed Countries
NGO	Non-Governmental Organization
ODIN	Open Data Inventory
OECD	Organization for Economic Cooperation and Development
OHCHR	Office of the United Nations High Commissioner for Human Rights
OTA	Over-The-Air update
SDGs	United Nations Sustainable Development Goals
SIDS	Small Island Developing States
SMEs	Small and Medium-sized Enterprises
SNA	System of National Accounts
UNCTAD	United Nations Conference on Trade and Development
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UN ESCWA	United Nations Economic and Social Commission for Western Asia
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDIR	United Nations Institute for Disarmament Research
UNOOSA	United Nations Office for Outer Space Affairs
WEF	World Economic Forum
WFP	United Nations World Food Programme
WHO	World Health Organization
WSIS	World Summit on the Information Society
WTO	World Trade Organization

I. Introduction

At a time when digital connectivity defines our lives, the importance of data in shaping the trajectory of global development cannot be understated. As economies and societies become increasingly interwoven with digital technologies, data emerge not only as an asset but as a catalyst for transformative change. While data-driven insights harbour the potential to spur innovations and foster sustainable development, the pathway is riddled with both unparalleled prospects and formidable challenges.

This publication seeks to unravel the multifaceted relationship between data and sustainable development, probing into its vast potential and the inherent risks, especially in the context of the 2030 Sustainable Development Agenda. Through an in-depth exploration of relevant literature and country case studies contributed by the members of the United Nations Commission on Science and Technology for Development (CSTD) and international organizations, we aim to offer a comprehensive understanding of how nations, both developed and developing, can harness data as a formidable ally in their quest for sustainable progress.

In today's digital age, data are not just a mere information record. They serve as a fundamental building block for economic advancement and policymaking. Data fuel the creation of innovative business models and pave the way for transformative breakthroughs. When organizations adopt data-centric approaches, it not only redefines their governance structures and processes but can also amplify their productivity. By opening up new markets and catering to a myriad of customer needs, data stand out as a pivotal catalyst. More importantly, its ability to provide systemic evidence means we can better understand the intricate interplay of Sustainable Development Goals (SDGs) and their interconnected impact.

When managed wisely, data have the potential to combat pressing global issues, ranging from poverty eradication to climate change mitigation, from ensuring food security to disaster risk management, and in mounting responses to pandemics. However, it is crucial to remember that like all powerful tools, data come with its set of challenges. If mishandled, it can accentuate the disparities in developmental outcomes, magnifying the digital divide and potentially morphing it into a broader developmental chasm. This is especially concerning when we consider the widening gulf between the developed and developing nations. If left unregulated, data can inadvertently lead to market monopolies, spawn discriminatory practices, and even pose threats to fundamental human rights, among other issues.

In this publication, we uncover the channels through which data can invigorate developmental initiatives, streamline production systems, and champion evidence-informed policymaking—all of which culminate in the realization of the SDGs. Drawing from a rich tapestry of experiences—both from developed economies with advanced data infrastructures and developing nations embarking on their data-driven journeys—we spotlight invaluable lessons and best practices. These narratives not only serve as beacons of success but also offer replicable models for nations worldwide.

In addition to examining the potential of data in driving sustainable development, this publication unpacks the intricate challenges that public and private sectors encounter in maximizing the benefits from data utilization. It emphasizes the pivotal role of data quality, robust infrastructure, and rigorous cybersecurity, underscoring the urgency for international standards that ensure data's integrity and security. The rise of systemic issues, including stifled market competition and ethical dilemmas stemming from data misuse, is brought to the fore. The publication examines the impact of data-centric business models, such as digital platforms, elucidating their propensity to engender imbalances in labor markets, market competition, and consumption patterns. By shedding light on the multifaceted nature of data-related challenges, this publication aims to stimulate informed discussions and catalyse strategic initiatives to bolster both effective and ethical data utilization.

To advance data governance for development, the publication proposes seven global data governance principles, consistent with the imperatives of multilateralism, multi-stakeholder approach and multidisciplinary consideration of data.

The structure of this publication is as follows: the subsequent three sections lay the foundation by exploring the nature of data (Section II), promises of data for sustainable development (Section III) and the associated challenges (Section IV). Section V examines the capacities of governments to benefit from data and address associated challenges. Section VI delves into data governance, focusing on three pivotal areas: global data governance, data taxonomies, and the social contract for data governance. It concludes by presenting seven principles of global data governance. Section VII concludes with recommendations and conclusions for the review of governments and the international community.

II. Understanding the multifaceted nature of data

This section delves into the intricate nature of data. It emphasizes data as products of technological, economic and socio-cultural processes, reflecting the biases and choices of creators. The role of technology, including broadband networks, Internet of Things (IoT) devices, and mobile phones, is highlighted in expanding data's reach. Data are framed as a context-dependent resource, shaped by the systems within which they exist, underscoring the importance of governance that considers the interplay between technology, data, economic and socio-cultural dynamics for sustainable development.

Data, in their essence, can be defined as "observations that have been converted into a digital form that can be stored, transmitted or processed, and from which knowledge can be drawn" (Statistics Canada, 2019).[1] Observations, in the broadest sense, refer to any form of information or facts about the world around us, captured through various means such as sensors, human inputs, or automated systems. These observations can encompass a multitude of aspects—from physical quantities like temperature and pressure to more abstract concepts like human emotions or market trends.

The transformation of these observations into a digital form signifies the conversion of this information into a language that machines and digital systems can understand. The subsequent storage, transmission, and processing of digital data enable us to retain information for future use, share it across geographical boundaries, and manipulate data in ways that allow us to derive meaningful insights (UNCTAD, 2021a). Data, in their raw form, may not hold much value. It is through careful analysis and interpretation that data are converted into actionable knowledge, insights, or intelligence. Data value extends beyond just the private interests of organizations that manage specific data sets, potentially benefiting society at large (Coyle et al., 2020).

Data are increasingly recognized as a critical enabler of the SDGs (UN, 2022a). When effectively managed, data have the potential to support addressing significant global challenges such as poverty reduction, ensuring food security, mitigating climate change impacts, managing disaster risks, and responding to pandemics (UNCTAD, 2022a). However, if data are mishandled or mismanaged, it can exacerbate inequalities in development outcomes and undermine the development potential of the digital economy (Vinuesa et al., 2020).

[1] As referenced in UNCTAD Digital Economy Report 2021.

Box 1. Examples of frontier data-enabled technologies

Generative Artificial Intelligence (AI)
Generative AI refers to a subset of AI systems that are trained to create content, patterns, or predictions based on the vast amounts of data they have been exposed to. Generative AI is widely adopted globally for various applications such as software development, essays, business letters, and contracts. Generative AI is "a technology that leverages deep learning models to generate human-like content (e.g., images, words) in response to complex and varied prompts (e.g., languages, instructions, questions)" (Lim et al., 2023, p. 2). Unlike previous generations of AI systems, Generative AI stands out due to its dynamic context and unprecedented scale of use. Generative AI goes beyond existing AI solutions by not only providing a response but also generating the content within that response. It can create new and original responses that go beyond what it has been explicitly programmed for. This flexibility and creativity make Generative AI a powerful tool for tasks that require generating diverse and contextually relevant content, such as writing, creative expression, and problem-solving. The ability to generate content rather than simply providing predefined responses gives Generative AI a unique edge in various applications and expands its potential for innovation and creativity.

Quantum computing
Quantum computing's efficiency in solving complex calculations could greatly enhance machine learning and AI applications. This technology allows for the transplantation of entire learning techniques, such as neural networks, into the quantum domain. This could lead to quantum neural networks that can process and learn from information exponentially faster and potentially more accurately than their classical counterparts. Moreover, it promises to democratize AI by reducing the time and cost of training complex AI models, making them more accessible to smaller firms. Powered by quantum computing, data analytics can simulate chemical reactions at an atomic level, allowing us to understand the potential outcomes of different combinations of molecules better and at a level of detail far beyond the capabilities of conventional computers. This technological advancement opens up opportunities in manufacturing, enabling the creation of new materials with tailored properties that surpass the performance of existing alternatives. Quantum computing promises a transformative leap in a range of industries, including, but not limited to scientific research, manufacturing, food production, and healthcare.

Distributed ledger technologies
Blockchain and other distributed ledger technologies (DLTs) have emerged as transformative solutions for securing data and facilitating transactions in a decentralized manner, without the need for a central authority (UNCTAD, 2023a). By providing a transparent and secure digital transfer of value and ownership within a network, DLTs have the potential to revolutionize economic and data transactions. Every transaction recorded on the ledger is visible to all participants, creating a high level of accountability and reducing the potential for fraud or manipulation. This transparency can enhance trust among participants and enable new forms of collaboration and cooperation. DLTs serve as a foundation for complementary innovations and can reshape entire industries and economic systems. DLTs have already demonstrated their versatility, finding applications in various sectors beyond cryptocurrency, including supply chain management, healthcare, finance, and public governance.

In stark contrast to conventional production inputs such as raw materials or labour, data are not naturally occurring. Rather, data are a product of complex technological systems and socio-cultural interactions. When creating data, social actors, including individuals and organizations, make several choices about what information to focus on, what to record, and how to encode it (Aaltonen et al., 2023). These choices are influenced by a wide range of factors, including the actors' goals, values, and biases, as well as broader social, cultural, and economic factors. Data are not simply objective representations of reality. Instead, data reflect the choices and values of the individuals and systems involved in their creation. This non-neutrality shapes our perception and communication by determining what information is collected, how it is represented, and how it is interpreted.

Simultaneously, the creation and transformation of data into digital form are strongly influenced by the capabilities and limitations of digital technologies (**Box 1**), including their ability to handle, store, and process information. At the forefront of expanding the scope and efficiency of data communication are broadband networks. They enable the real-time transfer of large volumes of data across extensive geographical distances, thereby significantly enhancing the reach and speed of data exchange. Internet of Things (IoT) devices, ranging from home automation systems to industrial sensors, are another major source of data. By embedding connectivity and computing capabilities into everyday objects, IoT devices generate a constant stream of data about their operation and environment. Similarly, the ubiquity of mobile phones has led to an explosion in user-generated data. From geolocation data to social media posts, mobile phones provide a constant feed of digital data that reflects a wide range of human activities and behaviours. Proliferation of diverse types of technological systems plays a crucial role in the lifecycle of data, serving as both a source and a conduit for data.

The dependence of data on underlying technology affects how data functions as a filter of perception (Alaimo and Kallinikos, 2022). Viewing data as part of technological infrastructures highlights the fact that the value and significance of data are not intrinsic but emerge from the broader systems in which they are situated. Within these technological systems, data are transformed into facts that serve as the foundation for evidence-based decisions. The notion of "evidence" in this context possesses limited objectivity, as it is jointly shaped by socio-cultural perceptions and technological affordances. This perspective emphasizes the significance of the algorithms, models, and other analytical tools that accompany data throughout its value chain. Organizations must diligently design, manage, and update their data infrastructures, keeping in mind the accuracy, reliability, and fairness of the tools and methodologies employed.

In this context, data represent a new kind of resource—one that is inherently linked to the technological infrastructure that generates, manages, and uses it. As such, understanding and navigating the complexities of synergies between novel technological innovations and data is a crucial aspect of harnessing the potential of data for sustainable development. In order to leverage the full potential of data, it is essential for data governance efforts to recognize the inherent interconnectivity of data, digital technologies, and socio-cultural dynamics, and to treat data in context.

III. Promises of data for development

Section III provides an overview of how nations can leverage data to achieve the SDGs. This section introduces two perspectives on data that shape the narrative of the subsequent sections. The first perspective views data as an economic input. Data serve as a driving force for development, generating economic value and creating new market opportunities. The roles of digital platforms in global entrepreneurship and international trade are discussed in this context. The second perspective sees data as a crucial tool for decision-making, offering robust evidence to support effective policies and strategies. This includes its role in improving health and welfare, as well as in combating environmental degradation and climate change, and advancing scientific research.

The increasing integration of data into every aspect of society calls for heightened attention from policymakers across all fields. The facilitation of data access and exchange is projected to yield socio-economic advantages amounting to roughly 0.1% to 2.5% of a country's total Gross Domestic Product (GDP) in the coming years (OECD, 2019a). But these projections, as important as they sound, might just be the tip of the iceberg (Ker and Mazzini, 2020). Measuring the true value of data is a complex endeavour. The intricate nature of data, its multifaceted applications, and its potential for creating unforeseen synergies can make it challenging to assign an accurate numeric value to its worth. Therefore, while the current estimates already suggest significant gains, the actual impact on economies, when considering the cascading benefits and multiplier effects of data integration, could very well be substantially larger than the given range.[2]

The interplay between data and development encompasses two distinctive yet interconnected perspectives, each carrying equal significance. The first perspective situates data within the economic development process itself, viewing it as a key economic asset within the data value chain (Haskel and Westlake, 2017). In this context, data act as a catalyst for development, driving value creation.[3] This happens when raw data are processed and transformed into digital intelligence or data products. Data become a strategic asset, fostering innovation, optimizing operational efficiency, and steering companies towards more data-driven, knowledge-based business models. Data-driven innovations can increase productivity and facilitate transformative innovations that create new markets and foster novel ways of value creation (**Box 2**). Advancements in data-enabled technologies can also enhance the delivery of financial services to marginalized populations, thereby improving financial inclusion.

Box 2. How can data-enabled technologies support development programs: the case of industrial drones

We are at the beginning of the mass adoption of drones as a visionary, safe, and scalable solution in development programs. Over recent years, drones have begun to find increasingly specialized and innovative applications in a host of sectors from healthcare to agriculture. In the sugar cane farms of KwaZulu-Natal in South Africa, drones have been used to spray crops, reducing the amount of manual labor required and possibly enhancing the precision of the application (Caboz, 2020). Similarly, in Rwanda, drones have been successfully employed to transport blood, circumventing logistical inefficiencies related to the cold chain storage of blood supplies (Russo and Wolf, 2019). In the aftermath of Nepal's devastating 2015 earthquake, drones were used in surveying and mapping areas to facilitate post-disaster reconstruction efforts (Wang, 2019). The potential applications of drones are not just confined to these instances; they can revolutionize entire industries (Maghazei et al., 2022).

However, despite these promising developments, the full-scale adoption of drones in development programs is still embryonic. One of the main challenges is a limited understanding of the full spectrum of use-cases, benefits, and hurdles associated with drone technology. Another challenge lies in the absence of clear, actionable guidance on the best practices for drone adoption, from initial conception through to implementation. This includes tackling operational challenges such as flying drones either within line of sight or beyond, ensuring safe data collection practices, and seamlessly integrating these capabilities into existing systems. Regulatory barriers also pose substantial obstacles, from risk assessments to the cumbersome process of obtaining flight permits and other authorizations. Further complicating the landscape are organizational challenges, which can range from securing reliable access to drone vendors to navigating a maze of contractual and liability considerations. Behavioral aspects, including the acceptance and trust of this new technology by communities and stakeholders, must also be accounted for.

Lastly, there is an overarching need for comprehensive governmental policies and long-term strategic planning, particularly in developing nations, to fully leverage the potential of drone technology. Without these, even the most promising pilot projects are likely to remain isolated examples of what could be, rather than harbingers of a new era in developmental aid and industrial efficiency.[4]

[2] For more information, please refer to the following studies: WTO et al. (2023) Handbook on measuring digital trade. Second Edition. https://doi.org/10.1787/ac99e6d3-en
Statistics Canada, (2019), "The value of data in Canada: Experimental estimates", Retrieved from https:// www150.statcan.gc.ca/n1/pub/13-605-x/2019001/ article/00009-eng.htm.
[3] Contribution from the Government of Djibouti
[4] Contribution from Prof. O. Maghazei, University of Bath.

Concurrently, data can offer societal benefits that extend beyond the exclusive gains realized by companies (Coyle et al., 2020). The second perspective perceives data as a critical tool in decision-making processes, aiding in the achievement of economic, social, and environmental objectives (UNCTAD, 2022a). Seen through this lens, the correlation between data usage and development is quite explicit. The surge in data availability, facilitated by advancements in digital technologies, can substantially assist in progressing towards the SDGs. This is accomplished by furnishing robust evidence for decision-making, thus enhancing the effectiveness of policies and strategies.[5] Data-centred approaches can support policy decisions grounded in evidence, leading to more streamlined and impactful policy measures,[6] Data can also help us decarbonize our economies and make them more sustainable.

Data can facilitate a systems approach, enabling a more comprehensive understanding of the complex interactions among various SDGs (**Table 1**). By harnessing vast amounts of data, we can begin to identify and anticipate the ripple effects caused by actions aimed at a particular goal. This understanding allows for the design of interventions that are not only targeted but are also integrated, effectively addressing multiple SDGs simultaneously without undermining any one of them. The strength of this approach lies in its ability to build upon ongoing national and international efforts to define and track progress towards each SDG.

Data-centred approaches can effectively utilize the indicators defined for each goal, processing and learning from the corresponding data in a way that humans alone could not. By facilitating a more detailed and nuanced understanding of these indicators, data-driven innovations can support both the attainment of these goals and the monitoring of progress towards them. The use of data in this context also enhances transparency and accountability in the pursuit of SDGs.[7] With novel advancements in data analytics, stakeholders can continuously track progress, identify potential setbacks, and implement course corrections as necessary. In essence, the data-based solutions not only support more holistic and effective interventions towards the SDGs but also foster a more dynamic and responsive approach to sustainable development.

For countries in the global South, data-driven technologies offer the opportunity to bridge the socio-economic development gap.[8] Data can accelerate economic growth, allowing these nations to 'leapfrog' into a more advanced technological paradigm, bypassing intermediate stages. Furthermore, these technologies can help compensate for the lack of capital infrastructure and imperfections of institutional environments enhance the speed, scope, and depth of long-term planning, and refine sectoral policies.

Table 1. Contribution of data to SDGs

SDG	DECSRIPTION	EXAMPLES OF CONTRIBUTIONS
1	End poverty in all its forms everywhere	Data-driven initiatives can help map and understand the specific needs of impoverished communities, enabling the delivery of tailored solutions. Data can enhance productivity and efficiency in various industries, leading to cost savings and increased competitiveness, consequently lifting people out of poverty.

[5] Contribution from the Government of the United Republic of Tanzania.
[6] Contributions from the Government of Brazil.
[7] Examples of such initiatives include the National SDG Tracker developed by UN ESCAP and the SDG tracker developed by the Our World in Data team.
[8] Contribution from the Government of the Russian Federation.

2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Data collected from various sources (such as satellites, drones, or IoT sensors) can help farmers optimize their use of resources (water, fertilizers, etc.), increasing the sustainability of agriculture by reducing waste and environmental impact.
3	Ensure healthy lives and promote well-being for all at all ages	By analyzing data on disease patterns, vaccination rates, and healthcare facilities' reach, targeted interventions can be designed to improve healthcare access in underserved areas. Predictive analytics can help preempt disease outbreaks, ensuring timely responses and potentially saving lives.
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Data analytics can help in personalizing education according to a student's learning style, pace, and strengths, thereby enhancing the learning experience and outcomes.
5	Achieve gender equality and empower all women and girls	Granular data collection and analysis can help identify disparities in areas such as education, employment, health, and political representation, forming the basis for targeted policy interventions.
6	Ensure availability and sustainable management of water and sanitation for all	Data analytics can guide sustainable water management strategies, helping to conserve water and ensure its equitable distribution. Data from smart metering systems can inform the planning and development of water and sanitation infrastructure, ensuring it meets future needs.
7	Ensure access to affordable, reliable, sustainable and modern energy for all	Data from smart grids can help monitor and analyze energy consumption patterns, leading to the design of energy-efficient strategies and energy-saving technologies.
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Data on start-ups, patent applications, and R&D investments can help foster an environment that promotes entrepreneurship and innovation, key drivers of economic growth. By identifying the skills demanded by the job market and comparing them to the skills of the workforce, data can guide the development of effective education and training programs.
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Data can inform the planning, design, and maintenance of resilient infrastructure, taking into account factors such as population growth, urbanization, and climate change. Furthermore, data on technology use and digital connectivity can guide strategies to promote technology access and digital inclusion, key elements of a resilient infrastructure.
10	Reduce inequality within and among countries	Data on socio-economic dynamics can help measure and monitor socioeconomic disparities both within and between countries. This includes differences in income, access to opportunities, and resource distribution.
11	Make cities and human settlements inclusive, safe, resilient and sustainable	Data-driven approaches can help predict population growth patterns, optimize traffic and transportation systems, and assist in environmental sustainability efforts.

12	Ensure sustainable consumption and production patterns	Data from smart devices can be used to analyze the use of resources in production processes, helping businesses to identify ways to improve efficiency, reduce waste, and minimize environmental impact.
13	Take urgent action to combat climate change and its impacts	Climate data enable the development of targeted strategies and interventions to reduce greenhouse gas emissions, promote renewable energy sources, optimize resource management, and enhance climate resilience.
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Data on ocean-based economic activities like fisheries, tourism, and offshore energy can help balance economic development with sustainable management of marine resources. Data-centered approaches can further improve resource extraction from undersea geological formations to minimize the environmental impact.
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Data on forest cover, deforestation rates, and forest health can guide sustainable forest management practices, contributing to carbon sequestration and biodiversity conservation. Data can help design and implement measures to protect endangered species and halt biodiversity loss.
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Data on socio-economic dynamics can help assess the accessibility and effectiveness of justice systems, guiding reforms to ensure that everyone, especially marginalized groups, can access justice. Data on government activities can increase transparency and hold institutions accountable, strengthening rule of law.
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development	Data analytics can be used to track aid flows, assess the impact of development assistance, and ensure that aid is being effectively used to achieve the SDGs.

The following sections dive into data's dual role: as a fundamental economic input and a crucial tool for evidence-informed decision-making. First, we explore how data fuel transformative innovation, how they are redefining competition, the significance of platform-based ecosystems for sustainable development, data potential in shaping a circular economy, and their application in sustainable energy production and management. Shifting focus to decision-making, our exploration sheds light on the power of data analytics in combating climate change, its transformative influence on agricultural systems and nutrition, the role data play in contemporary urban planning, its importance in efficient disaster management, and its revolutionary impact on healthcare and scientific research. These discussions underscore data's potential in shaping development trajectories.

A. Data as an economic input

Data are the lifeblood of the modern economy. When data are harnessed as a crucial factor of production, they have the unique capability to exhibit increasing returns to scale (Varian et al., 2004). As we feed more data into the system or process, the output we receive is not merely proportional to the input. Rather, the output magnifies at a rate that is significantly larger than the incremental increase in data volume. This phenomenon sets the stage for a self-reinforcing virtuous cycle. As organizations delve deeper into data analysis, they unearth valuable insights. When these insights are effectively applied, it often results in an enhancement of product quality and an expansion in the scope of operations and their effectiveness. This, in turn, translates into the creation and accumulation of even more data. The cycle then repeats itself, each time providing the organization with richer datasets and more refined insights, thus constantly amplifying the positive performance outcomes. This continuous loop of data collection, analysis, application, and then regeneration of data serves as a powerful enabler for sustained organizational growth and innovation.

However, this increasing returns' dynamic also presents barriers to entry for newcomers. To take advantage of the virtuous cycle and benefit from learning effects, companies need to achieve a critical mass of data. New competitors lacking access to large datasets are thus at a significant disadvantage, which has important implications for market competition and regulatory oversight.

Adding another layer of complexity is the role of data complementarities. More value can be extracted when different types of data are integrated. For example, a company with access to both online shopping history and social media activity can potentially gain deeper and more nuanced insights than a company limited to just one type of data. Understanding how these complementarities work can offer additional perspectives on how data can generate value at scale. Companies are increasingly looking to deepen their customer understanding, sometimes through strategic mergers that combine complementary datasets. Such mergers can heighten "across-user learning efficiency," fortifying a firm's competitive edge even further (Hagiu and Wright, 2022). As a result, regulators need to be alert to these shifting market landscapes, particularly when increasing returns to scale and mergers of complementary datasets can potentially stifle competition.

Accumulating more data can yield valuable additional insights and increase profitability. However, in some cases, there can be diminishing or even negative returns from increasing data scale. While more data can improve the accuracy and robustness of insights, beyond a certain point, the returns may start to decline. For instance, on average, algorithmic suggestions on music streaming platforms (e.g., Spotify, Deezer) often surpass human selection in general efficiency. Yet, these outcomes also hinge on the proficiency of human editors, the volume of individual data accessible to the system, and fluctuations in the surrounding conditions that lead to changes in consumer demand (Peukert et al., 2024). Augmenting data analytics with human curation can help overcome the limitations of personalized algorithmic suggestions. Therefore, increasing data volumes will not contribute to higher returns by default. Companies also need to have complementary investments in human capabilities and skills to benefit from increasing data volumes.

Additionally, users might feel overwhelmed when presented with too many choices on digital platforms or they might opt for a smaller network on a platform to maintain their privacy (Tucker, 2018). For search engines like Google, Baidu or Yandex, extended periods of data retention might offer no significant benefits in terms of market shares (Chiou and Tucker, 2017). Managing vast quantities of data can become resource-intensive, and may not always yield proportionally higher benefits.

For data-driven companies, it is crucial to focus not just on the sheer volume of data, but also on the quality and relevance of the data collected. Additionally, it is important to consider how technological advancements can augment human skills and organizational capabilities. Companies with deeper data on user profiles will be at an advantage when facing novel tasks, as they can learn and adapt faster due to their more comprehensive datasets (Sapi and Schaefer, 2023). Therefore, next to data quantity, companies focus on data depth to achieve a competitive advantage. Understanding the dynamics of data control and its returns can be key to evaluating its role in competition and its implications for regulatory policy. Depending on how fast the returns to data diminish, the need for regulatory intervention will differ. The role of data complementarities, barriers to entry, and potential for learning efficiencies across users are all critical factors to consider in this landscape.

1. Transforming innovation and competition in the data-driven age

Data serve as a foundation for both economic production and fostering innovation (Nambisan et al., 2019; Plekhanov et al., 2023; Teece, 2018). By leveraging data, organizations can devise novel solutions to existing problems, optimizing processes and outcomes to a degree hitherto unattainable. In the context of sustainability transitions, the value of data lies in its potential to provide a balance between economic demands and sustainability requirements, thereby fostering more responsible growth and development.

The combination of data with recent advancements in digital technologies like AI sparks chains of innovations, creating a domino effect of interconnected and co-dependent innovation activities. This ripple effect increases the complexity of the innovation landscape due to the speed of changes and the interconnectedness of various elements of innovation processes. With this complexity comes unpredictability. The impacts of data-driven innovations can frequently exceed the initial expectations of their creators, leading to unforeseen consequences. These unexpected outcomes can stir further disruptions within organizations and industries, potentially necessitating additional investments to address new challenges and timely policy adjustments (UNCTAD, 2021a; Yoo, 2010).[9] Unintended outcomes can vary widely, from inherent biases in AI systems against certain societal groups to the deployment of data and algorithms in the development of lethal autonomous weapons systems (UNESCO, 2021; UNIDIR, 2021).

Data exchanges are increasingly becoming the epicentres of a transformative shift in innovation ecosystems, fundamentally redefining how we perceive and approach innovation itself. Traditionally, innovation was often seen as a linear process, proceeding from inception to product development to market release. However, in today's digital landscape, innovation processes are far from linear. Influenced by digital data and associated technologies, they have become fluid, dynamic, and highly interactive, with multiple touchpoints that allow for iterative feedback loops and constant refinements. This evolution of innovation activities necessitates business owners to recalibrate their innovation management strategies to remain competitive in the data-centric economy and underscores the need for novel approaches in innovation policymaking.

For instance, in the financial services industry, data exchanges are transforming how financial institutions and fintech companies innovate by sharing transactional data and consumer behaviour insights. This collaboration fosters the creation of more secure, efficient, and personalized financial products and services.

In the automotive industry, data exchanges are facilitating the evolution of autonomous driving technologies. Car manufacturers, software developers, and sensor technology providers exchange vast amounts of data to improve vehicle intelligence and safety features, speeding up the path towards fully autonomous vehicles. Additionally, over-the-air (OTA) software updates in modern cars exemplifies how a vehicle can significantly evolve after it is bought by a consumer, enhancing its functionality, safety, and performance without the need for physical modifications.

