Modern Economic Trends in a Digital Global Economy

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Preface

The global economy is undergoing a profound transformation driven by the rapid advancement of digital technologies. This book, Modern Economic Trends in a Digital Global Economy, explores this evolving landscape, where digitalization has emerged as a central force shaping productivity, growth and competitiveness across nations. In recent years, economies around the world have witnessed an accelerated shift toward digital platforms, digital services and global connectivity. This transformation has significantly influenced the way businesses operate, compete and interact in international markets.

Digitalization, characterized by the widespread adoption and integration of digital technologies into economic activities, is fundamentally altering the mechanisms of production, distribution and consumption. Automation, artificial intelligence and data-driven decision-making have enhanced efficiency, reduced operational costs and expanded market opportunities. However, the benefits of digitalization are not distributed equally across countries, regions and social groups.

This book presents a comprehensive examination of how digitalization influences economic performance through multiple channels. It highlights key drivers such as investment in data-intensive sectors, the diffusion of digital technologies and improvements in total factor productivity. A critical dimension of the digital economy is the growing role of data as a factor of production. Data and algorithms now function as valuable tangible and intangible assets, driving innovation and enabling the development of advanced digital services.

Modern Economic Trends in a Digital Global Economy aims to provide readers with a clear and balanced understanding of these complex dynamics. It offers insights into the opportunities and challenges created by digital transformation and emphasizes the need for inclusive, balanced and forward-looking policy responses.

Authors

Modern Economic Trends in a Digital Global Economy

- Smart Cities and Digital Public Infrastructure
- Future of Global Trade in a Digital World
- Economic Resilience in a Digital Era
- Predictions and Strategic Directions for Policymakers

“The digital economy is no longer an industry among industries; it is becoming the economy itself.” — Satya Nadella, Chairman and CEO of Microsoft.

CHAPTER 1

INTRODUCTION TO THE DIGITAL GLOBAL ECONOMY

The digital economy refers to the expansion of economic activities through the Internet and digital infrastructure. It promotes economic growth, job creation and regional development when essential conditions such as infrastructure, connectivity, digital content and skills are available. Unlike traditional economic systems, the digital economy enables regions and nations to participate in global markets without depending solely on conventional production structures. It allows economies to develop activities that match their resources, capabilities and technological readiness. However, the benefits of digital transformation are not equally distributed across regions. While digitalization has contributed to economic growth worldwide, its impact varies depending on the availability of infrastructure, institutional support, investment and digital literacy. Therefore, participation in the digital economy should not be viewed as an automatic outcome. It is a capability that must be developed through policy support, technological investment and human resource development. The digital economy has evolved from the early foundations of the Internet. Initially, digital systems were used mainly for scientific and institutional purposes. Over time, the Internet expanded, became more accessible and gradually transformed business, communication, governance and trade. During the first decade of the twenty-first century, digital growth accelerated further due to mobile broadband, cloud computing, data analytics and global connectivity. As a result, many productive activities are shifting from traditional systems to digitally enabled platforms, creating a transformation comparable to earlier major economic revolutions.

1.1 MEANING AND SCOPE OF THE DIGITAL ECONOMY

A digital economy refers to the business ecosystem based on the production, distribution and consumption of digital goods and services and the connectedness of its members through the Internet. However, digitalization must be distinguished from the digital economy. When digitalization or digitization is referred to, it generally means the use of data and digital technologies across the entire economy and society. Digital technologies include digital hardware and software such as digital communications technologies and the various algorithms and platforms that utilize and put to use the tens of millions of apps. At the current stage of economic development, the digital economy is formed around six key components, the actors involved in it and the indicators used for the quantitative analysis of its development. Two features of the digital economy are worth mentioning. First of all, the reach of the digital economy is global and does not recognize geographical borders. Secondly, the digital economy is permeable and has the capacity to include those who are the most disadvantaged, those who are excluded from the financial system and those in rural areas far from basic services. At the same time, however, the digital economy also includes aspects that are difficult to quantify.

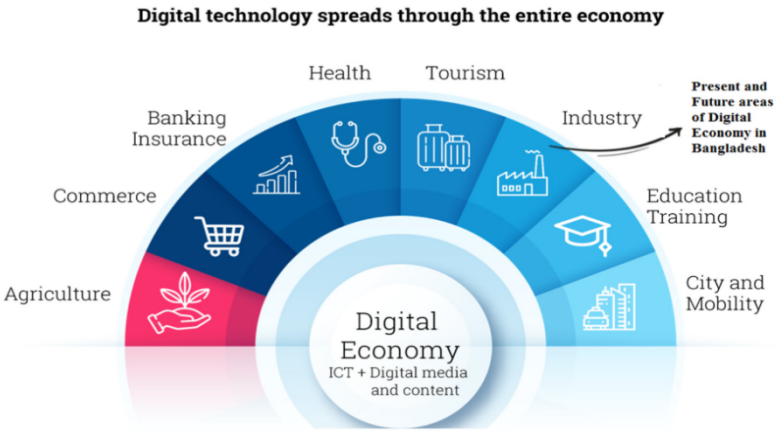

Figure 1.1 digital economy

1.2 EVOLUTION FROM TRADITIONAL TO DIGITAL ECONOMIC SYSTEMS

The transition from a traditional economic system to a digital one unfolds gradually, somewhat like an intergenerational shift and the slow evolution of a species. Discerning the precise stage of this evolution remains highly subjective. Analyzing the present scenario reflects the influence of digitalization, but establishing its boundaries is a challenge. Four major forces can be highlighted. The need for resilient digital infrastructure for production, distribution and transaction purposes has never been greater. Broad-based digital connectivity has become a prerequisite for performing virtually any activity, whether in government, business or daily life. Flows of data and their usage by individuals and firms have multiplied tremendously. Finally, expanding digital ecosystems actively orchestrated by major digital platforms lead firms and individuals into digitalized business and social processes and environments. The combined effect of these drivers is expected to reshape the economy and society in the near future and to drive and accelerate the needed changes for the next generations. The transition from a traditional economic system to a digital economy differs from the evolution of the global economy from industrialization via deindustrialization to re-industrialization stimulated by the digital revolution. A digital economy may be defined as a holistic system for organizing and performing economic processes and activities, one that is sustained and reshaped by digitally enabled production, distribution, consumption, transaction and labor processes.

1.3 KEY CHARACTERISTICS OF DIGITAL ECONOMIES

Cities have long been centers of economic activity, offering businesses access to consumers and the workforce, firms opportunities to cooperate and associate and the chance to complete a diverse range of economic activities. The rise of new digital platforms and social media may shift aspects of this, but the fundamental economic geography of physical proximity remains. However, with the increasing digitalization of many aspects of life and work and the growing distribution of digital capacity, it is not just cities but a set of ecosystems that interlink to create economic value. Such ecosystems offer a set of economic and social activities that centers of a large city

might offer but with lower costs of establishment and operation. In this sense, the multi-location nature of digital economies is radically different from pre-digital service economies. Economies and economic structures have transformed over time, moving from agriculture to manufacturing and now to services. Within these transitions, the underlying factors of production have also shifted: centers of production no longer need access to land for primary production, but services have still retained a close connection to their physical location for the provisioning of goods and other services. In this new stage of digitalization, the traditional economy is increasingly breaking down into its constituent parts. Distribution services are rapidly shifting to digital models. Production processes have enabled new digital and physical cross-border convergence—the digital trade of an intangible good in one territory bulk produced with physical production in another. Labor markets are now hollowing out and how work is done via the gig economy is reshaping social safety nets.

- Information Abundance and Network Effects

Abundance of information and network effects are prominent features of the digital economy. The pervasive collection, storage and processing of information are essential ingredients for people's, businesses' and governments' decision-making. The basing of many business models on networks and communities favors dynamic effects, creates overwhelming advantages for first movers and stimulates the emergence of monopolies and consequently market failures. The cost of collecting data is plummeting. Internet-enabled sensors measure and transfer a plethora of data, while shifting costs for affordable storage make accessing and processing very large data sets feasible. Over-the-top services significantly lower the cost of information distribution. People are continuously leaving a gigantic trail of data in cyberspace, with their online persona seldom matching their real personality. As a result, abundance economics based on zero marginal cost is challenging Robinson Crusoe and his economy of closed doors and self-sufficiency. Information asymmetries no longer support intermediaries but may foster communities, networks and trust.

- Platform-based Business Models

Synthesis of information abundance, network effects, platform-based business models, data as a core asset and an emphasis on agility, innovation and ecosystem collaboration capture the key characteristics of digital economies. These impactful characteristics are also reflected in the nature of participation in the digital economy and have profound implications for government policy. The digital economy generates a welcome shift of emphasis toward demand creation in a supply-constrained world. Although the capacity of the economy to absorb increased supply is limited, the appetite for information, services and experiences continues to grow. New technologies—cloud computing, mobile services, social networks, machine learning and a growing number of others—make it possible to satisfy these increasing demands and provide new income-generating opportunities for many people. Data have become an indispensable factor of production, yet the very use of data as a production resource has increased its value exponentially. The relationship between tool and trade has been fundamentally altered. It is no longer expensive to create tools, but the cost of trade has remained fairly constant; thus, people are searching for more effective ways to grow and exploit their own tools and use them in trade. Internet-based platforms therefore emerge as the underlying architecture of the digital economy. Unlike other organizational forms, platforms utilize innovative business models based on openness and external participation and collaboration to achieve their goals. Digital economy platforms stand out not just as dynamic engines of innovation and economic growth but possibly as the most important trend in business organization today.

- Data as a Core Asset

In digital economies, data and algorithms have emerged as valuable economic resources in digital economies. Unlike oil, the value of data does not diminish as it is accessed and employed by ever more people. Nor does the extraction and use of data incur high costs; rather the opposite is true. The indisputable sourcing of these invaluable natural resources without paying a fair price raises serious ethical, legal and economic concerns regarding ownership, compensation and fair use. Moreover, information is so abundant that it now has the negative value of becoming junk; its

optimal use is filtering and curating rather than collection and hoarding. But not just the sheer volume of data is crucial; the development and delivery of algorithms that extract usable information from big data are also indispensable. Big Data Analytics focuses on the discovery of hidden patterns and established relationships in data sets. A prominent example is the use of big data from multiple sources to isolate fraud within banks, insurance companies, stock exchanges, telecommunication operators and governments. Consequently, a quick response and preventive action might be feasible with less conventional methods. Thanks to services like Google Maps and its various contributors, the escape routes and traffic-light sequences of nearly all cities on planet Earth are being processed with the ultimate aim of notifying policemen and emergency services as to the most efficient routes for avoiding traffic jams. Such actions, based on data currently available, can assist in reducing economic damage even before the event has actually occurred. Big Data Analytics thus brings risk management strategies to a higher level, enabling organizations to prepare for external events such as terrorist attacks, natural disasters and the effects of climatic change—before these events actually happen. Massive data generated by private companies and available via the Internet can be used for public purposes. Data on tourist movements, travelers' preferences and pollution in cities can be freely collected and shared. These data could guide the allocation of public resources, enabling governments and citizens to perform their duties more efficiently in these difficult moments. Nevertheless, private companies must be compensated for these services, as they incur costs and have a right to appropriate the value of the data they offer.

- Agility, Innovation, and Ecosystem Collaboration

Digital economies place heavy emphasis on agility, rapid innovation cycles, continuous experimentation and collaboration within multisided ecosystems. Responses to shifts in customer preferences and behavior or the threat of new business models introduced by competitors often need to be extremely rapid—but without conditioning long-term investments on excessively short-term returns. To achieve speed and boldness in innovation, corporations increasingly rely on the theory of the dynamic capabilities of the firm. Continuous experimentation, with resources devoted

to "fail-fast" programs in new areas, is becoming widely accepted; in some sectors (most notably in software development), the “jump to beta” is an established approach. In bringing bold new innovations to market, corporate venturing and acquisition of start-ups in fields of potential disruptive innovation are essential. Often, the challenge relates less to invention than to scaling the innovation fast enough to achieve the necessary market leadership. Going to market in partnership with partners is a well-trodden path; leading-edge firms are also exploring participation in greater ecosystem networks in order to add capabilities and enhance speed of development. In fields driven by deep technological competence, like pharmaceuticals and biotechnology, collaborations among leading companies are commonplace, relying on relatively loose arrangements directed to specific projects.

1.4 ROLE OF INTERNET AND DIGITAL INFRASTRUCTURE

Connectivity and bandwidth—essential factors in the quality of digital services—surpass even low access costs as a driver of globalization in trade and services. To illustrate this synergy, one can consider two massive trends reshaping global services: offshore business process services and capital-intensive technology-intensive tourism. Networked digital economies depend closely on a range of digital infrastructure elements. Among them, cloud computing and edge computing can be viewed as macro-digital services necessary for the provision of a range of other services in transport and tourism, business process outsourcing and professional and advanced services. Cloud computing also facilitates the deployment of the Internet of Things (IoT), enabling a new wave of investment in physical infrastructure. Host-to-host connectivity across national borders comprises more than just connectivity between consumers and service providers; it must also interconnect the digital ecosystems of large cloud vendors, notably AIaaS investments that permit the development of AI-fuelled products and services in the absence of an extensive local R&D ecosystem. A third element is the set of standards, APIs and protocols that permit the interconnected delivery of services across borders, not only between user and supplier but also across the ecosystems of service providers. The smooth delivery of IT and telecommunications services is itself predicated on those elements and thus accounts

for a significant share of cross-border services. A fourth feature is a set of preconditions in terms of security, privacy and trust that underpin user willingness to engage with potentially distant and unknown third parties. The delivery of transport and tourism services requires a high degree of trust in the ability of the supplier to deliver as promised. Services becoming part of a broader global service ecosystem rather than being delivered from one market to another must therefore also satisfy such preconditions.

- Connectivity and Bandwidth

Connectivity has been and continues to be the foundation of any successful digital economy, as well as a prerequisite for any other constituent element in a digital economy to flourish. Requisite network bandwidth is essential for assuring low latency and enabling rich multimedia applications, many of which have become ingrained business and social processes. In order to access more distant markets, regions or economies of scale, countries have always needed to establish, develop and maintain physical transport infrastructures (roads, rail, shipping and so on). Digital economies face a similar need for digital transport infrastructures that interconnect large numbers of users with limited delays. The efficacy of these digital transport infrastructures depends on their speed and latency, which have remained the key drivers of their underlying capital expenditure and operating expenditure. Bandwidth has also become the critical metric with which to assess the commercial provision of digital transport services, both spatially and topologically. Disparities of access to these services have persisted and even worsened in some developing countries.

- Cloud Computing and Edge Computing

Digital Economy Promotion Agencies emphasize the need for general-purpose cloud computing facilities for individuals, start-ups, micro, small and medium enterprises (MSMEs) and educational institutions. Cloud computing lowers the entry barriers to adopting new technologies since it does not require owners to invest in expensive on-premise infrastructure, hardware systems or software. Cloud computing services have therefore proliferated in recent years. Edge computing extends cloud computing resources and capabilities to the extreme ends of the network, closer to where data are

being created. Moving computing out of remote cloud data centres to the edge of the network improves response times, reduces round-trip latency and helps optimize bandwidth use in scenarios such as digital twins for connected factories, 5G networks, connected automobiles and drone operations. Future-ready digital economy strategies should consider the growing ecosystem of edge computing services to meet developers' demands. Governments are pivotal in the emergence of digital technologies capable of disrupting many sectors of the economy and society, whether in healthcare, education, research or financial services. Dramatic changes are anticipated in the provision of public infrastructure and in public administration. Public–private partnerships will also become models of success worldwide for the redefinition of social benefits through the provision of services that can generate new economic opportunities. The growth of digital-saturated economies calls for a new matrix—one that reflects the interactions between societies and technologies in the search for higher levels of wealth. Hence, these digital-tangible ecosystems interlink less internationally and more regionally with technology hubs that open new paths of development based not only on the built and natural resources of territories but also on their cultural resources.

- APIs, Standards and Interoperability

For economic entities to build solutions, there is a great need for APIs, standards and interoperability. Digital goods and services should be affordable, sustainable and made available widely. The availability of APIs lowers the barrier for digital market players because they can use the functions of other players instead of developing everything in-house. APIs can help in faster development, lowering entry costs, improving quality and enabling easy collaboration, thereby fostering a dynamic, diverse and healthy market. Schneider et al. show how the Nordic open government data program is supporting innovation by allowing the public sector to share diverse data and helping the private sector build products and services tailored for Nordic societies, making the region more attractive for both local and international investments. These initiatives indicate how government efforts can impact innovation and competitiveness beyond their borders. Standards are essential for ensuring the

interoperability of digital platforms, services, goods, processes and data. Lack of interoperability leads to fragmentation, which has the potential to adversely affect investment, productivity, quality and government policy. Poor quality, awareness and accessibility of data standards can also have a negative impact on business. It is therefore important to develop proper standards for digital-micro, digital-meso and digital-macro goods and services to mitigate data-related risks and costs.

- Security, Privacy and Trust

Security, privacy and trust are prerequisites for economic participation and engagement in society, whether on a personal, commercial or institutional level. The broader ecosystem shapes users' perceptions and experiences of security and privacy online. In uncertain environments, users develop an inherently low level of trust in the digital world, but security stewards can play a facilitative role and help establish equilibrium in the regulatory space. Security failures and breaches, while not necessarily widespread, can be devastating; high-impact incidents can affect the bottom line, reputation and long-term health of organizations, while the costs of ransomware attacks are spiraling. There is a trinity of risks to users' experience of security and privacy: the security of digital technologies, the security of data and the integrity of data. Users can proactively take steps to protect themselves, but key stakeholders must also act: businesses need to secure their systems, data custodians must ensure the security of the data they manage and systems that aggregate or facilitate transactions require strong governance. Security by design should be mandated. Public policy can also create the right incentives for collaboration at multiple levels to strengthen trust in the digital environment. The user experience of security and privacy strongly affects the level of engagement and participation and hence influences associated value creation. Shaping the environment is crucial to support early adopters and pioneers and to prepare the ground for early investors, as fostering a favourable user experience is essential to accelerate positive network effects.

1.5 GLOBAL SHIFTS IN ECONOMIC PATTERNS

Changes in consumption and production patterns have far-reaching implications. Digital technologies satisfy demands across borders—shifting trade in goods toward services. Labor markets are reconfigured, with services available in every country. Users of platforms often become suppliers in their own right, but their traded services fall outside normal employee contracts. As cocreators, they share risks with businesses but have less certainty. Security and privacy risks affect appetite for cross-border data flows; regulatory responses to these concerns differ. Innovation hubs are emerging, but the global diffusion of digital economy activities is uneven. Increasingly around the world, internet services and digital infrastructure, including cloud hosting and server farms, are provided from specific hubs. Digital services are products of research and development, engineering and consultancy in one region. Digital networks across borders absorb services produced in places with lower productive capacity. For many countries, digital infrastructure, data, business models and service provision of higher income economies are “integrating” economies rather than the physical goods of the past. Beyond services, digital technology permits service production in countries where factor endowments offer little comparative advantage.

- Transformation of Trade and Services

Recent developments in international trade have changed traditional paradigms and perspectives. The structuring of trade flows has altered, now comprising a more complex and fragmented set of global value chains. The bulk of trade comprises not goods but services and the fastest-growing element of trade has been in digitally enabled services. These trends and phenomena undoubtedly reflect the impact of digitalization and an increasingly digital economy on international trade. The shift from trade in goods and services to trade in data signifies change, management and policy consideration. Digitalization has also initiated rapid restructuring in domestic economies. The world economy has always been dynamic. New technologies, market demands, political and even ecological crises of various kinds have constantly given new momentum to change. Yet this time, arguably, the speed and scope of

transformation of entire sectors, the reconfiguration of the labour market and the practical functioning of services as capable of straddling borders and time zones are all without historical precedent.