[9] More on these challenges can be found in the following section *"Challenges of data for development"*.

One of the most compelling developments catalysed by the data-driven change of innovation activities is the emergence of distributed value creation ecosystems (Plekhanov et al., 2023).[10] This is evident across various industrial sectors, including manufacturing companies, healthcare providers and mobile operating systems (e.g., Android or iOS). Business ecosystems dismantle the centralized models of value production, placing greater emphasis on collective efforts and participatory mechanisms. Companies are no longer isolated entities but nodes within an interconnected network of service providers and clients, extending across geographical boundaries. A substantial portion of internal processes are no longer strictly in-house, but rather, are increasingly outsourced to or integrated with third-party providers through digital channels. Utilizing data from external sources yield substantial benefits for companies (Lei et al., 2023). Customers, once merely passive consumers, have become active contributors, even co-creators, involved in various stages of product development and refinement. This involvement not only democratizes the innovation process but also enriches the final product through real-time, user-generated insights.

Building on this concept of distributed collaboration and co-creation, online communities exemplify the power of collective effort in the digital era. Online communities come together to innovate and solve complex problems collaboratively, breaking down traditional geographic barriers and empowering individuals in remote areas. Online communities like GitHub and Wikipedia operate without a formal managerial hierarchy and under a copyright license that prevents any entity from having proprietary control (Benkler, 2017). Yet, the results of collaboration in online communities can be not only innovative but also highly competitive (Dahlander et al., 2021). Linux is a prime example of successful peer production. The operating system's kernel was developed by Linus Torvalds and is released under the general public license (GPL). Over the years, thousands of contributors have improved and expanded upon it. Today, Linux powers everything from supercomputers to mobile phones, and no single entity controls it.

For low- and middle-income countries, the rise of open-source online communities is especially significant. It offers them a unique advantage in bridging the technological gap. Instead of investing time and resources in developing software from the ground up or procuring it from expensive vendors, these nations can tap into the open-source community and try to catch up with the technological frontier. Proliferation of online communities like GitHub increases the rate of entrepreneurship and also stimulates the emergence of globally-oriented ventures in developing countries (Wright et al., 2023). For instance, software developers in Central Europe and Asia contribute to tens of billions of dollars in services each year by leveraging the resources of open source online communities (Agrawal et al., 2016; Barach et al., 2020).

Another way data-driven innovations can support the economic growth of developing countries is through the reduction of border frictions and optimization of market transactions. These innovations diminish language barriers and lowering transportation costs (Goldfarb and Tucker, 2019). For many remote countries, their geographic location and inadequate physical infrastructure pose significant obstacles to trade. These countries are hampered by the sheer logistics and cost of transporting goods to markets where these goods are in demand. But the advent of the data economy presents a unique opportunity for these countries. If they can cultivate the necessary human capital to create digital goods and services, they may be able to circumvent these physical challenges. Digital goods, by their nature, do not incur the same transportation costs or logistical complexities as physical goods. The marginal cost of delivering digital products across vast distances is negligible. As such, lower language barriers, combined with the ease and low cost of digital product delivery, could create a promising future for these countries.

[10] The next section of this report, titled "*The rise of platform-based ecosystems and implications for sustainable development",* provides more details on the rise of platform-based ecosystems and their role in the economy.

To summarize, due to the data revolution, the very nature of innovation is undergoing a transformative shift (Nambisan et al., 2019; Ozalp et al., 2022; Plekhanov et al., 2023). Innovation processes become more participatory and inclusive, facilitated by the integration and analysis of data from a multitude of stakeholders. With heightened internal and external collaboration and reduced transaction costs, organizations can solve more complex problems than ever before, opening up new opportunities for growth and development.

2. The rise of platform-based ecosystems and implications for sustainable development

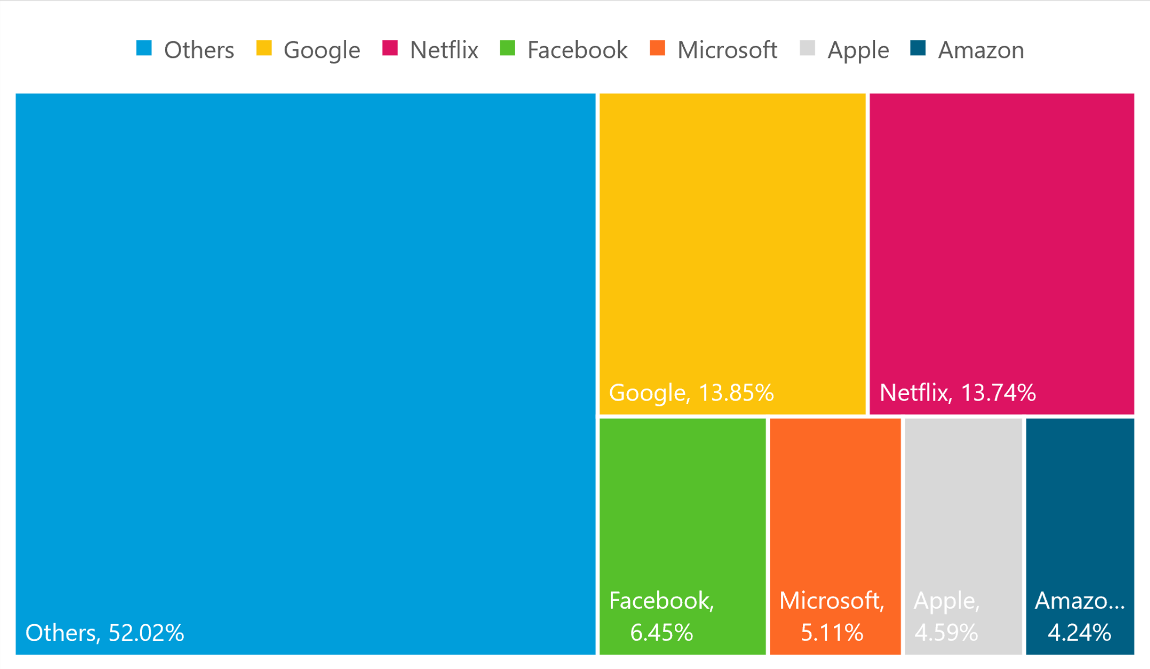
The paramount role of data has not gone unnoticed in global markets. The most successful companies today by market capitalization, including Alphabet, Alibaba, Amazon, Microsoft, Tencent are owners of data-based business models. Such companies, given their data-driven core, have effectively capitalized on their ability to aggregate, analyse, and apply data to drive business strategies, offer tailored services, and create a competitive advantage. The market's increasing appreciation for data-centric business models is evidenced by the surge in venture capital investments targeting data-intensive firms. These investments reflect a growing recognition of the transformative potential of data, especially when coupled with cutting-edge technology and innovative business models.

Among the frontrunners of this data revolution are platform-based ecosystems, including, but not limited to search engines, social media, and e-commerce. These platform-based ecosystems, standing at the vanguard of market trends, have integrated data into their core activities. Digital platforms thrive on their ability to harness and analyse significant data volumes, enabling them to tailor user experiences, match consumer needs with merchant offerings, and provide advertisers with highly targeted opportunities. Global Internet data traffic is significantly dominated by a handful of platform companies (Sandvine, 2023). Six US-based platform companies were responsible for generating over 47 percent of the world's Internet data flows in 2023 (Google, Netflix, Facebook, Microsoft, Apple, and Amazon) (**Figure 1**). In essence, platform companies have effectively turned data into a valuable asset and a strategic tool, unlocking insights that drive decision-making, innovation, and value creation (Evans and Schmalensee, 2016). They provide incentives, conflict resolution mechanisms, and technological infrastructure, allowing for participatory innovations driven by a large number of users and developers (McIntyre and Srinivasan, 2016).

Underpinned by extensive data resources, platform-based ecosystems are a new powerful nexus of innovation and entrepreneurship, thus stimulating economic development (**Box 3**). A platform-based ecosystem is a business environment that centres around a digital platform as its primary actor, as seen in examples such as the iOS and Android ecosystems that created new markets for mobile applications and enabled innovations across various industries (Kapoor and Agarwal, 2017; Wareham et al., 2014). Platform-based ecosystems are distinct from other organizational forms because of the presence of network externalities and specific platform strategies deployed. Within this framework, there are four primary participants: (1) platform owner who has control over the intellectual property and is responsible for governing the platform; (2) providers who facilitate the interaction between the platform and its users; (3) producers who create and present the various offers or services available on the platform; and finally (4) consumers who utilize the products and services available through the platform and participate in business co-creation (Van Alstyne et al., 2016). Digital platforms can be described as "semi-regulated marketplaces" where entrepreneurial activities are facilitated by the platform owner.

By providing a coordination structure, digital platforms empower ecosystems of value co-creators to develop and sell new products and services that rely on complementary offerings (Foerderer et al., 2021; Gawer, 2014; Tiwana et al., 2010). Essentially, platform-based ecosystems act as an interactive arena where parties can create, exchange, and augment value, often creating outcomes that no single party could achieve alone. This interactive feature is driven by complex algorithms that curate and personalize experiences, streamline processes, and offer solutions that are tailored to the needs of the users, thus maximizing the value of each interaction.

Figure 1. Share of global Internet traffic by firm, 2023



Source: Sandvine (2023).

More than just acting as a facilitator, platform-based ecosystems have evolved into powerful engines that drive innovations. They do not merely transmit and facilitate the exchange of existing knowledge and data, but also promote the generation of novel ideas and solutions. This transformative aspect is one of the most profound values that platform-based ecosystems offer, reshaping industries, social interactions, and economies in fundamental ways across developed and developing countries. Platform-based ecosystems pave the way for a type of collaboration that transcends traditional organizational boundaries (Kretschmer et al., 2022). They bring together multiple contributors, who may be dispersed across various geographical locations and might not have had the opportunity to interact or collaborate otherwise. Through these ecosystems, geographical and temporal barriers are significantly reduced, fostering the creation and sharing of knowledge on an unprecedented scale.

Box 3. The dual role of digital platforms in employment and economic development

Digital platforms bring new dynamics into standard employment (Davis, 2016). They play a crucial role in effectively connecting employers with potential new hires. Digital platforms offer several advantages for both employers and workers.

Firstly, employers benefit from a broader pool of talent and have access to a diverse range of individuals with specialized skills. Platform allows employers to find candidates who possess the specific expertise they require, enabling them to make more targeted hiring decisions. Secondly, digital platforms provide workers with enhanced opportunities to explore and discover new job openings that align with their interests and availability. Additionally, these platforms often provide tools and algorithms that match workers with relevant job opportunities, based on their qualifications and preferences. This not only enhances efficiency in the job search process but also provides workers with a more flexible approach to finding employment that fits their schedule and personal requirements.

Digital platforms play a significant role in supporting remote work by providing the necessary infrastructure and tools for individuals to collaborate, communicate, and perform their tasks from anywhere. The global division among countries is evident in the remote work landscape, with developed countries' remote platform workers attracting the majority of high-skilled job opportunities, while many countries in the Global South have limited participation (Braesemann et al., 2022). Remote jobs tend to concentrate in large cities, leaving rural areas at a disadvantage. Workers with in-demand skills have better prospects and higher wages, while others face intense competition and lower incomes (Liu et al., 2022). To harness the full potential of remote work for economic and rural development, it is necessary to complement it with local skill development, infrastructure investment, and labour market programs. By doing so, remote work has the potential to address the global imbalance between highly educated graduates in the Global South and Global North and the growing global demand for talent (Palfreyman, 2012). Moreover, remote work can contribute to the growth of resilient and sustainable local communities, particularly in rural areas, offering an alternative to physical migration in search of better job opportunities and higher wages, provided that platform work can offer sustainable sources of income (Hjort and Poulsen, 2019).

By harnessing the capacities of digital platforms, organizations can tap into a global pool of talent and expertise, irrespective of geographical constraints. This empowers companies to access specialized skills in an efficient manner and leverage cost advantages available in different regions (Bauer, 2018). Consequently, this fosters the expansion of global value chains and contributes to the advancement of emerging economies.

Nevertheless, digital platforms and algorithmic management of workers can bring various undesired negative consequences (Rani and Furrer, 2021). There are broader ethical concerns about how companies use digital platforms to bypass labour regulations. The operational models of freelance platforms allow companies to dictate their terms and conditions, leading some experts to label some of these workplaces as "digital sweatshops" (Tan and Cabato, 2023). The online freelance sector is burgeoning, particularly in developing countries, where workers seek opportunities but often encounter limited choices, making them susceptible to exploitation. Governments in these countries recognize the challenges associated with online freelance workers but appear uncertain about how to regulate this rapidly expanding industry.

To make large-scale collaboration not only feasible but also sustainable, platform-based ecosystems incorporate sophisticated mechanisms for resolution of conflicts among providers and consumers and systems of incentives for platform participants to maximize the value. This is accomplished through algorithms that resolve disputes, mediate interactions, and establish rules and norms for behaviours. The true power of platform-based ecosystems lies in their capacity to harness the collective intelligence of a diverse set of contributors, ensuring sustained collaboration over time. They leverage an extensive pool of knowledge, skills, and resources, combining them in highly effective and efficient manner to enable radical forms of innovations.

Platform-based ecosystems offer powerful solutions to some of the most formidable obstacles hindering sustainable development, such as difficulties in accessing resources and people, knowledge sharing, and mobilizing collective action (Hellemans et al., 2022). By utilizing platforms, organizations can tap into the collective resources of a vast network of contributors. The ability to repurpose and reuse resources, along with creating value via intermediating transactions, rather than engaging in independent production, introduces a more sustainable approach to economic activity.

Digital platforms and ecosystems serve as catalysts for collective action, uniting actors from various knowledge domains for joint problem-solving (Ciulli et al., 2020; Jacobides et al., 2018). Due to the intricate nature of sustainability challenges, a diverse range of participants are required to devise effective solutions. Platform-based ecosystems can bring together disparate actors, creating a nexus for the exchange of information and resources that directly contribute to tackling sustainability challenges. By widening the participant base and diversifying the knowledge involved in the problem-solving process, platform-based ecosystems enable a unique mobilization of insights from varying perspectives. This fosters a rich, collaborative environment for the co-creation of large-scale innovations to tackle complex sustainability problems.

While platform-based ecosystems have introduced innovative approaches to sustainable development, they also present significant challenges that cannot be overlooked. A holistic perspective that considers the multifaceted challenges associated with privacy, ethics, governance, and environmental impact, is essential for harnessing their potential responsibly and effectively (please refer to the section IV of this report).

3. How data-driven innovations power the transition to sustainable production

In a traditional linear economy, the flow of goods follows a "take, make, dispose" model, where raw materials are extracted, processed into products, and ultimately discarded as waste. This not only strains the planet's finite resources but also leads to environmental degradation. The concept of a circular economy presents an alternative, offering an ecosystem-centric business model that aims for sustainability, waste reduction, and the creation of closed loops where materials and resources are continually reused, refurbished, and recycled (UNCTAD, 2023b).

Data-driven innovations are instrumental in supporting the transition towards a circular economy and decarbonization, by utilizing digital technologies across various stages of the product life cycle (Kamble et al., 2018). Through advanced analytics, Internet of Things (IoT) sensors, machine learning algorithms, and real-time tracking, data-driven systems can accurately map the flow of materials and energy across an entire value chain. This level of transparency allows businesses to identify inefficiencies, waste points, and opportunities for material recovery or new revenue streams (IEA, 2017).

Data-centred approaches have a potential to enable sustainable production through various pathways, including immediate operational efficiency, product and service innovations, and stakeholder alignment (Plekhanov et al., 2023). By leveraging data-centred approaches, manufacturing companies can identify patterns, anomalies, or early warning signals that indicate a potential failure in machinery or infrastructure (Senoner et al., 2022). This allows for timely interventions, such as repairs or replacements, to be carried out, preventing costly breakdowns and minimizing downtime. Data-enhanced pre-emptive maintenance reduces the consumption of resources and energy associated with reactive repairs, as well as the waste generated from replacing entire systems due to failures. By addressing problems before they escalate, pre-emptive maintenance improves operational efficiency, extends the lifespan of assets, and reduces unnecessary resource consumption.

One of the transformative implications of data is in the refinement of manufacturing processes. The move away from centralized production facilities and adoption of a distributed model, for instance, brings manufacturing processes closer to the point of demand (Srai et al., 2016). This reduces the need for long-distance transportation of goods, resulting in lower carbon emissions and energy consumption associated with logistics (UNCTAD, 2022b). The refinement of manufacturing processes to align with individual consumer needs and changes in demand not only boosts market optimization, but also encourages an environment-centric future, thus synergistically bolstering both ecological and social aspects of sustainability.

An illustrative industry example of this model is in the furniture manufacturing sector. Furniture manufacturers have started exploring ways to implement distributed manufacturing principles by setting up smaller, regional production hubs that utilize digital fabrication techniques, such as Computer Numerical Control (CNC) routing and 3D printing, to manufacture products. This approach allows for the customization of furniture based on local consumer preferences and reduces the distance between production and consumption points. As a result, there is a significant reduction in transportation costs and carbon footprint, aligning with the goal of sustainable development. Furthermore, this model supports the local economy by creating jobs and engaging with local suppliers, showcasing a practical implementation of distributed manufacturing that enhances both ecological and social sustainability.

Data analytics can enhance product design, making it possible to create products that are more durable and eco-friendly (Kristoffersen et al., 2020). The use of advanced computer modelling and simulation allows for the optimization of product designs to enhance their durability and ease of repair. This results in extended product lifespans, thereby reducing waste and contributing to the circular economy (Rajput and Singh, 2019). Sustainable materials can be selected during the design phase, thus further supporting decarbonization. For instance, powered by extensive data volumes, quantum computing can precisely simulate systems like molecules, polymers, and solids. In the chemical industry, this could lead to efficient molecular designs for specific tasks, predicting their effectiveness prior to physical synthesis (Cao et al., 2019; McArdle et al., 2020). The outcome ranges from improved catalysts to innovative batteries. In the manufacturing and construction sectors, this knowledge transfer from molecular to material level can expedite the design of new alloys, fabrics, and coatings, leading to more effective and sustainable production (Zwerver et al., 2022).

Furthermore, data-driven technologies allow companies to create digital twins, or virtual replicas, of their products (Jones, 2018). These digital models can simulate how a product behaves under different conditions, helping businesses to refine their designs and make them more durable and efficient. By reducing the need for physical prototypes and by optimizing product performance, this approach can significantly decrease resource use and emissions.

Data-enabled servitization offers another layer of sustainability (Sklyar et al., 2019). Servitization can be broadly defined as the transformation of manufacturing companies from solely producing goods to delivering comprehensive solutions and services related to those goods. Some examples of manufacturing companies that use data-centred approaches to transition to service-focused business models include, but are not limited to, Rolls-Royce, Philips, Kone, and Hilti. Data-enabled servitization can decouple economic growth from resource consumption, creating a more sustainable and eco-friendly industrial landscape (Plekhanov et al., 2023). Servitization focuses not just on selling products, but also on selling the utility that those products provide, via a blend of products and services. One of the goals is to fulfil customer needs while minimizing environmental impact. For instance, consider the use of smart sensors and IoT technology. These can provide a wealth of data on product usage and performance. Analysing this data allows businesses to understand how their products are used, and can inform product refinements and the development of services that enhance the product's utility. This shifts the business focus from value-in-transaction to value-in-use, reducing resource use and emissions.

By integrating data-centred approaches across the product lifecycle, businesses can reduce waste, increase resource efficiency, and lower carbon emissions, thereby contributing to a more sustainable future.[11]

4. Data for sustainable energy production and management

The transition to a more sustainable and energy-efficient society is one of the most pressing issues of our time. Data-driven innovations have emerged as a vital solution in facilitating this

[11] Data plays a role as a double-edged sword in sustainability transitions. More on challenges associated with data use is listed in the section IV.

change, offering considerable benefits including improved quality and cost savings for users (Ardito et al., 2018). This synergy between data, energy efficiency, and sustainability is discernible through diverse technologies such as advanced metering infrastructure (AMI), energy management systems, predictive maintenance solutions, and demand response programs. The data these systems produce can potentially play an instrumental role in decarbonizing the energy sector, providing crucial insights that optimize resource usage, boost efficiencies, and facilitate the integration of renewable energy sources (Watson et al., 2010).

Data-driven innovations can optimize the real-time monitoring and management of electricity flow, allowing for more efficient routing and reduced transmission losses. Approximately 8% of the total electricity generated is lost during transmission and distribution processes (IEA, 2017). This loss, equivalent to the combined electricity demand of global iron and steel industries, residential and commercial lighting, and cooking applications, paints a vivid picture of the scale of these losses and the need for improving electricity systems' efficiency. In regions like Africa, Latin America, and India, the losses exceed 15% of the total electricity generated, nearly twice the global average. This high loss rate underscores the challenges these regions face in setting up efficient and reliable power grids (IEA, 2017). Countries can optimize their energy consumption by integrating data-enabled features like automated adjustments, demand response, and preventive maintenance. The result is not just economic savings but also a reduced carbon footprint, as less power needs to be generated to meet the same demand.

Data analytics offers further advantages, like extending the operational lifespan of power plants and network components (Jiang et al., 2022). This extension is made possible by advancements in maintenance practices and by minimizing the physical stresses on equipment. With the aid of extensive data from power plants and network infrastructure, potential issues can be pre-emptively addressed before escalating into severe problems that could lead to equipment failure. Predictive analytics, in this case, can detect patterns and anomalies in operational data that could indicate wear and tear or impending malfunction, facilitating targeted repairs and preventing costly breakdowns.

The longevity of power plants and network components carries a twofold economic advantage. On the one hand, it increases revenue for asset owners by extending the operational lifespan before replacement is needed, thereby improving the financial viability of power assets. On the other hand, it reduces investment requirements for the entire power system by prolonging equipment lifetime, leading to significant cost savings for the power sector and economy as a whole. These saved resources could be funnelled towards other critical areas such as research and development or renewable energy initiatives.

Moreover, the reach of data analytics is not confined to macro-level power system planning alone. It holds equal importance at the micro level, influencing the design of individual projects and augmenting their contribution to the system (Garcia Marquez and Peinado Gonzalo, 2022). Take the design of new wind power projects, for instance. Data aid engineers in creating more complex and efficient designs for wind farms. It helps in choosing the most suitable turbine technology and guides the strategic positioning of turbines within a wind farm. The optimization of wind resources and the mitigation of issues associated with wind power integration into the power grid are significant benefits of such data use.

Bridging the gap between micro and macro-level planning, data-centric approaches not only enhance individual projects but also revolutionize the broader energy landscape by breaking down traditional silos (Li et al., 2023; Lu et al., 2017). Currently, energy production and management often operate in silos across many countries, with sectors like electricity, gas, and heat, largely independent. This compartmentalization breeds inefficiencies and forgoes potential synergies. However, data-centric methodologies herald a sea-change. They have the potential to revolutionize the energy generation paradigm, transitioning from centralized to distributed models (Cheng and Yu, 2019). Such a transition promises electricity production closer to its consumption point, reducing transmission needs, and saving on infrastructure costs. These innovative methods allow us to better align generation sources with demand across different energy sectors, reducing strain on the transmission lines. Such cross-sectoral communication sets the stage for innovations like demand response, wherein power consumers adjust energy usage in response to supply changes or price signals. This adjustment, in turn, contributes to overall system balance and efficiency.

Looking at the larger picture, data-driven innovations have the capacity to weave renewable energy sources into the power grid fabric, thus enhancing overall sustainability (Abdalla et al., 2021; Kumar et al., 2021). The challenge posed by the intrinsic variability of renewable sources like solar and wind power due to weather conditions is considerable. This variability unsettles traditional energy systems designed around predictable power sources. Yet, it is here that data's pivotal role converts this challenge into an opportunity for a more resilient, sustainable energy future. Advanced data analytics aid in predicting renewable energy production based on weather forecasts with increasing precision. This application allows grid operators to adjust to fluctuations in power output, thereby reinforcing grid reliability and resilience.

Green energy platforms, another crucial development, link energy producers and consumers in novel ways, thereby introducing new cooperation forms among market players (Menzel and Teubner, 2021). This capability unlocks the potential of numerous small-scale generation and storage units, which had hitherto remained underutilized. Through effective coordination and bundling, these platforms maximize renewable resource usage and decentralize energy provision. The emergence of these green energy platforms also invites new players into the market. This influx introduces healthy competition into sectors previously monopolized or marked by oligopolistic tendencies (Richter et al., 2022). The resultant stimulation of innovation, reduction in prices, and improvement in service quality are clear boons for consumers. Concurrently, these digital platforms effectively manage the complexity brought by the decentralization of the energy sector. As the sector diversifies and spreads out, digital platforms provide the necessary architecture to organize, control, and optimize resources, ensuring energy distribution efficiency (Duch-Brown and Rossetti, 2020).

The adoption of a data-centric approach thus allows energy projects to maximize energy production and efficiency, contributing to a more sustainable power system. By doing so, we can push the future of renewable energy production towards increased sustainability, reliability, and cost-effectiveness. The strategic use of data analytics, thus, empowers us to turn the vision of an optimized, efficient, and sustainable power system into a reality.

B. Evidence-informed decision-making

Policymaking does not stay immune to the data revolution. Data-driven approaches can enhance policy formulation and design by leveraging more refined, real-time data analysis, potentially leading to better resource allocation (OECD, 2018). By linking data across various agencies, digital infrastructures can offer a broader context for policy matters, thus promoting a more cohesive inter-agency policy design.

The prospect of integrating different data systems, which include information on housing, economic indicators, environmental factors, and social data, for policymaking is extremely promising. This could pave the way for more comprehensive and effective decision-making. This increased connectivity could lead to a comprehensive data ecosystem encapsulating a nation's entire socio-economic dynamics. Armed with such a vast and integrated data resource, policy makers would be in a unique position to derive concrete interrelations, e.g., between publicly funded research and real-world impacts. This could span from discerning the impact of science on economic growth, to understanding the role of regional start-ups in sustainability transitions.

Real-time policy data can enable prompt policy modifications and the identification of trends, contributing to strategic policy planning. Policymakers can use insights derived from data analysis to allocate resources efficiently to maximize their impact. Data help identify regions or communities that are most in need, ensuring that resources are targeted to address disparities and inequalities effectively. Insights drawn from data analytics can guide policymakers in resource allocation to optimize outcomes.[12] By pinpointing the areas or populations with the highest needs, data ensures that resources directly tackle disparities and imbalances effectively.

Box 4. Selected examples of data use in policymaking

In Cameroon, the Displacement Tracking Matrix (DTM) gathers and analyzes data to disseminate critical multi-layered information on the mobility, vulnerabilities, and needs of displaced and mobile populations. This initiative enables decision-makers and responders to provide context-specific assistance, thereby improving the lives of populations facing challenging situations, such as those affected by Boko Haram's activities in northern Cameroon.[13]

UN ESCAP is collaborating with 16 nations in Asia and the Pacific to deploy the National SDG Tracker, a tool designed to monitor progress on the SDGs. This tool facilitates countries in inputting their data, setting national target figures, and effortlessly visualizing their progress. Additionally, ESCAP is partnering with several countries to enhance their civil registration and vital statistics systems, which form the foundation for various government services, including digital ones.[14]

UN ESCWA introduced the ISPAR platform to guide policymakers in selecting optimal policies and procedures to improve national performance across various indicators, including the Open Data Inventory index (ODIN). This platform provides a comprehensive view of a country's standing in official statistics and data accessibility, aiding in the identification of areas for improvement and benchmarking progress against international standards.[15]

The extensive data available through public data systems not only help in trend predictions and policy modifications but also serve as a goldmine for information discovery (OECD, 2020a). The data, spanning a broad range of inputs, outputs, and activities, can identify emerging issues (box 4). One of the potential avenues is the use of data for gender mainstreaming. Data-centred approaches can identify, monitor, and address gender disparities, paving the way for a more equitable world. By revealing disparities, guiding interventions, and tracking progress, data can help policymakers ensure that citizens have an equal opportunity to succeed in every function and at every level. But the key lies in not just collecting the data, but in using it responsibly and effectively to drive meaningful change.