- Labor Market Reconfigurations and Gig Economy

Global economic system transformation has led to a realignment of labor in production and intermediation. New digital channels of work enable multiple business models that support income generation and reduce risk. Workers exercise more choice in whom, when and where they work but require investment in skills, social protection coverage and earnings equal to conventional jobs. New economic activity emerges in the informal sector and gig economy, leading to increased policy attention and digital framework establishment. As demand for on-demand services rises, so too do platforms willing to supply them. Facilitating rapid growth, these intermediaries often affiliate existing suppliers and can use technology to decrease entry barriers, identify demand spikes before they occur and recruit workers on short notice. They fit into three categories: labor market platforms that connect diverse workers with supply-demand mismatches in larger businesses (task rabbits, extra help at busy restaurants, translators via the Net); capacity-expansion platforms that enable privatization of spare capacity within the workday; and replacement platforms that enable full-time workers to leave their salaried jobs for project-style work.

- Cross-border Data Flows and Digital Regulation

Vast cross-border data flows are a defining feature of a digital economy. Increasingly, international transactions rely not only on the movement of goods or the provision of services but also on the flow of sensitive information that connects consumers to suppliers and the supply chain. Although international trade in services remains relatively smaller than trade in goods, it grows more rapidly; within services, the quickest growth comes from the supply of tourist and business services via the Internet. The digital economy is thus transforming global maps of trade and services, contributing both to wider geographic access to markets and to the reconfiguration of value chains across borders. In this context, the regulation of data in both exporting and importing countries will remain a sensitive subject in international trade

negotiations. Questions of how privacy legislation on personal data is translated across borders by different economies—when such information is allowed to flow, when it can be stored and when it must be released—will make the large-scale supply of services across borders a complicated and risky business. Ways to cooperate internationally to facilitate cross-border data flows while also protecting sensitive information will remain hotly debated at all levels. In the service sector, cloud computing is also transforming industry, laying the groundwork for new business models. Businesses no longer need to invest heavily in information and communications technology (ICT) infrastructure and business applications. Instead of building, maintaining and upgrading their own systems, they can rent capacious virtual services and online applications hosted in the cloud. This opens new business opportunities in such areas as the development of software as a service (SaaS) and the provision of platform as a service (PaaS) and infrastructure as a service (IaaS).

- Innovation Hubs and Regional Disparities

Digital economies continue to create new opportunities for growth and technology-enabled entrepreneurship but often within clusters and constrained geographic regions. Technology hubs flourish around leading research universities equipped with substantial pools of risk capital, a cluster of entrepreneurs and business mentors—including former founders of successful technology companies—and networks of corporate support and collaboration. Globalization, the ability of entrepreneurs and business leaders to work over long distances and better communications tools have enabled a limited number of Silicon Valley-style hubs to provide innovation support over broader geographic areas. Nevertheless, gaps remain in standards of living and economic opportunity. For many developing countries, deeper participation in the digital economy is an important vehicle for sustained economic growth. The creation of digital innovation clusters focused on tailored semiconductors, artificial intelligence, quantum computing and clean technology, among others, is a key digital economy priority for a growing number of governments. Such clusters can enable advanced countries to reduce the costs of addressing key vulnerabilities and help developing countries leapfrog into digital sectors with much higher job creation and export

growth potential than those associated with traditional comparative advantages. The nurturing of digital economy hubs provides governments with the opportunity to introduce measures to improve global trade integration in key digital goods and services, redesign the international regulatory architecture governing data flows, put in place digital economy partnerships with leading trading partners and promote lifelong skills development for technology-based entrepreneurship.

1.6 IMPORTANCE OF DIGITAL LITERACY IN ECONOMIC PARTICIPATION

Participation in digital economies requires not only technical access through physical connectivity or equipment but also people's skills and understanding of the internet, networks and other digital and information-communication technologies. A combination of personal skills, cognitive abilities and attitudes is needed to make full use and benefit from these resources, which varies across both genders and the life cycle. Digital literacy is therefore a necessary complement to infrastructure investment for empowering individuals, communities and societies. Digital economies create new relationship structures, often requiring new job skills while also lowering the barriers to starting and operating small businesses. They also bring forth new forms of work and organizational structures. Workers may join an organization only for a short period of time to focus on specific tasks and may at the same time collaborate with different organizations or businesses worldwide. For a large share of the population not relying on the internet for a livelihood, job content is changing through the introduction of automated processes, machine learning, natural language processing and artificial intelligence. Digital technologies make it possible to serve a very specific market niche on a global scale. For many participants in gig-economy platforms, their engagement can be self-chosen and self-determined and may—at least for a certain period of time—serve as a transitional phase between two more conventional jobs. However, the share of people who are working as gig workers, teleworkers or in other non-standard employment contracts is also subject to greater insecurity and income volatility.

- Access, Skills and Inclusion

Digital economies offer both opportunities and risks. A wealth of online knowledge and resources helps to equip individuals as they seek employment, change careers or successfully participate in entrepreneurial ventures. However, access to these resources is often limited; many lack the devices or connectivity to leverage the information shared. Moreover, creating the digital products and services required for economic participation calls for a mix of technical and soft skills, often beyond the capacity of traditional education systems to deliver. Therefore, the ability of economies to harness these opportunities ultimately rests on the interplay between the availability of sophisticated training opportunities and the means of ensuring equitable access to them. Investment in digital literacy must encompass the entire lifecycle and be viewed as an essential area of public spending. Priority should centre on developing foundational skills for the young and on upskilling and reskilling those in the workforce. Given the rapid rate of skills obsolescence in the digital economy, there is a need for companies to take a more active role in equipping staff with the necessary skills. Companies must work closely with education providers to ensure that training is relevant to industry needs and help drive students into previously underattractive careers. Companies with a significant presence in the digital economy are increasingly adopting the role of training providers, yet the scale and sustainability of these upskilling initiatives are still limited.

- Lifelong Learning and Workforce Readiness

An informal economy with flexible employment, spontaneous entrepreneurship and low entry barriers acts as a breeding ground for digital skills. However, labor market dynamics and digital transformation have made lifelong learning mandatory for re- and up-skilling, resuming learning after completing formal education and preparing for future changes. Learning from digital devices and interactions supports the rapidly changing demands of marketing, operations, human resources, logistics and IT functions. Upskilling is equally critical for those remaining in the same occupation to maintain competitiveness and job security. A lack of favorable employment conditions, including work-life balance, recognition and the possibility of

advancement, results in inadequate interest in skill development and adoption of new technologies. Both internal and external drivers are important factors in motivating willingness to learn. The perception of technological advancement as a risk drives re-skilling initiatives, while the inclination to learn new technologies is shaped by technological importance for current work or future jobs. Regular practice, skills related to using the Internet and social media for business, the frequency of training and the usage of a wide range of ICT functions influence the level of digital literacy attained. Formal or informal training targeting digital skills and providing access to high-speed and mobile Internet decreases the gaps. A government-funded program with a budgetary allocation of about US$ 30.5 billion to impart digital skills across the population is seen as critical to ensuring the country's workforce meets the needs of the digital economy.

- Digital Literacy Metrics and Policy Implications

The promotion of digital literacy is central to widespread economic participation in the digital economy. As government services—and more broadly essential services—move online, it is paramount that individuals are digitally literate enough to harness the full potential of these services and not be excluded from their benefits. Consequently, governments must monitor their populations' fundamental digital skills to understand whether they are sufficiently prepared to take advantage of opportunities for social and economic development, including education and training, offered by the digital environment. Investment in digital literacy must also go further if labour markets are to remain healthy, inclusive and resilient. Individuals of all ages and backgrounds must continuously develop new digital skills if they are to adapt successfully to the evolving demands of increasingly digital economies. Numerous governments are increasing their investment in the digital skills necessary for career entry and progression. Lifelong learning policies—where governments subsidise specialised training for adults—must incorporate a digital skills element. Lifelong learning offerings should also pay special attention to the needs of displacement-prone sectors, such as traditional manufacturing. Education and training systems must also

prepare large cohorts for entry into fields such as data analytics, programming and cybersecurity that are foundational to the growth of the digital economy.

1.7 Chapter summary

The chapter introduces the concept of the digital global economy by explaining its meaning and scope in the contemporary world. It highlights how economic activities are increasingly shaped by digital technologies, where the production, distribution and consumption of goods and services are facilitated through digital platforms and networks. The digital economy extends beyond e-commerce to include a wide range of activities enabled by information and communication technologies, making it a critical component of modern economic systems. The chapter further traces the evolution from traditional economic systems, which were primarily based on agriculture and industry, to digitally driven economies characterized by knowledge, innovation and connectivity. This transformation has been gradual yet profound, driven by advancements in computing, the internet and data technologies. The shift has redefined economic structures, reduced geographical constraints and enabled new forms of value creation and exchange across global markets.

Key characteristics of digital economies are also examined, including the central role of data as a factor of production, the emergence of platform-based business models and the increasing importance of network effects. The chapter emphasizes the role of the internet and digital infrastructure as the backbone of this transformation, enabling seamless communication, real-time transactions and global integration. These developments have led to significant shifts in global economic patterns, including the rise of service-oriented economies, increased cross-border digital trade and the growing dominance of technology-driven industries. Finally, the chapter underscores the importance of digital literacy as a foundational requirement for effective participation in the digital economy. It argues that access to technology alone is insufficient without the necessary skills and knowledge to utilize digital tools effectively. Enhancing digital literacy is essential for promoting inclusive growth,

reducing inequalities and ensuring that individuals and communities can fully benefit from the opportunities created by digital transformation in the global economy.

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CHAPTER 2

FOUNDATIONS OF MODERN ECONOMIC TRENDS

Modern economic trends are shaped by several interconnected forces, including globalization, technological advancement, innovation, institutional development and changes in labour markets. Since the early 1980s, rapid globalization and technological progress have transformed trade, investment, production and income distribution across the world. These changes have created new opportunities for growth, but they have also produced inequalities between countries, regions and social groups. Therefore, understanding modern economic trends requires not only an analysis of technology but also a broader examination of policy, institutions, governance and human capital. Yet there have also been unsettling episodes of trade-disruptive malfunctions, excessive concentration in financial and real markets and income-supporting welfare states creating pressure on public budgets and undermining growth. Decomposing these moments into clearer bits of causal action shows some groups being much better able to respond to the ongoing change than others. Such considerations take the analysis into a more political level of economic organization, where issues of incentive compatibility, institutional development, policy design and governance capability become crucial to a mature understanding of recent transformations.

2.1 CONCEPT OF GLOBALIZATION AND ECONOMIC INTEGRATION

Globalization refers to the increasing interdependence of economies through the movement of goods, services, capital, technology and labour across national borders. It has been supported by reductions in trade and investment barriers, improvements in transport and communication technologies and the growth of international institutions. Economic integration has enabled countries to participate more actively in global

markets and has encouraged the expansion of multinational production networks. However, globalization has also created new challenges. While it has promoted trade, investment and economic growth, its benefits have not been distributed equally. Some countries, regions and social groups have gained more than others. As a result, policymakers must carefully manage the effects of globalization by promoting inclusive growth, supporting workers affected by structural change and strengthening international cooperation.

Figure 2.1 Globalization

➢ Historical Perspectives and Current Dynamics

Globalization is a multifaceted and complex phenomenon usually termed "economic integration". Historical milestones that have promoted economic integration connect back to three major waves, each founded by extraordinary innovations. The first could correspond to the period from the Industrial Revolution until World War I and the heyday of the British Empire and was driven by the expansion of railroads and ambitions for a global imperial trading system. The second wave of globalization took place after World War II and constituted an explosion in the development of transport and communication technologies, combined with the liberalization of international trade and financial flows. The current stage of economic globalization dates back more or less to the mid-1980s break-up of the Soviet Economic Area and is characterized by growing trade in manufactured goods among the newly industrializing economies of East Asia that then spread to include China and the breaking down of the former Iron Curtain. Currently, one is witnessing a new

expansion of economic integration determined mainly by the growth of cross-border services, capital movements, production-sharing networks—the use of different parts of the world for different stages of production within the same firm—and the emergence of regional trading blocs. Ten years prior to 2008, one of every ten dollars of GDP was generated by trade in services, three of every ten dollars were generated from trade among the member countries of regional trade agreements and four of every ten dollars corresponded to foreign direct investment or capital flows. The latter had replaced trade as the principal driver of goods flows. Whether or not unrestricted trade liberalization was a sufficient condition to ensure international convergence of per-capita incomes had become increasingly moot, for since the formation of the European Union the US had been negotiating new forms of economic interdependence—often outside the multilateral framework of the WTO—with a growing number of other countries or regions.

- Implications for Policy and Trade

The implications for trade and policy are complex but certainly momentous. The last two decades have witnessed a dramatic and widespread decline in tariffs, far above and beyond any back-and-forth cycles of trade negotiations such as the rounds of GATT/WTO negotiations. For many countries, the opening of trade in goods and above all manufactures has seemed a principal engine of success and stimulated a principled belief that trade negotiation was the key to development and that particular treaties should be sought, if necessary pursued without regard to theory. Trade theory based on comparative advantage had predicted that the distribution of production would change with trade but did not pay full attention to the actual distribution of resources and its change. The welcome benefits of these changes have now extended well beyond those nations, whether in the global South or the North, with low or declining tariffs, which for many years appeared to be the sacrificial lamb of some centres of economic power in particular Europe and North America. Nevertheless, further trade policy in relation to trade agreements has become more complicated. The theory of comparative advantage was based on closed economies and when trade starts or increases in volume, the effects also depend critically on how various

economies support or oppose trade either by tariffs or by aid. When trade changes from closed economies to open economies, the whole equilibrium character of the closed economy system is disrupted: domestic prices move relative to one another; some expansion approaches outline types of change; the system can move onto some new equilibrium path; and without coordination with other economies, it does so in an inefficient, often damaging way. Considered in the reverse direction, when trade is occurring some economies reach closed systems with trade as a small proportion of production and the outline processes change according to the now-traded products.

2.2 KNOWLEDGE ECONOMY AND INFORMATION SOCIETY

A knowledge economy is an economy in which the governance and use of knowledge assets in their broadest context—knowledge, skills and experience embodied in individuals and complexes of human capital and intellectual capital—are among the most important factors determining and influencing an economy's growth, sustainability and competitiveness. The focus is on the full depth of how knowledge in all dimensions generates and enables creativity and innovation, both of which in turn drive competitive advantages across all economic actors and sectors. The development of and investment in knowledge, education and skills remain pivotal for the sustenance of the knowledge economy. The information economy component focuses on key elements defining the information society, economy and information-driven economy. Connectivity remains a critical enabler for all economies across the globe, with new applications, platforms and transformations shaping conceptualizations of the information economy. The data economy and value creation based on data are receiving increasing focus, both from the perspective of generating competitive advantages and prosperity and from challenges in managing a fundamental resource. Data governance is a growing focus of many countries, with rapid decision making required to reap the full benefits of a digital economy based on data. These elements form the basis of knowledge-intensive societies and economies, which have become dominant features of a global movement in the digital economy era.

- Intellectual Capital and Human Capital

Intellectual capital and human capital are essential driving forces for a country's sustainable economic growth in the twenty-first century. In combination, these two forms of capital create a society of knowledge workers—an information society. Successful and competitive companies and countries are those that create, acquire, transfer and make the best use of knowledge. Investments in education and knowledge capital at an early age, with a focus on the key factors driving the creation of sources of innovation, will benefit trade and growth in the longer term. The key factors include investment in education, a risk-taking attitude, a degree of adaptability and the reduction of occupational mismatch. According to the World Bank, demand for digital and knowledge-based services has increased significantly in recent years, there has been an insatiable global demand for services such as data research, project implementation and creative execution. Labour demand makes it necessary for some developing countries to invest heavily in connectivity. Given the importance of knowledge capital mobility in a globalized world, countries and regions with well-respected university systems will attract talent from around the world and, in many instances, be able to export educational and knowledge-intensive services.

- Digital Infrastructure and Data Economy

Modern economies are progressively transitioning towards the knowledge economy and the information society, attempting to create value from KIS (Knowledge Intensive Services) by investing in digital infrastructure and broadening their scope of application. For businesses, digital networks allow for the generation, collection and processing of significant volumes of data and their transformation into knowledge—information with value—and therefore into opportunities. Increasing connectivity helps businesses reach consumers in real time and enables consumers to satisfy their needs by receiving exactly what they want when they want it. By identifying correlations and patterns between different variables, society can better foresee supply and demand conditions in order to adjust production and consumption processes. The data economy has multiple dimensions because it uses data with economic value. Companies of very different sizes can be seen as data producers using their own data

to optimize their operations. This is the outcome of proper investment in data and digital infrastructure made accessible to society and the optimal functioning of intellectual capital. An economy capable of creating data-driven value depends on its level of connectivity and the government's regulation of the data environment. Connectivity is at the heart of an economy based on digital infrastructure and new technologies. Physical, digital and social connectivity are key elements for the rapid sharing of ideas, know-how, knowledge, products, services and capital in a way that fosters growth and the generation of economic and social value. Platforms capable of broadly channeling economic, business and technology developments that lead to the mass production of goods and services are present in all sectors of the economy, including those with the lowest technology content. Their effectiveness depends on a regulatory framework that encourages competition and investment in infrastructure, guarantees appropriate treatment of data to avoid cartelization and abuse of dominant positions and, when necessary, enables centralized regulation of the industry to optimize the combination of different assets.

2.3 INNOVATION AS A DRIVER OF ECONOMIC DEVELOPMENT

Innovation ecosystems have become instrumental in driving long-term economic development across countries and regions. One of the critical aspects of these ecosystems lies in the establishment of linkages with universities for human capital and technology formation. The role of firms in the innovation process is multifaceted. Continuing the innovation and R&D investment strategies developed during the last two decades is vital for sustaining growth and higher productivity during the years ahead. The use of the research and development (R&D) intensity of a country as a proxy for economic growth in developing countries is frequently controversial. Nevertheless, there is a consensus that industrial innovation, technological capability and productivity are essential components for sustained growth. R&D and patent data, turnover from innovations and other factors of knowledge absorption are often analyzed in their links to growth. Economic development via innovation is today widely accepted. Countries tend to devote more and more financial resources to R&D and there is a clear rise in patenting activity. Micro data suggest that more significant

results for patents follow for a subset of countries with higher levels of novelty, indicating that true innovation is relatively rare and that patent data are subject to damaging selectivity. It is also widely recognized that the development of innovation and technological capability takes time; hence, changes in the flow of patents are likely to lag productivity growth. Furthermore, econometric evaluations of the growth of production and income indicate that innovation is more fundamental to growth in developing countries than in industrialized countries. There are innumerable links between R&D and growth, but three areas for deeper investigation stand out: the role of R&D in enhancing multifactor productivity growth, the patterns of public and private efforts in R&D and the effects of R&D on trade balances.

- Innovation Ecosystems and Industrial Policy

Economic growth, structural change and innovation are intimately connected. The establishment of an innovation ecosystem with an appropriate set of relationships between government, firms, universities and a supporting industrial policy is critical for growth. The innovation ecosystem comprises the network of agents, organizations and institutions that serve as preconditions for the generation of innovations. The involvement of universities—through the creation of highly skilled researchers and graduates, training, the provision of R&D support and technologies—is essential but not sufficient. Independent and private sectors and industrial policies are as important as universities themselves. In many economies, however, the private sector is weak or nonexistent, funding for R&D is insufficient and industrial policies are often ineffective because they are implemented in an uncoordinated manner. Consequently, industrial policies should be used carefully, as excessive and uncoordinated use tends to produce suboptimal results, especially in economies at an incubating stage. A coherent industrial policy that encompasses the entire innovation ecosystem is more effective than the sum of isolated policies promoting knowledge creation, diffusion and use. Such coordination can be achieved through a council on science and technology, which consists of representatives of relevant ministries, and through close interaction between ministries and leading universities. Once the council identifies the main nodes of the innovation ecosystem, it can prioritize action in the identified weak

areas. Policy instruments need to be adapted to existing local technology capabilities, whether strong or weak. The fact that innovation continues to be concentrated in a few technologies in developed economies points to a clear policy implication for other economies. They need to invest their scarce R&D resources in areas defined by existing comparative advantages or disadvantages, as the case may be.

- Metrics of Innovation and Productivity

Growth and productivity are linked to innovation measured by research and development (R&D) intensity, patent filings, product and process novelty and the diffusion of new technologies. The growing emphasis on innovation arises from its relationship with long-term economic growth and improved quality of life. Since the late 1990s, increased investment in R&D across many countries has provided a clearer foundation for measuring innovation and its role in the economy. In particular, the emergence of new sectors based on information and communications technology (ICT), the digitalization of economic activities and rising living standards in China have heightened interest among policymakers. However, despite these linkages, the impact of innovation on growth and productivity remains complex and influenced by country-specific conditions. On the supply side, the impact of innovation on growth is likely to be stronger in countries with more efficient national innovation systems. Such systems allow research and new technology to be generated internally while also diffusing new products and processes. On the demand side, the effects of innovation are transmitted through a more advanced industrial structure, which reflects the importance of new sectors in shaping demand conditions and providing opportunities along the product cycle.

2.4 ROLE OF RESEARCH AND DEVELOPMENT IN GROWTH

The share of GDP spent on R&D, the overall size of public and private expenditure and the structural breakdown of R&D spending into applied and basic components can provide clues about the role of R&D activity in economic growth. R&D expenditures in the United States, for example, are much higher than in all other OECD countries, but they are almost exclusively financed by the private sector and are concentrated in large firms and a small number of industries. In these respects, the United States is an

exception among industrialized economies. Other OECD countries show a more balanced allocation between private and public funding, a wider range of industries supporting R&D activities and increased significance of smaller firms in the industrial R&D sector. The high share of public-sector research in R&D activity in most countries and the large proportion spent by universities and research institutes indicate that the allocation of these expenditures is guided more by national goals than by market forces alone. The role of government funding of R&D also deserves special attention. It is widely accepted that much of the R&D carried out by private firms is profitable, if successful, and that a market economy would provide sufficient R&D if other factors remained constant. However, factors such as the spillover of knowledge generated by industrial R&D to other companies and even other nations lead to the belief that insufficient R&D would be forthcoming in an unregulated environment. Estimates of factor input elasticity, encompassing university education and training, support the argument that the social return from a nation's expenditure on R&D exceeds the private returns from such expenditure. It is worth stressing, however, that while such analysis provides an economic rationale for government support of R&D, it does not by itself provide a clear indication of the amount or type of economic activity that should be supported.

- Public and Private Investment in R&D

Although higher productivity usually accompanies higher levels of research and development as a share of GDP, not all countries with high research intensity necessarily exhibit similarly high rates of growth. Across countries, the two sources diverge appreciably in terms of strategic priorities, with public investment oriented towards areas such as health, environmental sustainability and defence—where commercial opportunities may be limited—while private investment continues to favour ICT-related activities. Over time, the incremental returns to research have tended to diminish. The return on investment in R&D may also differ significantly across sectors and regions. These differences must be taken into account when assessing investment policy. The growth rate in a knowledge economy depends not only on the absolute resources allocated to R&D but also on the balance between

public and private investment reflected in gross R&D expenditure. Attempts to compare these rates are complicated by methodological differences across countries and by varying underlying assumptions. From another perspective, most models that investigate the relationship between R&D and growth conclude that a substantial share of organized R&D activity, whether public or private, is crucial for achieving sustained growth. The channels through which R&D influences growth include mechanisms that facilitate the production and adoption of new goods and services incorporating new technologies or processes within firms. These growth-enhancing channels operate through private R&D spending, public R&D investment, the use of domestically generated knowledge, the absorption of knowledge from other countries or regions, the stock of human capital and the level of physical capital in the economy. The production of knowledge and the conditions that favour its diffusion remain central to these mechanisms. For open economies, the innovative efforts of trading partners also contribute to productivity growth in proportion to specialization in R&D-intensive sectors. Changes in the capital-labour ratio, the degree of domestic competition and trade openness further influence the growth effects of R&D.

- Collaboration, Spillovers and Knowledge Diffusion

Collaboration is a key feature of knowledge generation, diffusion and commercialization. Several forms of collaboration are evident, including knowledge spillovers and technology diffusion through inter-firm networks, trade and foreign direct investment; formal collaboration through joint supranational research programmes; and open innovation, where firms source ideas and knowledge externally to enhance their innovative capacity. Greater collaboration generally improves the effectiveness of private research investment and increases the social returns on public funding. Regional R&D networks, characterized by complementarity between public and private investment and supported by informal collaboration, play an important role in driving local economic growth. Public investment in collaborative R&D networks facilitates stronger innovative linkages among firms, enables closer partnerships with foreign companies and research institutions and contributes positively to private R&D investment intensity. Local knowledge environments and

proximity factors also play a significant role in sustaining collaboration in innovation activities, particularly within manufacturing sectors.

2.5 STRUCTURAL TRANSFORMATION IN MODERN ECONOMIES

Across advanced economies, economic activity has gradually shifted from manufacturing to services and further changes towards a digitalized economy are taking place, producing new activity in both traditional and new sectors. The impact of these movements on relative productivity levels—along with constraints on growth, income distribution and globalization—has long been of interest to economists. The issue of labor absorbing the imbalance between the growth of the labor force and the demand created by GDP growth has also attracted research attention. Striking a balance between adjustment costs and economic efficiency is a continuing concern of economic policy. The demonstration of an underlying propensity for growth in unskilled-labor-intensive sectors of emerging economies, shifting labor demand toward higher-skilled workers and the associated difficulties in adjusting labor supply from less-skilled-abundant developing countries results in new currents of research. Indeed, deeper insight is sought into understanding how labor markets anticipate flows toward growth poles, how these flows can be eased through appropriate labor policy or whether stimulation of declining sectors offers a way out for the affected labor market.

- Shifts from Manufacturing to Services

Modern economies are undergoing profound and convergent transformations. Economic structures are shifting from manufacturing towards service provision; in the majority of economies in Europe, North America and Asia, the employment share of modern services is steadily rising. New areas of activity, including education, health care, finance, trade, hotels, information technology and business services, offer new opportunities for capital accumulation. Within traditional industry, modernization and restructuring are creating new industries such as computer software and equipment, biotechnology and resource-based activities such as mineral extraction and oil refining. Nevertheless, the service sector is more complex, with expansion taking place at varying intervals and within different sub-sectors. Digitalization enables the

production, distribution and consumption of products and services with a low material base. Consequently, the sectoral alignment of employment is expected to change significantly in the coming years. Artificial intelligence and robotics are making their development processes increasingly independent of knowledge derived from physical or real-world experience. Digital technologies change the limits of product creation and usage, enhancing them with new product properties and direct consumption experiences engineered through digital channels. In some advanced regions, the limit on digital product consumption may even approach zero. For many forms of economic activity, where physical location becomes less crucial and technological structures evolve, creativity in product development will become a key economic driver. Such changes are likely to affect both the level and nature of employment in the service sector. A significant portion of service-based employment may be substituted by machines with advanced AI applications, while demographic factors continue to influence demand.

- Labor Market Adaptation and Skills Transitions

Modern economic development and structural transformation are accompanied by changing patterns in employment and labor market dynamics. A trend underlying the shift from manufacturing to services is that while services account for a rising share of GDP across most economies, productivity in many service activities has increased more slowly than in manufacturing. This imbalance creates a widening gap in relative productivity between manufacturing, where output is increasingly concentrated and services, where productivity growth tends to lag. Although some advanced economies have offset the effects of slower productivity growth in services through reductions in employment share, historical evidence shows that such adjustments can be complex, particularly when services continue to absorb a growing share of total employment. The implementation of innovation processes induces changes in products, processes, methods and organizational structures, including those resulting from the development of new technologies and their diffusion across economic activities. These changes affect not only production and consumption but also people, the environment, society and the economy as a whole. In response, labor market dynamics often require short-

term adjustments through changes in education and training systems or through reskilling and upskilling programs, while in the long term new employment opportunities may emerge. Changes may also occur in labor demand across regions or skill levels, although the pace of technological adoption may influence the extent of these shifts. Because labor market elasticities differ, adjustments across worker groups and job types are rarely smooth.

2.6 ECONOMIC IMPACT OF TECHNOLOGICAL ADVANCEMENT

Technological advancement is a key global development shaping modern economies. The application of technology for automation and productivity increase has strong effects on income growth. These processes are associated with rising productivity, increasing per-capita income and economic growth. On the other hand, as highlighted by the recent transformation caused by the digital economy, the adoption of new technologies imposes pressures on labor markets, creating both opportunities and risks for job creation. New technologies can replace labor in specific sectors and jobs, particularly those requiring routine tasks. However, the risk of job destruction differs greatly across sectors, with varying impacts on different categories of workers. Technological change can widen existing inequalities and inequalities in access to technology can slow down growth. Some digital technologies can help mitigate both effects. Their adoption can increase labor productivity while at the same time creating a greater number of jobs. It is therefore important to assess whether technical progress has become more inclusive and can support balanced economic growth. The application of new digital technologies can also broaden the range of possible policy interventions to keep the growth process open to all if, by diminishing or eliminating existing constraints, they facilitate access to knowledge and education for everyone. Inclusive access, alongside equitable allocation of resources, is a precondition for generating technology- and development-enabling visions, for establishing structures where innovation originates and for strengthening the knowledge base for decision-making and policy implementation benefiting all groups. Pragmatic development policies with a people-centered approach, supported by functional collaboration and

partnerships, can make technology a true means of bridging previously existing divides.

- Automation, AI and Productivity

The potential of automation and artificial intelligence to enhance productivity is widely acknowledged. While it is uncertain whether productivity growth will accelerate significantly in the near future, the demand for higher productivity to alleviate potential labor shortages and raise real wages remains strong. Analysis of sectors expected to experience productivity gains requires caution: while most national and regional economies are moving toward automation and digital transformation of traditional industries, these sectors are also those where jobs are most at risk and where early displacement may have significant economic and social consequences. Forces of technological expansion often generate visible pressures on jobs and labor markets, especially in regions with a high concentration of routine tasks. At the same time, automation and artificial intelligence are expected to create new employment opportunities in high-tech industries involved in developing and deploying these technologies. Technological progress is inherently heterogeneous, as not all innovations contribute equally to productivity or job creation. The dual nature of technology—both labor-creating and labor-displacing—is evident in areas such as automated chatbots in service industries, which simultaneously drive efficiency and reshape employment structures.

- Digital Technologies and Inclusive Growth

The growing use of digital technologies has intensified discussions on how they can support inclusive and sustainable growth where no one is left behind. Various studies indicate that the economic benefits of digital investments are unevenly distributed, with the digital divide becoming an increasing concern. In particular, unequal access to digital infrastructure limits contributions to GDP growth and reduces opportunities for workers and firms. While consumer data can enhance competition and lower prices, inadequate regulation may lead to concentration of data ownership and increased market power. Efforts to expand access to digital technologies through public investment are essential but not sufficient. Alongside technological adoption,

appropriate regulation and redistribution policies are required to ensure equitable outcomes. Digital equity extends beyond access to infrastructure and includes digital literacy, skill development, the ability to engage with technology, affordability and the distribution of costs between producers and consumers. Those who are most distant from technological advancements often face limited demand capacity and reduced access to resources. If left unaddressed, these challenges can hinder adoption, particularly among new entrants and small businesses. Addressing these issues requires coordinated and sector-specific policies that span multiple domains and ensure inclusive participation in the digital economy.

2.7 Chapter summary

The chapter lays the foundation for understanding modern economic trends by examining the concept of globalization and economic integration. It explains how the removal of trade and investment barriers, along with advancements in technology, has facilitated closer economic interdependence among nations. Globalization has reshaped production, trade and investment patterns, creating both opportunities for growth and challenges related to inequality, policy coordination and economic stability. The chapter emphasizes that economic integration is not only global but also regional, influencing the dynamics of development across both advanced and emerging economies. It further explores the emergence of the knowledge economy and information society, where knowledge, skills and data have become central drivers of economic value. In this context, human capital and intellectual capital play a critical role in enhancing productivity and competitiveness. The increasing importance of digital infrastructure, connectivity and data-driven decision-making has transformed traditional economic systems into knowledge-intensive ones. The chapter highlights that investment in education, skills and digital capabilities is essential for sustaining growth in such economies.

Innovation is presented as a key engine of economic development, supported by research and development (R&D) activities. The chapter discusses how innovation ecosystems, involving collaboration among governments, firms and academic institutions, contribute to technological advancement and productivity growth. It also

examines the role of R&D investment, both public and private, in fostering new products, processes and industries. Despite the clear link between innovation and growth, the chapter notes that the outcomes of R&D depend on factors such as policy frameworks, institutional capacity and the ability to absorb and diffuse knowledge. Finally, the chapter addresses structural transformation in modern economies and the economic impact of technological advancement. It explains the shift from agriculture to manufacturing and increasingly to services, alongside the growing influence of digital technologies. Technological progress has improved productivity and created new economic opportunities but has also introduced challenges such as labor market disruptions and inequality. The chapter concludes by emphasizing the need for balanced policies that support innovation, ensure inclusive growth and enable economies to adapt effectively to ongoing structural and technological changes.

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CHAPTER 3

DIGITAL TRANSFORMATION AND ECONOMIC GROWTH

Digital transformation has become one of the major drivers of economic growth in the modern world. The adoption of information and communication technology, cloud computing, big data analytics and artificial intelligence has improved productivity, reduced operational costs and created new opportunities for businesses and industries. These technologies help firms produce goods and services more efficiently, reach wider markets and make better decisions based on data. Digitalization also contributes to GDP growth by improving efficiency across sectors and encouraging innovation. However, the impact of digital transformation differs across countries and regions. Economies with strong infrastructure, skilled human resources and supportive policy frameworks are able to benefit more from digital technologies than economies with limited access and weak institutional systems.

3.1 IMPACT OF DIGITALIZATION ON GDP AND PRODUCTIVITY

Digitalization has a significant influence on GDP and productivity. The use of digital technologies enables firms to improve efficiency, reduce costs, increase output and expand market access. Information and communication technologies help businesses coordinate activities, manage data and deliver services more effectively. As a result, digitalization contributes to higher productivity and supports economic growth. Empirical studies generally show a positive relationship between digitalization and economic performance, although the strength of this relationship varies across countries. Economies with advanced digital infrastructure, skilled workers and supportive institutions are more likely to experience stronger productivity gains. In contrast, countries with limited connectivity, weak digital skills and inadequate policy support may not fully benefit from digital transformation. Cloud computing, big data

analytics and artificial intelligence further strengthen this process by enabling flexible business models and data-driven decision-making. However, these technologies must be widely adopted across sectors before their full impact on economic growth can be realized.

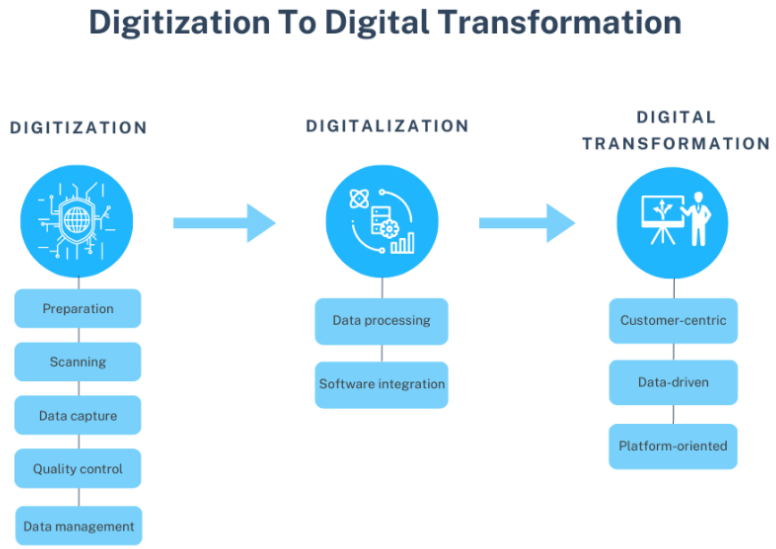

Figure 3.1 Digitalization

3.2 ROLE OF ICT, CLOUD COMPUTING AND BIG DATA

Information and Communication Technology (ICT) has been a crucial driver of digitalization across economies, positively impacting GDP and productivity growth. Leveraging an extensive body of literature, this section explores the role of ICT infrastructure, its penetration in business and consumer markets, digital skills, workforce preparation and ICT-oriented research and innovation. Together, these factors are essential prerequisites for a successful digital transformation journey.

- ICT Infrastructure and Access

The availability of good-quality, reliable and affordable ICT infrastructure is a necessary condition for digitalization. A modern and extensive ICT infrastructure enables enterprises to leverage digital technologies and integrate them into their business processes and operations. It also encourages more extensive usage of technologies such as cloud computing, big data analytics, advanced robotics and artificial intelligence. Inequalities in access to standard ICT infrastructure can hinder

the standardization of digital services and the resulting productivity gains. In particular, growing evidence suggests that access to high-speed broadband is linked to higher economic growth and productivity gains. The impact of ICT infrastructure and access on aggregate productivity is a prominent strand within the literature. Alongside direct productivity effects through basic services and the integration of ICT into production processes, growth may also stem from the increased adoption of data-driven practices or the wider diffusion of fintech services. A country's level of access thus influences productivity not just in ICT-intensive industries but also in the rest of the economy. While past research has often examined the impact of mobile broadband penetration, the role of fixed broadband remains crucial. Beyond investment in access, the capacity of telecommunications networks to support increased data demand is fundamental. In the business sector, the accessibility and quality of digital services are now fundamental for companies in all economic sectors, including the public sector. Industries that are digitizing rapidly are most dependent on reliable, fast and secure telecommunications services, and the development of a robust digital communications network is a high priority for them. A key conclusion here is that the combination of strong growth in cloud services combined with continued skills and artificial intelligence maturity gaps will nevertheless act as a brake on overall productivity contributions for the foreseeable future.

- Digital Skills and Workforce Transformation

Digital skills are crucial for the success of digitalization initiatives at all company levels. As noted previously, the use of many of the underlying new technologies is often limited to specialized work roles that represent only a small percentage of total employment. Nevertheless, as the capability to analyze and act on data matures, demand for advanced and often automated analytics is growing across all business functions, including applications such as Robotic Process Automation and Natural Language Processing. However, the benefits of these technologies are reduced in environments of limited or unreliable data quality, data governance and security. Treating data as an asset, with appropriate quality standards and dedicated management, can therefore enhance the payoffs from cloud computing and analytics.

Evidence on the connection between analytics maturity and productivity is strong. In the USA, early data-driven adopters grew 126% over seven years compared to 92% for other companies, and more recent adopters achieved 2–5 times the revenue growth of less mature analytics users. Similar findings have also been indicated for Europe, where data-driven companies grew three times faster in terms of workforce compared to similar but non-data-driven companies. Advanced analytics solutions have therefore been linked to higher gross value added, as firms continue to invest in technology, digital skills and human capital, with increasing returns across these dimensions.

Cloud Computing and its Economic Implications

Cloud computing is a key pillar of digital transformation. Grounded in the principles of utility computing, cloud solutions allow information technology resources and services to be provided in a pay-per-use model. Clouds are hosted in large data centers and dynamically provisioned to support multiple users and clients. Compared to traditional computing infrastructures, cloud computing offers distinct advantages in terms of cost savings, scalability and agility. Successfully leveraging the power of the cloud allows organizations to deliver services faster, innovate more quickly and respond easily to new demands and market opportunities. Furthermore, evidence from several industries suggests that organizations with a high degree of cloud computing use enjoy an additional productivity boost. As the information technology industry evolves toward a cloud computing ecosystem, it is important to explore cloud adoption trends and patterns across industries.

Because cloud computing enables companies to consume information technology resources in a utility model, it reduces barriers for organizations seeking to invest in information technology. For small and midsize businesses, which may have less flexible budgets, predictable pay-per-use models for information technology services with reduced upfront investment in capital infrastructure help accelerate adoption. Furthermore, labor efficiency is boosted because a cloud services model enables small businesses to focus on delivering services to customers instead of managing and maintaining computing resources. In addition, by encouraging the establishment of cloud-based information technology services that deliver services to customers,

companies in the information technology sector serving small and midsize businesses can also be more productive since once developed, these services are delivered incrementally at low marginal cost.