1. Data analytics to combat the climate change

Climate change poses a grave threat to humanity, and data-driven innovations both contribute to the problem and offer potential solutions.[16] Data-driven innovations can mitigate climate change risks by providing insights and solutions for effective environmental management (Pee and Pan,

[12] Contribution from the Government of Egypt.
[13] Contribution from the Government of Cameroon.
[14] Contribution from the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP).
[15] Contribution from the United Nations Economic and Social Commission for Western Asia (UN ESCWA).
[16] UN Economic and Social Council resolution, *Socially just transition towards sustainable development: the role of digital technologies on social development and well-being of all*, E/RES/2021/10, (8 June 2021), available from undocs.org/en/E/RES/2021/10.

2022). The transformative potential of data extends far beyond its ability to optimize energy consumption, decrease water usage, or minimize land utilization. While these benefits are certainly significant, they represent just the surface of what data-driven innovations can truly contribute to individuals and society at large. The deeper, more profound value of data can be found in its ability to galvanize effective environmental governance. Understanding the potential of data in environmental governance necessitates an appreciation of the complex interplay between various ecological, social, and economic dimensions that underpin the climate change (Cowls et al., 2023).

Climate change challenges require concerted and coordinated efforts from multiple stakeholders to address them effectively. Data-centred approaches could act as a critical tool for understanding environmental patterns, predicting future scenarios, and thus, supporting the formulation of policies that consider the full range of environmental and societal implications. Data can also aid in monitoring and enforcement, which are two critical aspects of environmental governance. Granular and timely data insights can be leveraged to monitor compliance with environmental regulations and to identify instances of non-compliance swiftly (Denney, 2022). This would not only foster accountability but also ensure that corrective measures are taken in a timely manner, thus preventing further environmental damage.

A key facet of data's potential lies in its capacity to support both nature-based climate mitigation methods and innovative technological solutions for greenhouse gas removal (Cowls et al., 2023). Nature-based climate mitigation measures, like reforestation, agroforestry, and peatland restoration, rely on the power of ecosystems to absorb and store carbon dioxide. Implementing these measures effectively requires a detailed understanding of numerous factors, such as the types of vegetation best suited for carbon sequestration in a given area, the optimal planting strategies, and the likely impacts of climate change on these ecosystems. This is where data-driven innovations can play a pivotal role. For instance, earth observation data can be used for monitoring terrestrial ecosystems as they have sufficient electromagnetic spectral resolution to be able to distinguish between plant species based on how they reflect light. These insights enable governments and communities to develop targeted measures to conserve biodiversity.[17] By processing vast amounts of data—from climate patterns to soil composition—data analytics can provide new insights and assist in the design and implementation of more effective nature-based solutions.

Furthermore, data analytics can enhance the efficiency of carbon capture and storage (CCS) technologies, a promising yet intricate solution for greenhouse gas removal (Priya et al., 2023). AI algorithms can be utilized to optimize their efficiency and cost-effectiveness. For example, it can help predict where carbon capture is likely to be most effective, optimize the operation of capture technologies, and monitor the safe and permanent storage of carbon (Whitman et al., 2021). By doing so, data-driven innovations can be instrumental in scaling up the deployment of these vital greenhouse gas removal technologies.

Space technologies offer another avenue, generating indispensable data to monitor and assess the triple planetary crisis, which consists of climate change, biodiversity loss, and pollution (**Box 5**). These technologies provide accurate and timely information about the scale and progression of these interconnected crises, as well as the resulting impacts on ecosystems, economies, and societies. By tracking changes in temperature, precipitation, land use, and other environmental factors, space technologies can reveal trends and patterns that inform mitigation and adaptation strategies.

Data analytics' ability to delve deep into marine ecosystems is also noteworthy. Data-centred approaches can uncover patterns and trends within ocean data, enabling us to understand and

[17] Contribution from the United Nations Office for Outer Space Affairs (UNOOSA).

determine the level of industrialization and resource extraction that marine ecosystems can sustain (Lowerre-Barbieri et al., 2019). This approach involves collecting and analysing data related to marine biodiversity, population dynamics of aquatic species, pollution levels, climate change impacts, and human activities such as fishing and offshore drilling. Data-centred approaches can further improve resource extraction from undersea geological formations to minimize the environmental impact. By collecting and analysing data, we can gain valuable insights into the carrying capacity of marine ecosystems, which can assist in setting sustainable quotas for industrialization and resource extraction.

In the business sector, data analytics can play a pivotal role in carbon footprint tracking. Everything from the sourcing of raw materials, manufacturing processes, distribution methods, usage patterns, and end-of-life disposal is accounted for. AI algorithms can then process this large and complex dataset, providing a precise calculation of the carbon footprint (Rolnick et al., 2022). With this detailed and data-driven understanding of their carbon footprint, organizations can identify the most carbon-intensive aspects of their operations or products. This is an essential first step in formulating effective strategies for carbon reduction. For example, a manufacturing company might find that a significant portion of its emissions comes from its energy consumption. In response, it could invest in energy-efficient technologies or transition to renewable energy sources.

Box 5. Satellite data for the Sustainable Development Goals (EO4SDGs)

Space-borne satellite communication networks have become a critical asset in providing internet connectivity to communities worldwide, especially in developing countries where terrestrial infrastructure is either unreliable or non-existent. Satellite communication systems have contributed to bridging the digital divide, bringing internet access to remote areas, and enabling individuals, communities, and businesses to access a wealth of information and resources previously unavailable. One of the key reasons that satellite communication networks are invaluable for internet connectivity in developing countries is their ability to provide coverage over vast geographical areas without the need for extensive physical infrastructure. In regions where it is difficult or prohibitively expensive to lay down cables or build cell towers due to geographical challenges, such as mountainous terrain, deserts, or islands, satellite communication offers a viable alternative.

This capability is especially crucial for isolated communities or areas vulnerable to natural disasters like earthquakes, floods, or typhoons, where terrestrial infrastructure can be easily damaged or disrupted. Satellite communication networks also offer a level of resilience and redundancy that terrestrial networks may struggle to provide. With a satellite network, communication can still be maintained even if one or more ground-based facilities are compromised or disabled. This level of resilience is crucial in regions prone to natural disasters, political unrest, or other disruptions to terrestrial infrastructure. Space-based communication networks also offer rapid deployment capabilities, which is essential in emergency situations or for quickly establishing connectivity in newly developed regions. Satellites can be launched, and ground stations can be set up within a relatively short timeframe compared to the time required to build an entire terrestrial network.[18]

Data-driven technologies like blockchain can provide a transparent and immutable record of a company's carbon emissions data (Upadhyay et al., 2021). This traceability not only allows businesses to demonstrate their sustainability efforts to consumers and regulators, but it also enables third-party verification of emissions data, fostering trust and accountability. Data-driven carbon management can go beyond direct operations and encourage more sustainable behaviour across the supply chain. For instance, companies can use carbon footprint data to favour suppliers that adopt low-carbon technologies. This not only reduces the total emissions associated with the company's products but also incentivizes other companies to reduce their

[18] Contribution from the Group on Earth Observations (GEO).

own emissions. Predictive data analytics can also play a critical role in CO2 reduction efforts. Predictive models can forecast future emissions based on various factors like production levels, energy sources, and technology use. With these insights, companies can make proactive changes to their operations and strategies, mitigating their future environmental impact. The resulting decrease in CO2 emissions is not just good for the planet but also beneficial for businesses as they navigate a world with increasingly stringent environmental regulations and growing consumer demand for sustainable practices.

In summary, the true value of data in the battle against the climate change lies not just in how it can help us use resources more efficiently, but more importantly in how it can facilitate a more comprehensive, informed, and effective approach to environmental governance. This elevated understanding empowers us to craft policies and strategies that are more robust and tailored to our specific needs. Data equips us with the information we need to formulate policies that are not only reactive but proactive, enabling us to anticipate future environmental challenges and address them before they escalate. Through enabling better understanding, policy formulation, and enforcement, data holds immense promise in fostering a more sustainable and resilient world. By implementing these data-centred approaches, organizations can take significant strides towards reducing their carbon footprint, contributing to global climate change mitigation efforts. These efforts, multiplied across numerous organizations globally, can contribute significantly to the larger, collective fight against climate change.

2. Data-driven transformation of agricultural systems and improved nutrition

Data-driven innovations hold enormous potential to transform agriculture, creating a more sustainable and equitable food system that could help end hunger and improve nutrition worldwide (Basso and Antle, 2020) (**Box 6**). Data from various sources—such as weather forecasts, soil sensors, satellite imagery, and drones—can be harnessed to inform precision farming techniques. Public authorities can aggregate data—like food security information, weather, population size, conflict, hazards, nutrition, and macro-economic data—to predict and monitor the food security situation in near real-time.[19] Data analytics can optimize the use of water, fertilizers, and pesticides, increasing yields while reducing the environmental impact. For instance, predictive models based on weather data can guide farmers on the best times to plant and harvest, minimizing crop losses (**Box 7**). Similarly, soil sensors can provide real-time data on nutrient levels, moisture content, and pH, enabling farmers to tailor their farming practices accordingly, enhancing soil health and crop productivity.

Box 6. The impact of data-driven technologies on agriculture

Land assessment: data-driven technologies facilitate the detailed evaluation of the land's quality, productivity potential, and its susceptibility to diseases and pests. It incorporates the usage of satellite imaging and remote sensing technologies to provide critical insights about the land's condition, including soil moisture, vegetation indices, and topographical features.

Soil-crop suitability: intelligent algorithms help in understanding which crops are best suited for particular types of soil, based on its properties like pH level, fertility status, organic content, and more. The technology utilizes data science to analyse and interpret vast amounts of soil data, enabling farmers to make informed decisions regarding crop selection and rotation.

Weather forecasting: advanced predictive modelling techniques are used to forecast weather patterns. This includes predicting rainfall, temperature fluctuations, humidity, and potential extreme weather events. Such detailed meteorological information allows farmers to optimize their farming schedules and safeguard their produce against adverse weather conditions.

[21] Contribution from the United Nations Office for Outer Space Affairs (UNOOSA).

Precision farming: By leveraging tools like AI-powered drones and sensors, real-time monitoring of crops is possible, leading to early detection of diseases, precise estimation of biomass, and prediction of yields. This level of granular observation optimizes productivity and reduces losses. The introduction of precision farming, a methodology that relies heavily on data and technology, has helped farmers optimize their inputs and resources. By employing GPS, satellite imagery, and IoT-based sensors, precision farming ensures that each portion of a field receives the exact care it needs. This results in reduced wastage of resources and an increase in overall yield.

Agricultural supply chain management: data analytics can help optimize the routes for delivery, reducing fuel consumption and ensuring timely deliveries. Additionally, smart packaging technologies can monitor and control the storage conditions to extend the shelf-life of the products. At the consumption stage, these technologies can help track and reduce food waste by providing insights into consumer behaviour. In the realm of agro-waste management, smart technologies can enable efficient waste segregation, recycling, and disposal, contributing to a sustainable agricultural system.

Agriculture, being a vital component of the global economy, is also a significant contributor to greenhouse gases (GHGs) emissions, including carbon dioxide, methane, and nitrous oxide. These emissions emanate from a variety of agricultural practices such as synthetic fertilizer usage, deforestation for farmland, livestock rearing, rice cultivation, and burning of agricultural residues, all contributing significantly to global warming and climate change. In this context, data-based agricultural practices emerge as a beacon of hope, offering a potential solution to these existing challenges. These data-centred approaches holistically integrate the benefits of sustainable production, climate resilience, and reduced GHGs emissions, painting a promising picture of the future of farming. For instance, by analyzing data on livestock rearing practices, feed optimization techniques can be introduced to reduce methane emissions from cattle. Similarly, the use of digital tools can facilitate a shift towards more sustainable farming practices, like agroforestry or organic farming, that sequester carbon and reduce the use of synthetic fertilizers, thereby lowering emissions.

Box 7. Empowering sustainable development: leveraging remote sensing data and GIS for agriculture

By leveraging high-frequency satellite and aerial imagery of our planet, remote sensing data, combined with geographic information systems (GIS), provide capabilities that extend well beyond traditional data sources such as censuses, administrative records, and surveys. With the ability to accurately identify and assess cropland classifications promptly, especially when integrated with machine learning algorithms, satellite data holds the potential to revolutionize agricultural and crop monitoring systems. It optimizes agricultural practices, efficiently allocates resources, and responds swiftly to evolving conditions.

The effectiveness of satellite data in addressing food insecurity is particularly evident in its ability to create precise cropland classifications. Such classifications not only enhance crop monitoring systems but also bolster disaster management mechanisms. As the effects of climate change continue to exert significant pressure on the agricultural and food security systems of developing countries, the need for these advanced tools becomes even more pressing.

In this context, satellite data prove indispensable in evaluating crop damage resulting from adverse climatic events, such as monitoring floods and assessing agricultural loss in developing countries using readily available remote sensing data. By mapping flooded areas quickly and determining crop survival rates, decision-makers can derive critical insights into the location, scale, and severity of a crisis. This vital information aids in formulating precise response strategies and allocating resources efficiently, thereby reducing the potential impacts on food security. Such advancements edge us closer to a future where crop yields maximize their potential, food security is fortified, and our global food systems are both adaptive and sustainable.[20]

Data can revolutionize food supply chain management, promoting fair distribution systems. By tracking and analysing data along the entire supply chain, we can improve transparency and traceability of products (Dora et al., 2022). This ensures that farmers are paid fairly for their produce, encourages sustainable practices, and reduces food waste by matching supply with demand more accurately. Blockchain technology, for instance, is being used to create immutable records of transactions, fostering trust and accountability in food supply chains (Vu et al., 2023).

In terms of nutrition, data-driven insights can guide policymaking and intervention design. By analysing data on dietary patterns, malnutrition rates, and the availability of nutritious food, targeted strategies can be developed to improve access to and consumption of nutritious food (Ben Ayed and Hanana, 2021; FAO, 2022). This can help address malnutrition in all its forms — from undernutrition to overweight and obesity. Furthermore, data can facilitate research and development in crop breeding. By analysing genomic data, researchers can identify traits linked to disease resistance, drought tolerance, or nutritional content, accelerating the development of more resilient and nutritious crop varieties.

In conclusion, data have the potential to create a more sustainable, resilient, and equitable food system. From the field to the dining table, data-driven insights can optimize resources, improve yields, foster fair trade, reduce waste, and enhance nutrition. As we face the challenges of climate change and a growing global population, leveraging data in agriculture becomes ever more crucial.

3. Data-centred approaches in urban planning and development

Data-driven innovations offer transformative opportunities in urban development. Data analytics can aid in anticipating demographic growth patterns, streamlining traffic and transport systems, and supporting environmental sustainability initiatives (UNCTAD, 2022c). Data also hold the key to promoting equitable urban growth, exposing socio-economic divides, and enabling specific, targeted intervention strategies (Zekić-Šušac et al., 2021). The landscape of urban data collection is expanding. Sources range from social media and mobile phone data to satellite imagery, all of which can enhance our existing models. These resources enable quick, informed decisions.

The role of Earth Observation data

Earth Observation (EO) data, in particular, are instrumental in evaluating vulnerabilities when planning infrastructure locations, particularly in areas susceptible to natural hazards like floods and fires (**Box 8**). Additionally, EO data contribute to climate modelling, enabling assessments of evolving risks from climate projections. After infrastructure construction, both EO and Global Navigation Satellite Systems (GNSS) data can be used to monitor land deformation and detect shifts in the Earth's surface that could lead to infrastructure damage due to instability.[21]

Box 8. The Global Heat Resilience Service

The Global Heat Resilience Service is an initiative spearheaded by the Group on Earth Observations (GEO) that brings together partners to create a service aimed at providing every urban area worldwide with insights into the health risks associated with exposure to extreme heat. By leveraging global, regional, and local data, including Earth observations from satellites and in-situ measurements, as well as statistical and geospatial data, local surveys, and field measurements, this decision-support tool aims to help cities better understand the health risks posed by extreme heat. This user-centric,

[21] Contribution from the United Nations Office for Outer Space Affairs (UNOOSA).
[21] Contribution from the United Nations Office for Outer Space Affairs (UNOOSA).

trustworthy, free, and open-access tool will enable cities to collect, analyse, and integrate data and knowledge from various sources, including weather, health, demographics, the built environment, infrastructure, and social factors, in order to develop adaptive plans that reduce the impact of extreme heat on citizens' health and local economies. Furthermore, by incorporating citizen-science and data collection initiatives, the service aims to empower communities, including young people, to actively participate in enhancing knowledge about heat vulnerability within their cities.[22]

Crowdsourcing for urban planning

A particular method of non-traditional data collection gaining significance is crowdsourcing (Brem et al., 2023). Crowdsourcing relies on voluntary input from the general public, democratizing data collection and fostering a sense of community cooperation. Crowdsourcing can identify and illuminate gaps in our current understanding and measurement of the SDGs, potentially leading to the development of new goals and targets (Fritz et al., 2019). This underscores its capacity to facilitate bottom-up approaches to problem identification and solving, bringing forth insights that traditional data sources may overlook or be incapable of capturing. Digital platforms leveraging crowd-sourced data herald a shift in our comprehension of, and approach to, urban planning (Brabham, 2009). These platforms integrate and interpret data collected from a wide range of sources including city inhabitants, tourists, urban planners, and policymakers. The result is an all-encompassing, detailed knowledge repository that can substantially improve our understanding of intricate problems faced by urban areas.

Crowd-sourced data platforms offer real-time, geo-specific insights into an array of urban complications such as traffic bottlenecks, pollution intensity, utilization of public infrastructure, and housing requirements, to name a few. By involving the city's inhabitants—essentially forming a community of contributors—these platforms promote a sense of participation and ownership over the planning and developmental processes (Crooks et al., 2015). This democratic approach can result in a more intricate understanding of urban issues and can empower citizens to take an active role in formulating solutions.

Moreover, the incorporation of crowd-sourced data in urban planning bears significant implications for enhancing the accessibility and inclusivity of urban spaces. Accessibility, in this context, encompasses not just physical access but also social and economic inclusivity. For example, data shared by individuals with disabilities can pinpoint accessibility challenges in public spaces—such as insufficient wheelchair ramps or inadequate public transportation services—and can instigate the necessary modifications. Likewise, feedback from socio-economically underprivileged communities can illuminate shortcomings in public services or infrastructure, thereby guiding more equitable urban development strategies.

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Data-enabled technologies for urban planning

On the technological front, digital twin technology and Building Information Modelling (BIM) are making significant inroads in urban development (Opoku et al., 2021). Digital twin technology is an innovative method for modelling, understanding, and predicting the functioning of different systems or objects in dynamic environments. This technology uses real-time data to construct a

[22] Contribution from the Group of Earth Observations (GEO).

virtual 'twin' of a physical object, enabling in-depth simulation of its operation under diverse conditions. The predictive insights gathered from these simulations can significantly influence decision-making processes to optimize maintenance and plan more proactively (Boje et al., 2020). For instance, EO and GNSS data can be used to create digital twins of cities through 3D modelling, enabling a comprehensive virtual representation of urban areas. These digital twins allow for real-time visualization, monitoring, and prediction of natural and human activities within the city.[23]

BIM supports sustainable urban development by facilitating more energy-efficient designs by predicting the performance of various systems such as heating, ventilation, and air conditioning (Succar, 2009). BIM also allows for a cradle-to-grave analysis, considering the environmental impact of materials from extraction and manufacturing to use, maintenance, and eventual demolition. Finally, it enables accurate estimations and efficient planning during the construction process, thus minimizing waste production (Volk et al., 2014).

By creating a detailed, dynamic, digital representation of physical structures, it becomes feasible to visualize, monitor, and manage the building's lifecycle from inception to demolition. Digital twin and BIM technologies offer a comprehensive, data-driven perspective to observe and predict how the building will interact with various environmental factors and usage patterns over its lifespan. In addition, data-driven innovations like smart grids for utilities like electricity and water, which can optimize usage and reduce wastage, contributing to more sustainable cities (Barai et al., 2015).

In conclusion, advanced data applications can trigger a transformation in urban planning, by encouraging community participation, empowering decision-making, optimizing resource use and enhancing the accessibility and inclusivity of urban spaces. This represents an encouraging trajectory towards the establishment of more habitable, sustainable, and resilient urban areas.

4. Data-centred approaches for disaster management

By leveraging vast amounts of data, analytical tools can provide crucial information during and after natural disasters, consequently helping in effective disaster relief and mitigation efforts.[24] Data analytics can help map floods with a high level of precision. This mapping can be pivotal in shaping the response strategies of relief agencies by directing them to the hardest-hit areas. Not only that, but these models can also be used to forecast future flood events based on climate data, enabling preventative measures to be taken. Similarly, AI can be instrumental in locating refugee camps using satellite data (Logar et al., 2020). During major disasters, the prompt location and assessment of refugee camps become essential to determine the necessities and priorities for relief efforts. Algorithms can help locate these camps even in remote or inaccessible areas, ensuring that aid reaches those who need it most.

Digital platforms effectively dismantle geographical boundaries during disaster management. With these data-driven innovations, online emergency responses are not confined to specific localities but instead can span across continents, connecting affected people with a global network of helpers. This global reach, enabled by data-driven approaches, has fundamentally changed the dynamics of disaster response, making it more inclusive, immediate, and effective (Nan and Lu, 2014).

During the southern California wildfires in 2007, Hurricane Katrina, 2014-2016 Ebola outbreak, and COVID-19, ordinary people utilized online forums as a means of citizen engagement, communication and coordination in these crises (OECD, 2020b; Palen et al., 2009; Sutton et al.,

[23] Contribution from the United Nations Office for Outer Space Affairs (UNOOSA).

[24] Contribution from the United Nations Office for Outer Space Affairs (UNOOSA). UNOOSA designed the UN-SPIDER platform to support countries throughout the entire disaster management cycle using space technologies. This technological assistance enables countries to become more resilient when a disaster strikes.

2008; UN, 2015). In response to the devastating floods that struck Pakistan in 2022, Code for Pakistan, a local civic innovation organization, launched a crowdsourcing platform called Floodlight (WEF, 2023). Floodlight was established to gather and share flood-related data from across the nation. Tapping into the power of collective data from millions of citizens affected by the floods, the initiative aimed to create a comprehensive, real-time map of the impacted regions. This effort proved instrumental in understanding the scope of the flood's impact, helping to address the needs of affected communities more effectively.

In the similar vein, geographically dispersed volunteers used digital platforms during the 2007 San Diego wildfires and the 2008 Wenchuan earthquake to create a complex system of information sharing, aggregation, and visualization orchestrated by these volunteers (Majchrzak and More, 2011; Nan and Lu, 2014). The suite of data-driven technologies deployed demonstrated how such tools could significantly augment the capacity of ordinary citizens to respond to disasters and share critical information in real-time through crowdsourcing.

5. AI: the new frontier in accelerating scientific discovery

Enhancing and aiding research may represent the most significant economic and social benefit derived from AI and other data-enabled technologies. By enabling quicker data analysis, reducing operational costs, fostering novel hypotheses, and facilitating groundbreaking discoveries, AI not only streamlines the scientific research but also unlocks new knowledge, potentially accelerating progress across various fields and catalysing innovation (King et al., 2009; Van Noorden and Perkel, 2023).

By analysing vast amounts of data and identifying patterns that may not be evident through conventional research methods, AI can uncover unique insights into local problems such as climate adaptation strategies. This can lead to more targeted and effective policy interventions, specifically tailored to the needs and conditions of these regions. AI's ability to process and interpret local data can thus play a crucial role in shaping research agendas that address the specific challenges faced by developing countries.

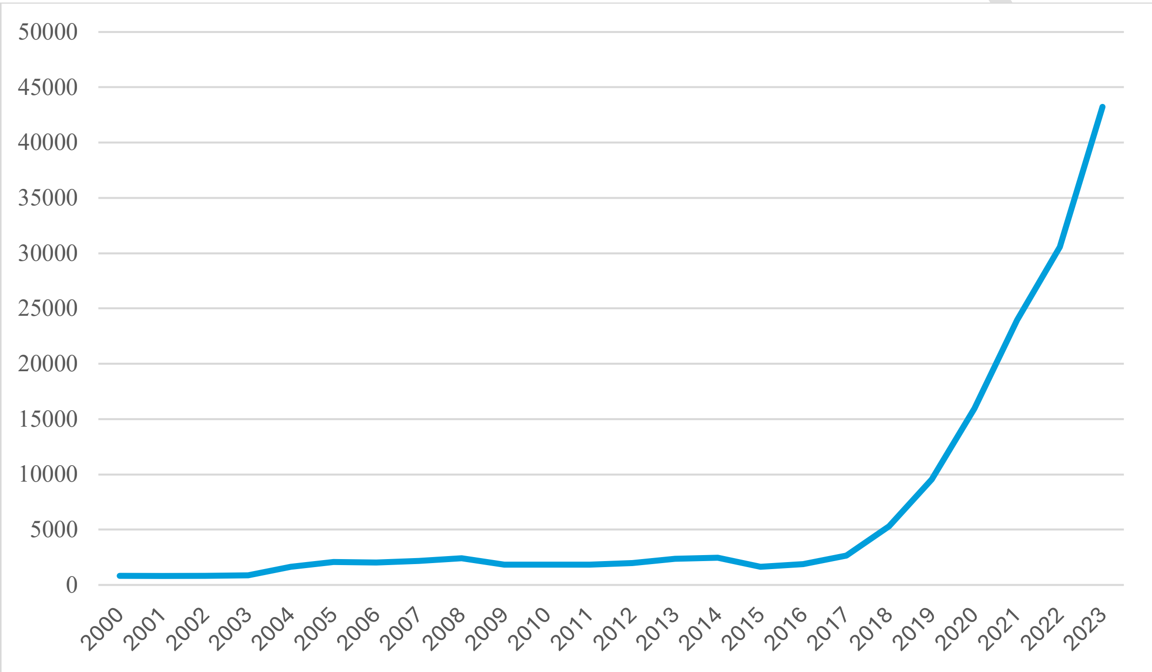
AI has become a hot topic in academic research, with a relatively stable and modest number of publications up until about 2016 (**Figure 2**). From 2016 onwards, there is a noticeable increase in the number of articles, with a sharp exponential growth beginning around 2019. In 2023, the majority of articles on AI were published in the fields of information and computing sciences, biomedical and health sciences, and engineering. Additionally, the field of management and business research experienced a significant increase in academic articles on AI, rising from 277 in 2017 to 3,271 in 2023, thereby becoming one of the largest fields for publishing research related to AI.

The integration of AI into scientific research promises to enhance human capacity to analyse complex systems and interpret vast datasets beyond human ability alone. In the field of nuclear physics, scientists utilized reinforcement learning, a form of machine learning, to master the control of super-heated plasma within a tokamak[25] for nuclear fusion experiments (Degrave et al., 2022). This AI-powered approach enabled precise manipulation of plasma shape and stability, solving a complex optimization challenge that has long baffled nuclear physicists. By facilitating risk-taking in experimental settings that would otherwise be deemed too hazardous, AI broadens the scope and scale of research exploration. Reinforcement learning uncovered new plasma configurations, marking a significant advancement in nuclear fusion research.

[25] A tokamak is a device used in nuclear fusion research, designed to contain and control hot plasma with magnetic fields, enabling the conditions necessary for fusion reactions to occur. It represents one of the most promising methods for generating sustainable electric power.

Deep learning methods represent a leap forward in life sciences, providing a powerful tool for unravelling the complex relationship between protein sequences and their structures, which is crucial for understanding protein function (Senior et al., 2020). Proteins are made up of long chains of building blocks (amino acids) that fold in specific ways to form a unique 3D shape. This shape is crucial because it determines what the protein can do in our bodies. Traditionally, figuring out these 3D shapes required lots of time and expensive experiments. But now, researchers can train neural networks to learn from patterns of how different proteins have folded before (Hassabis, 2022). AI can predict not just which parts of the protein will be neighbours but also how the entire chain will look in 3D space. This capability has huge benefits for medicine, such as accelerating drug discovery and enhancing our understanding of genetic diseases.