- Cost, Scalability and Agility

One of the greatest attractions of cloud computing is the opportunity it offers to transform capital expenditures into operational expenditures. Because they provide the ability to pay only for what is used, public clouds are cost-effective and appealing to organizations of all sizes. Cloud computing democratizes the use of computing infrastructure and big data by making them affordable. Thus, cloud computing lowers the barriers for organizations to apply analytics on large datasets and consequently contributes to the rising importance of data-driven decision-making. Cloud computing also provides lifecycle management, scale during peak demand, enables the development of new services and enhances IT function agility. The cloud allows organizations an on-demand capability that enables IT service renewal and development after failure without capital investment. Further, the rapid provisioning capabilities of the cloud allow IT services to scale quickly, whether up or down, in response to increased demand or expected demand decline, thus freeing skilled people and other resources from managing infrastructure to focusing on application development and delivery. Organizations can also provision human resource-related services through the cloud, ranging from IT networking and development services to recruitment, payroll, training and agency support.

- Cloud Adoption Trends across Sectors

Studies show increasing adoption of cloud services across all sectors, with Communications, Media and Technology (CMT) leading by a wide margin and several sectors reporting public cloud spending growth rates exceeding 30%. Research indicates that companies at all stages of cloud maturity have increased their spending commitments and that multi-cloud configurations have become the dominant deployment model. In India, consumer protection agencies have recommended that the development of the country's cloud-based computing model should focus on leveraging emerging technologies such as 5G and adopting a cloud-ready mindset as

an integral part of business strategy and policy. In Singapore, the rapid pace of cloud adoption has prompted strategic knowledge-sharing efforts on cloud security verification among public sector agencies. In Brazil, cloud infrastructure services grew significantly in recent years, reflecting strong demand for digital transformation. Governments around the world are investing in their cloud computing capabilities. Digital governments are using cloud technology to reinvent operations and processes, make better use of data for decision-making and innovation, scale digital initiatives and enhance partnerships with businesses and civil society. A well-defined public cloud strategy outlining objectives, vision and guiding principles can improve the delivery of government services with greater agility, resilience and security. Such strategies also promote collaboration across sectors by enabling shared services such as identity, payment and location systems within the broader digital governance ecosystem.

3.3 DIGITAL TRANSFORMATION IN INDUSTRIES

Digital transformation is typically associated with a range of information technology investments that affect the operation and performance of firms and economies but not every investment in ICT network infrastructure, cloud computing or big-data analytics directly results in such a transformation. To qualify as a digital transformation effect, the adoption of digital technologies in firms should occur at a rapid pace and deeper modes of cloud and big-data adoption should be associated with higher productivity growth. A close examination of the real-world experiences of these industries suggests that the nature of ICT investments made at the sectoral and aggregate levels of the economy matters for the economy's growth performance and productivity. Birth- and death-rate statistics capture the dynamism of new firms entering and exiting the market while the contribution of high-growth firms to employment and productivity growth highlights the role of startups as engines of job creation and renewal. Research on the profile of innovative startups shows that they grow faster or inject dynamism when they engage in innovation and networking activities. Startups also achieve higher productivity if they depend on a conducive external environment and receive

support from the public sector in the form of public investment, demand-pull policies and targeted policies for specific sectors.

- Manufacturing and Supply Chains

Manufacturing and distribution industries are broad adopters of digital technologies, especially automation and data analytics, which can enhance productivity and supply chain resilience. However, digital adoption in supply chains and logistics lags behind that of manufacturing. Research clarifies the economic implications of digitalization of manufacturing and supply chains. Manufacturing is one of the most advanced industries regarding the adoption of digital technologies: 77% of all manufacturers reported using automation or sensors, process control or cybersecurity. According to the DQ Institute, 42% of APEC manufacturers have yet to identify any form of productivity gain from using digital technologies. Digitalization can improve traditional sectors' productivity and service quality in the services sector and help firms deal with recession risks; such gains are considered more significant for USA service industries' niche segments and less for large-scale industry sectors. Smart manufacturing represents the current trend of digital transformation in the manufacturing domain; especially private organizations have been active in investing in it. A subject-controlled research review presents eight opportunity areas for digital transformation across the chemical process supply chain ecosystem supported by four enablers for transition. A remote synthesis and DEMATEL-based cross-impact analysis prioritizes cyber risk factors in intelligent manufacturing. Analyses of manufacturing ecosystems in Asia also present areas requiring investment, trade facilitation, fair market adoption, GHG emission reduction and an inclusive development lens. Evidence of such relationships is found for Taiwan's manufacturing using gross value added (GVA).

- Services and Finance

The impact of digitalization on economic productivity is notably large for the service sector. Although most service industries are not yet sufficiently scalable and therefore do not benefit fully from cloud computing, the scope of cloud computing as a game changer for services is significant. Financial services, especially banks and insurance

companies, have long started to reap substantial benefits from cloud computing. With the rapidly growing availability of data from smart mobile phones, banks and insurance companies are now able to predict likely criminal activities and negative financial behavior among customers. Such analytical capabilities are helping both banks and insurance companies reduce financial losses. The demand for cloud computing, especially IaaS and PaaS offerings, is stronger than in any other segment and these standardized services can therefore be offered more scalably. Moreover, the infrastructure is scalable and another game-changing capability of cloud computing is the ability of customers to develop and run their applications on service providers' platforms. This allows customers to build applications based on infrastructure provided by companies such as Google, IBM, Amazon, Alibaba and Microsoft without worrying about underlying systems. These cloud activities have already provided agility to manufacturing, and now it is up to service industries such as movie and game production to exploit cloud computing at an even greater scale.

- Healthcare and Public Sector

Cloud computing is reshaping healthcare delivery and accelerating digital transformation in public sector organizations. In response to rising costs and changing economic conditions, hospital operators are adopting cloud services to improve security, lower development expenses and enable real-time data sharing across devices, platforms and enterprises. Cloud technology is helping government agencies achieve better value for public expenditure, allowing them to deliver more responsive services, create new communication channels and collaborate more efficiently across departments. Various national governments are pursuing ambitious cloud strategies; for example, the European Union has planned significant investments to stimulate adoption across both public and private sectors. Public administration systems in many countries are approaching an e-government breakthrough due to the adoption of specialized Web 2.0 applications in the cloud combined with expanding broadband access. E-governments are now able to develop accessible web services that function as one-stop information centers across multiple domains. Public service providers are establishing personalized service channels and increasingly promoting transparency in

their processes. Direct and indirect strategies are encouraging greater user engagement through multiple digital channels including social networking platforms. Public service portals have shown increased usage due to simple web-based applications while cloud computing enables both businesses and citizens to participate more actively in governance and decision-making processes.

3.4 CONTRIBUTION OF STARTUPS AND INNOVATION ECOSYSTEMS

Both the economic contributions and the role in driving ecosystem innovation for strong growth, productivity and job creation justify greater attention on ICT startups in the context of economic digitalization. Policy and investment environment factors that support startup creation and growth stimulate the digital economy and create positive spillovers when embedded in rapidly digitizing economies and the digital transformation of established firms in all sectors. Startups contribute to productivity growth in several ways. Rapid growth of technology startups in mature economies in recent years has been a critical factor in boosting productivity: successful new ventures are becoming larger at an earlier stage of their development than they did in the past; technology-based firms in the United States, United Kingdom, Sweden and Finland are generating a disproportionate share of jobs; and the productive potential of the digital economy is increasingly resting in the ability of larger and older enterprises to effectively adopt and deploy technology to support innovation in product and service offerings, processes and business models.

- Startup Contributions to Productivity

Digitalization of startups fosters GDP growth through productivity increases, with cloud computing and ICT adoption playing a pivotal role in scaling effects. However, these effects can be offset by relative performance challenges compared to established firms. Better institutional quality and greater access to finance enhance startup productivity through digitalization. Startups are playing an increasingly important role in the economies of many countries. Startup firms, defined as business ventures that usually emerge with a unique product or service to fill a gap in the market, are responsible for many advances in production, management and business models. They account for a major share of innovation investment and patents, make

entrepreneurship more attractive and act as engines of productive restructuring by introducing new business models, enhancing competition and replacing less efficient firms with innovative alternatives. Their effects on infrastructure demand, employment and training have been mixed. A sizable reduction in aggregate GDP would result from a sudden halt in all new ventures and a considerable decline would still follow even if all existing startup enterprises, including those less than five years old, were to close. In terms of employment, grassroots entrepreneurs typically account for a large share of job creation and a significant portion of new jobs originates from startups even though they represent a small share of the economy at any given time. It has been suggested that the relationship between startups and productivity may provide a better measure of their economic impact than innovation alone. Startups with fewer than 50 employees show the fastest productivity growth; however, the overall impact on GDP may become negative if rapid increases in startup numbers reduce relative performance. Hence, these performance dynamics are of considerable practical importance.

- Policy and Investment Environments

Two additional conditions influence the growth contribution of startups: the extent of digital technology adoption across industries and the overall business ecosystem's support for firm creation and scaling. The relationship between startup activity and productivity growth is stronger in countries that are more digitally advanced and have robust ecosystems of policies, capabilities and investments supporting startup development. A notable example is the United States, where several measures of digitalization are positively correlated with the number of technology startups per capita. Supportive institutional frameworks and administrative systems for young businesses facilitate new firm creation. Encouraging startups generates both direct and indirect productivity effects. In the Central and Eastern Europe region, key policy priorities for enhancing startup contributions to productivity include increasing investment levels and improving the effectiveness with which investments translate into innovation. Evaluations of support measures show that broad-based programs affecting the entire innovation ecosystem—such as investment levels and education

quality—play a crucial role in strengthening the participation of startups in productivity growth.

3.5 CASE INSIGHTS FROM EMERGING ECONOMIES

Compared to developed economies, cases from emerging countries show that while the basic pillars of digitalization—digital services, human and ICT skills, cloud computing, and big data—are indeed critical, they may not be sufficient for ensuring a rapid positive impact on GDP and productivity. Case A analyses the digitalization trajectory in nine emerging markets and highlights that the improvement in GDP per capita achieved during the COVID-19 pandemic is only temporary and confined to the happening years. During the digitization stage, the events of COVID-19 ultimately led to a stronger impact of the pandemic on GDP per capita that is both more pronounced and harmful than the one depicted by the standard approach. Infrastructure quality, cloud adoption by sped-up digitalization decisions of large firms, big data governance, data ownership, and guarantee structures were found to be relevant for GDP per capita during COVID-19. The possibility of retrieving online information from companies was also positively correlated with GDP per capita in these post-COVID-19 years, suggesting the need for more transparency or better governance with respect to the information put online by firms. Case B looks at how investment in cloud computing services and promotion of data-driven decision-making can support economic growth even in developing countries where cloud maturity is low. In these nations, the low level of technology adoption has historically limited the impact of the investment on increased productivity growth. However, with the shift to cloud computing and artificial intelligence for data analysis, local enterprises can now draw on international know-how and solutions. The migration of productive systems to a new model based on cloud services is creating the necessary connection to a larger ecosystem with greater skills and technology supply. In this context, the main challenge is the adoption of technology at a level that allows companies to become data-driven. Case C provides an empirical assessment of the effects of ICT adoption on GDP for several rapidly digitizing countries. Digitalization is a critical factor for economic growth and

ICT has increased growth through a double-coin effect—directly by stronger investment and indirectly through a better investment environment.

- Case A: Digitalization Trajectories in Emerging Markets

A also explores the economic ramifications of digitalization for emerging markets that have recently scaled up investment in digital technologies. Digital transformation can affect GDP and productivity from multiple angles. A first-order effect occurs when investment in digital technologies leads to an acceleration of GDP. A second-order effect arises from a productivity gain in those sectors lagging behind in digitalization and where productivity growth has the greatest impact on productivity at the aggregate level. A detailed analysis covering 33 rapidly digitizing economies considers the role of cloud computing, big data analytics, and e-finance services for economic growth. The results suggest that with the appropriate policy environment, digitalization can contribute positively to GDP growth and productivity during the current phase of the digital wave. A third-order effect would materialize if expanded digital services were able to generate part of a new demand—beyond the classic GDP components—capable of stimulating investment in the digital infrastructure on the supply side. Any danger of digitalization producing an economic slowdown thus seems unfounded. GDPCAP—or GDP per capita—in high and upper middle-income states for which data is available indicates highly unequal levels of per capita income within regions and overall. Performance and risk indicators offer warnings that macroeconomic stability is at risk even in some richer countries. Nevertheless, these limits stem more from poor macroeconomic policy than lack of internal stability. Digitalization pathways of the next few years will be critical for containing these spillover effects, but at least cloud services, e-commerce, and big data appear to remain powerful sources of growth for these regions.

- Case B: Cloud and Data-Driven Growth in Developing Economies

An empirical assessment of Cloud and Data-Driven Growth in developing economies suggests that developing nations have yet to reach a critical mass of cloud adoption. Cloud computing and the analysis of big data are likely to enable more agile business operations and generate a strong set of new data. However, it is only when cloud

computing is deployed across economic sectors that real growth effects on TFP and GDP become significant. These effects only appear when a greater share of enterprises adopt cloud computing. A mature cloud ecosystem is also important for a thriving analytics services industry; indeed, cloud computing is increasingly viewed as a platform for enabling innovation in the economy. Public policy can stimulate the growth of data-driven economies through an economy-wide cloud-first strategy focused on the aggregate adoption levels of cloud computing. Fit-for-purpose evidence creates the foundation for setting priorities and directing public resources to the appropriate areas. Many countries are increasingly supporting data-driven economies by stimulating broader supply and demand-side adoption of analytical capabilities, investing in a highly skilled workforce, liberalizing the cross-border flow of information, and adhering to protocols that foster trust. One particularly important pillar of this support framework is the promotion of cloud-first policies. Such policies stimulate a smarter and more efficient use of public sector resources while generating a critical mass of cloud computing activity that drives innovation, lowers costs, and improves responsiveness and service delivery across the economy.

- Case C: ICT Adoption and GDP Effects in Rapidly Digitizing Nations

Large-scale studies by the International Telecommunications Union (ITU) reveal that in rapidly digitizing countries, improvements in ICT adoption exert a strong impact on GDP growth, driven primarily by expanding Internet use. A 10% increase in the Internet access index enhances GDP growth by 0.61% and a similar growth in the Internet user index raises GDP growth by 0.59%. Increases in mobile-cellular subscriptions per 100 inhabitants and social media penetration also contribute positively, albeit to a lesser degree, while growth in fixed-telephone lines fails to affect GDP growth. In terms of digital dividends, rapid uptake of ICT can stimulate GDP growth in the short term whereas in the medium term thorough integration of ICT into the economy remains essential for longer-lasting dividends. In line with these findings, a cross-country panel analysis for a large set of European economies suggests that broadband infrastructure, Internet usage, and digital delivery of government services positively affect GDP growth. An assessment of the contribution

of Cloud services to economic growth also indicates that moderate Cloud adoption has a positive short-term effect on GDP growth, but this effect becomes more substantial with higher levels of Cloud maturity. Finally, a comparison of firms operating in countries with diverse rates of Cloud adoption reveals stronger gains in productivity and profitability for those located at advanced stages of Cloud adoption.

3.6 CHALLENGES IN MEASURING DIGITAL ECONOMIC GROWTH

Three principal themes emerge from the analysis of barriers and enablers that shape the digital economy of a country: (a) the institutional and regulatory ecosystem; (b) the development of capabilities and talent; and (c) the enabling digital infrastructure. First, the institutional and regulatory conditions must provide a conducive environment for concurrent development and adoption of digital products, processes and services. Barriers such as lack of government support and regulations can hinder development in these areas; therefore, the establishment of regulation and supervision regimes is of utmost importance in blurring the transition from trial-and-error experimentation to full-scale production. Second, to ensure that the positive impacts of digital transformation on economic growth and structural change materialise in the long term, it is crucial to cultivate talent that has the skills needed to absorb and exploit the new digital technologies. Growth in demand for specific digital skills is outpacing supply. Third, the availability of reliable, high-performing infrastructure and connectivity remains a critical factor for businesses to operate and societies to achieve inclusive development, even after accounting for these factors in the measuring phase. Furthermore, cybersecurity is increasingly becoming a concern, with companies that do not provide a secure digital experience losing boys. Governments and firms must work together across the policy spectrum to create measures that maximise the benefits of the digital economy. Targeting the specific needs of key digital economy sectors, aligning measures and incentives across sectors and agencies and ensuring that regulatory barriers do not inhibit hybrid business models and new players are key aspects of a holistic enabler approach. Collaboration and stewardship of the digital economic ecosystem provides an effective mechanism to enable the cross-cutting digital transformation of the entire economy.

- Institutional and regulatory dimensions

Digital transformation in industries, startups and ecosystems: the formal consideration of digital growth requires a survey of barriers and enablers. For the digital economy, the barrier/enabler discourse squarely identifies the role of institutions and institutional bases. Fulfilling the role requires major actors—governments, businesses and individuals—to regulate, manage and offer capacity and skills for cyberspace confidence; ameliorate the unequal access to infrastructure and information; and build the investment capacity for partnership ecosystems and relations, trust and confidence among rural citizens. The most complex and difficult part of improving digital growth is institutional. The fast-growing speed of the digital economy has created legislative and governance sluggishness and inefficiency of the institutional system. Administrative processes lag behind the rapid development of the digital economy and cannot restrain and punish unscrupulous behaviours. Digital economic development requires the coordination of multiple governmental groups. The institutional framework for digital economic growth is still maturing and incomplete. Post-epidemic growth needs increased attention on cyber legality, the soundness of e-commerce, a reliable transaction environment and the prevention of network fraud, as trust is a prerequisite for the application of the digital economy. Rapid changes in cyberspace demand timely relevant laws and regulations. The lack of laws and supervision covering all aspects of the digital economy hinders development and innovation. The online economy has expanded faster than traditional economic activities, but legal costs have increased and user experience has declined. Cameras now monitor speeding but trust remains lacking in e-finance, entertainment, travel and hotels. The transition from the physical economy to the digital economy requires more than investment and upgrading; the basis of the entire economy is still cement and steel.

- Capability development, talent and skills

Digital transformation entails a demand for new and emerging skillsets and capabilities across all industry sectors. Talent is an essential factor for successful digital adoption, with digital skills shortages or mismatches acting as deterrents to

growth across the economy. Governments can help meet the demand for skilled graduates across areas of greater need, while individual firms often invest in training physical and technical skills internally because existing supply is insufficient. Collaboration with businesses during educational program development also helps graduates acquire more relevant skills as the economy transforms. Consequently, the entire education ecosystem—HEIs, VET organizations and training suppliers—should teach students the analytical and cognitive thinking capabilities essential for successful digital adoption. In addition, addressing deeper-seated issues that foster an unwillingness to learn—for example, burnout, work overload and peripheral vision—has the potential to positively influence talent development. Collaboration and knowledge-sharing facilitate transformational adjustments to IT and business processes—accelerating improvements to financial performance, product development cycles, customer experience and cost structures—while empowering employees to take the initiatives necessary to keep their organizations competitive. Yet the integration of sustainability and digitalization is often hindered by the lack of expertise to connect these two aspects within the same organizational context. Unfortunately, it is this exact skillset that is in highest demand when seeking employees with deep capabilities at the intersection of sustainability and technology. Simulated experience-based learning is one learning strategy that can facilitate this type of capability development and is associated with improved use of digital assets and enhanced customer experience due to the greater laissez-faire and exploratory orientation enabled by the technology infrastructure.

- Infrastructure, connectivity and cybersecurity

Limited, outdated or dysfunctional infrastructure typically exposes firms to significant service delivery risks. Insufficient road networks hinder effective transportation of goods and consequently increase delivery costs and times thus affecting profitability. Moreover, the lack of reliable power supply—one of the most frequent operational constraints reported by firms in developing economies—is often an important factor whenever there are global supply-chain disruptions. Such conditions might prevent companies from operating effectively or place them at a competitive disadvantage.

Rampant cybersecurity breaches, despite being hardly considered a constraint by companies in developing economies, have severe repercussions on established firms and erode resilience. Cybersecurity readiness continues to be neglected in many developing countries. Several factors inhibit the effective implementation of policies formulated by governments. Cybersecurity is not viewed by senior management as a threat to business continuity and operation, leading to a lack of budget allocation and subsequent investment. Such lack of investment then results in insufficient or ineffective incident response and communication procedures within the organization. Furthermore, companies continue to resist allocating higher budgets for cybersecurity and primarily see compliance and governance issues as the main drivers for implementing cybersecurity-related processes.

3.7 Chapter summary

Digital transformation has emerged as a central driver of economic growth, significantly influencing GDP and productivity across economies. The adoption of digital technologies enhances efficiency, reduces operational costs, and enables firms to scale rapidly, thereby contributing to higher output and improved economic performance. Empirical evidence suggests a strong positive relationship between digitalization and productivity, although the magnitude of impact varies across countries depending on their level of technological maturity and institutional readiness. While digitalization supports income convergence within economies, disparities persist between developed and developing regions due to uneven access and adoption. Information and Communication Technology (ICT), cloud computing, and big data analytics play a foundational role in enabling digital transformation. ICT infrastructure facilitates connectivity and data exchange, while cloud computing provides scalable, cost-effective solutions for businesses to innovate and expand. Big data analytics enhances decision-making by allowing firms to extract valuable insights from large datasets. Together, these technologies create a dynamic ecosystem that supports automation, artificial intelligence and advanced digital services, ultimately driving productivity improvements and fostering new business models.

Digital transformation is reshaping industries by modernizing production processes, optimizing supply chains, and enabling service innovation. Traditional sectors such as manufacturing are integrating automation and smart technologies, while service industries are leveraging digital platforms to enhance customer experiences and operational efficiency. Startups and innovation ecosystems further accelerate this transformation by introducing disruptive ideas, fostering competition, and generating employment opportunities. These ecosystems thrive on collaboration between firms, governments, and research institutions, contributing significantly to technological advancement and economic dynamism. Insights from emerging economies highlight both the opportunities and challenges associated with digital transformation. While investments in digital infrastructure and technologies can stimulate growth, their impact is often constrained by limited adoption, weak institutional frameworks, and skill gaps. Additionally, measuring digital economic growth remains complex due to difficulties in capturing intangible assets, data-driven value creation, and rapidly evolving technologies. Addressing these challenges requires comprehensive policy frameworks, improved data measurement techniques, and sustained investment in digital capabilities to ensure inclusive and sustainable economic development.

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CHAPTER 4

E-COMMERCE AND PLATFORM ECONOMY

Digitalization has contributed to a major transformation of commerce and trade over the last two decades. The platform-based economy has emerged as an important feature of the digital global economy, and e-commerce has become a major driver of business growth. Online marketplaces have created new opportunities for businesses of all sizes by allowing them to reach global markets without establishing costly physical distribution networks. Both sellers and buyers benefit from the wider product selection, price transparency and convenience offered by digital platforms. Different commercial models have developed within these platforms, including business-to-business, business-to-consumer and consumer-to-consumer transactions. Digital platforms also support cross-border trade by reducing transaction costs and enabling small and medium enterprises to participate in global markets. However, the rapid growth of e-commerce has also created regulatory challenges related to taxation, consumer protection, competition, data privacy and digital governance.

4.1 GROWTH OF ONLINE MARKETPLACES

An analysis of the expansion of online marketplaces like Alibaba Amazon Booking and Airbnb reveals strong growth and a shift to new business models. Over the past decade Internet sales in North America and Western Europe have increased yet the share of the online sector has started to stabilize. In much of the rest of the world especially in developing countries online sales still represent a small percentage of total sales but continue to record robust growth rates. This trend is accompanied by the rapid growth of platform-based digital marketplaces where companies and consumers meet. Marketplaces include business-to-business (B2B), business-to-consumer (B2C) and consumer-to-consumer (C2C) platforms. Marketplaces like

Alibaba and Amazon provide B2C services while Booking.com and Airbnb organize C2C or C2B services. Global trade through digital platforms and their impact on logistics and supply chains are essential for a deep understanding of e-commerce. Marketplaces are two-sided digital platforms that enable the exchange of goods services or information through a community of users. Two-sided markets charge users a fee for connecting with each other lowering the transaction costs that buyers and sellers confront in direct exchanges. According to an OECD analysis the outbreak of the coronavirus pandemic spurred a temporary surge in global e-commerce trade: the value of goods traded online increased by 18% in 2020 reaching US$26.7 trillion. The current challenge is making this growth sustainable fostering productivity gains across supply chains especially in the logistics sector and ensuring that developing countries reap a good share of the benefits.

Figure 4.1 online marketplaces

4.2 BUSINESS MODELS SUCH AS B2B, B2C AND C2C

The business models of well-known digital platforms, such as Amazon and Alibaba, are able to connect multiple categories of users with the platforms built around them, who benefit from the mutual increase in the market, thereby creating a robust

incentive for only the platform operator. Digital platforms operate through different business models depending on the relationship between buyers and sellers. The most common models are business-to-business, business-to-consumer and consumer-to-consumer. These models enable firms, consumers and individuals to exchange goods and services through online platforms. By reducing transaction costs and improving market access, they have become central to the growth of the platform economy.

- B2B Models

Business-to-business and business-to-consumer online marketplaces are a major source of innovation in the platform economy. Business-to-business (B2B) marketplaces include trading platforms focused on the wholesale or semifinished product exchanges often used by manufacturers and distributors for raw materials and supplies; these services are offered by operators like Alibaba.com and ThomasNet. These systems also include online software applications to support product development and production management, logistics and supply chain integration, and sales management and product marketing. One firm that developed and brought to market a comprehensive suite of B2B sourcing, procurement, and supply chain services is SciQuest—the model was later replicated by many other smaller players in the B2B space. B2B transactions account for the largest share of online marketplace activity, surpassing other segments combined. Last-mile services enable firms to fulfil consumer demand by bringing smaller shipments directly to residences. Freight transportation and logistics management are among the services offered by several of these operators.

- B2C Models

The sales model offered by airlines exemplifies the potential advantages of using a digital e-commerce platform. According to data from Statista, in 2021, almost 30 percent of air travelers in the U.S. purchased tickets directly from an airline's website, more than any other source. Airlines usually provide low prices at their websites to promote these transactions, but ticket prices are the same regardless of the reservations source. Since a website reservation incurs a very low cost, airlines also wish travel agents to use their own websites. To facilitate such use, many airlines

maintain a direct connection with major travel agency systems to provide current information about price, seat availability, and flight schedules. Such a direct connection avoids the cost of the GDS and can help the airline better manage the information flow. Incentives are very important to the performance of digital e-commerce systems. The key issues are whether customers are encouraged to purchase directly from the seller, whether businesses will pay to place their products in the store, and whether a good user experience will attract customers to return often and also become sellers. An online store has lower operating costs than a physical store, but it will still be necessary to charge merchants a commission on sales—usually a very small percentage. Digital markets such as Amazon have relied on maintenance by third-party sellers for many years due to their size. Amazon continues to encourage first-party sellers via payment and logistical support because they profit when customers visit their sites.

- C2C Models

In a C2C platform, a business entity is involved at a lower level. These platforms, often called 3rd role marketplaces, allow individuals to provide services or products directly to other individuals. These services or products are typically non-new and are provided in small quantities. The main player in the C2C model can be an individual or a micro-enterprise. Prominent examples of C2C electronic marketplaces include eBay, Craigslist, and OLX. These marketplaces rely on user participation to develop their content and keep it updated, which motivates the emergence of C2C transactions. The model also encourages the emergence of virtual eco-systems in which users with similar interests exchange and share not only products and services but also experiences, competences, and knowledge with each other. Examples of C2C platforms tend to fall into two major categories: general marketplaces, where users can trade goods and services from any category, and category-specific marketplaces, which restrict the range of goods and services to a specialized area or category. About 1% of C2C transactions meet the requirements defined by elaborate auction rules. The overwhelming majority of C2C transactions. besides a lack of sophistication, also lack clear market structures such as price at transaction time. In the majority of C2C

transactions, bargaining plays a central part. Users of C2C platforms remain very focused in terms of how they want to position themselves in the marketplace and to whom they are furnishing products/services. As most of these transactions do not generate high volume revenues, the marketing significance of these platforms at present seems much more relevant and visible for service providers than products or goods offerings.

4.3 ROLE OF DIGITAL PLATFORMS IN GLOBAL TRADE

The technological infrastructure of the Internet and the semantic web are accelerating the shift from www to ggg—web3, g, gigantic. The evolution of the web has shifted attention from supplier-oriented e-commerce to demand-oriented digital commerce and marketplace economies such as social commerce. Consequently, digital platforms are rapidly becoming the key agents driving new product markets and empowering consumers to shape their own offerings. Enabled by AI and pioneering platform-business-model innovations, these agents are also unleashing entirely new demand cycles by radically shrinking the life cycles of demand. Digital commerce has the potential to reshuffle market power, redefine the very nature of trade activities, and trigger a new wave of globalization by creating demand-source markets. Digital platforms are among the fastest-growing service sectors in the global economy. They have been redefining supply chains, reshaping critical infrastructures, and ushering in a new wave of globalization by democratizing access to resources such as knowledge, skills, and technology—resources that had previously been tightly controlled by the most powerful communities. A growing number of research studies suggest that marketplaces are also redefining trade activities and their associated development patterns. Emerging platforms now allow all participants in the world economy—from buyers and sellers to investors, manufacturers, distributors, and even logistics and payment service providers—to develop embedded businesses and offer any kind of products and services for any market worldwide.

4.4 CONSUMER BEHAVIOR IN ONLINE ENVIRONMENTS

Consumer behaviour in online environments is shaped by convenience, trust, price transparency, digital literacy and the quality of user experience. Online consumers often compare prices, read reviews, examine product ratings and depend on secure payment options before making purchases. Personalized recommendations, targeted advertisements and social media influence also play an important role in shaping purchase decisions. Trust is one of the most important factors in e-commerce. Consumers are more likely to use platforms that provide reliable product information, secure payment systems, transparent return policies and timely delivery. Therefore, online marketplaces must focus not only on product availability but also on customer confidence, data protection and service quality. Consumer behavior in online communication environments (either supportive chats, conveyors of products or services, or platforms) is a pioneering research topic. The online behavioral model applied to communication is based on the premises of the political economy of communication. These premises posit that the media and communication channels are bound by power relations, conflicts and balancing interests at the level of multinationals, states, regional and local interests. These interests and power relations condition the economic viability and competitiveness of the media and communicational support channels competing in the market. The analysis of those channels can be summarized as put by Guarinos: "Media systems do not operate as independent, isolated structures, but rather represent a dynamic environment shaped by the interplay of forces emanating from pattern changes, ideologies and interests in the economy, society, culture and politics." The political economy of communication acts like a behavioristic theory, as it explains such behavior without particular reference to the characteristics of the products or services being promoted or sold. Psychological and sociological studies have also been undertaken. Noever moves in a theoretical, sophisticated environment but advocates the importance of "stress, sensation seeking and openness to experiences", which "influence one's basic patterns of involvement processing about receiving external information" and affect one's vulnerability to advertising. Socio-demographic parameters of marketing research already seem out of place.

4.5 LOGISTICS AND SUPPLY CHAIN DIGITALIZATION

Logistics and supply chain digitalization have become essential for the growth of e-commerce. Digital platforms use data analytics, cloud computing, automation and artificial intelligence to improve inventory management, demand forecasting, order tracking and delivery efficiency. Platform data can help suppliers understand consumer demand and adjust production and distribution accordingly. Cross-border e-commerce has also increased the need for efficient logistics networks. Digital tools enable coordination among producers, warehouses, transport providers, distribution centres and customers. Technologies such as real-time tracking, automated warehouses, route optimization and drone-based delivery systems are gradually transforming supply chain management. These developments improve speed, transparency and responsiveness in e-commerce operations. E-commerce platforms are the driving force behind the digitization of logistics and supply chains, which is still backed by technology and elements that use technology to meet market demands. A number of e-commerce sites, including Alibaba's AliExpress, offer platform-based, global, and expert supply chain services. Some prominent Chinese e-commerce companies, like YHD.com, fully utilize their logistical capabilities to provide B2C supply chain services via separate logistics channels. The benefits of logistics help recently established businesses like YHD.com thrive in the market. Cross-border e-commerce has been increasingly popular in recent years and has attained multidimensional digitization; platform data on purchase intent is utilized to initiate supply-demand coupling by assisting suppliers in seizing the right moment to offer for sale rather than passively waiting for orders. From ground and distribution layers to maritime transportation, multidimensional digitization is at the forefront of the logistics industry. The artificial intelligence reasoning underpinning the sharing of logistics agencies and the coupling of all logistics linkages is based on intelligence, large-scale cloud computing, and resource sharing. All demand players, including producers, global major international transportation providers, transportation agencies, and other shipping forwarders, receive data analysis and sharing from all distribution centers, including hub and regional DC fulfillment centers, in the ground layer. Autonomous cars and trackless technologies are gradually digitizing ground

transportation in distribution. The digitalization of "flotten in detections, operations, and on-road output start to sprout; Massive numbers of intelligent drones are encouraged by large-scale intelligent-detection-sharing technologies in the air to link fully digitalized operations with trackless technologies on the ground.

4.6 REGULATORY CHALLENGES IN E-COMMERCE

Growing e-commerce activity is triggering demands for updated regulation in various areas relevant to online transactions. Tax authorities seek to address potential tax evasion. Companies compliance officers are concerned regarding anti-money-laundering law compliance. Consumer-protection agencies wish to regulate false advertising and introduction of unsafe goods in online platforms. Competition agencies are worried about the market power gained by platform operators. Taxation authorities perceive a need to tax digital transactions where the service is provided and the revenue is generated rather than where the supplier is. Some countries attempt to implement a digital services tax on platform operators. Taxation, consumer protection, money laundering, and competition are the main areas regarding which activities related to electronic commerce are considered for enhanced regulation or specific legislation. The recommendations of the G20 summit are for cooperation among governments based on the premise that international trade should not be unduly hampered by taxation issues. The necessity for international cooperation among tax agencies operating in different countries with a common database on e-commerce companies is vital in order for governments to avoid double jeopardy, enabling them to get the taxes they are entitled to while avoiding chasing online transactions to the point that they take down this eagerly awaited golden goose..

4.7 Chapter summary

The chapter on E-Commerce and the Platform Economy highlights the rapid expansion of online marketplaces as a central feature of the digital economy. Platforms have transformed traditional commerce by enabling businesses of all sizes to access global markets with reduced operational costs. The growth of internet penetration, mobile technologies, and digital payment systems has accelerated the adoption of e-commerce worldwide. These marketplaces have created new

opportunities for small and medium enterprises while also enhancing product variety, price transparency, and consumer convenience, thereby reshaping competitive dynamics in global trade. A key aspect of the platform economy is the diversity of business models, particularly Business-to-Business (B2B), Business-to-Consumer (B2C), and Consumer-to-Consumer (C2C). B2B platforms facilitate large-scale transactions between firms, supporting supply chain integration and procurement efficiency. B2C models connect businesses directly with consumers, often leveraging digital marketing and personalized services to drive sales. Meanwhile, C2C platforms empower individuals to trade goods and services, fostering entrepreneurship and peer-to-peer exchange. Together, these models illustrate the flexibility and scalability of digital platforms in catering to different market needs.

Digital platforms play a transformative role in global trade by acting as intermediaries that connect buyers, sellers, and service providers across borders. They reduce transaction costs, streamline logistics, and enable real-time communication and data exchange. At the same time, consumer behavior in online environments has evolved significantly, influenced by factors such as convenience, personalized recommendations, social interactions, and trust in digital systems. The rise of social commerce and data-driven marketing further demonstrates how consumer preferences are increasingly shaped by digital engagement and platform ecosystems. The chapter also emphasizes the importance of logistics and supply chain digitalization in supporting e-commerce growth. Advanced technologies such as data analytics, automation, and cloud computing enhance efficiency, transparency, and responsiveness in supply chains. However, the rapid expansion of e-commerce has introduced several regulatory challenges, including taxation, data privacy, consumer protection, and competition policy. Governments and international organizations must develop coordinated and adaptive regulatory frameworks to ensure fair competition, protect stakeholders, and sustain the long-term growth of the digital marketplace.

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CHAPTER 5

FINANCIAL TECHNOLOGY AND DIGITAL PAYMENTS

Financial technology, commonly known as fintech, refers to the use of digital technologies to improve and deliver financial services. It includes digital banking, mobile wallets, online lending, digital payments, insurance technology, wealth management platforms, blockchain-based services and other technology-enabled financial solutions. Fintech has transformed the financial sector by making transactions faster, more convenient and more accessible to users. The growth of fintech has been supported by increased internet access, smartphone penetration, digital infrastructure and the demand for convenient financial services. Although fintech is often described as a disruptive force outside traditional banking, it is increasingly becoming integrated with conventional financial institutions. Banks, technology firms, payment service providers and regulators now operate within a connected financial ecosystem. This makes fintech both an opportunity for innovation and a challenge for regulation, security and consumer protection.

5.1 EVOLUTION OF FINTECH SYSTEMS

Fintech focuses on the application of software and web-based services covering all areas of finance in both business-to-consumer (B2C) and business-to-business (B2B) markets. The fintech market is growing rapidly facilitated by increased Internet and smartphone penetration coupled with a large unbanked population, an insufficient banking infrastructure and regulatory support. Bitcoin, having garnered unprecedented media and market attention, highlights the huge potential for a new wave of disruptive technologies built on blockchain. In addition peer-to-peer (P2P) lending, a growing number of players are offering services such as remittances, insurance, wealth management, e-commerce, personal finance management and payments, many

targeting the underbanked population. China dominates the back-end support growth of fintech. In a digital ecosystem, consumer touch-points are often outside the traditional banking sector creating potential disintermediation challenges for banks. While traditional banks and financial institutions continue to play an important role in areas such as payments and lending, a broad range of technology companies and other third parties are supplying services that were previously the preserve of banks and financial service providers. The speed of adoption of technological innovation in the market has the potential to outstrip that of traditional banking products in terms of market penetration. With this in mind, several sources have examined the growth of the fintech market, explored how fintech has developed and provided direction for future research. Key growth curves for recent fintech areas and applications are presented together with major regulatory milestones—proactive, permissive or reactionary—along with historical and projected adoption rates by region.

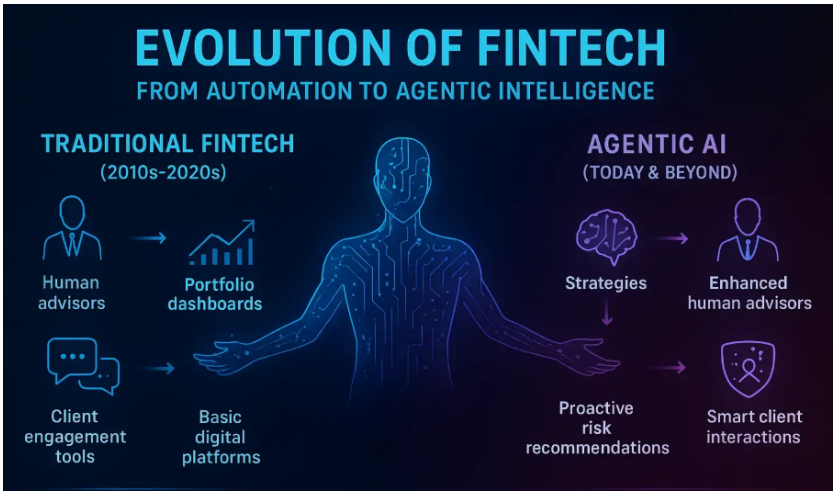

Figure 5.1 Fintech

5.2 DIGITAL BANKING AND MOBILE WALLETS

Digital banking, mobile wallets and financial inclusion are important elements of financial and economic growth, especially in developing countries. Digital banks, whether licensed or new-age banking-as-a-service offerings, are becoming part of the financial ecosystem directly catering to retail consumers. Furthermore, the tremendous growth of digital wallets even among individuals with minimal financial literacy is shrinking the last-mile barrier for service delivery. Past research has highlighted these

facts and pointed toward the positive impact of fintech development toward the reduced costs of money transfers especially those aimed at underserved populations. While blockchain technology and cryptocurrencies are futuristic in nature they present a larger discussion for addressing, enhancing and supporting the digital banking, payment and wallet ecosystems either directly or indirectly. Blockchain technology can address the security issues in digital banking that are often being faced by traditional banking networks. Digital payment systems such as the Unified Payments Interface in India need to be studied with respect to their underlying architecture, regulatory environment, consumer protections and possible horizontal violations. Digital platforms such as mobile wallets share the credit for the success observed in transfer payments over the last couple of years. However, the very presence of these digital platforms is also creating new socioeconomic divides. The discussion should not only focus on the success factors for the digital payments ecosystem but also on the factors that can promote inclusion.