Figure 2. AI-related academic articles



Source: Dimensions.AI

Moreover, AI can be used to design enzymes—proteins that speed up chemical reactions—with specific characteristics or improved functionalities, thereby aiding in enzyme engineering (Siedhoff et al., 2020). Researchers to create enzymes that are more efficient, stable, and tailored to particular industrial needs. This capability is particularly beneficial for the production of biofuels, where enzymes are used to break down biomass into usable fuel, or in industrial processes, where they can catalyse chemical reactions more environmentally friendly at lower costs. In environmental management, engineered enzymes can be used to degrade pollutants or convert waste into valuable products, thus contributing to sustainable development and environmental conservation efforts.

Despite the tremendous role AI plays in accelerating scientific research and increasing its productivity (OECD, 2023a), there are several challenges that need to be addressed to fully unravel the catalytic role of AI in science. Data-driven AI models face challenges in generalization and validation, such as failing to recognize new variables not present during training (Kelly et al., 2019). Efforts to develop fully validated AI models with quantifiable failure risks are underway but require significant innovation for real-world applications. Additionally, AI models, adept at identifying correlations, require the development of causal models to distinguish between correlation and causation, an area ripe for further research facilitated by AI's ability to simulate real-world scenarios (Hünermund and Bareinboim, 2019; Schölkopf et al., 2021). Differentiating between correlation and causality is especially crucial in fields such as medicine, where reliance solely on statistical correlations can pose significant risks (Liu et al., 2021).

AI could help bridge the gap in research capabilities by providing developing countries with tools to leapfrog to advanced research methodologies, bypassing some of the traditional barriers such as limited infrastructure and funding. AI could potentially democratize access to high-level scientific analysis. This could be achieved through shared AI resources, collaborative platforms, and open-source AI models that do not require extensive computational resources. On the other hand, the effectiveness of AI in the Global South is contingent upon the availability of high-quality data and the ability to train models that are relevant to local needs and challenges. Without adequate training data, technical expertise, and contextual adaptation, there is a risk that AI could widen the existing scientific gap, as more developed countries continue to accelerate their capabilities at a faster rate. Therefore, while AI presents significant opportunities for developing countries, international efforts are necessary to ensure AI tools are accessible and adapted to meet local needs, thereby potentially narrowing the scientific divide between the Global South and the Global North.

The pursuit of resolving these challenges within the application of AI in research underscores the critical need for open science and open access on a global scale. Open science facilitates the unrestricted sharing of knowledge and methods among the global research community, enhancing transparency and reproducibility in scientific endeavours. By promoting open access to datasets, algorithms, and research findings, scientists from diverse backgrounds and regions can collaborate more effectively, leveraging collective expertise to tackle the complexity of AI challenges.

The democratization of knowledge not only accelerates scientific discovery but also ensures that innovations are widely accessible, reducing geographical and economic disparities in research capabilities. Furthermore, open science principles encourage the creation of multidisciplinary approaches necessary for developing robust AI systems that are safe and effective across different contexts and cultures. As AI continues to evolve, fostering an open and collaborative scientific environment is essential for advancing data-enabled technologies in a manner that is both inclusive and ethically sound, ultimately bridging digital divides and addressing climate change.

6. *Data-driven innovations in healthcare and health research*

Data-driven innovations provide the foundation for the digital healthcare revolution, delivering improvements in individual care and advancing innovation in medical research. Data can contribute to (1) precision medicine conceptualized as "the right drug, for the right patient, at the right time" (Abrahams, 2008); (2) evidence-informed healthcare governance that can streamline organizational routines and optimize costs (UNCTAD, 2022d); (3) breakthroughs in medical research and drug development (Burki, 2020).

Data-driven management practices can help identify inefficiencies in various healthcare processes, from patient admission to treatment and discharge (Langell, 2021). By analysing data from these processes, providers can pinpoint where bottlenecks occur, how much time is wasted, and where errors are most likely to happen. Data-driven lean management in hospitals can enhance patient safety and quality of care (Chakraborty et al., 2023). By reducing errors and inefficiencies, providers can deliver more reliable and effective treatments. Data-driven approaches can also minimize the risk of errors, such as misdiagnoses or medication errors, by standardizing procedures and implementing safety checks.

Telehealth, the use of data and digital technology to provide remote healthcare services, is another transformative innovation enabled by data (Dorsey and Topol, 2016). An example of such an initiative is the Philippines' RxBox, a telehealth system that enables health workers to diagnose, monitor, and treat patients within rural health facilities.[26] Particularly in regions with underdeveloped healthcare infrastructure, telehealth bridges geographical barriers, ensuring that healthcare reaches even the most isolated communities (Weinstein et al., 2018). This aspect was critically highlighted during the COVID-19 pandemic when telehealth proved to be an essential tool for healthcare delivery amidst lockdowns and social distancing mandates (Behar et al., 2020). The decreased use of medical resources through the adoption of telemedicine can result in significant cost savings. This efficiency can help direct the saved resources towards other pressing healthcare needs, thereby enhancing the overall effectiveness of the healthcare system (Lin et al., 2017).

Novel technologies can analyse information that is well beyond the grasp of human cognition, managing to discern patterns and associations that may elude even the most experienced medical practitioners. They can consider a plethora of variables simultaneously, assessing probabilities and outcomes based on a multitude of factors. This ability to weigh complex data and make decisions based on probabilities is instrumental in driving advancements in healthcare. Advanced imaging techniques allow for the intricate analysis of the human body, leading to early detection of diseases (Link, 2012; Ng et al., 2021).

Data-enhanced medical imaging can spot early-stage tumours, complications from diabetes, heart-related issues, infections like COVID-19 in the lungs, and even the progression of neurological disorders like Alzheimer's. For instance, the Peruvian Ministry of Development and Social Inclusion collected eye data from patients to develop a digital application for early detection of anaemia.[27] The early identification of these conditions is pivotal. Recognizing a disease like cancer using nuclear medicine in its initial stages and promptly following up with treatments such as radiation oncology can greatly enhance treatment outcomes and reduce mortality.[28] In essence, the marriage of data and healthcare through these advanced technologies facilitates proactive medical interventions and more personalized patient care.

Technological advancements can also improve the field of pharmacogenetics by offering a powerful toolset for genetic data analysis, interpretation, and decision-making. Pharmacogenetics, which is the study of how genetic variations influence an individual's response to drugs, relies on the ability to interpret and analyse vast amounts of genetic data. Data analytics enable researchers to sift through large databases of genetic information more rapidly and accurately than ever before. Some public and private institutions already apply AI to genomic data from thousands of oncology patients and enable a continuous data loop from identifying a patient, confirming genomic signature, treatment selection, and monitoring outcomes (Boev et al., 2021; Fedorov and Gelfand, 2021). Rapid genome sequencing could help identify genetic markers for diseases, enabling earlier detection and potentially leading to breakthroughs in designing targeted treatments (e.g., Alzheimer's, Parkinson's) (Emani et al., 2021; Marx, 2021).

In conclusion, the transformative potential of data-driven innovations in the healthcare sector is undeniable. From enhancing individual patient care through precision medicine to revolutionizing medical research, data play a central role in contemporary medical advancements. As we continue to harness and integrate data-driven solutions and methodologies, the future of healthcare looks increasingly promising, underpinned by efficiency, inclusivity, and groundbreaking discoveries.

[26] Contribution from the Government of Philippines.
[27] Contribution from the Government of Peru.
[28] Contribution from the International Atomic Energy Agency (IAEA).

IV. Challenges of data for development

Section IV provides an in-depth analysis of the challenges faced by both public and private organizations when attempting to leverage data for decision-making or business innovation. The section highlights the fundamental prerequisites that organizations must fulfil to effectively use data. Elements such as data quality, the availability of digital infrastructure, and the organizational embrace of data-driven approaches are critical. Beyond these foundational requirements, the section also examines the systemic challenges arising from data utilization. These systemic problems are highly varied, covering issues from negative impacts on market competition to discrimination based on data.

In the past, technological advancements expanded human capabilities, such as facilitating heavy transportation and enabling faster mathematical calculations. However, the current wave of technological changes introduces data-driven innovations that possess the ability to learn faster than humans and operate autonomously without human intervention. For example, the proliferation of IoT and advancements in machine learning algorithms enable the creation of self-regulating factories (lights-out factories) that can perform operations with minimal human involvement. Unlike the past, where many innovations relied on human labour, the current focus of data-driven innovations is on reducing labour and resource costs, which leads to a decreased demand for a highly skilled workforce and contributes to knowledge and wage inequality (Korinek et al., 2021).

Previously, the rapid diffusion of technologies across countries and firms held the promise of future convergence between developed and developing nations. However, with the advent of the data economy and automation, the traditional competitive advantages of developing countries based on low labour and resource costs are being dismantled (UNCTAD, 2023b). The emergence of new technologies can also introduce additional hurdles to participation in Global Value Chains (GVCs), in the form of requirements for specialized knowledge, skilled personnel, and substantial capital investments (Banga, 2022; WTO, 2021). Examples of successful economic modernization in East Asia and Southeast Asia were able to leverage low labour and resource costs to attract foreign direct investments (FDI) and gradually transition to more advanced production stages. However, the current technological and data landscape poses challenges to following this previous pathway of modernization and instead leads to divergence and greater inequality among nations.

The data economy poses challenges for all countries, irrespective of their development levels (**Figure 3**). High levels of market concentration and the disproportionate increase in market power of a few technology companies result in rent-seeking behaviours and the diversion of investments away from sectors that enhance productivity. Digital platforms enable firms to establish unique pricing regimes and employ discriminatory advertising and pricing instruments, undermining the efficiency of free market mechanisms (Cennamo, 2021). Competition policies are struggling to keep up with technological developments and are not always able to address these issues in a timely manner (UNCTAD, 2021b).

Another significant challenge lies in the impact of data-driven innovations on employment. Proliferation of data-driven innovations may render a significant portion of workers redundant and contribute to a global surge in unemployment (Frey and Osborne, 2017). On a brighter note, data analytics can optimize repetitive job tasks while creating new opportunities for human creativity and more fulfilling professional occupations (Balsmeier and Woerter, 2019). AI has a promise to complement and augment human capabilities rather than replace them outright (Gmyrek et al., 2023). This collaborative synergy between humans and AI can unlock enhanced productivity and pave the way for new avenues of innovation, instead of merely leading to job displacement.

However as AI systems become increasingly more capable of performing non-routine tasks (Brynjolfsson et al., 2018), there is a danger that this optimistic view on the link between technology and employment will not hold for too long. Large Language Models (LLMs), like GPT series, exhibit an enhanced capacity to execute cognitive tasks that were traditionally the domain of humans, including, but not limited to, analysing vast amounts of text and crafting documents and messages. As a result, contrary to the automation waves of the past which predominantly affected manual and repetitive jobs, this fresh wave of AI-driven automation has its sights set on clerical jobs. A significant portion of tasks associated with these roles falls under medium to high exposure to potential automation, while about a quarter of these tasks are at an elevated risk of being entirely automated (Gmyrek et al., 2023). This technological shift has profound societal implications, particularly for developing countries. Historically, clerical roles have been instrumental in propelling female employment in these regions. However, with LLMs on the rise, there is a tangible possibility that many such positions might never materialize in developing countries and transition economies.

Figure 3. Summary of data-related challenges

Data prerequisites

- Data quality, portability and interoperability
- Data infrastructure
- Complementary skills and capabilities
- Digital security
- Organizational acceptance
- Legal frameworks

Systemic challenges

- Data divides
- Market competition
- Data ethics and violations of human rights
- Disinformation and misinformation
- Power imbalances
- Adverse effects on sustainability

The spectre of automation-driven unemployment looms large, casting a shadow across both developed and developing nations. The potential negative consequences of automation on employment and social well-being have prompted some developed countries, like Finland, and Switzerland, to consider the introduction of universal basic income and improve retraining schemes and life-long learning programs (Stadelmann-Steffen and Dermont, 2020). However, a global consensus on how to adapt education and labour policies to address the needs and challenges of the data economy has yet to be reached.

Given the magnitude of the data promises and the complexity of associated challenges, data governance has become a central concern on the global political agenda. Public and private organizations increasingly recognize the importance of data as a major driver of sustained competitive advantages and a response to various modern challenges. However, failures in managing the negative effects of technological advancements pose a significant danger to social well-being and can exacerbate inequality. Balancing the benefits and challenges of data economy through effective policy measures is essential to ensure equitable and sustainable growth. The growing influence of data underscores the necessity for a more inclusive data governance, where benefits are not confined to a selected few and where every individual has an equitable opportunity to shape, and be shaped by, the digital future.

A. Challenge concerning data prerequisites

Benefiting from data is not an easy endeavour. It necessitates that countries fulfil several prerequisites that encompass a range of areas, from the quality of data to its management and security. Foremost, countries must ensure that the available data are of high quality. The adage "garbage in, garbage out" applies here: without high-quality data, any derived insights or decision-making would be flawed or, at worst, detrimental. It is not enough for data to just be plentiful—it must be accurate, complete, timely, relevant, and consistent.

Alongside data quality, the interoperability of this data across different technological systems is of paramount importance. As our world grows increasingly interconnected, different systems, applications, and devices must be able to exchange and make use of the data effortlessly. Ensuring such interoperability allows for seamless communication and integration, eliminating potential data silos that could hinder comprehensive analysis and interpretation.

Furthermore, necessary technological infrastructure must be made available by the countries. This infrastructure forms the foundation on which data can be collected, stored, processed, and accessed. Without this, the entire data lifecycle could be compromised, preventing countries from maximizing the value of the data.

Yet having access to high-quality, interoperable data housed on sound infrastructure is not enough. Countries must also possess the necessary capabilities and skills to extract insights from data. This means investing in the development of data literacy, analytical skills, and technical expertise among their workforce. Only then can countries turn raw data into actionable insights and informed decisions.

Equally important is the establishment of trust in these data systems.[29] The governments must ensure their citizens' confidence in how data are managed and used. This trust can be fortified by maintaining transparency in data practices, and also by actively working to minimize organizational resistance against data-centred approaches. In an era where data misuse and breaches are frequent, it is crucial for countries to win their citizens' trust by demonstrating and fulfilling commitment to ethical, responsible data practices.

The necessity for data safety and security cannot be overstated. With the rise of cyber threats, countries must have robust mechanisms in place to protect their data assets. This includes measures to prevent unauthorized access, detect potential threats, respond to incidents, and recover from attacks or data loss.

Lastly, but certainly not least, is the provision of necessary funding for data infrastructures and data management. Managing data effectively is a complex task that requires substantial investment. Countries need to secure funding for everything from constructing and maintaining the infrastructure, to the tools and personnel necessary for data management, to the training and development programs that build data skills.

All these elements intertwine to form a comprehensive framework for countries to truly benefit from data. Only when these prerequisites are met can countries hope to fully harness the power of data in driving decision-making, innovation, and overall societal progress.

1. Defining high-quality data: accuracy, interoperability, and contextual fitness

Data quality, as a concept, presents distinct challenges due to its inherent dependency on the designated use of the data. Data considered high-quality within certain contexts may be deemed

[29] Contribution from the Government of Japan.

subpar or insufficient when applied to different scenarios. According to the OECD (2012), the measure of data quality is not solely contingent on the accuracy of the data. Even impeccably accurate data cannot be deemed high-quality if their production is so delayed that their use becomes outdated or irrelevant. Similarly, if data cannot be conveniently accessed or if they seem to contradict other data sources, their quality is undermined. In essence, high-quality data are data that are fit for their intended use. If the data do not match the problem scope, lack crucial variables, or are in a format that is incompatible with the tools used, their utility decreases, thereby reducing their quality for that particular application.

In addition, factors such as completeness, consistency, credibility, and comparability are also critical in determining the quality of data. Incomplete data can lead to inaccurate insights, inconsistencies can breed confusion, a lack of credibility can question data authenticity, and non-comparable data can limit its application scope. Thus, maintaining high data quality is an intricate balancing act, requiring thorough understanding of the purpose of the data, the context of their use, and their inherent characteristics. This multifaceted concept underscores the importance of implementing rigorous data management processes to ensure the 'fitness for use' of data in relation to their intended purpose. It also emphasizes the need for continuous evaluation and improvement of data quality, as user needs and contexts can evolve over time.

High quality data are also interoperable. Interoperability, in this context, refers to the ability of different datasets and systems to work together, enabling the seamless sharing and integration of data. This not only allows for more effective data utilization but also enables the combination or linking of different datasets to generate new insights. The journey towards achieving data interoperability necessitates legislative measures that extend beyond simply promoting data access. It calls for regulations that ensure data can be seamlessly interconnected and used effectively. These provisions should touch on the quality of data and the conditions under which data should be published. Best practices for enhancing data interoperability include adhering to the FAIR and CARE principles (**Box 9**). These principles advocate for data to be easily discoverable, accessible with well-defined conditions, compatible with other datasets, and reusable for various research purposes.

An important aspect of adhering to these principles is the publication of data in machine-readable formats. Machine-readable data are structured in a way that can be easily read and understood by computers, enabling efficient processing and analysis. In addition, providing data access via Application Programming Interfaces (APIs) can further boost interoperability. APIs allow different software applications to communicate with each other, enabling external systems to access and use the data. To further strengthen the interoperability of data and digital systems, adopting harmonized standards, preferably open standards, is advisable. Open standards are specifications for hardware or software that are publicly available and collaboratively developed, usually by international standard-setting organizations. These standards are designed to cater to user needs and ensure that data and systems can seamlessly interact within a particular market or sector.

Data portability is understood as both a technical capability and sometimes as a fundamental right. It allows individuals or organizations to ask a data custodian to share specific data about them. This data can be sent either back to the person making the request or to another chosen entity. The shared data are provided in a widely accepted, structured format that machines can read and understand (OECD, 2021). This data transfer can be either sporadic, done upon request, or systematic. The right to data portability grants individuals (known as the data subject) three specific rights:

- The right to receive a copy of the data they provided to the data custodian (controller).
- The right to send this data to a different data custodian.

- The right to request that the data be directly transferred from one custodian to another.

Box 9. International data principles

FAIR guiding principles for scientific data management and stewardship

- *Findable:* metadata and data should be easy to find for both humans and computers;
- *Accessible:* once users find the required data, they need to know how they can be accessed, possibly including authentication and authorisation;
- *Interoperable:* data need to interoperate with applications or workflows for analysis, storage, and processing;
- *Reusable:* metadata and data should be well-described so that they can be replicated and/or combined in different settings.

CARE principles for indigenous data governance

- *Collective benefit*: data ecosystems shall be designed and function in ways that enable Indigenous and Marginalized Peoples to derive benefit from the data.
- *Authority to control:* Indigenous Peoples' rights and interests in Indigenous data must be recognised and their authority to control such data be empowered. Indigenous data governance enables Indigenous Peoples and governing bodies to determine how Indigenous Peoples, as well as Indigenous lands, territories, resources, knowledges and geographical indicators, are represented and identified within data.
- *Responsibility:* Those working with Indigenous data have a responsibility to share how those data are used to support Indigenous Peoples' self-determination and collective benefit. Accountability requires meaningful and openly available evidence of these efforts and the benefits accruing to Indigenous Peoples.
- *Ethics:* Indigenous Peoples' rights and wellbeing should be the primary concern at all stages of the data life cycle and across the data ecosystem.

The introduction of data portability has significant implications for both businesses and individuals (De Hert et al., 2018). For companies, it not only challenges traditional competition laws but also offers a potentially complex opportunity to achieve seamless integration across varied systems. For individuals, this right signifies an enhanced command over their personal data, giving them a stronger voice in the data economy. This leads to a more user-centric relationship between different digital services. On a broader scale, it aims to reset the balance between data subjects and data controllers, or in simpler terms, to restore the equilibrium between users and the digital platforms they engage with. Digital tech giants have the capacity to exploit their extensive data reserves to break into and possibly monopolize new sectors (Borgogno and Colangelo, 2019). Considering the hesitancy of market incumbents to freely share their data, there is a burgeoning demand for reciprocal data access. Data portability, in this context, can be instrumental in diluting the monopoly of market leaders, thereby preventing them from establishing their dominance.

Effective regulation of data portability and interoperability necessitates robust cross-agency collaboration. This is largely because these two concepts are underpinned by various issues, ranging from user privacy and consumer rights to competition enforcement. It is not just about sharing data. It is about doing so securely, efficiently, and in a manner that upholds the rights and interests of all stakeholders. Given the specialized nature of various sectors, it is quite possible that sector-specific nuances exist in terms of how data are handled and transferred. This makes the involvement of sector-specific regulators crucial. A telecommunications regulator might approach data differently than, say, a health services regulator. Their combined expertise can ensure comprehensive regulation.

One of the significant hurdles to realizing effective data portability and interoperability lies in the implementation phase (Borgogno and Colangelo, 2019). Current regulations, although recognizing the importance of these concepts, often fall short of providing granular guidance on how businesses and organizations should actualize them. This regulatory ambiguity poses challenges for entities, which might be unsure about how to proceed without contravening any laws or guidelines.

The absence of clear-cut provisions or detailed frameworks accentuates concerns over the effectiveness of interoperability and portability frameworks in practice. If businesses are unsure about how to achieve interoperability, they might either avoid it altogether or implement it poorly. Moreover, such ambiguity can lead to legal uncertainties where businesses may inadvertently flout regulations, leading to punitive measures. If left unchecked, the freedom given to market players in designing their interoperability solutions could have serious repercussions. For instance, adopting insecure or flawed mechanisms can expose vulnerabilities. These vulnerabilities could be exploited, leading to significant data breaches, undermining user trust, and posing substantial cybersecurity threats. A stark reminder of the pitfalls of lax data interoperability measures is the Cambridge Analytica scandal. Here, vast amounts of user data were harvested without explicit consent, showcasing the potential misuse of poorly implemented portability and interoperability measures (Isaak and Hanna, 2018; Polanski, 2018).

As the data economy continues to evolve, the call for effective data portability and interoperability becomes even more urgent. While the motivation is clear, ensuring these concepts are effectively and securely realized requires a concerted effort from regulatory bodies, sector-specific experts, and businesses. The stakes are high, but with the right measures, the benefits of interoperability and portability can be reaped without compromising security or user trust.

2. Data infrastructure and universal and meaningful digital connectivity

Participation in the data economy extends beyond simply connecting individuals to the internet. It also necessitates developing robust data infrastructure at national and local levels, especially in low- and middle-income countries. In the absence of local data infrastructure facilities, many countries continue to rely on overseas resources. This dependence necessitates the transfer of large amounts of data in and out of the country, leading to slower internet speeds and higher costs. Such dependencies can significantly hinder these countries' ability to fully partake in and benefit from the data economy. A strong foundation for this infrastructure begins with sufficient international bandwidth, enabling fluid and unrestricted access to the global internet commons.

The global imperative for universal and meaningful connectivity has gained substantial momentum, as delineated by a 2019 report from the United Nations Broadband Commission for Sustainable Development (ITU and UNESCO, 2019). This document articulates a trajectory for the international digital connectivity, targeting a broadband penetration rate of 75% globally by 2025. Within this framework, specific benchmarks include a 65% broadband proliferation in developing economies and a 35% penetration rate in the least developed nations. The United Nations advocates for each nation—irrespective of its developmental index—to formulate a national strategy to realize universal broadband access by the stipulated timeframe.

However, achieving these targets is challenged by the existing digital divide. Research by the International Telecommunication Union (ITU) in 2022 showed that nearly 2.7 billion people worldwide lacked meaningful Internet connectivity (ITU, 2022a). There is a clear North-South divide to where these unconnected populations reside. Connectivity rates in both Europe and the Americas are healthily above 80%, the Arab world has 80%, while we see significant drop-offs in Asia (64%) and, most of all, in Africa (40%). Such inequalities are further compounded across minorities and other groups within these regions. Thus, for instance, 264 million less women were seen to be using the internet than men (GSMA, 2023). Similarly, on average, the connectivity rates of urban populations were seen to be double that of those living in rural and remote areas (Signé, 2023).

This disparity in access to the digital world is not only limited to internet connectivity but also extends to crucial digital infrastructure like data centres. While there are ~3 data centres per million people in North America, the ratio drops to ~0.8 per million in South Asia (World Bank, 2021a). The cloud computing market is also vastly concentrated in a few hands. In fact, recent estimates suggest that nearly 65% of the market has been cornered by just three firms, Amazon, Google, and Microsoft.[30] Such dominance creates dependencies around the storage and processing of data that can then be leveraged exponentially as more and more firms provide data to the cloud layer and deepen their control over digital intelligence.[31]

Data's pivotal role in forming informed policy decisions, propelling social and economic growth, and enhancing public services is immense. However, contrary to their significance, adequate funding and resources are frequently not dedicated to sustaining and upgrading data systems. The lack of funding can adversely affect the quality and dependability of data, thereby obstructing the ability to generate accurate insights essential for competent decision-making. The repercussions of underinvestment in data infrastructure are expansive and notable. For example, it could lead to data gaps that impede policymakers from acquiring a thorough understanding of socio-economic issues, thereby obstructing their capability to formulate effective strategies and policies. Furthermore, underfunded data systems can result in obsolete or unreliable statistics, causing misguided policy decisions with long-term societal and economic implications.

Another hazard is that underinvestment may intensify inequalities. Low-income countries, already challenged with data availability and quality, may face even greater struggles to fund their data systems. This could amplify the global data divide, leaving these countries further marginalized in a world where data are progressively driving socio-economic changes.[32] The situation underscores the dire need for escalated investment in data systems. It is crucial to secure funding and resources that allow nations to develop robust, comprehensive, and efficient national statistical plans. Doing so would not only enhance data quality and reliability but also enable governments to make more informed decisions, leading to beneficial social and economic outcomes.

High-quality data are fundamental in steering evidence-based policy decisions, informing effective strategies, and assessing the impact of government initiatives. However, the complexities of data collection, management, and analysis can often be intricate and not easily comprehended by those overseeing budgetary allocations. This lack of understanding can result in underestimating the amount of funding needed to uphold robust, reliable, and comprehensive data systems. Moreover, the returns on investing in data systems might not always be immediately perceptible or tangible. This can contribute to a lack of incentives for budgetary decision-makers to prioritize funding for data systems, especially when there are contending demands for resources across different sectors.

[30] Rikap, C. (2022). *Big Tech: Not Only Market But Also Knowledge and Information Gatekeepers*. Institute for New Economic Thinking. Retrieved on 3 October 2023 from https://www.ineteconomics.org/perspectives/blog/big-tech-not-only-market-but-also-knowledge-and-information-gatekeepers

[31] Jeet Singh, P. (2018). *Digital Industrialisation in Developing Countries—A Review of the Business and Policy Landscape*. IT for Change. Retrieved on 3 October 2023 from https://itforchange.net/digital-industrialisation-developing-countries-%E2%80%94-a-review-of-business-and-policy-landscape-0

[32] Contribution from the Government of South Africa.

3. Skills and capabilities to harness productivity gains from data

Promises of data-driven decisions for improved business performance are numerous. However, if the use of data for business decisions is the current "best practice," why do not all firms adopt and benefit from it? Even though investments in digital technologies have been increasing consistently for years, there has not been a corresponding rise in productivity globally (Andrews et al., 2016). This halt in productivity is not confined to specific regions or sectors but is a broad-based phenomenon witnessed across the vast majority of companies from developed and developing countries (McGowan et al., 2015).

The slowdown in productivity growth is a long-term trend, effectively becoming a permanent phenomenon in global economic dynamics. There are diverging viewpoints on this matter. The first perspective argues that current technological advancements, as groundbreaking as they may appear, might not match the magnitude of transformative changes brought about by previous technological revolutions (Gordon, 2000). Examples of these include the advent of electricity or the introduction of the internal combustion engine, both of which significantly altered the course of human progress and productivity in a manner that current digital technologies have yet to replicate.

However, this perspective is not universally held, and a more optimistic outlook suggests that we may be underestimating the productivity impacts of the present wave of technological evolution (Brynjolfsson et al., 2021). The data-driven innovations we invest in today necessitate time, along with complementary investments and capabilities, to yield substantial productivity gains.