5.3 ROLE OF BLOCKCHAIN AND CRYPTOCURRENCIES

Blockchain technology offers potential benefits such as transparency, decentralization, improved traceability and reduced dependence on intermediaries. In financial services, it may support faster settlement, smart contracts and secure record-keeping. However, blockchain-based systems also face challenges related to scalability, regulation, energy use, volatility, consumer protection and illegal financial activity. Therefore, blockchain should be understood as a promising but still evolving technology that requires careful governance. Investors and users have shown strong interest in cryptocurrencies, often driven by expectations of high returns. Others have praised the technologies as possible solutions to certain socio-economic and geopolitical challenges. Such exuberance is understandable in the context of economic growth, profit opportunity and the quest for a better life. At the same time the foundation of blockchain technology and the underlying concepts of cryptocurrencies warrant critical examination. Do they truly have the potential to transform the financial industry and facilitate financial inclusion? What role do blockchain and cryptocurrency actually play both now and in the near future? In addressing these

questions it is vital to consider digital banking and mobile wallets as focal areas. Blockchain is a decentralized distributed ledger built as a chain of data records across a distributed network of nodes. Each block or batch of data is linked using cryptography to the previously added block thereby ensuring the integrity of the stored data and providing a trustworthy source of truth for all network participants. Changes to data in a block are agreed upon by a consensus mechanism that enforces business logic on a specified set of nodes. Use of Ether and Ethereum's smart contract facility enables the creation of software tokens which can be engineered to follow specific rules aimed at creating a controlled economy around the token's usage. Crypto-economics concerns itself with defining a system of incentives and disincentives within a network to ensure honest behavior and optimum outcomes for its users.

- Fundamentals of blockchain technology

Blockchain consists of an unalterable distributed ledger of transactions that exist across an authenticated network of nodes within the system. Every participant can obtain a copy of the distributed database without any single entity controlling it. This ledger is often updated in real time and maintained collectively. Rather than relying on the typical centralized system of one entity verifying all transactions and trusting that entity’s integrity blockchain proposes a new way of management where every transaction is secured via cryptographic techniques instead of the participants’ trustworthiness. The consensus across all those taking part in the process is the key concept for security in blockchain. Consensus is vital in enabling all parties to agree that a new transaction has a genuine originator and has been validated within the rules of the system. Consensus handles the solution of disputes among participants or nodes that may propose contradictory results. A final decision is taken by the majority of participation nodes and only the part of the transaction that most nodes agree upon is valid. Consensus models vary between systems providing the solution appropriate to each specific application. Smart contracts—vital for executing contractual terms without needing to trust counter-parties—are another layer of complexity. The combination of consensus and smart contracts extends the utility of simple cryptocurrency exchange and allows automated trusteeship and secured transaction

handling of any sort where normally trust is required. As a result a multitude of variations around these two concepts and the associated applications have emerged. Security relies not only on the cryptographic techniques involved in transactions and consensus but also on the sharing of the ledger entry by all participants. Indeed altering a single ledger entry of a single host is futile because all other parts of the system would disagree and raise an alarm as the consensus would not be satisfied. However the very fact that any participant can read all the history of the operation in the ledger also enables identification of illegal activities (e.g. speeding or tax fraud). Scale poses the serious challenge of ensuring that transactions are completed within an acceptable time frame as the number of participants grows.

- Cryptocurrencies and token economics

A cryptocurrency is defined as a digital currency that secures transactions using public-private key cryptography. There is no universally accepted classification of cryptocurrencies due to their diversity. Tokens are created on top of existing blockchains and represent an underlying asset or utility. Initial Coin Offerings (ICOs) for tokens are similar to Initial Public Offerings (IPOs) of stocks but do not offer the same protections. Tokens may represent or entitle holders to a share of a company's assets, expected profit or interest payments. Cryptocurrencies can therefore be classified depending on the tokens that they issue. Cryptocurrencies and tokens can also be categorized based on the economic model that governs their creation. Economic models that govern the creation and allocation of cryptocurrencies determine their supply under different market conditions. There are three primary categories of issuance models—fixed supply, variable stablecoins and elastic stablecoins. Examples include Bitcoin (BTC), Tether (USDT) and Ampleforth (AMPL) respectively. Such models act as monetary policy whether with rules or discretion; presence or absence of a central authority; central bank digital currency dependencies; market intervention; and the concept of token distortion—misallocation of funds based on excessive speculation on short-term price change rather than fundamental value.

- Implications for digital banking and wallets

Although the core foundations of the finance and banking sector have remained unchanged for decades technological advancements in areas such as mobile and digital technology, biometrics and communications have made banking operations increasingly more cost-effective and operationally efficient. Blockchain will further revolutionise the finance and banking sector by reshaping the way trust is achieved and users are identity-verified in online transactions thus expediting settlement time between banks. Operating costs would be significantly lowered—first from paper-based banking processes to fully online operations and next from trusted yet costly intermediaries to a consensus-based trust mechanism. These changes will in turn speed up transaction settlement time reduce transaction costs for users and aid in interoperability. Instant payment solutions such as UPI improve settlement speed and other developments like Stable Coins promise to provide a solution to the problem of trust that users dealing with crypto and blockchain protocols face. Designing such an Inter-wallet-Operability—an enterprise where one wallet can send and receive money from another wallet even if they are not operating on the same backbone—will also be a big breakthrough for the banking sector in general and for FinTech players and digital wallets that operate as small banks without the requirement of a dedicated banking license in particular. However the use of even a StableCoin is still controlled by an intermediary and institutional investor funds and other large amounts still require a KYC process and must be kept in a Bank Custodial Account. These considerations result in the inevitable and indispensable presence of the bank as a trusted entity even in the world of blockchain and crypto.

5.4 DIGITAL PAYMENT SYSTEMS SUCH AS UPI

Digital payment systems are providing much-needed resiliency in the payment infrastructure of governments. On the other hand, the proliferation of private digital payments has led to concerns about the potential concentration of the payment ecosystem. New players have emerged and grown rapidly, forcing the evolution of an ecosystem that addresses concerns related to interoperability, quality-of-service provisioning and cybersecurity while unlocking the innovation that can come from

open APIs. Payment systems such as the Unified Payments Interface (UPI) enable efficient payments and are likely to be widely adopted in other economies. A better understanding of the architecture, key components, ecosystem players, ongoing interplay between private digital payments and the official infrastructure and the associated regulatory challenges and trade-offs can facilitate a more resilient and efficient payment ecosystem. A payment system connects the financial infrastructure of an economy to facilitate the transfer of money between different participants. Payment systems are considered critical national infrastructure and should be sufficiently resilient to support the continuing functioning of businesses and the economy. A robust official digital payment infrastructure provides a key public good and helps ensure a resilient payment system for the economy. Private digital payment methods provide a quicker and better experience for consumers. However, the widespread adoption of private digital payment solutions may lead to concentration and increased risk. Ensuring the continued quality and resiliency of the official payment infrastructure while enabling rapid innovation in the private space is essential.

- Architecture and interoperability

A digital payment system combines various channels, platforms and instruments—together referred to as rails—to facilitate transactions between participants. Its architecture consists of a central switch, along with a routing infrastructure that defines participants' interconnections. Each routing partner handles the required functionality within its domain (e.g. booking and processing the transaction, ensuring sufficient funds, processing end-user queries or dealing with any settlement risks). API integration allows front-end service providers to interact with multiple back-end service providers seamlessly and efficiently. Core components define rules and functions that should be standardized for greater interoperability. These components fall into multiple categories: rails that connect users' payment accounts across banks and payment service providers, routing mechanisms that determine transaction paths and standards that specify technical APIs and the exchange of information for different payment categories. A diverse ecosystem of players participates in providing these components, including technology and payment infrastructure providers,

independent service operators, financial institutions, aggregators and market players. The need to comply with government-mandated KYC and AML requirements for the payment system users raises consumer protection challenges. Adequate preventive measures such as privacy controls, mechanisms for mediation and dispute resolution and compliance testing can help address these challenges.

- Regulatory and consumer protection considerations

User-initiated payment systems such as the Indian Unified Payments Interface (UPI) require regulatory scrutiny and clarification to mitigate the risk of fraud targeting consumers and their bank accounts. KYC and AML norms must be applied to ecosystem players that provide payment services but do not need customer accounts, such as telecommunications companies, payment service providers and merchants. These requirements may be burdensome for smaller players without adequate scaling in their customer acquisition process. The regulatory environment should foster growth in digital payments and security for all ecosystem participants while being proportionate to the level of risk involved. Digital payment systems such as UPI require clear regulatory oversight, consumer protection mechanisms and dispute-resolution frameworks to address fraud, privacy and transaction-related risks. Privacy protection is also an area for concern. With UPI payments shared between users of different mobile wallets, concerns about whether the providers can and do monitor these communications are obvious. In addition, the merchant discount rate is currently zero; consumer protection for nonpersonal payment systems should be larger than zero to ensure that failure of a mobile wallet can be absorbed by the merchant and not passed on to the customer. Because the financial protection for consumers is based on contract law, resolution of disputes requires time and is resource-intensive.

- Cross-border and domestic payment efficiencies

Developing and emerging economies have long faced challenges related to slow, costly and unreliable cross-border payments. Digital payment systems can reduce transaction costs, improve settlement speed and increase transparency in both domestic and international payments. Systems such as UPI demonstrate how interoperable payment infrastructure can support real-time transactions among

individuals, businesses and institutions. However, digital payment systems also face practical challenges. Digital literacy, smartphone access, user experience, cybersecurity and regulatory compliance influence adoption. KYC and AML requirements are necessary for preventing fraud and financial crime, but repeated or complex verification processes may discourage small merchants and low-income users. Therefore, payment systems should adopt user-friendly verification, privacy-by-design principles and minimum data collection wherever possible. Payment systems can also help with regulatory requirements for KYC and AML, even if they are somewhat of a burden for consumer and small merchants. The user does not want to make KYC every-time, and neither do the small merchants. KYC can be a privacy and psychological factor when it becomes redundant or repetitive. For a user, the pleasure of transacting with his friends and family is what matters, and not going through long queues at KYC counters looking for identity proof every-time. For small players, the costs in doing KYC is more cumbersome than profits from running the service. Data privacy also play a key role; hence, the adoption of privacy by design, where minimum data is captured along with custodial non-custodial options along with user control of data.

5.5 FINANCIAL INCLUSION THROUGH DIGITAL PLATFORMS

Digital platforms play an important role in expanding financial inclusion by providing low-cost and accessible financial services to unbanked and underbanked populations. Mobile wallets and digital banking services allow users to store value, make payments, transfer money and participate in digital commerce without depending entirely on physical bank branches. However, access alone does not guarantee inclusion. Many users face barriers such as limited digital literacy, lack of smartphones, poor internet connectivity, complex user interfaces and difficulties in completing KYC procedures. Therefore, digital financial inclusion requires simple onboarding, affordable services, consumer protection, data privacy and strong grievance-redressal mechanisms.

- Digital access and onboarding

Recent developments in mobile and internet access have enabled digital banking services to flourish. These mobile digital services have been successful in penetrating

several customer segments that have remained underserved by physical banking in the past. However, despite the increases in access and usage, the majority of the economically weak sections are still struggling to use certain aspects of digital banking services. Several barriers such as a lack of digital literacy, a lack of access to smart devices and complex user experiences still hinder the usage of these services. A decent step forward for the economically weak sections in the digitally connected world is the digital wallet. Digital wallets are a step toward achieving financial inclusion for large segments of people who still remain unbanked or underbanked. A digital wallet allows customers to add money to it and make use of all digital banking functions within a wallet or ecosystem, like sending money to another wallet customer or making online payments directly from their wallets using the balance stored within it. Digital wallets are free from the complexities of managing minimum balance requirements or KYC documentation and offer the flexibility of microtransactions that suit the needs of the economically weak population. Faster KYC for digital wallets, especially with one-time KYC facilities, can deepen the usage within the economically weak segments.

- Digital wallets for underserved populations

Digital wallets for underserved populations offer access to transactional accounts for individuals without existing banking relationships. The continued mainstreaming of mobile wallet services, particularly in India and Africa, has demonstrated that adoption among financially unincluded users is possible if they are not burdened with high service costs. Digital wallets could indeed emerge as the primary bank account for low- and middle-income users, provided that the right ecosystems are in place. These accounts would remain digital and transactional in nature, with only a small proportion of users displaying saving behavior. An inclusive ecosystem, however, requires additional components that the market alone is unlikely to provide. Service providers are naturally incentivized to develop low-cost, low-friction solutions for the included and vehemently excluded populations. However, those consumers with homes, jobs and families positioned near the bottom of the pyramid still require special consideration to ensure that digital wallets can support their day-to-day digital

transactions. These users often want a means of making low-value digital payments without going through the pain of creating formal financial identities for KYC/AML requirements or incurring the fees associated with low-cost bank accounts. It is an almost universal desire in India and Africa to be able to make payments without needing to go through a bank and maintain a pre-paid balance in the bank. This implies a transfer system that allows them to pay easily and conveniently in critical transactions—receiving wages, paying school fees and so on—without holding a prepaid balance in the system for months on end.

- Policy and governance for inclusive ecosystems

Ecosystem participants should work together to ensure that products and services are available to everyone at a low cost without compromising quality. The role of government in an open, mixed economy is to provide continuous investment in digital and telecommunications infrastructure, promote pilot projects for the adoption of digital wallets by underserved populations, assure the general public that the integrity of data is protected and require and facilitate an interruption-free operation of public services. Digital trust can be ensured, for example, through bank–government partnerships, much as the Aadhaar and UPI projects grew out of a coordinated and collaborative public–private approach. Governance over the ecosystem of cross-rail integrated payment systems—important for universal acceptance and frictionless operation of wallets—should provide continuous assurance of data privacy. Governance must, therefore, ensure that all sensitive personal information is anonymized along the entire payment chain. Such a regime also needs to provide a data-minimization framework for digital wallets and create conditions for user-controlled consent on the use of their data. Of particular importance is a regime for effective dispute resolution that protects users without placing unduly onerous obligations on service providers. Regulators also need to balance the costs and risks of KYC and AML compliance against the benefits that derive from performing these checks. Excessive compliance burdens may lead some players to avoid an or create an entry barrier—specifically, for the lower-end segment that digital wallets seek to serve.

Finally, standards for security and risk management are needed to ensure the resilience of all participants, together with continuous monitoring.

5.6 RISKS AND SECURITY CHALLENGES IN FINTECH

Fraud, cyber threats and a lack of adequate risk management strategies remain key challenges threatening fintech adoption and the benefits associated with it. A well-architected threat model, comprehensive security controls and a robust incident-response capability can mitigate the threats posed to fintech products. Although there are significant investments made in product security controls, absence of a threat model may lead fintech companies to overlook crucial parts of their systems. Given the complex nature of the operations and the consolidated ecosystem built around each digital financial product offering, fintech companies are highly attractive targets for criminals for committing fraud. Avoiding the implementation of a structured threat modelling technique can lead to lack of identification of some important avenues resulting in financial loss for customers of the service. This loss may not only pertain to financial loss but can also affect the reputation of the fintech brand and cause a trust deficit among the customers, leading them to opt for other set of product offerings. Privacy has emerged as one of the biggest corporate battle lines, with customers willing to pay extra for services that keep their data safe. Nevertheless, a security breach still poses a reputational risk to products. The Alert Logic findings support this, showing that two-thirds of adults are concerned their information will be used without their permission, while 92% report a desire to control their own data. The intense scrutiny faced by several technology companies in recent years suggests that regulatory requirements will only increase, driving up liability and operating costs.

- Fraud, cyber threats and risk management

Fraud and cyber threats represent crucial challenges for fintech service providers. The rapidly changing threat landscape suggests that existing controls may soon become outdated. Vendors and service providers may also resort to cloud-based solutions with little or no control over risk management. Threat intelligence has thus become an integral aspect of risk management. The entire threat modeling process can be described by the question: "What can go wrong?" Threat models are under constant

review, because once a cyber incident takes place, it is too late to find a solution. Fraud attempts are on the rise across sectors, and businesses are spending heavily to detect and mitigate fraud incidents. A six-step framework can be deployed, covering:

- ✧ Identify fraud scenarios and determine a fraud risk rating.
- ✧ Identify potential fraud detection controls to be implemented.
- ✧ Estimate fraud losses for the current year.
- ✧ Determine the cost of fraud prevention controls.
- ✧ Assess whether control measures are value for money.
- ✧ Assess the adequacy of fraud detection and prevention controls.

The first step involves identifying and prioritizing business-critical fraud scenarios, and then employing technology that can analyze millions of data points in seconds to identify patterns of activity within businesses that indicate fraud in progress. Controls can be automated—fraud screening on merchant accounts is performed for every new connection to a payments processor—and upskilled staff can be freed down the chain for further investigation of the flagged transactions. Regardless of these precautions, the reality is that the vast majority of organizations will be breached. Therefore, it is important to create a response plan tailored to the specific organization, simplify the process and execute it.

- ➢ Privacy, data protection and consent

Rising concerns over breaches of privacy and misuse of personal data have propelled data protection to the top of regulators' priority lists. Different countries have responded with laws and regulatory regimes at varying levels of strictness, complexity and compliance cost. In the EU, the General Data Protection Regulation (GDPR) seeks to protect data from unauthorized access while giving data subjects greater control. The regulation's data-minimization principle, which discourages the unsolicited collection of personal data, imposes challenges on fintech service providers, many of which rely on rich data sets to improve their service offerings. To ease the burden of compliance and support consent management, legislative measures,

including data portability and user-friendly consent mechanisms, are necessary. Governments also play a role in reducing the cost of compliance, especially for smaller fintech firms. The principle of proportionality requires regulators to calibrate the levels of complexity of compliance in relation to the size, risk and functional nature of the service provider. The call for centralization of KYC and AML mechanisms—for a "one person, one time" principle connected to the relevant service provider—reduces duplication, lowers costs and enhances user experience without increasing risk.

- Compliance, AML/KYC and operational resilience

The importance of compliance and operational resilience for fintech systems is increasingly recognized. Ongoing monitoring of user activity to detect fraudulent transactions and compliance violations is critical. High-risk transactions and customers require special scrutiny; businesses must maintain a record of suspicious activities and report them to authorities promptly. Regular examination of the institution's AML/CFT systems and controls is advisable; it helps detect lapses that could attract adverse regulatory attention or facilitate money laundering, terrorist financing or other illicit activities. Governance processes should support compliance responsibilities and standards; the complexity of operations, type of customer, range and volume of products and geographical exposure should be considered. Business continuity plans ensure continuity of critical operations during disruptive incidents such as natural disasters or cyberattacks. Mechanisms enable timely restoration of normal operations, while information security and disaster recovery functions protect data confidentiality, integrity and availability. These tenets support availability to customers and counterparties. Building user trust involves comprehensive risk management; respecting user privacy by handling information securely, lawfully and transparently; minimizing the data collected; and allowing users control over their personal information can encourage adoption and growth. Privacy-protecting technologies such as data anonymization, encryption and device biometrics should be leveraged.

5.7 Chapter summary

Financial Technology (fintech) has evolved rapidly from a set of niche innovations into a core component of modern financial systems. Initially driven by the emergence of new digital players outside traditional banking, fintech has increasingly become integrated with conventional financial institutions. This evolution has been supported by advances in mobile technology, internet penetration, and demand for convenient and efficient financial services. As a result, fintech ecosystems now encompass a wide range of services, including digital lending, payments, wealth management, and insurance, contributing significantly to economic efficiency and financial system modernization. Digital banking and mobile wallets have emerged as key drivers of this transformation, particularly in developing economies. These technologies enable users to access financial services without relying on traditional bank branches, thereby reducing costs and improving accessibility. Mobile wallets, in particular, facilitate low-value and high-frequency transactions, making them highly suitable for underserved populations. By offering simplified onboarding processes and minimal documentation requirements, digital financial services have expanded access to banking-like facilities for individuals who were previously excluded from the formal financial system.

Blockchain technology and cryptocurrencies represent another important dimension of fintech innovation. Blockchain, as a decentralized and secure distributed ledger, enhances transparency, reduces transaction costs, and minimizes the need for intermediaries in financial transactions. Cryptocurrencies and token-based systems further extend these capabilities by enabling peer-to-peer value exchange and programmable financial contracts. Despite their potential, these technologies also raise concerns regarding regulation, volatility, and scalability, necessitating careful policy oversight and technological refinement. Digital payment systems, such as the Unified Payments Interface (UPI), have revolutionized the way transactions are conducted by enabling real-time, low-cost, and interoperable payments. These systems play a crucial role in promoting financial inclusion by connecting individuals, businesses, and governments within a unified financial ecosystem. However, the rapid expansion

of fintech also introduces risks, including cyber threats, fraud, data privacy concerns, and regulatory challenges. Addressing these risks through robust security frameworks, effective governance, and user awareness is essential to ensuring the sustainable growth and trustworthiness of digital financial systems.

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CHAPTER 6

ARTIFICIAL INTELLIGENCE AND AUTOMATION IN ECONOMICS

Artificial Intelligence and automation are among the most significant forces shaping the modern digital economy. AI enables machines and systems to perform tasks that normally require human intelligence, such as learning, reasoning, prediction, decision-making and problem-solving. Automation, on the other hand, refers to the use of technology to perform tasks with reduced human intervention. Together, AI and automation are transforming production systems, service delivery, business operations and labour markets. They improve productivity, reduce operational costs, enhance decision-making and create new opportunities for innovation. At the same time, they raise important concerns related to employment, skill requirements, inequality, data privacy, bias and ethical governance. Therefore, understanding AI and automation is essential for analysing the future direction of economic growth and digital transformation. In some countries, there are also questions about excess inflation volatility attributed to the non-fundamental expectations of a subset of young agents focused on the short run. An interconnected area of concern involves labor markets and skill premia. Concerns include how automation will create and destroy jobs, which jobs will be created and destroyed and how shifts in demand associated with these labor market dynamics will be cushioned in the short and medium run by policies that repair and retrain the displaced and disadvantaged. At the level of the entire economy, attention centers on variations in overall tax burdens, the associated trade-off between equity and efficiency, the consequent levels of inequality and how these issues relate to the emerging age structure of demand.

6.1 AI IN ECONOMIC DECISION MAKING

Artificial Intelligence (AI) encompasses computer programming that attempts to replicate decision-making processes or capabilities usually assumed to require human intelligence. Economic decision-making may involve predicting uncertain future states, selecting the best alternative from a finite set of choices or determining an optimal strategy for sequential interactions. AI decisions assist rather than replace human controllers; entirely automated economic decision-making constitutes autonomous automated decision-making. AI is increasingly used for predictive analytics (discovering prediction relationships), nonlinear complex modeling for optimization applications and reinforcement learning models that learn optimal policies by estimating the expected rewards of all possible actions. These capabilities are generally based on three types of data requirements. Predictive analytics applications exploit historical labeled data sets of the form (X, Y) that specify attribute values without the attribute E. Optimization and reinforcement learning applications usually require data in the form of (X, E), where each E is a decision or action that may achieve optimal rewards. Nonlinear complex models other than predictive analytics models require very large data sets with heterogeneous samples to capture the model's multivariate nature. Regulation and policy considerations associated with AI in economic decision-making are attracted mainly by the use of market processes for automated decision-making or decision-making with a non-human controller.

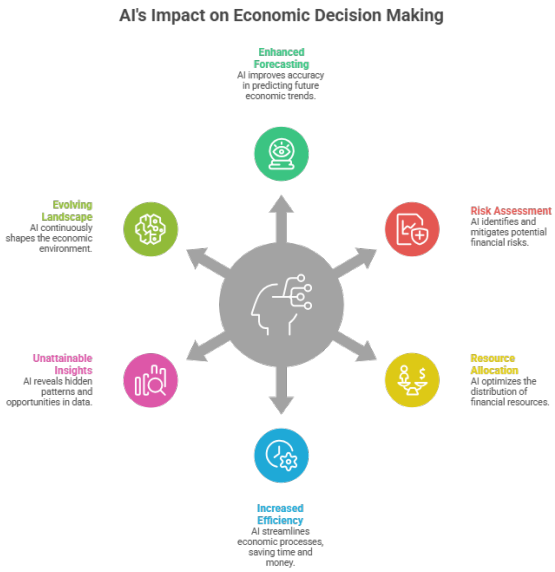

Figure 6.1 Economic Decision Making

➢ Methodologies and Data Considerations

Artificial Intelligence (AI) encompasses various technologies capable of endowing machines, systems and agents with the ability to mimic human-like functions and behaviors such as learning, reasoning and decision-making. In the economics domain, AI decision-making occupies many distinctive roles. Prediction, optimization and reinforcement learning tasks reflect three primary purposes around which decision-oriented AI models are developed. The most common data-driven methodologies for economic decision-making include prediction models, predictive analytics tools, optimization solvers and model-free or model-based reinforcement learning agents. These candidate frameworks require inputs that tend to differ in terms of structure, underlying data and combinations used for training and validation. Not all approaches suit any kind of application or business context. Advances in Big Data especially have altered the requirements for predictive methods. Today, the volume, variety and velocity of Big Data pave the way for innovative predictive models that offer fresh insights to economic and business decision makers. The plethora of available, relevant training inputs can yield highly accurate predictions and novel decision-relevant information in several business contexts, leading to intelligent competitive advantage and economic growth.

- Implications for Policy and Regulation

AI adoption necessitates regulatory adaptation within government and private sector decision-making. AI-driven decision making can affect the structure and access conditions of automated learning systems, AI market design, competition, privacy and accountability. Understanding the decision-making roles of government and private sector actors can identify market design assumptions that can inform privacy frameworks for sensitive data collected from vulnerable populations and enrich broad discussions about AI transparency. AI-powered prediction and optimization can also affect the sources and nature of market uncertainty faced by consumers and firms. These effects are distinct from risk—the analysis of risk focuses on decisions under uncertainty with known probabilities. Distinguishing risk from uncertainty provides more nuanced insights about the risk-disclosure implications of AI-powered optimization and allows consideration of AI-enabled services that move beyond predicting average unknown outcomes towards predicting more complex unknown distributions. Market design decisions affect the sources and nature of consumer surplus from the automated prediction of new or previously unseen tasks. AI-enabled withdrawal from tasks that cannot be performed better than the average can yield important benefits.

6.2 AUTOMATION AND PRODUCTIVITY ENHANCEMENT

Automation improves productivity by enabling firms to produce more output with fewer inputs or with greater efficiency. It reduces repetitive manual work, improves accuracy, increases speed and helps organizations maintain consistent quality. In manufacturing, automation can improve production efficiency, while in services it can support faster customer response, data processing and routine administrative tasks. However, the productivity impact of automation depends on several factors. These include the level of investment, the availability of skilled workers, organizational readiness, cost of technology and the ability of firms to integrate automation into existing processes. Automation may also create labour market challenges when machines replace routine human tasks. Therefore, productivity gains must be balanced with policies for reskilling, upskilling and social protection.

The productivity impact of automation can be assessed in three steps: first identify the main forms of capital investment in machinery and equipment in the economy; second examine how changes in this structure of capital investment have affected the capital intensity of the economy; and last analyse the apparent or actual trade-off between capital and labour risk in the cost-benefit evaluation of automation decision. Typically such assessments are made with reference to the changes taking place at the time. Population ageing does lead to a dramatic rise in skills and capital intensity. It is more unusual to widen the reference frame further back in time as was done to analyse the impact of the gap-induced increase in capital-labour ratios. One of the most success stories in terms of capital-labour ratios is that of the bank. In the financial area banks are less capital intensive to operate than other financial intermediation so that increased financial needs of the rest of the economy statistically reduce the capital-labour ratio of the banks when expressed in monetary units. However the magnitude of risk involved in IT using financial trading has prompted a dramatic increase in the share of profits of the banking sector relative to the rest of the economy.

- Productivity Metrics and Measurement

Measures of productivity quantify organizing economic activity particularly supply most commonly expressed as output per unit of input. Total factor productivity (TFP) a central concept in neo-classical economics assesses the efficiency of multiple inputs by associating them with a single measure of output. Multifactor productivity is a broader measure that allows for multiple inputs and can be used with conditions other than constant returns. TFP captures the economic impact of technological change as well as environmental influences that affect supply outside the system's direct control such as natural disasters. Data limitations often hinder the assessment of productivity at higher levels of sectoral aggregation and economic geography than say the common level of the firm. For automated production output typically comprises aggregate physical process or labour time in operations centres with material costs excluded if not wholly contained within the uptime procedure thereby explicit redundancy minimised. Input measurement then rests on determining the time associated with the overall capital stock that is total service units per period and how the service flows

from the physical assets mapped into overall physical production. Definitions of capital might shift as machines replace labour adding back the time removed from the overall organisation.

- Investment and Adoption Barriers

Certain factors stimulate investment in AI-driven automation; others slow or prevent it. On a macro scale capital intensity tends to increase as wages rise relative to the cost of machines. For an individual firm investments in new technology are supported by management capabilities strong balance sheets and healthy demand. Factors that slow individual adoption include the perceived value of the investment (driven by the visibility of likely technology gains relative to costs) its cost (driven by machine prices and financing terms) and the length of the payback period relative to the firm's risk appetite. In many instances a single firm's risk is small compared with the overall market where adoption at one company can spur or require investment at others. AI-based automation differs from previous generations of technologies in that it is often or even primarily focused on specific tasks rather than entire activities. In doing so it can produce strong gains in throughput quality or unit price without requiring a firm to bring together an entire process into a single workflow. Yet this very characteristic makes evaluation more difficult. The risk of investing in AI is not only in the specific technology but also in whether it will be or is or close to being adopted by rivals. A company's maximum advantage from leadership in a single technology may be captured before it completes the investment. The other companies are therefore not the main threat; the uncertain behavior of customers and suppliers is.

6.3 INDUSTRY 4.0 AND SMART MANUFACTURING

Industry 4.0 refers to the integration of digital technologies into industrial production. It includes the Internet of Things, cyber-physical systems, cloud computing, edge computing, robotics and data analytics. These technologies connect machines, workers, suppliers and customers through real-time data flows. Smart manufacturing uses these technologies to improve production efficiency, predictive maintenance, inventory management and supply chain resilience. Sensors and connected devices collect data from machines and production systems, allowing firms to identify problems early,

reduce downtime and optimize resource use. However, increased connectivity also creates new challenges related to cybersecurity, data protection and interoperability. Data generated by the cyber-physical systems deployed by producers and their suppliers is harnessed for improvement. Technologies in continuous development from sensors to advanced control are increasingly embedded in hardware systems that leverage IoT technology for real-time low-cost diagnostics and analytics. In addition to collecting information from sensors in machines and production processes these capabilities are collecting information on the health of assets and their operating environment. The cloud is being complemented by edge computing which allows data to be collected and analysed close to the source within the asset. While greater connectivity enhances the information available for improving physical systems its value is dependent on the actions it enables. In the short run the value of connectivity is determined by how much it raises asset utilization and thus productivity and economic performance. Traditionally asset utilization has been assessed in relation to the ability of producers to maximize output within a given set of constraints. This focus now calls for a shift in emphasis within smart manufacturing towards smart resiliency an approach to operations that broadens the traditional interpretation of uptime-based asset utilization. In this context increasing uptime is no longer limited to enhancing production throughput but extends to minimizing unplanned downtime by changing the operating regime of capital assets and the supply chain.

- Connectivity and Cyber-Physical Systems

The concept of Industry 4.0 emphasizes connectivity and the effect of the Internet of Things (IoT) through the establishment of cyber-physical systems that seamlessly integrate the physical and digital worlds. Connectivity makes it possible to collect and analyze data in real time using a variety of sensors thus enabling asset utilization and risk management. By connecting assets throughout the digital supply chain companies can better utilize their assets based on data flows providing both predictive and data-driven decision support to assist in the implementation of risk-management and business-continuity plans. For example collecting data on uptime weather conditions and market sentiment enables predictive maintenance operations and integrating these

insights with inventory and production planning systems allows optimizing inventories based on the risk of supply-chain disruptions. The combination of higher levels of uptime predictive maintenance and inventory optimization supports enhanced supply-chain risk management and resilience. In practical terms cyber-physical systems require a range of devices that connect and interact with machines and the physical environment. A common characteristic of Industry 4.0 operations is greater reliance on wirelessly connected sensors and actuators embedded within machines and deployed across factories warehouses and distribution centers. Such devices can then link into the cloud or to edge-computing platforms to capture high-frequency data that can drive decisions within seconds or milliseconds. In addition to enabling the collection of high-frequency data from far more sources the IoT increases demand for real-time analysis of data flows across multiple assets. These connections offer greater opportunities to integrate systems together to drive faster or lower-cost decision-making. However they also contribute to higher requirements both for data protection and cybersecurity.

- Asset Utilization and Supply Chain Resilience

The connectivity enabled by the fourth industrial revolution ushers in a new phase of technological progress comprising cyber-physical systems the Internet of Things (IoT) and edge computing. Access to connected intelligent and distributed devices such as sensors digital cameras and industrial computers provides the capability to monitor and control physical assets and processes so real-time and up-to-date data can flow from the shop floor and the supply chain to software applications in the cloud and at the edge which process the data and return insights and instructions. For many manufacturers the straightforward joining of systems has extended to interoperability across technologies as a result of industry collaboration on common standards and protocols. The emergence of platforms that combine comprehensive service offerings for processing the data and managing the analysis back to the asset or the supply chain has opened new pathways for companies to connect analyze optimize and control. Until now asset utilization has typically focused on uptime preventive maintenance and scheduling. With the availability of enhanced monitoring and analysis

organizations can consider predictive and prescriptive maintenance and optimized scheduling. The high price of maintaining excess inventory also generates strong pressure to optimize stocks along the supply chain. Analysis can identify interdependencies and model the full supply network to assess risk point to the location of the highest impact of the weakest partner enable risk transfer and improve robustness against failure through excess capacity allocation.

6.4 IMPACT ON BUSINESS OPERATIONS AND SERVICES

Automation directly influences process efficiency enhancing throughput quality and reliability while indirectly enabling solid planning fast service delivery accurate inventory management effective risk reduction and improved customer interaction. Workflow automation employs robots and software bots for discrete tasks in clearly defined processes. In areas such as customer experience that cannot be entirely isolated workflow redesign automates with tool support and data-driven guidance. Recent examples showcase substantial improvements in cycle speed manufacturing cost and service quality: Wistron's claim of a tripling of throughput time for new product introduction; Uber's service transaction time slashed from 8–12 minutes to under 2 minutes and delivery speed from 36–40 minutes to 20–25 minutes; JPMorgan Chase and Bank of America adopting artificial intelligence systems that might reduce lending costs by 30%–40%. Interaction with customers through online channels is being transformed with the customer experience becoming the key integrating factor. Decision-automation techniques are being applied to personalize offers track customers across channels and increase database joint usage. Tools that provide personalized interaction support service staff and speed up service delivery. Integration of data from various channels permits delivery of superior customer experience while balancing service speed and data protection.

- Process Automation and Service Delivery

Process automation workflow redesign and the integration of service delivery are redefining business operations. In the transactional services sector where traditional services cannot be automated service delivery excellence is still a critical competitive advantage. Business process automation aims to reduce operational costs through

efficiency and productivity improvement. Companies can obtain throughput growth without losing quality through automation. Excess quality of customer service also increases business success thus investing more in customer service than the standard of excellence or slightly above the competitor's level results in market share gain. Automation is affecting services offered in all sectors through self-service devices. Credit card companies are capable of processing 115 card transactions a second and the movement of money around the world has been drastically shortened through simple transaction requests on computers by customers. The banking sector is the one that has implemented automated systems strongest. Despite the large investment self-assigned systems operate without the intervention of a banking employee in more than 80% of cases. Companies have automated parts of the services offered without client participation. Investments in process automation must be evaluated in terms of total costs. The full cost of investment includes not only the costs necessary for the acquisition of self-service devices but also the induction of the cost of human resources required to oversee the operation of the automated processes.

- Customer Interaction and Experience

Two major drivers of AI's impact on customer interaction and experiences are enhanced personalization and the speed at which services are rendered. Businesses can gather increasingly rich datasets about individuals in areas such as purchase history interaction history and demographics. These datasets can feed machine-learning methods designed to segment customers in finer detail than traditional methods which often use the statistical concept of nearest neighbor (i.e. looking at the attributes of customers who purchased the same item in order to suggest additional items). AI-driven personalization can operate at the individual level and take into account not just customer attributes but also how the decision-making context changes over time eliminating signal events that can lead to seemingly contradictory preferences (e.g. studying for an exam versus booking a vacation). AI also has the potential to improve customer service throughout the entire interaction supply chain. In particular the ongoing discussion on conversational agents is streamlining communication and support interactions. The cost savings measured in terms of volume of human queries

handled and response times have made these agents a key investment for many large corporations. At the same time the combination of machine-learning algorithms with omnichannel service delivery capabilities can provide actionable insights that drive improvements across the entire service-delivery process. However AI's ability to provide answers quickly at the right times for customers with complex needs is still limited and a decrease in data privacy might alter consumers' willingness to interact with agents.

6.5 ETHICAL CONSIDERATIONS IN AI ADOPTION

AI applications can introduce unintended bias into decision processes. Such bias may arise from the data on which machine learning models are trained the design of prediction algorithms or the way in which algorithms interact with users. Proposals for reducing and measuring such bias and for developing bias-disclosure practices deserve serious consideration. As organizations adopt AI in a way that is biased against protected demographic groups their actions may become inconsistent with broader societal goals of ensuring fairness and promoting equal opportunity and equality. To address this problem AI systems should be transparently monitored for biases at every stage of the decision process. Different stakeholders such as banks and insurance companies applying predictive algorithms for granting loans or replenishing insurance products should be explicitly encouraged to measure any potential discriminatory effects of their prediction algorithms and to reduce these effects when possible. Disclosure should be provided as well. Organizations would then be required to not only assess whether their AI-generated decisions are biased but also to disclose the extent of that bias to relevant stakeholders and the public at large. The rise of AI also engenders a growing need for a reexamination of the potential for labor displacement combined with the need for social responsibility. The highest short-term concentration of displaced workers is likely to be among middle managers scientists and computer specialists workers with decision-making responsibilities not manual low-skilled workers. Consideration should also be given to equity concerns and the possible distribution of costs associated with the transition to an AI economy and its subsequent growth.

- Bias Transparency and Explainability

Just as firms and their stakeholders face ethical issues associated with the use of AI technology AI systems themselves may be subject to ethical pitfalls. These commonly identified ethical considerations have not received as much attention in the economic literature yet any adoption of AI will also involve the design and or selection of an AI system and the inability to measure or mitigate undesirable properties associated with an AI will hinder the uptake of the technology. In this respect bias transparency and explainability are often noted as critical considerations in the adoption of the technology. While these matters are usually encountered as a concern when a company plans to deploy an AI system that will operate independently of a direct human controller they are relevant to any project where an AI system has been trained and the results of its operation will then be utilized. Even when the AI system provides only a recommendation to a human who then chooses how to act the same properties remain pertinent. Measures of these three characteristics have been proposed although they are not yet standardized. As an example of bias consideration suppose that a company wishes to select a target group for a new product launch. The model predicts the probabilities of success associated with each group however its historical training data has some relevant outcome missing for some ages which causes systematic underprediction of the probability for any age in that range. In proportion to the natural size of the segments based on age the overall predicted success can be too high or too low nevertheless the bias in that specific age segment can be much worse and produce a negative outcome. Since nobody knows in advance how the world will actually react this system will blindly favor one of the age groups just because of a bias. When a bias measure is attached to the model the company can take corrective actions such as simply reweighting the importance among segments or more generally estimating an ensemble model made up of biased sub-models to produce a more reliable decision distribution. Transparency issues are analogous with AI settings being made much more evident for any stakeholder in the business processes involved by transparency measures for the given AI system.