Therefore, productivity growth might not be immediately visible, but it does not necessarily mean it is permanently stifled. The full effects may just take longer to manifest than previous technological shifts due to the complexity and uniqueness of the current stage of the data revolution (Bharadwaj, 2000). Productivity gains derived from data analytics hinge not merely on the technology itself but also on a range of critical mechanisms and complementary assets:

- Organizations need to carry out *organizational reforms and investments in management skills* (Bloom et al., 2012; Bresnahan et al., 2002). It is essential to create organizational structures and organizational cultures that can adapt to technological changes and leverage them effectively. This transformation often necessitates significant changes to existing business processes and investments in leadership development, strategic thinking, and change management skills at all levels of the organization.
- *Significant investments in Research & Development (R&D) and innovation capability* play a crucial role (Bartelsman et al., 2018; Beck et al., 2023; Plekhanov, 2023). Innovative technologies often require equally innovative processes to unlock their full potential (Wu et al., 2020). Firms must invest not just in acquiring the technology but also in R&D to develop new and efficient ways to use it, creating bespoke solutions that align with their specific business needs.
- *The development of human capital and the nurturing of relevant skills* is a crucial driver of productivity (Gal et al., 2019; Tambe et al., 2012). Technological advancements are of limited use if there is a lack of skills necessary to implement and utilize them effectively. Continuous training and skill development, therefore, form an integral part of the process of technological adaptation.
- *Collaboration with external partners* is fundamental (Tambe et al., 2012). This includes knowledge sharing, strategic alliances, and cooperation with other firms, institutions, and stakeholders. By forming such collaborative partnerships, organizations can tap into a wider pool of resources, knowledge, and skills, speeding up technology adoption and driving productivity gains.

Securing productivity gains from the data revolution is not merely a matter of pouring financial resources into new technological applications. It requires a multi-faceted approach that addresses organizational structures, skills, alignment of business strategies, and strong partnerships, all of which play critical roles in harnessing the potential of data for productivity enhancements.

The challenge of skills acquisition and enhancement becomes particularly prominent. With the rapid advancements in digital technologies, the capabilities of skilled workers are significantly augmented, enabling them to generate new business value with greater effectiveness and efficiency (Acemoglu and Autor, 2011). For countries to fully capitalize on these technological advancements, they must invest in developing a workforce that possesses the requisite skills to navigate and exploit the complexities of the digital landscape. Countries that combine high-skill employment with high volumes of technology-intensive manufacturing exports are expected to benefit the most from Industry 4.0, characterized by the integration of advanced digital technologies into manufacturing processes (**Figure 4**).

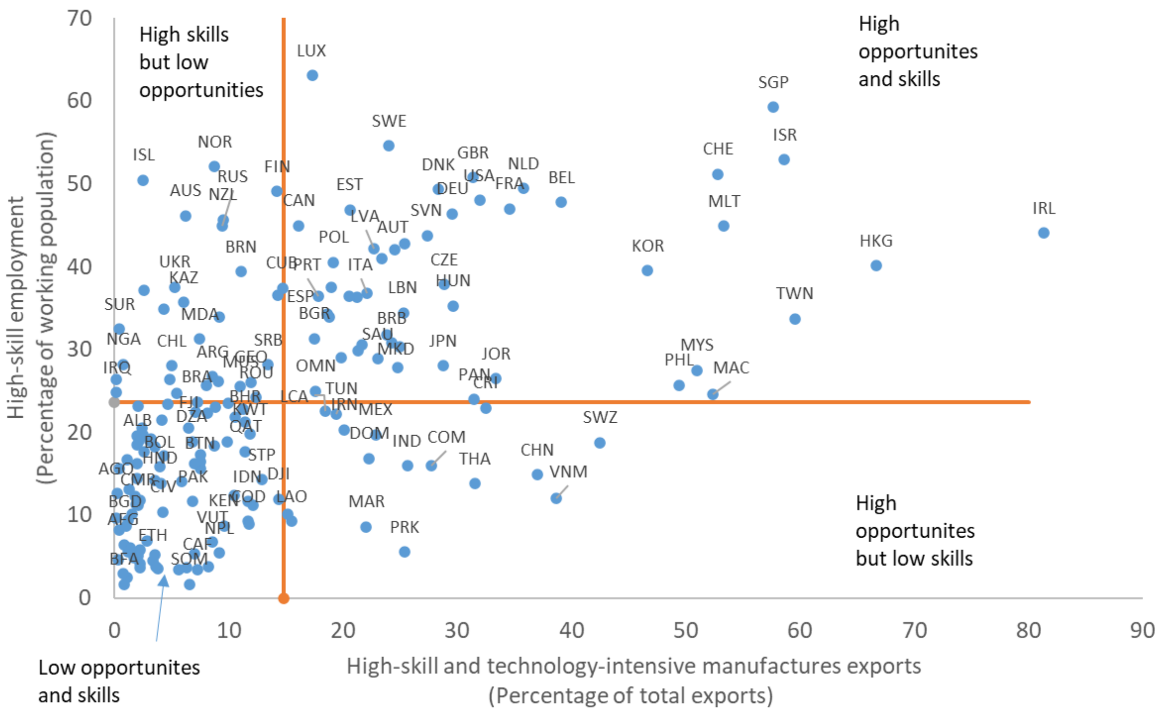
The challenge of translating investments in digital technologies into productivity gains is universal, yet it is particularly pronounced in developing countries. As studies by the Asian Development Bank (ADB) (2022) and the World Bank (2021b) have shown, the demand for digital skills (from foundational literacy to advanced competencies) is rapidly advancing across Asia and Africa, but large parts of these continents are struggling to keep up. It was estimated that by 2030, nearly 230 million jobs in Sub-Saharan Africa will require digital skills. However, in countries such as Chad or the Central African Republic (CAR), only minuscule percentages of people (1.6% and 2.4%, respectively) have experience in even the basics of operating digital technology (Lay and Fietz, 2023). In addition to reducing the developing world to suppliers of cheap, low-skilled labour, these gaps may also entrench inequalities in more advanced sectors. Developing countries also struggle to retain data science and information technology professionals (UNCTAD, 2021a), generating a vicious cycle whereby these countries lack the talent pools to attempt productive activity at higher levels on the digital value chain.

Developed countries, despite their advantage of sophisticated technological infrastructure and a highly skilled workforce, are experiencing a prolonged period of slow productivity growth (Andrews et al., 2016). This is paradoxical, considering their substantial investments in data-enabled technologies. There is a notable variation in productivity within these countries and across their various sectors, revealing a growing divide between top-performing companies and the rest.

In this context, a small number of tech companies have shown consistent growth in productivity. These companies have successfully leveraged data and digital technologies to achieve significant economic gains and large market shares. However, this is not the case for a substantial segment of businesses, particularly small and medium-sized enterprises (SMEs). These companies have not experienced similar growth, facing challenges such as limited access to capital, a lack of digital skills, organizational adaptability issues, and obstacles to innovation. This productivity gap has tangible impacts on the economy, affecting market competitiveness, wage levels, and overall economic health.

These observations raise critical questions. Is the technological and policy environment inherently biased towards top-tier companies? What obstacles are preventing a wider range of businesses from realizing productivity gains from their investments in data-enabled technologies? And importantly, how can reforms in policy, education, and economic development be implemented to ensure that the benefits of the digital revolution are accessible to a broader segment of the economy?

Figure 4. Which countries may be initially better positioned to benefit from the diffusion of Industry 4.0?



Source: UNCTAD (2022). Industry 4.0 for Inclusive Development.
Note: The solid lines represent the global unweighted averages under these two indicators. Data labels use International Organization for Standardization economy codes.

4. Cybersecurity risks: the double-edged sword of interconnected business in the data economy

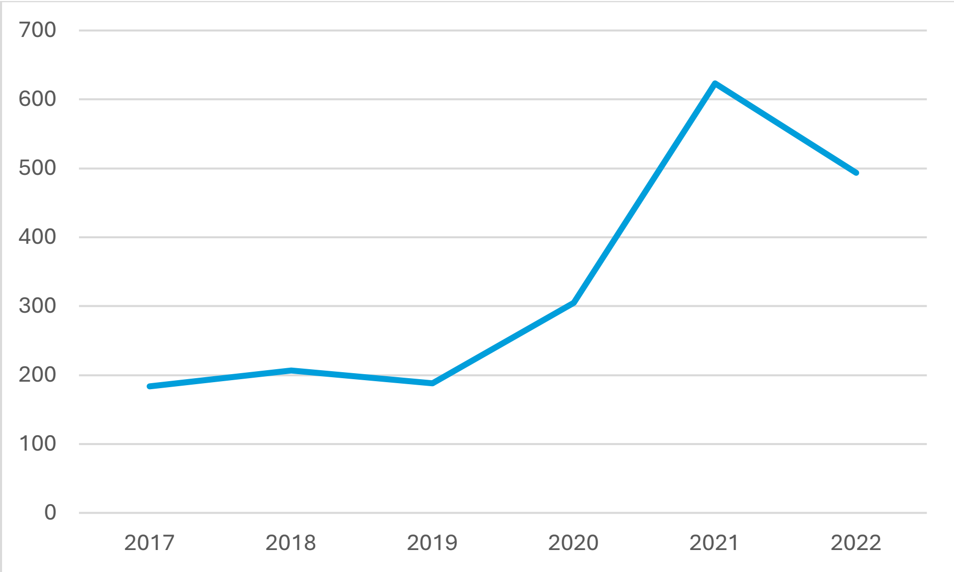
The increasing interconnectedness of business processes, physical devices, and the widespread adoption of digital technologies present opportunities for value creation and the development of new business models. However, this interconnectedness also brings about a new frontier of digital security risks, exposing firms to various threats such as denial-of-service attacks and ransomware incidents (Lu and Da Xu, 2018). The erosion of boundaries between digital systems and firms in the digital economy intensifies the severity and spread of digital attacks, as evidenced by the rising costs of data breaches. The COVID-19 pandemic has further emphasized the importance of digital transformation,[33] with a significant surge in the consumption of digital content and services, necessitating a shift towards remote work and digital operations. Consequently, ensuring robust data security measures has become increasingly vital for public and private organizations across diverse sectors (**Figure 5**).

A cyberattack on a power grid can lead to widespread blackouts, affecting everything from hospitals to homes, and causing immediate life-threatening situations. Similarly, disruptions in communication networks can prevent essential information flows, isolating communities and potentially hampering emergency response efforts. If transportation systems, such as air traffic control or urban rail networks, are compromised, it can result in delays and accidents.[34] Furthermore, continuous disruptions caused by cyberattacks can erode public trust in the governments' ability to protect their citizens.

[33] Contribution from the Government of Cuba.
[34] Contribution from the International Telecommunication Union (ITU).

Data breaches can have significant negative impacts on the economy.[35] They can result in substantial financial losses for businesses and individuals. When sensitive financial information such as credit card details or bank account information is compromised, it can lead to fraudulent transactions, unauthorized access to funds, and financial theft. Businesses may also face costly legal settlements, fines, and damage to their reputation, which can impact their revenue and profitability.

Figure 5. Annual number of ransomware attacks worldwide, in millions[36]



Source: Statista

Data breaches can expose valuable intellectual property (IP), including trade secrets, patents, and proprietary information (Andrijcic and Horowitz, 2006). This can lead to significant financial losses as competitors may gain access to confidential information, resulting in lost competitive advantage, decreased market shares, and potential revenue decline. Data breaches often erode trust and damage the reputation of businesses. When customer data are compromised, it can lead to a loss of confidence among existing and potential customers (Cavusoglu et al., 2009). This loss of trust can result in reduced customer loyalty, decreased sales, and a tarnished brand image. Rebuilding trust can be a long and challenging process, further impacting the economic standing of the affected organization.

Despite of the importance of data, companies often tend to underinvest in cybersecurity measures, primarily because the economic ramifications of any potential data breach are typically borne not by them, but by the clients whose data are compromised (WEF, 2022). This creates a disconnect between the party responsible for data security and the party that suffers the most significant consequences in the event of a data breach.

Given this situation, there is a pressing need for government intervention to counteract firms' tendency to underinvest in cybersecurity. This could involve both incentives and regulations. Governments could provide financial incentives, such as tax breaks or subsidies, to companies that enhance their cybersecurity measures. This could potentially make cybersecurity investments more financially attractive to firms.

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[35] Contribution from the Government of Hungary.

[36] Ransomware attacks are cyber extortions where attackers encrypt a victim's data and demand payment for its release.

On the other hand, stricter regulations could be imposed to ensure that companies are held accountable for their cybersecurity infrastructure. Such regulations could include mandating specific security standards or imposing significant penalties for data breaches. This could encourage companies to take proactive steps towards enhancing their cybersecurity measures to avoid regulatory sanctions. However, it is important to strike a balance between encouraging firms to enhance their cybersecurity measures and not overburdening them with excessive regulation, which could stifle innovation or create barriers for smaller players in the market.

5. Organizational resistance to data use: protecting data integrity against manipulation

Reliable high-quality data are essential instruments in the machinery of governance, acting as an objective lens that reflects the performance and consequences of policy decisions. Data provide a measure against which the effectiveness of political strategies can be appraised, thereby serving as an important regulator on governmental activities.

Beyond their evaluative capacity, trustworthy data also have the potential to counterbalance concentrations of power. By their very nature, statistical data act as a democratizing force, fostering transparency and accountability that can facilitate a more equitable dispersion of power throughout society (United Nations, 2023). They illuminate government performance and societal trends, and in doing so, create an informed public capable of engaging more meaningfully with the political process. In this capacity, reliable statistics serve as a formidable tool for public empowerment, enabling citizens to keep their governments answerable and demand change where necessary.

Nevertheless, the very strength of data—its ability to propel transparency, accountability, and democracy—also renders it attractive to those with ulterior motives. There exists a significant risk that these parties, aware of the transformative potential of data, may endeavour to interfere and manipulate decisions related to its collection, reuse, and dissemination. Such interference could be aimed at distorting the data to serve their interests, conceal inconvenient truths, or mold public perception to their advantage.

This interference could manifest in various ways, from dictating what data are gathered and how it is interpreted, to controlling who can access the data and dictating how data are circulated. The objective is typically to maintain the status quo, safeguard individual or group interests, and curtail the potential for data to drive policy changes. Given these risks, it is vital to insulate the processes surrounding data collection, reuse, and sharing against such manipulations. Only with such safeguards can we ensure that data continue to be a force for good governance, public scrutiny, and active democratic participation.

6. Legal frameworks for equitable data governance

In the data age, there is a pressing need for comprehensive legal frameworks that support and regulate data-driven innovations. Central to this need is the quest for greater legal certainty, which can be achieved by implementing transparent and consistent domestic policies across sectors. When laws are consistent and clear, it alleviates ambiguity, fostering an environment where innovation thrives and all stakeholders, from businesses to consumers, have clarity regarding their responsibilities and rights. Rather than imposing burdensome regulations that apply broadly to all data-driven technologies, it is imperative for governments to tailor regulatory actions to be context-specific and outcome-oriented. This means prioritizing regulations based on the application of data-enabled technologies, instead of focusing on the technologies in isolation.

Rather than getting mired in procedural formalities, these laws should be outcome-oriented. They should zero in on providing effective protection to individuals. This involves a commitment to prioritize real-world privacy and security outcomes, ensuring that data-driven innovations not only respect the sanctity of privacy rights but also shield personal data from unauthorized access. In cases where these safeguards fail, clear avenues for redress should be in place. Diving deeper into data management, the legal frameworks should champion principles of data minimization and integrity. Only the necessary data should be collected, and its accuracy must be diligently maintained. Furthermore, when it comes to data sharing, the consent of users should be explicit, and data exchange practices must adhere to the highest ethical standards. In a globalized world, fostering international data transfers is crucial. However, these transfers should not compromise data protection standards; rather, they should facilitate a global exchange of ideas, technologies, and best practices.

The challenges posed by data do not fit neatly into the limited functional areas of vertically organized government departments. Data challenges cut across multiple policy areas. For instance, decisions in trade can impact privacy or intellectual property rights, given the pervasive nature of digital technologies. An exemplar of the intersection of policy areas is copyright law. As digital technologies evolve, there is an increasing realization that copyright needs to transition from an exclusionary right to one that emphasizes access. Historically, copyright was a tool for authors, but with the emergence of large tech conglomerates, there is a risk of it becoming restrictive, hindering the free flow of information and market competition.

In the wake of rapid advancements in AI, the very act of inventing is undergoing a paradigm shift. As AI systems become increasingly proficient, they are not just assisting the invention process by making it more cost-effective. The technological evolution heralds the dawn of AI-generated inventions—innovations not crafted by human minds but autonomously conceptualized by AI software (Kitano, 2021). Such an inevitable transformation demands a corresponding evolution in our patent systems. It is essential for these systems to be primed to recognize and accommodate the nuances of AI-generated inventions (de Rassenfosse et al., 2023). They need to address the complex questions of ownership, novelty, and intellectual property rights in a landscape where the creator is not a human but a machine.[37] The challenge lies not just in acknowledging AI's role in innovation but in structuring legal frameworks that can effectively protect these new forms of invention and resolve associated challenges (**Box 10**).

The global nature of data and data-enabled technologies underscore the importance of ensuring laws are globally harmonized. As trade flows increasingly rely on the Internet, legal frameworks must strike a balance: protection that is too lax can erode consumer trust, but overly stringent regulations can hamper business growth. Furthermore, a key pillar of this harmonized approach is the effective implementation of these policies. A transparent environment, bolstered by these regulations, will ensure that digital solutions are harnessed for the broader societal good. This approach should not only set clear objectives and standards but also promote multi-stakeholder partnerships, laying the foundation for a digitally inclusive society.

Box 10. Copyright in the age of generative AI

The advent of the generative AI revolution has illuminated complex ethical dilemmas, particularly centering around the consumption and utilization of public and copyrighted knowledge. With AI systems being trained on a plethora of texts, audio, and video archives, the traditional boundaries of fair use and copyright law are being rigorously tested and challenged.

In the context of copyright law, the principle of fair use has always served as a balancing act, ensuring that the utilization of copyrighted works does not infringe upon the rights of original authors and content creators. However, the unprecedented scale at which generative AI consumes and processes this information raises profound ethical and legal questions. Does the extensive use of copyrighted works for

[37] Contribution from the Government of the United Republic of Tanzania.

training AI transcend the permissible boundaries of fair use? Are the authors and content creators adequately compensated or acknowledged for their contributions in the era of AI?

Some scholars have proposed that evaluation of fair use in this scenario may require the introduction of a new ethical principle – that one can term "fair learning" – in order to balance access to the commons of public knowledge that is essential for building ethical and non-discriminatory AI while ensuring the output of such AI systems does not pose "significant substitutive competition" to the authors/content creators whose works have been used. In this view, "If the purpose of the AI's use (of copyrighted input material) is not to obtain or incorporate the copyrightable elements of a work but to access, learn, and use the unprotectable parts of the work, that use should be presumptively fair (Lemley and Casey, 2020)."

However, this emerging ethical landscape is intricate. The implementation of "fair learning" requires rigorous legal, ethical, and technological scrutiny. Legislation and policies must evolve to encapsulate the complexities introduced by AI. Concurrently, AI developers and users must be cognizant of the ethical implications of their innovations, ensuring that the technologies are not just legally compliant but also ethically sound.

The global nature of data and data-enabled technologies underscore the importance of ensuring laws are globally harmonized. As trade flows increasingly rely on the Internet, legal frameworks must strike a balance: protection that is too lax can erode consumer trust, but overly stringent regulations can hamper business growth. Furthermore, a key pillar of this harmonized approach is the effective implementation of these policies. A transparent environment, bolstered by these regulations, will ensure that digital solutions are harnessed for the broader societal good. This approach should not only set clear objectives and standards but also promote multi-stakeholder partnerships, laying the foundation for a digitally inclusive society.

Taxation in the digital economy further exemplifies the need for international collaboration. The current misalignment between where digital platforms extract value and where they are taxed poses critical challenges. Especially for developing countries, where users significantly contribute to these platforms, there is a pressing need to ensure they receive their fair share of tax revenues. International discussions on digital taxation must be inclusive, giving developing nations a seat at the negotiation table.

B. Systemic challenges

The transition into the digital age has opened unprecedented opportunities for progress, but it also bears inherent systemic challenges. A significant issue is the emerging data divide. Many regions and societal groups, especially those in lower-income countries, struggle with data accessibility due to lack of infrastructure, economic constraints, and digital illiteracy. As a result, they remain mere raw data suppliers while tech giants mostly developed countries extract the primary value. The dominance of these tech giants in the global platform economy suppresses lower-income countries' voices in decision-making processes related to data governance.

Simultaneously, this data-driven environment has led to market competition concerns. A few powerful companies have monopolized large data sets, leading to potential wealth concentration and market power abuses. This dominance can also facilitate algorithms that support anticompetitive pricing strategies. Addressing this requires innovative regulatory frameworks, as traditional antitrust methods may fall short.

Human rights also come into focus in the data landscape. Data and the associated technologies, like AI, may inadvertently violate rights such as privacy and freedom of expression. Cultural differences in ethical norms further complicate matters. Biased AI systems can reinforce existing societal prejudices, affecting sectors like employment and criminal justice. These biases can lead to data-based discrimination, where companies might adjust prices based on personal data or specific groups might remain invisible in data processes due to unequal digital resource access.

Lastly, while the data revolution promises efficiency and growth, it also has notable environmental impacts. Technological efficiencies can unintentionally boost consumption, offsetting potential eco-friendly advantages. For instance, data consumption's surge, propelled by digital platforms, data centres, and LLMs, increase significantly electricity consumption. This rise in digitalization also produces more electronic waste, posing significant challenges to developing countries that are ill-equipped to manage it. As the world grapples with these challenges, it is evident that collaborative actions between the civil society, public and private sectors, and technical communities are pivotal to harmonize the digital transition with broader sustainability and climate goals.

1. Data divides and how to ensure equitable participation in the data economy

The economic advantages that can be derived from data and are neither automatic nor uniformly dispersed amongst or within countries (UNCTAD, 2019). Data-driven progress, while offering immense potential for societal advancement, has unfortunately contributed to the exacerbation of inequalities and the deepening of data divides.[38] This phenomenon has disproportionately favored specific groups or regions, creating significant challenges for lower-income countries striving to participate equitably in the global data economy. The rising value of data has fueled competition for its collection, resulting in practices that are often unsustainable and inequitable. Such practices can exacerbate power imbalances, putting developing countries at a disadvantage and potentially widening disparities in their access to and control over valuable data resources.

The data divide compounds existing disparities as data-intensive frontier technologies can only reach their full potential in countries with the necessary infrastructure, including high-speed internet and data collection and analysis capabilities. Given that these data-driven processes often rely on large amounts of data, countries with large populations play a vital role as sources of raw data for many businesses. This situation risks relegating developing countries to mere consumers of data, lacking the capacity to fully harness the value of data themselves.

Regions like Africa, South and Central America, and Central Asia are underrepresented in global data governance debates, which shows that "the international debate over ethical AI may not be happening globally in equal measures. More Economically Developed countries (MEDC) are shaping this debate more than others, which raises concerns about neglecting local knowledge, cultural pluralism and global fairness (Jobin et al., 2019)." The equitable sharing of benefits from the productivity gains enabled by data and AI technologies in the international political order is often overlooked in ethical debates.[39]

While a majority of the global population now has access to the Internet, there are still millions of people who lack connectivity, particularly in marginalized and underserved communities (ITU, 2021). As of 2023, about 2.6 billion people worldwide, or 33% of the global population, were without internet access (ITU, 2023). Achieving universal internet access is particularly challenging in the least developed countries (LDCs) and landlocked developing countries (LLDCs), where internet penetration stands at just 35% and 39%, respectively. This vast number of people without internet connectivity represents a significant data divide, impacting their ability to access and benefit from digital resources and opportunities (**Figure 6**).

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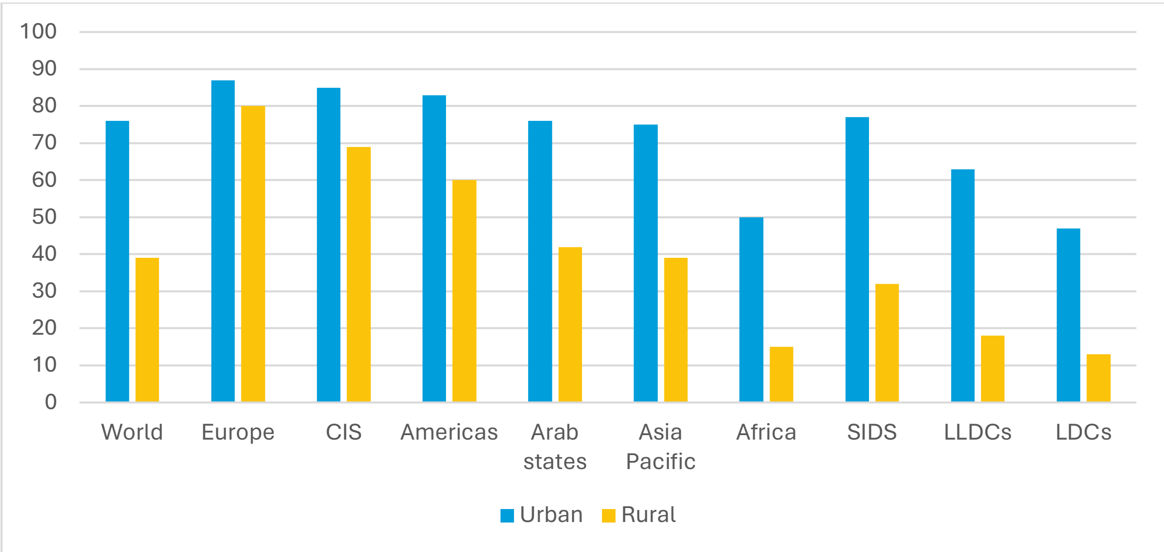
[38] Contribution from the Government of Gambia.

[39] Paris Peace Forum Working Group on AI (2022). Beyond the North-South fork on the road to AI governance: An action plan for democratic and distributive integrity. https://parispeaceforum.org/wp-content/uploads/2022/03/Initiate-PPF-Global-South-AI-Report-EN.pdf

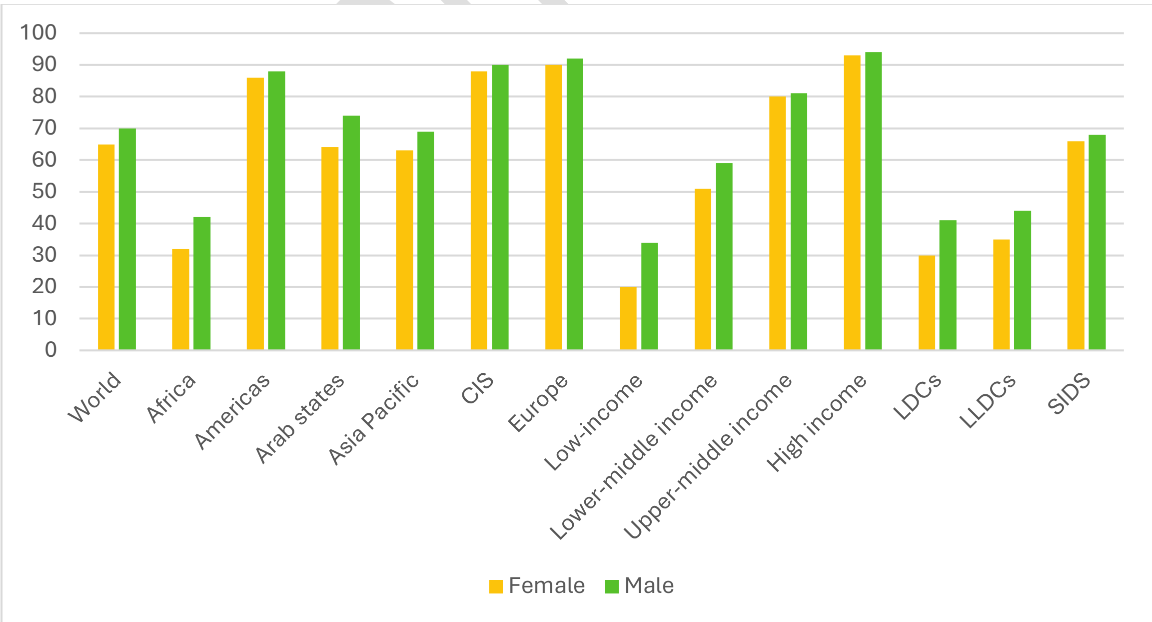
The gender divide in internet connectivity is a significant issue that reflects broader social and economic inequalities (**Figure 7**). In 2023, a noticeable gap existed between male and female internet usage globally, with 70% of men having access compared to 65% of women (ITU, 2023). This disparity not only highlights issues of access and equity but also indicates the potential for a widened digital divide, where women may miss out on the educational, economic, and social opportunities that internet access can provide. Such a divide can perpetuate existing gender disparities in many aspects of society, reinforcing barriers to women's empowerment and participation.

Figure 6. Percentage of the population using Internet in urban and rural areas, 2021



Source: ITU

Figure 7. Percentage of female and male population using the Internet, 2023



Source: ITU

This lack of access creates disparities in opportunities and hinders the realization of the full benefits of the data economy (ITU, 2022b). Even among those who have access to the Internet, limited connectivity poses a barrier to fully harnessing the potential of the data economy. Slow or unreliable connections limit the ability to engage in online activities, access information, and utilize online services effectively. This further exacerbates the inequality between digitally empowered individuals and those with limited connectivity. Internet access and the necessary connectivity devices can be prohibitively expensive for many individuals and communities, particularly in low-income areas. The high cost of connectivity acts as a barrier to entry, preventing equal participation in the data economy and impeding access to the opportunities it offers. Furthermore, the availability of relevant and localized digital content and services is essential for promoting inclusivity and equality. A lack of culturally appropriate content and services can alienate individuals and communities, making it challenging for them to benefit from digital resources (UNCTAD, 2022a). Ensuring that digital content caters to diverse needs and languages is vital for fostering inclusion and equal participation in the digital world.

Digital skills and literacy also play a crucial role in bridging the data divide. Many individuals, particularly in underserved communities, lack the necessary knowledge and skills to navigate digital technologies effectively. This limits their ability to fully engage in online activities, utilize digital tools for personal and professional development, and take advantage of the opportunities presented by the digital age.

In many developing countries, companies often face a subordinate position in the global data landscape, as data and the value derived from it tend to be concentrated in the hands of a few dominant global digital platforms and multinational enterprises (UNCTAD, 2019). This concentration of data ownership and value capture can pose significant challenges for developing countries, potentially leading them to become mere providers of raw data while having to pay for the digital intelligence extracted from their own data.[40]

Given this context, it is necessary to explore ways to achieve more inclusive development benefits from data. This involves improving the ability to collect, share, and analyse high-quality data, including across national borders, in a manner that leaves no one behind. While all countries need to allocate more domestic resources to develop data-related capacities and capture its value domestically, many countries may face limitations in meeting these needs due to financial, technical, and other resource constraints. Therefore, international cooperation and capacity building efforts are required to bridge the gap and support countries in achieving their data-related goals (United Nations, 2024).

Moreover, the involvement of lower-income countries in global data markets and their influence over the governance of these markets can be quite challenging to achieve. Power dynamics, imbalanced relationships, and barriers to entry often prevent these countries from actively participating in decision-making processes that shape global data policies. As a result, their voices may be marginalized, and their specific needs and concerns may not be adequately addressed. In addition to the infrastructure and governance challenges, establishing the institutional and regulatory frameworks necessary to instil trust in data systems can be a complex and resource-intensive undertaking for lower-income countries.

Building robust data protection and privacy laws, ensuring data security, and promoting ethical data practices require significant financial and technical resources. Many lower-income countries may struggle to allocate the necessary funding and expertise to develop and enforce these frameworks, leaving their citizens vulnerable to data misuse and privacy violations. The UN Environment Programme (UNEP) assessed in 2019, prior to the start of the COVID-19 pandemic and related setbacks to the Sustainable Development Agenda, that there was not sufficient data to comprehensively measure the progress of 68% of environment-related SDG indicators and called for data sources that can improve spatial and temporal coverage.

[40] Contribution from the Government of Latvia.

Addressing these challenges requires concerted efforts and collaboration at multiple levels. International organizations, governments, and private sector entities need to work together to bridge data divides by investing in infrastructure development, providing technical assistance, and promoting digital literacy programs in lower-income countries. Efforts should also focus on empowering these countries to actively participate in shaping global data policies, ensuring their perspectives are represented and their unique needs are addressed. Capacity building and knowledge sharing initiatives can help lower-income countries develop the skills and expertise needed to harness data effectively for their own development. International partnerships can play a crucial role in facilitating technology transfers, sharing best practices, and supporting local innovation ecosystems.

As we move towards a more data-centred world, we often neglect areas where data are scarce or unavailable. Data divides lead to "data invisibility" of marginalized communities, including women, tribal groups, castes, religious and linguistic minorities, and migrant workers (UNCTAD, 2022e). The invisibility of these communities in national or global data landscapes can result in their voices being muted and limit their active participation in social, economic, and political spaces. Relying heavily on automated data collection methods can inadvertently exclude these already vulnerable groups. This exclusion can further deteriorate their trust in digital tools and potentially amplify biases that affect the performance and accuracy of data analytics. This scenario highlights the urgency for enhanced transparency in how data are collected, processed, and used, ensuring fair and equitable digital representation.[41] As our reliance on data for decision-making grows, we may inadvertently overlook regions and societal groups lacking data. We must remember that the absence of data does not equate to an absence of change or impact.[42]

2. *Adverse effects on market competition and how to ensure fair play in the data economy*

The increasing data connectivity between firms in today's business landscape has led to a higher level of mutual reliance on each other's business models. Traditional competition between stand-alone companies has evolved into competition within networks of firms, wherein the dynamics of collaboration and competition become intertwined (Cenamor et al., 2017).

Digital ecosystems and platforms create network effects, wherein the value of the ecosystem increases as more participants join (Schilling, 2002). This phenomenon makes it difficult for competitors to appropriate value independently, as the success of one participant enhances the value and attractiveness of the entire ecosystem. As a result, firms are incentivized to actively participate in these ecosystems to access a larger customer base, leverage shared resources, and benefit from network effects. Within these interconnected networks, the boundaries between competitors and collaborators become blurred (Ritala et al., 2014). Direct competitors might see the advantage in working together, realizing that partnership can bring mutual benefits even as they continue to compete in other markets or market segments. By pooling their complementary strengths and resources, they can achieve shared goals, enhance their competitiveness, and create new value within the ecosystem. Collaborative activities such as joint product development, shared marketing initiatives, or even co-creating innovative solutions become common strategies in such ecosystems.

The current business landscape is characterized by the dominance of a few large platform companies that control vast amounts of data.[43] This concentration of customers information within a limited number of entities raises concerns about market power and the potential for discriminatory practices. The privileged position of these platform-based companies gives them

[41] Contribution from the Government of South Africa.
[42] Contribution from the Government of Brazil.
[43] Contributions from the Governments of Latvia, Portugal, and the Russian Federation.

the ability to exert influence over markets and potentially engage in practices that unfairly advantage certain groups while discriminating against others. The control exerted by major platforms and data providers over the digital economy can skew the distribution of wealth it generates. This dominance could potentially obstruct local value creation and capture, making it challenging for smaller entities and new market entrants to compete and prosper (UNCTAD, 2022a). Some potential risks include an abusive use of personal data to set high prices for goods for certain customers (Adams, 2017). Additionally, a leading search engine could display search results that unduly promote particular retail sites (EC, 2017). Similarly, a major national provider could hinder the functionality of an international rival (Zhong and Yuan, 2021). Furthermore, a dominant tech company might exert disproportionate influence over governments (Blumenthal, 2017).

Algorithms can threaten consumer welfare by supporting anticompetitive behaviors. Companies use algorithms to set prices for goods or services. However, if multiple companies are using similar algorithms and data, this could result in price collusion even without any explicit agreement between these companies. This can happen roughly in two ways: (1) either the algorithms are programmed to follow a price leader, adjusting their own prices in line with that leader's; (2) or they independently arrive at similar pricing strategies based on their analysis of market data. In either case, this can lead to higher prices for consumers, even though there is no explicit formal collusion between the firms.

These competitive dynamics highlight the importance of carefully examining market concentration and potential abuses of power resulting from data accumulation. It is crucial to establish robust regulatory frameworks that promote competition, prevent anti-competitive behaviour, and safeguard against discrimination based on data control. Such regulations can help ensure a level playing field and foster a more equitable and inclusive digital ecosystems.

Effective regulatory measures may include antitrust policies that prevent monopolistic practices and promote fair competition. This can involve scrutinizing mergers and acquisitions in data-driven industries to prevent excessive consolidation and promote diversity and innovation. Additionally, regulations can focus on data privacy and protection, ensuring that individuals have control over their personal information and preventing its unauthorized use or exploitation.

In the data economy, traditional antitrust regimes may not be entirely effective. Data-driven firms often possess intangible assets such as data and algorithms rather than tangible ones like real estate or physical equipment. As traditional antitrust thresholds often consider tangible assets, many data-driven firms might not meet these criteria, hence escaping antitrust reviews. Many data-driven firms, particularly start-ups, may not generate significant revenues initially as they focus on user acquisition and product development. Therefore, their financial footprint may be insufficient to trigger a review under traditional antitrust regimes, which typically consider revenue size as a criterion. While data-driven firms may start small, their potential for rapid and exponential growth due to network effects is substantial.

Given these factors, traditional antitrust mechanisms may need to be updated to account for the unique characteristics of data-driven firms. Specifically, adjustments in merger notification thresholds can ensure antitrust authorities have the opportunity to review potentially anti-competitive mergers involving data-driven firms. This change would allow authorities to scrutinize mergers and acquisitions that, while seemingly minor in the present, could potentially lead to significant market concentration in the future. It would also ensure that antitrust regulation stays relevant in an increasingly digital and data-driven global economy, helping to maintain competition and protect consumers.

While advances in data-driven innovations are built on global collaboration, encompassing contributions from universities, public research institutions, and various global companies, the resultant technologies' ownership largely remains in the hands of a select group of companies.

These market leaders, predominantly situated in a few developed countries, exert overwhelming control in the data economy. By cornering the knowledge and infrastructure essential for refining and capitalizing on the technology, these companies have cultivated dominant market positions, particularly in areas of deep learning and neural networks, both of which are data-intensive domains. The significant concentration of power within a few entities brings forth pressing concerns. Among these are issues of accountability, the transparency of operations, and the overarching question of how democratic control can be asserted over data and AI systems, especially given the profound influence they have on our daily lives.

3. *When data meet ethics: addressing the ethical implications of modern data practices*

The use of data-driven approaches has the potential to impact human rights, including issues related to privacy, freedom of expression, and discrimination. It is crucial to ensure that data systems respect and uphold fundamental human rights and do not perpetuate or exacerbate existing inequalities or biases. Ethical guidelines and frameworks are necessary to guide the development, deployment, and use of data in an ethical and responsible manner.

Data ethics takes centre stage, especially in scenarios where the gathering and manipulation of personal information complies with legal norms set out in privacy law, yet triggers a broader array of moral, cultural, and societal issues. These concerns could potentially lead to direct or indirect unfavourable consequences impacting individuals or collective social groups. It is not merely about the legality of data acquisition and processing, it involves the moral implications associated with the methods utilized to collect data, the respect for individual privacy, the intentions behind collecting such data, and the potential implications of its misuse.

Cultural considerations also come into play in data ethics. In a diverse global community, what may be considered ethically acceptable in one culture may not be viewed the same way in another. Therefore, the culturally-sensitive handling of data is crucial to ensure that no harm is done to people's cultural beliefs and values. Moreover, societal aspects of data ethics involve evaluating the potential consequences of data collection and processing on different social groups. The potential impacts could be as subtle as reinforcing existing social biases or as severe as causing discrimination or social harm.

Therefore, while privacy laws provide a legal framework for data collection and processing, they may not necessarily address all ethical concerns arising from the broader implications of data practices. This highlights the need for a robust data ethics framework, encompassing moral, cultural, and societal considerations alongside legal compliance.

The vast amounts of data processed by AI systems raise concerns about individual privacy. Data sharing and utilization can lead to unintended negative consequences. For instance, when individuals willingly share their data online, it can be exploited to gather information about others who did not give their consent, thus undermining their privacy (Acemoglu et al., 2022). Advancements in data analytics have simplified the process of associating ostensibly non-personal data with identifiable or identified individuals, blurring the line between personal and non-personal data. That poses challenges to regulatory methods that rely solely on a static understanding of "personal data" to establish the relevance of rights and responsibilities (OECD, 2019b).

AI systems learn from vast amounts of data, and if the training data are biased or reflect societal prejudices, the AI algorithms can inadvertently perpetuate those biases (**Box 11**). For example, if historical data used to train an AI algorithm exhibits discriminatory patterns, the algorithm may make biased decisions or predictions, leading to increased discrimination in various domains such as employment, criminal justice, or lending practices. This bias amplification can further deepen existing social disparities and marginalize certain groups.

AI algorithms may exhibit biases associated with factors such as gender, race, ethnicity, geography, and socio-economic variables (such as education, income, and zip codes). It has been observed that when companies integrate AI into their products and services, individuals from disadvantaged backgrounds are more likely to experience adverse effects (Zou and Schiebinger, 2018). Decisions driven by AI can have far-reaching impacts on individuals' lives, such as influencing job prospects (through automated resume screening), access to financial services (through credit scoring algorithms), or even legal outcomes (through predictive policing or sentencing algorithms). However, these AI systems can be prone to biases or errors, especially when trained on skewed or discriminatory data, leading to unjust or harmful outcomes. Yet, affected individuals often lack information about these systems and their potential impacts, undermining their ability to contest decisions or seek redress.

Box 11. Perils of 'Data for social good' initiatives

Initiatives aimed at utilizing data for societal benefits can sometimes lead to increased surveillance, inadvertently normalizing the reliance of public systems on private firms that can be extractive in nature.

An example of this can be seen in a collaborative project between a prominent tech company and a regional government that aimed to apply AI in preventing teenage pregnancy and reducing school dropout rates (Viera Magalhães and Couldry, 2021). This initiative involved the creation of a "permanent" monitoring system to track the habits and well-being of disadvantaged women and children, leading to comprehensive surveillance of these vulnerable individuals. However, addressing these complex social issues effectively would require a focus on strengthening institutional systems, such as education and universal access to health and reproductive care.

In another instance, a tech giant's suite of educational tools and software, offered to schools often at no cost, has faced criticism (Viera Magalhães and Couldry, 2021). While intended to facilitate learning and accessibility, concerns have been raised about the collection of extensive personal information from underage students without parental consent, as the use of these tools is often mandatory in many educational settings.

These two cases illustrate the nuanced and delicate intersection between leveraging data for societal welfare and ensuring the privacy and autonomy of individuals. Ethical considerations are paramount and call for a comprehensive dialogue involving all stakeholders to ensure that data are used responsibly and ethically, balancing societal benefits with individual rights and privacy.

These risks can contribute to discrimination along socioeconomic lines, further entrenching existing inequalities. Specific groups that have limited access to digital tools such as mobile phones, the internet, and banking services, including women, could become less visible in data and decision-making processes if algorithmic bias is allowed to persist in the use of biased datasets. Decision-making based on data about a person's social interactions, such as friends and neighbours, can also amplify discriminatory effects. For instance, an individual's poor credit score could indirectly lower the scores of those within their neighbourhood or social network. Further complexities arise when alternative scoring tools are used to identify vulnerable individuals who may be susceptible to predatory loans and other exploitative product offerings.

Such practices underscore the importance of ensuring fair and equitable use of data and algorithms. Ensuring this requires a multi-pronged approach, involving stringent regulation, transparency in algorithmic decision-making, and public awareness about data privacy and rights. Unchecked, these practices could further exacerbate socio-economic disparities and discrimination, and unfairly disadvantage already marginalized groups. Therefore, it is crucial that these issues are adequately addressed to prevent such outcomes and promote a fair and equitable digital ecosystem.

4. *Disinformation, misinformation, and the role of data*

Disinformation has emerged as a global issue of concern with serious consequences for democracy and human rights (OHCHR, 2021a). There is extensive documentation of the surge of misinformation and disinformation campaigns during the COVID-19 pandemic jeopardizing public health (OHCHR, 2020), interferences with electoral processes (Bradshaw and Howard, 2019), and attacks on minority groups (OHCHR, 2021b). Disinformation also intensifies political polarization and negatively impacts society's trust and cohesion (Matasick et al., 2020). While disinformation is not a new problem, data-enabled technologies such as social media platforms, AI, and Big Data analytics have created new avenues for false or manipulated information to be created, disseminated, and amplified at a scale, speed, and reach never known before. As a RAND Corporation report on 'Hostile Social Manipulation' observed, "the role of information warfare in global strategic competition has become much more apparent in recent years (Mazarr et al., 2019)."

There is no clear definition of, or shared common understanding and approach to, the terms disinformation, misinformation, and fake news (UN, 2022b). The difficulty of formulating precise definitions of these terms is accurately captured by Irene Khan, the UN Special Rapporteur on Freedom of Expression and Opinion (OHCHR, 2021a):

"*Part of the problem lies in the impossibility of drawing clear lines between fact and falsehood and between the absence and presence of intent to cause harm. False information can be instrumentalized by actors with diametrically opposite objectives. Truthful information can be labelled as "fake news" and delegitimized. Opinions, beliefs, uncertain knowledge, and other forms of expression like parody and satire do not easily fall into a binary analysis of truth and falsity. Furthermore, false content that is spread online with the intent to cause harm (disinformation) can be picked up and shared by innocent third parties with no such intent (misinformation), the innocent vector boosting dissemination and adding credibility to the malicious campaigner. Intentionally or not, the harm occurs. Some forms of disinformation can amount to incitement to hatred, discrimination, and violence, which are prohibited under international law.*"

Several attempts have been made to bring conceptual clarity to these often misunderstood, interchangeably used, and misused terminologies. One such attempt that subsequently came to be cited widely is the following taxonomy of information disorder developed by Wardle and Derakhshan (2017):

- *Misinformation:* when false information is shared, but no harm is meant.
- *Disinformation:* when false information is knowingly shared to cause harm.
- *Malinformation:* when genuine information is shared to cause harm, often by moving what was designed to stay private into the public sphere.

The European Commission's Independent High-Level Group on Fake News and Online Disinformation noted the appropriation and misleading use of the term "fake news" by powerful actors to dismiss disagreeable coverage (EC, 2018). Consequently, the UK government has prohibited the use of "fake news" in official policy documents and papers.

Digital platforms leverage the large-scale data collection of users' online activities, including their browsing activity, purchasing history, location data, and more, to provide users with content they are most likely to engage with, in turn, spending more time on the platforms, which converts to more advertising revenue for the platform. As users regularly encounter content that aligns with their political affiliation and personal beliefs, this enables confirmation biases (Lai, 2022). Further, even if a user wants to engage with different content and viewpoints, the infrastructure of the platforms hinders her from doing so without a considerable 'effort tax' (Sunstein, 2015). In this time-scarce world, such personalization can result in individuals unconsciously limiting their perspective to what the algorithms curate for them (Solove and Schwartz, 2009). This inhibits the capacity of an individual to reflect on their values, motivations, and decision-making involved in engaging with content. In turn, this allows the spread and cementing of misinformation. As the Special Rapporteur on Freedom of Opinion and Expression noted, “disinformation thrives in an online environment when there is less accessibility to plural and diverse sources of information” (OHCHR, 2021a).

The large-scale data collection of users by digital platforms and the use of AI and Big Data analytics have enabled micro-targeting of users with specific content. These innovations have been game-changers in the recent waves of disinformation, and have amplified its damaging impact to unprecedented levels. Political campaigning has also moved into a new phase in which digital technology is used to launch sophisticated microtargeting of segmented groups of voters, donors, and supporters.[44] This poses a risk of undermining free and fair elections. For example, racially targeted disinformation campaigns were used to suppress votes from communities of colour in the three most recent major elections in the United States.[45]

Users are often unaware and have little control over the kinds of data collected about them. They also have very little control over how they have been profiled by social media and how that impacts the content they see on their feeds, or how what they see compares with other users (Lai, 2022). Microtargeting technologies provide state and non-state actors with extensive access to voter data on race, political affiliation, religion, and more, to hone their messages or agenda and maximize the effectiveness of reach (OHCHR, 2021a). The technology enabling these practices ranges from relatively simple computer programs, such as bots that operate fake social media accounts, to more advanced technologies like machine learning algorithms capable of generating realistic-looking profile pictures, videos and deepfakes. These technologies can be used to amplify specific narratives, manipulate public opinion, and even spread disinformation. The proliferation of fake accounts and deepfakes complicates the information landscape, making it challenging for users to discern between authentic and manipulated content.

What is evident from the above is the enormous power that the Big Tech platforms today possess to fundamentally restructure our information channels and influence our digital information diet with serious implications on individual agency and on our capacity to make informed decisions as citizens (Ward, 2018). The problem is made acute with not only non-state actors but also with governments increasingly harnessing the attention economy logic of these platforms as a “highly effective tool for disseminating propaganda...spread[ing] misinformation and to monitor citizens” (Horowitz and Lowe, 2020).

This excessive power and potential for misuse underscore the necessity to reevaluate and strengthen the regulatory frameworks governing these platforms. A critical aspect of this is addressing the fraught issue of revenue sharing between digital platforms and news media. Ensuring equitable arrangements is pivotal to maintaining information integrity and averting crises like the one witnessed in Canada during the wildfires, attributed to a lack of access to crucial data. Australia and Canada have set precedents by requiring tech giants such as X (formerly, Twitter) and Meta (formerly, Facebook) to compensate media publishers for sharing their content, promoting trusted and fair journalism.

Disinformation and misinformation threaten democracies, civic participation, and efficient governance. They jeopardize the right of the public to be well-informed and to discuss societal issues based on reliable, high-quality, accurate information based on the public interest. All forms of disinformation can negatively impact the enjoyment of human rights and fundamental

[44] Mie Kim, Y. (2018). *Voter suppression has gone digital*. Brennan Center for Justice. https://policyreview.info/articles/analysis/political-microtargeting-towards-pragmatic-approach
[45] Ibid.

freedoms, as well as the attainment of the SDGs.[46] The proliferation of sensationalist content and partisan information makes citizens prone to responding to public and democratic issues emotionally rather than by rational reasoning.[47]

During the past decade, there has been a flurry of laws prohibiting 'false news' of various forms on the internet and social media platforms, with at least 17 States adopting legislation in the past years alone to address pandemic-related problematic information.[48] However, as the UN Special Rapporteur observed, "many of these 'false news' laws fail to meet the three-pronged test of legality, necessity, and legitimate aims set out in article 19 (3) of the International Covenant on Civil and Political Rights (OHCHR, 2021a)." Most of these laws do not define with sufficient clarity what constitutes fake or false information, and also do not mandate a clear and robust connection between the act committed and the resulting harm. Further, the authority to decide what constitutes fake news is often vested in political executives rather than judicial bodies and accompanied by harsh criminal punishment, which poses a serious threat of state censorship of dissident and dissenting voices. Given these implications for freedom of speech, UN human rights bodies "have made it clear that criminalizing disinformation is inconsistent with the right to freedom of expression".[49]

When introducing legal measures to counter disinformation, states must commit to approaches where any legal restrictions on speech are clearly and precisely prescribed by law, only introduced where they are necessary to protect other fundamental values, and are proportional to the specific threat at hand.

5. Power imbalances in the data economy

Data have gained a currency-like stature, serving as a critical economic asset and playing a decisive role in shaping our societies. However, data have also resulted in inequalities. We define data inequality as the disproportionate distribution of benefits derived from digital resources, which owe their value to the collective contributions of numerous stakeholders. Tech conglomerates that gather data wield disproportionate power, leaving customers and individual entrepreneurs feeling helpless about their data's usage and ownership.

This disparity originates from the absence of transparent processes and insufficient ways for individuals to influence the acquisition, storage, and deployment of their data. Often, people lack the essential information or knowledge to engage effectively with those who collect their data. They might not fully understand how their data are used, the value it possesses, or the potential negative outcomes its misuse can trigger. As a result, their control over their data is limited, curtailing their ability to negotiate within the data economy. This gap in digital literacy and data awareness can intensify feelings of alienation as individuals struggle to understand and navigate the complexities of the digital economy.

Furthermore, data-based business models deliberately create disparities in data access and utilization, tipping the scales to benefit the proprietors of these models. Platform owners exercise their power primarily through their control over the platform's architecture, which in turn allows them to set rules and maintain exclusive access to information and digital resources. These

[46] UN General Assembly. (2022). *Resolution adopted by the General Assembly on 24 December 2021*. A/RES/76/227. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N21/416/87/PDF/N2141687.pdf?OpenElement
[47] Turcilo, L., & Obrenovic, M. (n.d.). *Misinformation, Disinformation, Malinformation: Causes, Trends, and Their Influence on Democracy.* Heinrich Böll Stiftung. https://www.boell.de/sites/default/files/2020-08/200825_E-Paper3_ENG.pdf
[48] International Press Institute. (2020). *Rush to pass 'fake news' laws during Covid-19 intensifying global media freedom challenges*. https://ipi.media/rush-to-pass-fake-news-laws-during-covid-19-intensifying-global-media-freedom-challenges/
[49] Organization for Security and Cooperation in Europe. (2019). *International Standards and Comparative National Approaches to Countering Disinformation in the Context of Freedom of the Media, Prepared by Dr. Audrey Rikhter.* Office of the OSCE Representative on Freedom of the Media, Vienna.

capabilities may tempt them to exploit their power imbalance with other stakeholders involved. An important enabler of such power shifts is data submitted by customers, e.g., evaluations generated by peers regarding the quality of products and sellers on third-party platforms. Typically linked with digital platforms like eBay, Amazon, Uber, and Airbnb, these work settings represent new power dynamics characterized by two distinct features:

- Firstly, instead of traditional two-way exchanges, customer reviews establish three-way relationships between the platform operator, the buyers, and the sellers. These relationships give rise to multiple levels of accountability, which adds a layer of complexity to the interactions.
- Secondly, anonymous customers constitute an unseen “crowd”. This crowd impacts each individual seller’s profile and reputation through public online evaluations (Orlikowski and Scott, 2015). This means that sellers must be mindful not only of individual transactions but also of how they are perceived by the wider community of users.

The dynamics of online reviews create a power asymmetry because the parties involved have differing abilities to take action. For example, platform operators control the underlying systems and algorithms, buyers can publish reviews that affect sellers’ reputations, and sellers often have limited means to defend themselves or challenge negative reviews. As such, the increased reliance on customer reviews in these settings brings about a shift in power dynamics that favours those who can best leverage these new mechanisms of evaluation and control (Curchod et al., 2020)

In the case of ride-sharing and ride-hailing platforms, data-based control mechanisms extend from the software algorithms that match drivers with riders to the systems that determine pricing and payouts. This control enables them to exert influence and control over the platform’s operations, leading to a significant power imbalance between them and the workers.

Workers, on the other hand, often find themselves in a noticeably inferior power position, as they must operate within the confines set by the platform. This can lead to a feeling of dominance by the platform. This power imbalance is particularly notable because platform workers, unlike traditional employees, typically do not have formal employment contracts or protections. They are more akin to independent contractors, relying on the platform to connect them with customers and generate income. This reliance further exacerbates the feeling of dominance and the subordinate position of power experienced by the workers.

Another example is algorithms of e-commerce platforms that compile numerous evaluations into a single average score, thereby expressing the collective wisdom and consolidating buyers into a unified group. This sense of facing a collective entity rather than individuals amplifies the seller’s feeling of isolation. Hence, the disaggregation and aggregation mechanisms bolster power asymmetries by creating actor categories with varying agency levels and separating those who monitor from those being monitored.

Platform owners can vanish into inaccessibility at any moment, leaving the less powerful at their mercy. This form of power, characterized by a blend of network and algorithmic surveillance, creates a confusing environment for those subjected to it, causing stress and anxiety. Sellers, despite being part of a large network of users with whom they freely transact, find themselves within a formal, hierarchical power structure. The encoding of actions into the algorithm can empower some actors (for instance, by giving buyers the right to evaluate sellers) while disempowering others (for instance, by denying sellers the right to respond to negative evaluations). It also establishes protocols that govern interactions on the platform, such as setting evaluation criteria for buyers or demoting sellers with low scores.

When implemented, algorithms execute the set of instructions defined in the code, thereby influencing the actors' actions. For instance, an algorithm might allow buyers to engage in aggressive practices under the shield of anonymity, or contribute to a dehumanized work environment where interactions with the platform owner are virtually non-existent. In this context, the data algorithm takes on a structuring role, shaping asymmetric relationships on the platform. Through ongoing online interactions, social actors carry out the encoded actions, thus continuously reproducing these power imbalances.

In addition to their role in structuring power imbalances, algorithms also codify and script social relations on the platform, thereby reducing the space for individual agency. This process of codification occurs as algorithms consolidate a multitude of subjective opinions into a single, authoritative computation. Sellers operate in an environment where their success is defined by percentages of positive ratings, recalculated continuously as buyers post new reviews. This creates anxiety for sellers, as a single negative review can lead sometimes to an automatic status downgrade. The frustration and sense of powerlessness sellers experience is partly due to feeling surrounded by impersonal algorithms rather than human beings, rendering communication and justification of their actions almost impossible.

Algorithms also script interactions on platforms. In contrast to traditional, non-algorithmic settings where sellers could use rhetoric or persuasion to seek support or achieve desired outcomes, in algorithmic settings, their actions are dictated by predefined categories and automated procedures. Sellers are forced to follow a script that inevitably leads to customer evaluations, often making them feel at the mercy of buyers. Even their appeals or complaints are met with automated, preformatted responses. This heavily scripted environment significantly curtails the space for agency for sellers, underlining the considerable influence of algorithms on power dynamics and individual agency in the platform economy.

Similarly, traditional ethics of practice need a redefinition in the allocation of moral responsibility in networked interactions where human and machine agents are jointly undertaking actions in a distributed manner. Think of the case of an AI agent developed jointly by human and AI co-pilot programmers that leads to individual discrimination and/or collective harms. Ethicists have highlighted how "too often 'distributed' turns into 'diffused': everybody's problem becomes nobody's responsibility. This is morally unacceptable and pragmatically too risky (Floridi, 2016)."

To prevent biases in the digital economy and foster innovation, regulators must pay close attention on algorithmic governance within data-driven organizations. This involves creating policies that prevent algorithms from deepening current socio-economic divides or creating new disparities. By ensuring algorithms are transparent, fair, and accountable, regulators can help prevent the biases the digital economy, making it more inclusive and driving innovation by encouraging diverse and equitable use of data. This approach aims to mitigate power imbalances and ensure the digital economy serves the broader society, not just a privileged few.

6. *Negative effects of data on sustainability transitions*

For data-enabled technological change to be truly sustainable, it is crucial to find a balance between technological advancement, economic growth, and environmental preservation (UNCTAD, 2024). The way the data economy is organized today creates adverse environmental externalities at four stages: (1) rebound effects, (2) large-scale energy and resource consumption, (3) the manufacturing and mining processes that underlie digital devices, and (4) legacy systems for dealing with electronic waste.

Rebound effects of data-driven innovations

The rebound effect, as related to the data revolution and climate change mitigation, is a complex phenomenon that can counteract the potential benefits of efficiency gains from technology advancements. Essentially, it highlights the paradox that while data-driven innovations can make the production of goods and services more efficient, thereby reducing per unit energy and material use, the overall demand for these goods and services might increase due to reduced prices and increased disposable income, leading to a net increase in total energy and material consumption.

The underlying premise is that as data-centred approaches improve efficiency in production, the cost of production decreases. This reduction is often passed on to consumers in the form of lower prices. Moreover, advancements in technology can also lead to productivity enhancements, contributing to economic growth and potentially increasing disposable incomes. These factors together can stimulate increased demand for goods and services. While each unit of product or service might require less energy and material to produce thanks to digital technology, the sheer growth in the number of units consumed can offset these per unit efficiency gains. This is the rebound effect in action.

Digitalization reduces transaction costs and increases accessibility, which in turn encourages consumption. For instance, the rise of online streaming platforms like Netflix and Spotify has led to a significant increase in data consumption. While this may not directly translate into physical waste, the energy consumed by servers to keep these platforms running contributes to environmental degradation. The rise of the internet economy has undoubtedly stimulated more production activities. Companies like Amazon and Alibaba have thrived due to the increasing trend of online shopping, leading to an upsurge in the production of goods to meet consumer demand. However, this growth comes with a high environmental cost, such as the increased carbon emissions from transportation and higher waste generation due to packaging.

Data and energy consumption

A prevalent concern around making the data economy sustainable is its high rates of energy consumption, particularly with respect to data centres and cloud servers. Recent research has estimated that the data economy represented about 5% of global primary energy consumption in 2020, and based on trends, is likely to nearly double over the next 10 years to above 9%.[50] This problem is further compounded by the significant quantity of greenhouse gas (GHG) emissions that the various activities around the digital economy are responsible for.

Data centres, which are essential for storing and processing vast amounts of digital information, are projected to contribute significantly to the rising power demand. They require a considerable amount of electricity for multiple purposes, such as powering the servers that run the computations, cooling systems to maintain optimal hardware temperatures, and supporting infrastructure such as security systems and lighting. In 2020, data centres consumed approximately 200 terawatt-hours of power, accounting for around 1% of the global electricity consumption (Jones, 2018). As a result, some data-intensive technologies like cryptocurrencies based on distributed ledger technologies can consume more power globally than some nations (Truby, 2018), contributing significantly to energy demand and, consequently, the global carbon footprint (Mora et al., 2019).

New developments on the frontiers of datafication are even more environmentally strenuous. Recent research around the training of 2022-era generative AI models, for instance, showed that this process could emit as much "500 metric tons of carbon emissions, roughly equivalent to over a million miles driven by an average gasoline-powered car."[51] The environmental footprint of data centres does not stop at energy use. They also require large amounts of water for cooling,

[50] Brouillard, P. (2023). *Environmental impacts of digital technology*. The Shift Project. https://theshiftproject.org/en/article/environmental-impacts-of-digital-technology-5-year-trends-and-5g-governance/

[51] Luccioni, S. (2023). *The mounting human and environmental costs of Generative AI*. Ars Technica. https://arstechnica.com/gadgets/2023/04/generative-ai-is-cool-but-lets-not-forget-its-human-and-environmental-costs/

which can put stress on local water supplies. The heat they generate contributes to urban heat island effects. Their construction and operation can also contribute to habitat destruction and pollution. As the reliance on data centres continues to grow, it becomes crucial to focus on energy-efficient designs, cooling systems, and renewable energy sources to mitigate the environmental impact associated with their operations.

The steep environmental cost of mineral extraction

The extraction of rare-earth minerals may well be the stage that has the most impact on the environment within the life cycles of digital technologies. This is largely due to these operations being hugely unsustainable in their current form. For instance, looking at just two central minerals that are needed for the creation of batteries, lithium and cobalt, can demonstrate the extent of the problem. Grave concerns have been voiced about the impact of lithium mining on the Atacama salt flats ecosystem in Chile, and its consequences for precious fresh-water supplies (Tapia and Pena, 2020). Similarly, industrial-level cobalt mining in Congo has been blamed for extensive damage to crops, pollution of water bodies, and severe air pollution (Kara, 2023). All of this is not to mention the high human costs associated with these extraction industries as they currently exist in these regions, and the cases of violence and exploitation that have been associated with them.

The politics of electronic waste

The electronic waste generated from ICT products is another environmental concern. This e-waste comes from various sources such as computers, mobile phones, and a host of other digital devices that have become an integral part of our lives. As these devices reach their end of life or become obsolete due to rapid technological advancements, they turn into a burgeoning source of e-waste. The Global E-Waste Monitor indicated that the world generated 53.6 million metric tons of electronic waste in just the year 2019 (Forti et al., 2020). This immense volume of e-waste, if not managed and disposed of correctly, poses significant threats to the environment and human health. E-waste often contains hazardous substances like lead, mercury, and cadmium, which can contaminate soil, water, and air, leading to a multitude of environmental and health problems.

Developing countries bear a significant brunt of the e-waste problem (Nižetić et al., 2020). Many of these countries have seen a surge in the use of digital devices, driven by digitalization and the increased affordability (Dwivedi et al., 2022). However, a major issue arises from the shorter lifespan of these devices, which is often a result of 'planned obsolescence' in their manufacturing. This leads to faster turnover rates and consequently, elevated levels of e-waste generation. 'Planned obsolescence' is a widespread practice where electronics are designed with a limited lifespan, much shorter than technically possible, to encourage consumers to purchase replacements more frequently (Satyro et al., 2018; Taffel, 2023). This practice, while profitable for manufacturers, incurs enormous environmental costs. A compelling illustration of the environmental toll is provided by a study from the European Environment Bureau (2019). Their research revealed that extending the lifespan of smartphones and other electronics by just one year could mitigate carbon emissions equivalent to removing 2 million cars from the roads annually.

It is worth noting that there is a clear North-South dynamic at play in the ultimate impact of this e-waste, as the vast majority of the disposal work ends up being exported to the developing world. This is particularly harmful, as facilities to properly dispose or recycle such waste are scarcely available in these contexts. Due to insufficient infrastructure, regulatory oversight, and public awareness, a significant proportion of e-waste in these regions is dumped in landfills or incinerated. These practices not only create environmental damage but also waste valuable resources such as gold, silver, copper, and rare earth metals that could be recovered and reused from discarded electronic devices. Consequently, as case studies by Greenpeace (2008) and the

World Health Organization (WHO) (2021) have indicated, such waste can lead to severe forms of contamination in and around disposal sites, releasing toxins into the air and water, and setting off local sanitation crises.

The dangers of 'greenwashing' with data

Given various concerns around negative externalities in the data economy, there has been an active effort amongst large tech companies to champion the sustainability agenda. Pledges by major companies have been made to become 'carbon-free' and to move towards cleaner data centres and 'green batteries'. Other actors are sharing their datasets with climate scientists and government bodies to help with climate research or to offer access to cloud systems and analytics platforms to selected non-governmental organizations (NGOs) and researchers to gain more insights into their own fields/datasets.

While there are elements to these initiatives that are commendable, there is much that remains problematic (Espinoza and Aronczyk, 2021). Whilst the 'carbon-free' pledges, for instance, are aimed at switching away from fossil fuels in energy consumption, they have rarely commitments with regards to mitigating the environmental impact of mining operations, addressing planned obsolescence, or cleaning up the circuit of e-waste disposal. Such practices can be described as greenwashing, where companies or organizations give a misleading impression that their products, services, or overall operations are environmentally friendly or have a minimal ecological impact, which may not be the case. It is a form of marketing strategy aimed at capitalizing on the growing consumer demand for environmentally responsible products and services, without necessarily implementing substantive environmental practices. By overstating their commitment to sustainability or by focusing on minor green initiatives while ignoring more significant environmental harms, these entities can improve their public image.

Greenwashing can undermine genuine environmental efforts by obscuring the true impacts of activities and leading consumers to make choices that are not as environmentally beneficial as they are led to believe.

Researchers in the Global North are the main beneficiaries of resource-sharing initiatives, perpetuating asymmetries of climate knowledge. Moreover, they also perpetuate dependencies, and allow its AI tools to train on the datasets of nonprofits and public-sector research (Nost and Colven, 2022). As these critics point out, such efforts can easily lapse into cases of 'greenwashing', as they provide credibility and agenda-shaping power to these companies, while moving the spotlight away from the environmental costs of their business models.

Future outlook

While the use of data can bring significant efficiency improvements in various sectors, it is essential to consider the broader systemic effects. Without appropriate policies and measures to manage the rebound effects, the potential benefits of data for climate change mitigation could be compromised. This highlights the need for holistic strategies that integrate the data economy into broader sustainable development and climate action plans, ensuring that technological progress truly supports the SDGs.

To address these challenges, it is essential to invest in research and development efforts aimed at improving the energy efficiency of digital technologies. This includes exploring alternative computing architectures, optimizing algorithms, and promoting the use of renewable energy sources to power digital infrastructure. Collaboration between technology companies, policymakers, researchers and the society at large is vital to develop strategies that balance the benefits of digitalization with the goal of reducing energy consumption and minimizing the carbon footprint.

V. Fostering capacities to benefit from data and address associated challenges

Section VI offers an exploration of potential policies that governments can undertake to address the challenges of using data for development. Governments need to implement policies focused on enhancing interagency coordination and stimulating innovations in the public sector. Key focus areas include fostering public-private partnerships, establishing data sandboxes, and creating independent ethics review bodies. It is crucial to bolster the capacities of national statistical systems to collect and analyse data. This enhancement will not only inform policymaking but also contribute to the improved monitoring of progress towards achieving the SDGs.

A. A catalyst for change: the role of governments in maximizing data's potential

Governments stand as significant stakeholders in the data ecosystem, serving both as major producers and consumers of data. The availability and accessibility of this vast reservoir of data can act as a powerful catalyst for innovation (OECD, 2015). In 2017, the direct economic value of public sector data in the European Union was estimated to be €52 billion (World Bank, 2021a). This figure signifies the economic influence of accessible public sector data and their role in supporting a wide range of activities including research, policymaking, business development, and innovation, amongst others. The projection for EU member-countries that this value could escalate to a staggering €194 billion by 2030 implies an expected significant growth in the use and impact of public sector data (World Bank, 2021a).

Across the globe, national governments are taking active steps to provide digital services designed to facilitate the efficient access and utilization of government data by citizens, businesses, and other stakeholders. The concept of 'government as a platform' underscores the importance of open data initiatives, interoperability, and the strategic use of digital technologies to not only enhance government services but also to promote transparency and foster citizen engagement (Cordella and Paletti, 2019).

Opening up access to government data is not merely a symbolic move towards transparency. It has tangible implications for innovation and societal progress. By unlocking this trove of information, governments can empower citizens and businesses to leverage data for their own creative initiatives, make more informed decisions, and devise new services and solutions that add value to society. Some examples of open government data initiatives include data.go.jp (Japan) and data.gov.fr (France). Beyond their role as a facilitator of innovation, data also form the bedrock of evidence-informed policy making. Data analysis enables policymakers to gain insights, identify patterns, and make decisions that are grounded in empirical evidence. This data-driven approach to policy making can lead to more effective and efficient policies that tackle societal challenges head-on.

Through the smart allocation of resources, risk mitigation, and a clear focus on achieving desired outcomes, data-driven policy making stands to transform how governments operate. In essence, the availability of government data and the strategic use of data resources in policy making can play a pivotal role in enhancing public service delivery, fostering public sector innovations, and driving societal progress.

Governments worldwide may need to critically assess and refine their existing coordination mechanisms among public agencies tasked with designing and maintaining data infrastructures. The aim is to avoid resource fragmentation and the creation of isolated solutions, which often suffer from limited interoperability and functionality. A proactive solution could be the establishment of an inter-agency digital coordination working group. This entity would convene to discuss and consider the generation and usage of public data in a comprehensive and coordinated fashion. Such a group could act as a counterforce to resistance against data sharing, encouraging a more open and collaborative data environment.

One of the fundamental objectives of such cross-government coordination would be to cultivate a data-driven culture within the public sector. This transformation could be facilitated by implementing frameworks that promote data reuse and by investing in the necessary infrastructure to leverage the benefits of data optimally. The goal is to modernize government operations and services, driving them towards efficiency and effectiveness.

There also exist ample opportunities for enhancing the compatibility of standards and creating a framework for experimentation with advanced digital technologies to better serve the needs of citizens. With a plethora of public and private databases, there is considerable potential to adopt identifiers, ontologies, protocols, and common formats to align different datasets. Yet, readiness for deploying new technologies is not uniformly demonstrated across government agencies.

Another aspect worth considering is the public sector's tendency to create its own solutions instead of sourcing ready-made ones. While this approach has benefits in terms of customization and learning, it can turn out to be inefficient in the long run. Digital government infrastructures may greatly benefit from the input of "outsiders" to the IT departments in the public sector. Such external perspectives could offer innovative ideas, alternative approaches, and efficiency-enhancing strategies that could substantially improve the development and management of digital infrastructure in the public sector.

In this context, public-private partnerships can be an effective mechanism for maintaining and designing digital infrastructures for long-term sustainability of digital public services. Commercial data brokers and analytical solution providers can help governments extract more value, especially when the public sector lacks its own data or key complementary datasets. However, private sector involvement is justified when it offers higher-quality services than the public sector alone.

To foster innovation and reduce costs, procurement activities need to be streamlined. Long-term procurement contracts with significant funding may fail to promote competition or meet evolving needs, so shorter-term arrangements could be preferable in some cases. Contracts with the private sector must ensure that government agencies retain control over public datasets and prioritize data privacy. Vague specifications can lead to unintended loss of control, and public administrations may end up paying to access their own data.

Governments can explore policy instruments such as establishing independent ethics review bodies and data sandboxes to augment data governance. Independent ethics review bodies, for example, the UK's Centre for Data Ethics and Innovation, can promote transparency, accountability, and safeguard citizens' data rights. They scrutinize the data practices of public and private organizations, ensuring adherence to ethical standards. For instance, if a tech company misuses user data, this review body can step in to recommend remedial actions or impose penalties, reinforcing responsible data handling practices.

On the other hand, data sandboxes, akin to Singapore's Data Sandbox Programme, offer controlled environments for testing innovative data-driven solutions. These safe spaces allow organizations to experiment and innovate while ensuring data privacy and security. For instance, a fintech startup can utilize a data sandbox to test new AI-driven personal finance tools, ensuring they comply with data protection regulations while fostering innovation. This balanced approach ensures that the zeal for innovation does not compromise data privacy and security, aligning technological advancement with ethical standards.

In conclusion, the multidimensional impact of government in advancing data governance cannot be overstated. A holistic approach, anchored in cross-sectoral collaboration, agile procurement, and robust governance mechanisms, is essential to unlock the full potential of data. A future where data are not just abundant but also meaningful, accessible, and secure is within reach. It requires concerted efforts from government agencies, the private sector, academia, technical communities and civil society to foster a data ecosystem that is as dynamic and diverse as the societies it aims to serve. Today's decision-makers bear the responsibility to develop policy frameworks and invest in digital infrastructures, as well as in enhancing skills and capabilities. These should be resilient, adaptable, and tailored to meet the changing needs and aspirations of citizens.

B. A global mission to enhance statistical capacities for sustainable development

Robust and timely statistical data are crucial for tracking progress on the SDGs.[52] First, statistical data allow policymakers to understand where efforts are succeeding and where they are falling short, enabling targeted interventions to address specific challenges. Second, they provide a basis for accountability, allowing governments, civil society, and the international community to hold actors responsible for meeting their commitments. Third, they help to identify and address disparities within and between countries, promoting a more equitable and inclusive approach to development. To realize this potential of statistical data, national and international stakeholders need to solve associated challenges.

The tracking of progress towards the SDGs worldwide is hampered by significant gaps in the availability, timeliness, and quality of official statistical data.[53] These gaps make it difficult to assess the extent to which countries are meeting their SDG targets and to identify areas where additional efforts are needed. For example, for more than half of the indicators related to gender equality, there is insufficient data to provide an accurate and comprehensive assessment of progress (UN, 2022c). The data gaps are particularly pronounced in fragile contexts, where statistical systems are often weaker than in other parts of the world. Fragile contexts, which include countries or regions affected by conflict, political instability, or other forms of disruption, face unique challenges in collecting and maintaining high-quality data. These challenges may be due to a lack of capacity within national statistical offices, inadequate funding for data collection and analysis, or logistical and security constraints that make data collection difficult. The achievement of the 2030 Agenda for Sustainable Development is inextricably linked to how effectively these data gaps are addressed. Ensuring this necessitates unified efforts from national governments, international organizations, donors, and other key stakeholder.[54]

The relevance and usefulness of macroeconomic statistics are contingent on the ability to adapt systems of national accounts (SNA) and develop supplemental frameworks to respond to the changing needs of policymakers and other users. Digitalization has brought about several developments that require careful consideration in the context of macroeconomic measurement. Specifically, there are three key developments that need to be addressed for future valuation and treatment within statistical frameworks: 1) the concept of data as an asset, 2) the emergence of "free" digital assets, and 3) the provision of "free" digital services.

- *Data as an asset:* Digitalization has enabled the collection, storage, and analysis of vast amounts of data. This data, which include information on consumer behavior, market trends, and other variables, has become an increasingly valuable asset for businesses and governments. The SNA needs to account for data as an asset, considering its

[52] Contribution from the Government of Brazil and the Government of Djibouti.
[53] Contribution from the Government of the United Kingdom.
[54] Contribution from the Government of Belize.

potential to generate economic value, drive innovation, and inform decision-making. Developing methodologies for valuing data and incorporating it into macroeconomic accounts is a key challenge.

- *'Free' digital assets:* Digitalization has also led to the emergence of "free" assets, such as open-source software and user-generated content, which are available at no cost to users. These assets can contribute to economic growth, productivity, and innovation, but their valuation is complex due to the lack of market transactions. The SNA needs to develop approaches for valuing "free" assets and reflecting their contributions to economic activity.
- *'Free' digital services:* Many digital platforms provide services to users at no monetary cost, such as search engines, social media platforms, and online maps. These "free" services are often monetized through advertising or data collection. The SNA needs to consider the value of these services, as they can have significant economic and social impacts. Developing methods for valuing "free" digital services and incorporating them into macroeconomic accounts is essential for capturing the full scope of digitalization's effects on the economy.

The rapid advancements in data-driven technologies offer a unique opportunity to revamp data collection methods for national statistical agencies. National governments can leverage new technologies and alternative data sources to complement traditional data collection methods. For instance, using satellite imagery, mobile phone data, or barcode data can provide more frequent and granular insights about various SDG indicators.

One way how national governments can make a significant difference is by increasing the funding allocated to statistical systems. With adequate financial resources, national statistical offices can function more efficiently and provide more accurate, timely data. In addition to funding, providing training and technical assistance to national statistical offices is crucial. Nations should consistently enhance their capabilities, both in the conventional generation of official statistics and in devising methods to access alternative data sources. Such support can equip them with the necessary skills and knowledge to handle vast amounts of data and ensure that they are analysed appropriately.

Collaboration is key. If the global community comes together to enhance the availability, timeliness, and quality of data, we can ensure a more comprehensive understanding of our progress. It is not just about monitoring advancement, it is also about ensuring that every individual, no matter where they are, benefits from the fruits of the data economy. Thus, by refining our data collection and analysis methods, we take a step closer to the SDGs' overarching vision: to leave no one behind.

In addressing the pressing funding gap in data, the United Nations Hangzhou declaration (2023), titled *"Accelerating progress in the implementation of the Cape Town Global Action Plan for Sustainable Development Data"*, emphasized the immediate and continued need to boost investments in data and statistics.[55] It appeals to a wide range of stakeholders, spanning domestic to international actors and encompassing the public, private, and philanthropic sectors. The core aim of this call seeks to bolster the statistical capabilities of low-income countries and fragile states, bridge the data disparities faced by vulnerable populations, and fortify national resilience against an array of present-day challenges, ranging from economic downturns and geopolitical strife to the climate change.

Improving statistical and data capabilities is more than a practical requirement. It is a matter of ethical and moral duty. Each improvement we make to our data systems reaffirms our steadfast

[55] Contribution from the Government of the United Kingdom.

dedication to the core principles of SDGs —fostering a just, equitable, and inclusive world where no individual is overlooked or left behind. It is not merely about economic expansion but about nurturing the fullest expression of human potential in all its varied forms and richness.

VI. Data governance

This section delves into the intricate nature of data governance, underscoring the importance of the social contract in harnessing data's value in a fair and mutually advantageous way. The section offers an overview of three national paradigms concerning data governance. The section reflects on the consequences of such varied approaches, emphasizing the importance and urgency of establishing universally accepted guidelines for data governance. The section concludes by presenting seven global data governance principles for development.

A. Data taxonomies for global impact

In order to understand fully data impacts, it is essential to distinguish between different types of data. Data taxonomies are systematic classifications used to organize and categorize data based on certain criteria or attributes. These taxonomies play a crucial role in data management and analysis by allowing for the efficient organization, retrieval, and analysis of data. Different taxonomies are employed depending, among other factors, on the context, needs, and purposes of data usage. These classifications are often determined by factors such as the source of the data, the entities using the data, the timeframe of the data, the sensitivity of the data, and the nature of the data (UNCTAD, 2021a):

- *Purpose of Collection*: Data can be collected for various purposes, which often determine its classification. For example, data collected for commercial purposes typically include information on customer preferences, sales, and market trends. Such data help businesses understand their market, refine their strategies, and make informed decisions. In contrast, governmental data are usually collected for public policy formulation, planning, and governance. This data can include information on population demographics, economic indicators, and social trends.
- *Entity of Use*: Data can be classified based on the entity that uses it, whether private or public. Private sector data typically pertains to businesses, corporations, and private entities, often used for market analysis, business strategy, and operational efficiency. Public sector data, on the other hand, includes information used by government agencies and public institutions for governance, policymaking, and public service delivery.
- *Timeframe:* Data can also be categorized based on its timeframe, distinguishing between short-lived and long-lived data. Short-lived data, useful for under a year, are viewed as intermediate consumption bought from third parties or as a product of an ancillary activity within the same unit, as in the case of live traffic updates. Long-lived data, in contrast, refer to information with lasting impact that can be analyzed for trends, patterns, and insights. For example, historical weather data can be used to predict climate patterns.
- *Sensitivity:* Another important classification is based on data sensitivity, which depends on the nature of the information and the potential consequences of its disclosure. Sensitive data includes confidential information that could harm individuals or organizations if disclosed, such as financial records, health information, or trade secrets. Non-sensitive data, on the other hand, poses no such risk and can be shared more freely.
- *Nature of the Data:* Data can also be classified as personal or non-personal, depending on whether it identifies or can be used to identify individuals. Personal data includes names, addresses, phone numbers, and other identifiers, which are often protected by

privacy laws. Non-personal data, in contrast, refers to information that cannot be used to identify individuals, such as aggregated statistics or anonymized records.

Although various taxonomies are used to classify types of data, the taxonomies often differ globally based on the criteria employed (UNCTAD, 2023c). These discrepancies in data classification systems arise from several factors. Geographical differences play a role, as different countries or regions may have their own definitions of data due to cultural, legal, or economic factors. These disparities can lead to different understandings of what is considered public or private information, impacting data protection, sharing, and management practices. This can create challenges for international collaboration and the harmonization of data policies.

Industry-specific taxonomies also contribute to the variations. Different industries may classify data based on criteria relevant to their specific needs. For instance, the healthcare industry may focus on patient data, while the financial industry may prioritize transaction data. The evolution of technology is another factor, as new forms of data and data flows emerge, necessitating updates to existing taxonomies. Keeping pace with these technological changes can be challenging, and data classification systems may not always be up-to-date.

Given these complexities and variations, there is a pressing need for globally agreed common definitions and understanding of data-related concepts. Harmonizing data taxonomies can improve clarity, enhance collaboration, and facilitate data governance at both national and international levels. Achieving this would likely involve engaging stakeholders from diverse sectors, regions, and disciplines in a dialogue to identify commonalities, reconcile differences, and agree on standard definitions and classifications. A global consensus on data taxonomy would contribute to more effective and informed data policies, data management, and data-driven decision-making. Lack of data taxonomies harmonization can lead to inconsistencies and misinterpretations, causing delays in decision-making and implementation. In the context of the 2030 Agenda, such delays can hinder the achievement of its goals.[56]

B. Three main approaches to data governance

Across the globe, for the three major players in the digital economy—the United States, China, and the European Union (EU)—models of data governance vary , each reflecting different societal values and perspectives on data control (UNCTAD, 2021a). These models, while presented in a simplified manner, profoundly influence the way data are managed and utilized within their respective regions. The United States model generally favours private sector control of data. In this approach, businesses are primarily responsible for managing and controlling data. This is largely driven by the country's strong belief in free-market principles, where private entities are often seen as the most effective agents in innovation and economic growth. Data, in this context, are considered a competitive asset that can be leveraged for business growth and technological advancement.

The Chinese data governance model leans towards government control of data. In this case, the state has the dominant role in handling and managing data, reflecting China's state-centric governance structure. The government, under this model, oversees the data landscape, determining how data are collected, stored, processed, and used. This approach can serve national security and support state-driven development initiatives.

Meanwhile, the EU adheres to a model that prioritizes individual control of data, based on a commitment to fundamental rights and values. The EU champions personal data protection and privacy as a human right. This perspective is reflected in regulations like the General Data Protection Regulation (GDPR), which strengthens individuals' control over their data. In this

[56] Contribution from the International Atomic Energy Agency (IAEA).

model, the individual is central, with rights to access, correct, delete, and transfer his or her personal data.

Each of these three models presents its own strengths and challenges and serves as a testament to the diverse perspectives on data governance that exist worldwide. The three models underscore the importance of considering cultural, societal, and political contexts when crafting data governance policies and regulations. However, the differing priorities and approaches raise concerns about potential fragmentation of global data governance. When countries adopt divergent regulations, it can lead to inconsistencies and incompatibilities in how the Internet operates globally. This fragmentation poses challenges to the free data flow, cross-border collaboration, and the seamless functioning of digital services across national boundaries.

One of the many challenges in data governance arises from the proliferation of national regulations on cross-border data flows (UNCTAD, 2023c). This creates uncertainty and increases compliance costs, which can be particularly burdensome for micro and small enterprises, especially in developing countries. The interconnected nature of the data-driven digital economy means that national policies in this area can have spill-over effects on other countries. A prominent example is the GDPR in the EU, which has led many companies to make significant changes to their global data processing and business models to comply with it (Peukert et al., 2022; UNCTAD, 2021a).

Developing countries are confronted with the imperative of adhering to the data governance standards established by the major economic entities to be able to integrate effectively into global value chains. Developing countries often encounter limited representation in the conversations around global data governance. Their perspectives, challenges, and unique contexts might be underrepresented, leading to the formulation of standards and policies that are not entirely inclusive or considerate of their specific needs and constraints. To address this, there is a pressing need to amplify the voices of developing countries in international forums and decision-making bodies. Ensuring their active participation and contribution can lead to more equitable, balanced, and inclusive global data governance frameworks.

C. A social contract for data governance: balancing individual rights and collective good

Data can detail patterns of human behaviour, interactions, preferences, and even vulnerabilities. As such, data are often tied intrinsically to the human rights. The extent and manner of data collection, storage, analysis, and sharing can have profound implications on various fundamental rights, such as the right to privacy, freedom of expression, and non-discrimination.

Therefore, a holistic approach to data governance becomes imperative, one that safeguards the interests of all stakeholders and takes into account the multidimensional nature of data. If data can be perceived as a common good, akin to clean air or natural resources, it necessitates a corresponding framework for its protection and management that encompasses more than just individual control. While acknowledging the significance of personal agency in managing one's data, a fair and just digital economy requires an overarching paradigm shift from private data contracts to social contracts, transcending purely market considerations.

This complexity is reflected in the experiences of numerous countries that have delved into data governance, demonstrating the inherent challenges that go beyond mere data collection and analysis. One of the primary challenges is centred around the concept of a "social contract" (World Bank, 2021a). A social contract is the acceptance and trust of a community towards the use of data. It is a form of implicit agreement between data-handling entities and the people or organizations they gather data from, assuring that data usage respects ethical norms, privacy standards, and the overall public interest in an equitable manner.

Private contracts often reflect the dynamics of market power where a limited group of large technology firms mostly from developed countries usually have the upper hand. In the absence of proper governance framework, they typically dictate the terms of service, privacy policies, and other regulations pertaining to data handling. An individual's ability to influence these conditions is limited, often leading to a situation where they must either agree to the terms set by these firms or opt out of using the technological solution altogether. This 'take it or leave it' approach undermines the principle of informed consent and individual autonomy in data management.

For any right to have genuine meaning, it should empower the individual with the agency to exercise it thoughtfully, and without undue constraints. This perspective, when applied to data governance, prompts a significant reflection on our current data protection frameworks. While data's value is indisputable, the framework surrounding its ownership has increasingly come under scrutiny. The concept of "ownership" in the context of data is controversial as highlighted by UNCTAD (2021a), mainly because data often contain personal or sensitive information, and declaring ownership can imply control and rights that may infringe upon privacy and ethical considerations. Additionally, referring to data as a "commodity" is problematic. It simplifies the complex nature of data, overlooking the inherent privacy, security, and ethical concerns associated with its collection, storage, and usage. These terminologies can be misleading and fail to capture the multi-dimensional aspects of data governance and ethics. The conventional understanding of data ownership hinges on the premise that personal data are a private possession. Once shared with companies—whether voluntarily or inadvertently—it becomes a commodity, often controlled, and monetized by corporations with little to no input from the data's original owners. However, there are inherent issues with this model:

- *Diminished Agency:* When individuals share data, they often do so without fully comprehending the depth and breadth of its potential usage. Over time, as their data get parsed, analyzed, and circulated, they lose agency over it. It is no longer a simple transaction —it is ceding control. If users cannot make informed and meaningful choices regarding their data after sharing it, then can their right to data privacy truly be deemed a right?
- *Collective Nature of Data*: As data get aggregated and integrated into broader datasets, it takes on a collective dimension. Personal data points, when collated, shape societal trends, influence public policies, and even direct economic trajectories. While each data point originates from an individual, in aggregate, it becomes a reflection of communities and populations. In this light, treating such data purely as private property seems reductionist.

By shifting the paradigm and viewing circulating data as a common good rather than private property, we can ensure a more equitable data governance.[57] In this model, data aggregators and platforms transition from being proprietors to controllers or custodians. As controllers, their role is not to own data but to steward, protect, and manage it responsibly on behalf of the public. Recognizing data in circulation as a common good would mean enhanced transparency and accountability. Companies would be obligated to ensure that data are used ethically and benefits the broader society. Such a shift could also pave the way for more community-driven data initiatives, harnessing the collective power of data for public welfare, without compromising individual privacy. This approach acknowledges the collective nature of data as a common good and transcends the traditional market-based approach to data governance.

Transitioning from a private contract model to a social contract model offers a possible solution to this dilemma. A social contract represents a mutual agreement among the members of a society to cooperate for social benefits. Applied to the context of data, it would mean setting

[57] Contribution from the Government of Ecuador.

universally agreed upon rules and norms that guide the collection, usage, and sharing of data, considering the welfare of all individuals and society at large. This approach acknowledges the collective nature of data as a common good and transcends the traditional market-based approach to data governance.

In such a system, individual rights are not viewed as privately negotiated entities but as social obligations that must be respected by all parties involved, including technology firms. It will lead to the creation of a fairer, more equitable economy where the power imbalance between users and providers of data-enabled solutions is significantly reduced. Moreover, this approach implies a shared responsibility for ensuring that data usage is ethical and respects human rights, rather than placing the burden solely on the individual.

Furthermore, trust, an essential ingredient for any system dealing with data, can only be fostered if the ethical obligations and the duties of rights-respecting behaviours are not individualized, but rather socialized. By collectively agreeing on the rules and standards for data handling and ensuring their enforcement, we can create an environment where data flow freely and securely. Individuals can trust that their data are being handled responsibly, not because they individually negotiated the terms, but because society as a whole has agreed on a standard of data management that respects everyone's rights and interests.

The importance of securing a social contract cannot be overstated. Without the trust of the community, attempts to build data infrastructures can be met with resistance, scepticism, or even outright opposition. This could stem from concerns about privacy, data misuse, or potential adverse consequences that may arise from data-driven policy decisions.[58] Addressing these challenges involves not only adequate data protection measures to prevent breaches or unauthorized access but also policies that ensure ethical data usage. Individuals and institutions need to be confident that their data will not be manipulated or used in ways that could potentially harm their interests or reputation. Furthermore, there is a need for a clear legal and regulatory framework governing data usage. Such a framework should outline the rights and responsibilities of all parties involved in data handling and provide mechanisms for accountability and redress in case of violations.

At the same time, data can serve as a critical catalyst for the transformation of the social contract. The existing social contract was drafted for a period when technological changes occurred incrementally, and adaptative responses were still feasible. This model, however, is less applicable in our fast-paced digital society. Countries across the globe are now at a crossroads, necessitating a reframing of the social contract to align with the digital age. In this revised agreement, every phase of data management must encompass means for the free, active, and meaningful participation of all stakeholders, especially marginalized population groups. It indicates a shift where private and public organizations are called to shoulder increased accountability and responsibilities. Furthermore, government bodies are tasked with refining their approaches to offer prompt and proactive solutions that keep pace with the data revolution.

The newly designed digital social contract must prioritize transparency, applying to both public and private entities significantly involved in data affairs. The purpose of this adjusted digital social contract should be to democratize access to opportunities, spreading them across the globe and within countries rather than confining them to a privileged minority. Another key element is the need for more resilient, adaptable, and progressive regulatory strategies. Currently, many regulations tend to become outdated soon after their implementation due to the fast technological pace. For effective policymaking in the digital society, regulatory systems must integrate flexibility and have the capacity for swift adjustments and adaptations to keep up with

[58] Contribution from the Government of Burundi.

the evolving data landscape. Otherwise, government institutions will be incapable of satisfying citizen needs and resolving market failures.

While articulating the preferred attributes of the renewed social contract, it is essential to devise mechanisms that can soften temporary variances and flux during the transition. These safeguards would act as a buffer ensuring the progression towards the people-centred, inclusive and development-oriented information society does not exclude any individuals or communities, thereby ensuring societal balance during this transformative period. This approach will ensure that technological advancements are in line with people's needs and that human rights remain a primary guiding principle.

D. The need for a global consensus on data governance

As noted above, the strategies adopted by major economic and geopolitical entities to govern data flows, as well as the broader digital economy, differ substantially (UNCTAD, 2021a). Establishing a global data governance framework would facilitate worldwide data-sharing, and assist in the creation of public goods that could tackle substantial global developmental challenges, such as poverty, health, hunger, and climate change. Data play a crucial role in informing policies, measuring progress, and identifying gaps in these areas in the 2030 Agenda for Sustainable Development. This is set to become even more the case with growing reliance on AI, IoT T, and big data analytics. Hence, cross-border technical cooperation, ideally at a global scale, is critical to prevent additional fragmentation of the internet infrastructure and digital space.

The High-level Advisory Board on Effective Multilateralism in its report noted that until we put in place a global framework in which States and non-State actors participate fully in shaping our shared digital space and which promotes and supports interoperable governance across digital domains, responses to digital challenges will be incomplete.[59] The Advisory Board proposed the establishment of a new Commission on Just and Sustainable Digitalization.

In the absence of a common approach to data sharing, businesses and organizations may need to navigate complex, and sometimes contradictory, legal requirements to ensure they remain compliant when dealing with international data (OECD, 2023b). This can involve substantial resources and may expose organizations to risk if compliance is not effectively managed. This landscape of fragmented data sharing rules underscores the importance of developing international agreements and common approaches for sharing data. Such measures would not only facilitate seamless cross-border data access and sharing but also provide clear guidance and protection for both data providers and recipients. These could include mechanisms for harmonizing data protection laws, creating international standards, and developing trusted frameworks for data exchange.

Data flows increasingly feature as an issue in trade agreements (WCO and WTO, 2022). As digital transformation and globalization continue to expand, the movement of data across borders has become a crucial aspect of international trade. Trade agreements now often include provisions that govern data flows, addressing issues such as data protection, privacy, and cross-border data flows (OECD, 2022). However, due to unique characteristics of data (e.g., non-rivalry nature, zero to low marginal costs), trade policy cannot encompass its entire complexity, suggesting that national governments require broader governance approaches that go beyond trade regimes (UNCTAD, 2021a). Negotiating data protection within trade agreements risks deprioritizing privacy and national security issues due to the bundling of various elements, making objections more costly and potentially leading to inadequate safeguarding of data privacy. Furthermore, the

[59] Shift Four. Digital and Data Governance. Support a just digital transition that unlocks the value of data and protects against digital harms. Accessed on 12 October 2023 from https://highleveladvisoryboard.org/breakthrough/pdf/highleveladvisoryboard_breakthrough_Shift4.pdf

primary focus on economic benefits in trade agreements may lead to harmonization at the expense of human rights, as the tendency towards deregulation to promote free trade could weaken data protection standards. Therefore, international data governance should incorporate comprehensive approaches to unravelling the value of data for economic and trade development without jeopardizing human rights and the need of countries to regulate to achieve various other policy objectives (UNCTAD, 2021a).

Finding the right balance for multilateral, multi-stakeholder, and multidisciplinary engagement in data governance will necessitate innovative and forward-thinking strategies. These strategies need to encompass both top-down and bottom-up approaches, fostering a convergence of perspectives that is both inclusive and effective. The top-down approach typically involves guidelines, policies, and regulations initiated at a higher level, such as governments, international organizations, or large corporations. These entities have the ability to effect broad changes and can set universal standards or principles for data governance. Conversely, the bottom-up approach considers insights, experiences, and needs of individual users, communities, and organizations. This approach ensures that the voices of those most affected by data policies are heard and their rights are protected. Stakeholders, ranging from national government authorities to technical communities, need to develop global data governance frameworks that strike a balance between enabling innovation and economic growth while safeguarding individual rights and societal well-being.

The governance mechanism should aim for a symbiosis between these approaches, fostering a dialogue and mutual understanding between different levels of stakeholders. In practical terms, this could mean that not all aspects of governance need to be addressed simultaneously at all levels. Multilayered governance could be a viable strategy, where different governance aspects are handled by appropriate groups or levels, creating a more efficient and manageable system. Nonetheless, a higher-level coordinating system at a global level would be essential. This overarching system could ensure coherence, consistency, and coordination among the different layers of governance. It could help align the various stakeholders' efforts and facilitate collaboration, preventing fragmentation or conflicting initiatives.

The governance mechanism would also need to be inclusive. Developing countries, and especially the LDCs, are often poorly represented in present conversations around global data governance. Their perspectives, challenges, and unique contexts will then be underrepresented, leading to the formulation of standards and policies that are neither inclusive nor considerate of their specific needs and constraints. This underlines the need to amplify the voices of developing countries in future mechanisms and forums related to data governance, suggesting an important role for the United Nations.

Innovative strategies for multilateral, multi-stakeholder, and multidisciplinary engagement are required for effective global data governance. These strategies should encompass top-down and bottom-up approaches, consider new governance models, and embrace the evolving role of technology diplomacy to realize the full potential of data for sustainable development. The Commission on Science and Technology for Development (CSTD) has an opportunity to develop recommendations on how to strengthen a holistic dialogue in the United Nations on how to foster global data governance for sustainable development, possibly through a dedicated working group.

E. Towards global data governance principles

Data governance must be flexible enough to effectively navigate the rapidly evolving data landscape. Solely relying on command-and-control, top–down regulatory mandates may not be practical or effective given the complexity and unpredictability of technological advancements (OECD, 2023c; UNCTAD, 2020). These mandates are not always likely to address the nuanced and specific needs of different data-enabled technologies across various industrial sectors. A hybrid approach in data governance may combine both hard law and soft law mechanisms. “Hard law” refers to legally binding regulations that are enforceable through formal legal mechanisms, whereas “soft law” encompasses non-binding guidelines, principles, and practices that influence behaviour but are not always legally enforceable (UNCTAD, 2021a).

This combination of hard and soft law mechanisms allows for more nuanced and context-specific handling of data-related issues, recognizing that different sectors and technologies may require varied governance strategies. In managing data, stakeholders need to strike a balance between risk avoidance and the promotion of healthy competition and business innovation. A pre-emptive, precautionary approach to data governance may not always be well-suited to address potential future risks, which are constantly evolving with the emergence of new data-enabled applications.

Proactive hard law measures implemented before potential issues or harms occur should be mainly reserved for situations where a trial-and-error approach is unacceptable due to high risks. In other scenarios, an overly risk-averse stance may lead to prematurely judging data-enabled innovations as guilty until proven innocent. Ex ante regulations during the development stages of data-enabled technologies involve risks for innovation and market concentration, whose costs should be considered. This may also result in investment concentration in jurisdictions with lower risk aversion. Large firms and market incumbents, who possess the necessary resources, knowledge and networks to manage the burdens of regulatory compliance, are likely to emerge as winners in such a regulatory environment.

Given that legal frameworks often struggle to keep pace with technological advancements and regulators may lack the necessary technical expertise, bottom–up approaches can offer an alternative or a complement to traditional top–down rulemaking. This bottom–up strategy would rely on soft law mechanisms, such as social norms, good practices, third-party accreditation, whistleblower systems and voluntary codes of conduct and commitments. These methods are flexible and can be customized to address the specific challenges and opportunities posed by data.

However, soft law mechanisms are not without drawbacks. A significant concern is the phenomenon of “ethics washing”, where companies’ claims of ethical self-governance lack transparency and substance. This issue has been compounded by several high-profile governance failures in the technology industry (United Nations, 2018; White, 2022). Incidents involving the misuse of personal data, emissions test cheating and deceptive marketing of unverified technologies have all contributed to growing mistrust. These examples highlight the limitations and challenges of applying soft law for data governance, underscoring the need for a balanced and effective regulatory framework.

Effective data governance may therefore require strategically blending soft and hard law mechanisms, leveraging their strengths while mitigating their individual shortcomings. To enhance the efficacy and trustworthiness of soft law in data governance, it is essential to move beyond merely principles-based approaches, developing mechanisms for implementation of those principles and ensuring accountability.

Excluding any stakeholder group can diminish the overall efficacy of data governance. Civil society, businesses, academia, non-governmental organizations and technical communities should be involved in the development and implementation of robust data governance structures. An often overlooked but vital group is youth, whose perspectives are crucial in shaping data governance frameworks that consider the needs of future generations.

Data governance should find a balance between risk avoidance and the promotion of innovation.

To advance data governance for development, consistent with the imperatives of multilateralism, multi-stakeholder approach and multidisciplinary consideration of data, seven principles are proposed:

- *Foundation in human rights.* Data governance should be consistent with the Universal Declaration of Human Rights, upholding human rights in all aspects of data management and use.
- *Treating data in context.* As products of socio-technological systems, data are neither objective nor neutral. They reflect pre-existing social relations and technological limitations, making this context essential for ensuring the ethical design of data-based decisions.
- *Balancing risks and innovation.* It is crucial for data governance to balance risk aversion with innovation promotion. This involves recognizing and addressing risks inherent in data management, while simultaneously supporting and not unduly hindering data-driven innovations.
- *Empowering people.* To empower individuals, it is essential to enhance data skills and capabilities and provide access to data infrastructures and effective tools for data management, while protecting indigenous knowledge. These efforts should enable people to make informed decisions about their data and fully benefit from technological progress.
- *Multilayered approach in data governance.* Data governance should strike a balance between hard (legally binding) and soft law (guidelines and practices) mechanisms. This multilayered approach leverages the strengths of each, providing a robust yet flexible framework that can adapt to the evolving data landscape.
- *Multi-stakeholder inclusivity.* Effective data governance requires a multi-stakeholder approach. This includes engaging policymakers, businesses, academia, nongovernmental organizations, technical communities, civil society and other relevant groups. Excluding any stakeholder group can compromise the effectiveness and fairness of data governance.
- *Inclusion of youth for future orientation.* Finally, data governance should proactively incorporate youth perspectives. This helps in designing forward-looking, people-centred, inclusive and development-oriented information society. Inclusion of youth ensures that data governance is aligned with the aspirations and needs of future generations.

VII. Conclusion and recommendations

Section VII consolidates the primary insights gleaned from the preceding discussions and present actionable recommendations tailored for member states and the international community. The overarching goal of this section is to equip stakeholders with concrete steps to ensure that data are effectively leveraged as a pivotal instrument for realizing the objectives of the 2030 Sustainable Development Agenda.

The immediacy of the climate change crisis affords us limited time. Data, when properly used, can guide us to understand, monitor, and predict climate patterns, energy consumption, greenhouse gas emissions, and a plethora of other factors vital to combating climate change. Therefore, a more robust and effective utilization of data is integral in the fight against global warming.

As we find ourselves in a race against time, it becomes imperative to put in place robust policies and regulatory frameworks that ensure equitable data governance. Such measures could include enhancing data literacy, strengthening domestic capacities for data analysis and management, and establishing fair data sharing agreements at the international level. These initiatives should aim to create an environment where data flows benefit all parties involved and contribute genuinely to sustainable development. This requires a concerted effort from governments, international organizations, the private sector, academia, technical communities and the civil society, acknowledging the significance of data in the current era and its potential role in shaping the future of sustainable development.

Recommendations to the member states

The intrinsic nature of data, which is multidimensional and intertwined with various sectors, requires nuanced policymaking. Data governance policies should not only exist on a national scale but must also be extended to regional and international domains to ensure harmonization, cooperation, and shared growth. Recognizing the omnipresence of data, and the fact that data are cross-sectional, means that a siloed approach to data governance is inefficient. Instead, what is necessitated is a holistic strategy that permeates every level of governance. Such strategies must be built on the foundation of 'whole-of-government' approaches. This means that, rather than assigning data governance to a single ministry or department, every segment of the government, from health to education, from finance to agriculture, should be involved in the process.

For truly robust and encompassing data policies, multi-stakeholder inputs are invaluable. This involves engaging civil society, businesses, academia, technology experts. Their diverse insights, combined with governmental vision, can lead to a more grounded and comprehensive understanding of the intricacies of data management and utilization. A core vision, one that harmonizes these diverse needs while upholding principles of data protection and innovation, is essential. To cement such a vision, national governments are invited to follow a set of policy recommendations. These recommendations offer a roadmap that not only acknowledges the multifaceted role of data but also underlines the need for a delicate equilibrium between the drive for innovation and the imperatives of data protection. By heeding these guidelines, nations can position themselves to thrive in the data-driven era, ensuring that their data infrastructures and policies are both resilient and future-oriented.

To harness the benefits of data and digital technologies for sustainable development, national governments are encouraged to consider the following recommendations:

i. *Promote data literacy and education:* Governments should prioritize the education and training of their citizens and public servants in data literacy. A population skilled in understanding, analyzing, and interpreting data can more effectively engage in civic activities and drive innovation.
ii. *Encourage citizen participation in data governance:* Engage the public in decision-making processes related to data governance. Public consultations, town hall meetings, and open forums can provide valuable insights and foster trust.
iii. *Implement data auditing mechanisms*: Regularly audit data practices to ensure adherence to standards, protocols, and ethical considerations. External, third-party audits can provide unbiased insights into the effectiveness and integrity of data management practices.
iv. *Promote research and development in data technologies*: Allocate resources and funding for research in emerging data technologies, ensuring the nation remains at the forefront of data-driven innovation.
v. *Establish a national data ombudsman:* Appoint an independent body or ombudsman to oversee data governance issues, address public grievances related to data misuse, and ensure compliance with established data policies. Incorporating these recommendations can further solidify a nation's data governance strategy, balancing the dual goals of innovation and protection.

vi. *Open data policies:* Governments can adopt open data policies to promote data transparency, accessibility, and sharing. By making data available to the public and relevant stakeholders, opportunities for collaboration, research, and innovation are enhanced.

vii. *Invest in robust data infrastructure:* Infrastructure serves as the backbone for data governance. Investments in state-of-the-art technology like satellite systems, sensors, and data centers are crucial. International collaborations can facilitate technology transfer, funding, and expertise sharing, especially for nations with financial constraints.

viii. *Uphold data quality:* Ensuring data's reliability and accuracy is non-negotiable. By adopting internationally recognized data standards and protocols, governments can guarantee that their data-driven decisions are built on a foundation of trustworthiness and precision.

ix. *Integrate and value indigenous knowledge:* Indigenous communities often possess invaluable insights about their local ecosystems, cultures, and traditions. By integrating their knowledge into data collection and interpretation, it presents a more nuanced understanding of the region. Recognizing indigenous perspectives not only respects their rights but also enriches data resources, leading to more culturally sensitive and effective sustainable development strategies.

x. *Strengthening regulatory policies to promote digital innovative businesses through public-private partnerships (PPPs):* Encourage public-private partnerships can leverage private sector expertise and resources for sustainable development efforts. These partnerships can help bridge technology gaps and support data-driven initiatives.

Recommendations to the international community

The rapidly evolving data landscape has underscored the constraints faced by individual nations in constructing a robust data governance framework. The very organization of the Internet—characterized by its decentralized, borderless network—complicates the straightforward implementation of national data policies. The dominance of a few multinational technology giants, whose reach and influence permeate across borders, further exacerbates these challenges. Coupled with ambiguities regarding jurisdiction, variations in regulatory capacities, and discrepancies in enforcement abilities among nations, it is evident that national policies, while crucial, can only go so far in addressing the complex matrix of data governance.[60]

In such a scenario, international collaboration emerges not just as a desirable approach, but a necessary one. Data, the lifeblood of the modern digital economy, need to flow across borders with agility, yet not at the cost of compromising security, privacy, or equity. Ensuring that the benefits of this data-driven era are not hoarded by a few but are instead distributed equitably among nations and their populations is a task of paramount importance. Additionally, with data comes risk—risks of breaches, misuse, and unintended consequences. International cooperation can ensure a collective response to mitigate these threats.

The global discourse on data governance has gained momentum in recent years, shifting from preliminary discussions to actionable initiatives. Leveraging existing platforms, like the Internet Governance Forum (IGF), the World Summit for the Information Society (WSIS), and the United Nations Global Digital Compact (GDC) can provide valuable frameworks for these conversations.

The Commission on Science and Technology for Development (CSTD) is ideally positioned to examine the intricate links between data and sustainable development. Its role in this context is beneficial for several reasons. The Commissions' findings, which are submitted to the Economic and Social Council (ECOSOC), are the outcome of a discussion that considers inputs, but is distinct from, those held in other individual United Nations entities and adopts a

[60] Contribution from the Government of Latvia.

multistakeholder approach. This independence ensures that the conversation around the digital economy, data governance, and sustainable development is approached from a broader perspective, taking into account the various stakeholders and facets involved. This promotes a holistic approach that might be challenging within a more compartmentalized structure.

For international cooperation on data governance to be effective and inclusive, it is vital to embrace the diversity of perspectives. Nations, while sharing certain data governance challenges, each come with unique socio-political contexts. Recognizing these nuances, understanding the multidimensional nature of data, and appreciating the varied perspectives of stakeholders will be pivotal in crafting policies that are both universal in their vision and specific in their application.

The international community is encouraged to:

i. *Engage in a multistakeholder dialogue on the fundamental principles of data governance*. A significant step in this direction was taken by the 27th annual session of the CSTD which recommended in the draft resolution submitted to the ECOSOC to "consider establishing a dedicated working group within the CSTD that would engage in a comprehensive and inclusive multi stakeholder dialogue on the fundamental principles of data governance at all levels, as relevant for development under the auspices of the United Nations, taking into account the conclusion of the negotiations on the outcomes of the Summit of the Future including the Global Digital Compact".

ii. *Harmonize ethical guidelines for AI and data governance:* With the rise of artificial intelligence and big data analytics, there is a need for clear ethical guidelines to prevent misuse and uphold human rights. This includes considerations around bias, transparency, and accountability.

iii. *Support national statistical systems in developing countries:* Strengthen the institutional and human capacities of national statistical and data systems in developing countries, as well as other data producers and users, through investment, funding, training, partnerships and technical cooperation.

iv. *Transfer technologies and skills:* To reduce the technological disparity experienced by developing nations, it is essential to enhance and reinvigorate the UN Technology Facilitation Mechanism for technology and skill transfers.

v. *Support cross-border data flow frameworks*: Encourage international cooperation to ensure seamless and secure cross-border data flows while respecting sovereignty and local data protection regulations.

vi. *Advance global conversation on data taxonomies and ontologies*: Establish an international dialogue on data structures and vocabularies to ensure consistency in data collection, interpretation, and sharing across different sectors and departments.

vii. *Promotion of Open Access*: The democratization of knowledge is key to global progress. By advocating for open access to research findings and data, the international community can break down barriers that prevent innovative solutions from reaching a wider audience, thereby accelerating advancements in various fields.

viii. *Advocacy for comprehensive data security policies:* In a world where data are increasingly valuable, its protection becomes paramount. The international community needs to formulate comprehensive policies that ensure data's safety, its ethical use, and robust cybersecurity. By advocating for these policies, the international community can ensure that as we reap the benefits of the digital age, we also safeguard our digital assets and the rights of individuals.

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