- Labor Displacement and Social Responsibility

Investors generally view a company's AI adoption as an opportunity to enhance efficiency and profitability; the increased risk of staff redundancy is typically secondary in their assessment of the associated costs. Nevertheless for senior management and boards of directors such operational challenges are becoming a major concern. High-profile AI-driven layoffs in technical areas have triggered other companies to step back and consider the effects of a less harmonious more fragmented work environment creating longer-term risks to structural competitiveness as younger employees lose out on networking opportunities and the transfer of tacit knowledge is hampered. The ethical implications of AI-enabled automation are beginning to receive growing media attention not least because the technology can bias hiring decisions or reduce social responsibility when assessing projected cost savings. Such adverse effects in turn can expose companies to negative reputation risks and provoke regulatory responses. In recognition of these risks several companies are introducing audits of their AI systems assigning dedicated boards to oversee their implementation and using ethical risk registers combined with detailed disclosure statements to mitigate concerns and reassure all stakeholders.

- Governance Accountability and Risk Management

Bias unfair treatment and breakdowns motivate demand for risk management accountability governance structures clear lines of responsibility and independent audits or reviews. Responsibility matures into governance as AI adoption becomes extensive and systemic. Institutional structures exemplified by audit committees and boards of directors are established for AI systems deemed sufficiently significant. A risk management model ensures mitigation control and disclosure of ethical risks including responsibility for conceiving testing and monitoring risk levels. Significant investments are dedicated to governance and ethical risk registers that identify risks to privacy security intellectual property inclusion and explainability. Responsibility frameworks inform actions and disclosures relating to risk assessment methods use cases residual risks and residual exposures. Third-party and internal testing of models for disruptions may involve stress testing and assessments of operational viability over

extended periods. Consequently shifts in risk appetite involving increased openness to risks associated with greater speed or productivity may become explicit. Such shifts may also apply to individual assets and divisions if sound risk measurement and management practices are in place. Probabilistic assessment of possible deteriorations in key indicators and establishment of trigger levels stimulate investment in predictive maintenance to support just-in-time asset utilization rather than maximum uptime.

6.6 FUTURE OF AI DRIVEN ECONOMIES

All areas of life are being imbued with artificial intelligence (AI) and thus, one can reasonably expect that economics and more broadly all these economies will change the makeup of their production systems. Production systems are typically modeled with representative firms with some intrinsic productivity growth (exogenous technical change, for instance). However, it is now more appropriate to model economic systems with a high degree of sectoral and organizational transformation. This points to structural modeling with a classic multi-sectoral structure. Yet at the same time, the main economic implications can also be described in terms of simple factor distributions derived from general equilibrium models. The argument for an increase in inequality over time as economies become saturated with AI is typically made in terms of the AI winner-takes-all business models without any appropriate modeling of the supply chain implications. Yet supply chain issues are as central as the bias of technological improvement or innovation against labor. The response of economy-wide productivity growth to AI investment is showing up as a very long and observable U-shape but the second half of the U is becoming more apparent. Beyond the structural transformations and the sectors that gain and lose in the short to medium term—AI is expected to bring major disruption to traditional production and industrial systems—the winners in the long run are technology and research-intensive small and new firms. To respond to climate change, the only effective strategy remains to coordinate the public-sector funding of R&D in science, technology, and health with the private-sector expertise and implementation capacities. AI is also likely to bring about longer-term considerations regarding the spatial distribution of innovation and growth, the connectedness of global economies, and global value chains.

- Structural Transformations and Sectoral Shifts

Technological revolutions such as the application of Artificial Intelligence (AI) in economics invariably result in structural transformations that bring forth new economic sectors and entire guilds characterized as winners while minority factions are classified as losers. Nevertheless, adaptation to such metamorphoses occurs albeit not universally, as evidenced during preceding revolutions. Numerous industry reports agree that some sectors will experience greater capital efficiency and resultant GDP growth more quickly than others. Unexpected demand and supply constraints resulting from the pandemic and geopolitical tensions have accelerated the rise of Industry 4.0. This relies on greater real-time connectivity of data-generating sensors across the value networks that match the production of goods and services to end-user requirements more precisely. Nevertheless, the potential for higher business profitability may incur large market development costs in the near term, deterring adoption and producing liquidity risks.

- Innovation Ecosystems and Policy Imperatives

The pervasiveness of recent AI advancements necessitates a rethink of innovation ecosystems and policy imperatives. Governments should carefully identify areas within their economies where AI is likely to have the greatest effect by funding collaborative research projects, stimulating high-risk long-term research, and encouraging inter-connectivity and inter-disciplinarity in general. Coordination among policy makers and funding agencies is critical in order to induce the business sector to invest in the transformation of new knowledge, ideas, and discoveries into marketable and valuable products and services over the business cycle. In particular, the financing of long-term transformational projects requires specific budget processes that insulate investment decisions from short-term economic cycles. The aim of cohort-based funding is to enable a shorter cycle of experimentation and risk-taking in advanced AI research per se. The objective is also to establish a durable set of protocols and guidelines for the responsible transfer of knowledge and applications in often-sensitive areas such as biomedical research. Novel AI-related technologies will undoubtedly have repercussions on the real economy in terms of stopping, damaging,

or even reversing some of the dynamics of the past 20 years. Indeed, many of the sectors and business models that have been successful may soon begin to wane. At some stage, the winners of the AI race may face important adjustment costs concerning the entire value chain. Moreover, since technological change is likely to be a source of increasing returns, fast technological progress may intensify divergence, especially in developing countries and between high-skilled and low-skilled workers. Moreover, past AI revolutions have generally produced marked shifts not only in the composition of the labor force but also in the types of occupations performed. Nevertheless, structural transformation should not automatically be interpreted as a bad outcome. Such shifts may introduce greater efficiency in labor deployment, a more optimal allocation of economic resources, and higher per capita incomes.

- Long-Term Growth, Inequality, and Global Considerations

Accelerated technical change often yields exceptionally high growth which is subsequently dampened by diminishing returns. Sustained long-term growth therefore hinges on the general nature of AI-driven innovation and the possibility of systematic improvements in underlying productivity and quality factors. The continuing relative unproductivity of a substantial share of the global economy, especially in economic activities strongly associated with social interaction, suggests that innovation and investment can lead to improved performance and accelerating rather than slowing growth in these areas. Sharply decreased costs for many hardware components have given rise to the growth of world supply chains that have benefited from comparative advantages in assembling skilled and cheap labor. However, a calamity anywhere along the supply chain can lead to a stoppage of production worldwide. Shorter shipping costs and in-plant inventories are emphasized as important elements of risk management in increasingly integrated world supply chains. Increased production complexity together with the growing importance of non-automotive producers of components and systems for the automobile industry raises questions of how such producers manage risk and in particular whether they have reduced “just-in-time” risks. Moreover, the massive protection of agriculture and global trade relations are becoming important issues. Similar considerations come to the fore when examining

the structure of international trade in services. On the one hand, a number of economies have a relative comparative advantage in delivering services internationally that harness social interaction. On the other hand, inequality between countries appears to be a hindrance to greater equality of service access and trade. Global value chains (GVCs) offer a new perspective on trade in intermediate goods albeit at the potential cost of ignoring the broader picture of service flows. The structure of trade by stage of production too remains a crucial element of the GVC issue.

6.7 Chapter summary

Artificial Intelligence (AI) is increasingly transforming economic decision-making by enabling more accurate predictions, optimized resource allocation, and data-driven strategies. AI systems support complex decisions by analyzing large datasets, identifying patterns, and forecasting future outcomes, thereby improving efficiency in both public and private sectors. From predictive analytics to reinforcement learning models, AI enhances decision quality while still requiring human oversight in critical areas. As AI becomes more embedded in economic systems, it also raises important policy considerations related to transparency, accountability, and the regulation of automated decision processes. Automation plays a significant role in enhancing productivity by improving efficiency, reducing operational costs, and increasing output quality. By replacing or augmenting manual processes, automation enables faster production cycles and better resource utilization across industries. However, its impact on productivity is not uniform, as it depends on factors such as investment in technology, workforce skills, and organizational readiness. While automation can lead to economic growth, it also creates challenges related to job displacement, changing labor market dynamics, and the need for reskilling and upskilling workers.

The emergence of Industry 4.0 and smart manufacturing has further accelerated the integration of digital technologies into production systems. Technologies such as the Internet of Things (IoT), cyber-physical systems, cloud computing, and edge computing enable real-time data exchange, predictive maintenance, and improved supply chain resilience. These advancements allow businesses to optimize operations,

enhance asset utilization, and respond more effectively to market demands. As a result, industries are shifting toward more connected, flexible, and intelligent production environments that support innovation and competitiveness. AI and automation are also reshaping business operations and services by improving customer experiences, enabling personalized services, and streamlining workflows. At the same time, ethical considerations such as bias, data privacy, transparency, and accountability have become critical in AI adoption. Ensuring responsible use of AI requires robust governance frameworks and regulatory oversight. Looking ahead, AI-driven economies are expected to experience sustained growth, innovation, and structural transformation, but they must balance technological advancement with inclusivity, ethical responsibility, and long-term societal well-being.

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CHAPTER 7

LABOR MARKETS AND THE GIG ECONOMY

Digital transformation has significantly changed the structure of modern labour markets. The growth of online platforms has created new forms of work such as ride-sharing, food delivery, freelancing, online consulting, remote services and project-based employment. These forms of work are commonly described as part of the gig economy. The gig economy provides flexibility for both workers and firms. Workers may choose when, where and how they work, while firms can access labour without long-term employment commitments. However, this model also creates challenges related to income instability, limited social protection, unclear employment status, weak bargaining power and lack of job security. Therefore, the gig economy must be understood not only as a source of employment opportunity but also as a major policy challenge in the digital age. However, expanding gig supply capabilities may boost consumer choice and employment growth, leading to the perception of growing market and worker volatility. Enlarged gig markets may offer firms more flexibility, capacity expansion without long-term commitments, lowered unit costs, a broader range of market-responsive and innovative service products, and ultimately greater customer satisfaction. As firm-level adjustments may create a supporting infrastructure, further research, case studies, or tests may reveal the actual gig economy impact on labor markets and the economy.

7.1 RISE OF GIG AND PLATFORM BASED EMPLOYMENT

Platform-based work is defined as employment resulting from the matching of supply and demand through online platforms. More than 1 in 10 workers in the UK, the United States, and Australia report participation in platform work, with US-based platforms amongst the highest valued tech companies globally. Globally, Uber,

DoorDash, and Lyft account for a combined valuation of over US$100 billion. The share of workers engaged in app-based ride-hailing services has at least doubled in most countries where apps operate; in some cities, Uber and its rivals account for more than one-third of taxi journeys. Global surveys show that online freelancing grew at a faster pace than other types of job-based digital work—for example, in the US and the Republic of Korea. The combined effect of technological change, work fragmentation, business model evolution, and shifting labour supply and demand have transformed work in many sectors of the economy. Advances in mobile and cloud computing, high-speed broadband, natural-language processing, and facial recognition are reshaping service-sector jobs by enabling workers, customers, and companies to connect in real time, 24 hours a day, seven days a week. But while huge technical and cultural shifts have opened the door for new ways of working, the policies and protections underpinning today's labour markets have barely moved. Traditional definitions, such as employee and independent contractor, are breaking down. Because much of the new work is casual, off-the-books, and undertaken in a fragmented or piecemeal fashion, it is difficult to measure. The various global surveys offer different data sets, classifications, and definitions. No single data source covers the whole experience of countries and regions. Nor does any provide a holistic view of non-standard work.

- Definitions and landscape

Platform-based work can be understood as digitized work transactions that take place via dedicated web platforms or apps, and the term largely corresponds to the gig economy. In fact, gig work has, since 2017, grown faster than the overall labor force in the United States, representing an increasing share of labor demand and offering the most detailed historical data. A number of private-sector reports have estimated the size of the gig economy in multiple countries and regions, many of which suggest a steady increase but only a few have investigated the underlying drivers of this change. Existing reports chronicle trends in platform workers, examine potential worker profiles, and identify the segment of the population most likely to engage in gig work and the reasons for doing so. In addition to surveying the range of evidence—from

national statistical offices, trade unions, large corporates, consultancies, academics, and global organizations—research explored the reasons for this growth. Multiple factors push workers toward gig labor and expand supply structure rather than service demands: new technology that allows old and new ideas to come together to produce and even consume new commodities; the fragmentation of work into discrete tasks that can be done using these new techniques; demand for time-sensitive service delivery that could not be done before at a reasonable price; and shifts in labor markets. Well-known digital consumer platforms are driving, facilitating, and enabling gig work. These include experts such as Amazon, DoorDash, Grab, Uber, and Upwork, which allocate work among users as both drivers and customers.

- Drivers of platform-based work

Four principal drivers help explain the rapid rise of gig work in developed countries: advances in information and communication technology, the associated fragmentation of tasks and work, genre-specific demand patterns, and changes affecting the traditional labor market. Rapid mobile broadband and computing networks—together with cheap, widely available microdevices and fast development of a host of applications—provide an unprecedented opportunity for people at work to communicate and collaborate using such tools as instant messaging, Skype, Facebook, or Google Drive. The significant fall in the cost of computing and the obsolescence of hardware-embedded software determine that a lot of small firms do not need to hire fixed assets in the traditional way, renting instead services whose costs become variable rather than fixed. But the origin of such applications can more accurately be found in the home and city context of consumption.

- Measurement and data challenges

Measuring gig and platform-based work presents several challenges, driven by the diverse forms that such work can take, a lack of consensus around definition, differing national requirements for question sets in household surveys, limited availability of alternative statistical sources, and general data scarcity in many emerging and developing economies. Surveys that include specific questions designed to identify platform-based and job-based work usually show the largest levels of prevalence,

often followed by surveys using traditional questions adapted for wider use. In some emerging economies not covered by dedicated question sets, the identification is done through the inclusion of questions on using a digital platform for work with a cash payment. Classification difficulties originate from the dual nature of a large part of this work: workers simultaneously engaged as employees and as self-employed—for example, Uber drivers using the platform to find clients during their non-working hours in traditional contracts. As a consequence, results obtained by different measures can lead to different conclusions regarding the overall proportion of platform workers and the nature of the work relationship—formal or informal, dependent or independent, primary or secondary, etc. There is also a lack of direct questions about income volatility, social protection coverage, or access to employer-provided benefits, which are often determined indirectly.

7.2 FREELANCING AND REMOTE WORK TRENDS

Freelancing and remote work have become increasingly important in modern labour markets. Digital communication tools, cloud platforms, video conferencing and online collaboration systems allow workers to provide services from different locations. These technologies reduce the need for physical workplace proximity and enable firms to access talent across regions and countries. Remote work has especially benefited highly skilled workers in areas such as information technology, design, education, consulting, media and digital services. It has also reduced commuting time and created new opportunities for workers living outside major urban centres. However, access to remote work remains unequal. Workers with strong digital skills, reliable internet access and suitable work environments benefit more than those without these resources. The capabilities provided by digital tools, platforms, and practices—communication, file storage and transfer, video conferencing, and collaboration—have increased productivity by allowing for more effective coordination of people across different companies and locations carrying out parts of a project. The new tools reduce coordination costs between specialists—in research and development, design, programming, media, and logistics—act as a portal for remote sourcing and reduce the minimum firm size by making it easier to farm in distribution,

marketing, manufacturing, assembly, and logistics. Urban density effects are augmented by the communication networks of small-intermediate size cities and enabled by unregulated air travel as well as digital commuting.

- Growth patterns and demographics

The share of the workforce engaged in freelancing, defined as providing work on a non-contractual basis, is rising in many countries. Surveys of freelancers with a significant share of income from freelancing suggest growth in the relative size and number of workers who freelance at least some of the time. Nearly one in five persons in upper-middle- and high-income countries report having engaged in any form of freelancing over the past year, with one-quarter or more in the United States, Brazil, Peru, and Argentina. Growth trajectories vary: while share increases have been most marked in Europe and the Americas, the absolute number of freelancers is rising rapidly in the Asia-Pacific and Middle East–North Africa regions. Even in South Asia, where a relatively low share of the population participates, the number of freelancers is growing swiftly. The demographic profile of the freelancing population is diverse but homogeneous in important respects, and participation patterns are shaped by country income levels. Freelancers are overwhelmingly male in the Middle East, North Africa, and South Asia, where the share of female participation remains low at all income levels, while females constitute half or more of freelancers in Europe and North America. Participation is more evenly balanced in the Asia-Pacific region, driven by large shares of the population in the two largest economies. Remote work has also become commonplace in high-skill service occupations and sectors, supported by available technology and sustained demand: in some markets for digital services, productivity remains high even after the initial boom attributable to COVID-19. Digital collaboration tools have a wide and increasing range of applications across the economy. These developments allow more people to live farther from higher-cost urban centres, but so far their impact on typical commuting patterns has been modest. In a few locations, reduced commuting times have created a measurable increase in quality of life. In the United States, a small number of highly skilled workers can now afford to live full time outside their urban centres, taking advantage of both remote

work in high-skill service sectors and a nominally asset-light lifestyle. These arrangements, however, are not yet common enough to exert a visible effect on broader commuting patterns.

- Technological enablers and productivity implications

Freelancing and remote work have become important sources of labor supply in many economies. Advancements in digital communication and computing technology enable individuals to offer their services independently, to multiple clients, and at low costs, while allowing businesses to access a global pool of talent. The growth of collaboration platforms, in particular, has made it easier to deliver and manage projects across large numbers of collaborators at low transactional cost. However, despite the clear productivity advantages on offer for traditional businesses, there is little evidence to suggest that supporting independent provision of labor is raising productivity growth for these firms and the economies in which they operate. Digital tools allow freelancers, including workers that manage individual or small businesses, to provide services directly to clients and be paid across borders from the comfort of their homes or remotely via rental spaces. Freelancing has also been facilitated by the growing adoption of collaboration platforms among businesses, enabling them to manage numerous working relationships at low transaction costs. These platforms—Airbnb, Uber, Facebook, and LinkedIn, which support commercial activity, and Upwork and Fiverr, which provide transaction markets for human resources—are well known. They enable labor markets to allocate resources externally and address skill needs in commerce and service economies without traditional employer-employee ties. Digital technology, in effect, allows entrepreneurs or freelancers to operate on an "asset-light" basis, benefiting from the business infrastructure of companies such as Google, Facebook, Amazon, and Alibaba.

- Geographic dispersion and urban–rural dynamics

While remote work has historically been concentrated in wealthier, urban economies, the availability of online jobs in poorer and more rural areas is growing. A major driver of geographic dispersion has been the rising availability of broadband access, thus alleviating the geographical barriers to working for foreign clients. The COVID-

19 pandemic has accelerated these trends, with many jobs that previously required workers to be physically present transforming into remote-capable positions. Nevertheless, urban centers continue to perform an important liberalizing function, offering greater densities of online jobs and making them easier to find. The most proximate impact of remote work is a reduction in commuting, which opened up considerable productivity gains even before the pandemic by eliminating the associated travel-time burden, a major issue for workers in many urban areas. Future developments may be even more transformative. While remote work is still concentrated among the most privileged segments of the labor force, opportunities may grow more diffused. The emergence of hybrid work models, in which workers perform part of their job at the employer's physical premises and part remotely, creates new possibilities for regional labor market development. Best exemplified in the major employment hubs of Asia and the United States, these workplace arrangements are an opportunity for improved living conditions in other regions by filtering demand and supply toward more urban-type settings for only part of the work week.

7.3 IMPACT ON TRADITIONAL EMPLOYMENT STRUCTURES

The gig economy has changed traditional employment relationships. In standard employment, workers usually receive fixed wages, job security, social benefits and legal protection. In contrast, gig workers are often treated as independent contractors or self-employed workers. They may have flexible work arrangements, but they often lack benefits such as paid leave, health insurance, pensions and unemployment protection. This creates workforce segmentation. Some workers use gig work as an additional source of income, while others depend on it as their main livelihood. Those who rely entirely on gig work may face greater insecurity, irregular income and limited career progression. Therefore, labour laws must respond to the changing nature of work. Consequently, researchers frequently assess how the characteristics of platform-based work affect local labor markets by analyzing the distribution of these features across primary, secondary and gig economy domains, which allows for exploration of the relative security, rewards, and recognition afforded by each regime.

A growing number of studies examine these dimensions of traditional labor contracts in relation to the wider gig economy. In many countries, labor law classification is also under scrutiny, as gig exchanges and platforms advocate for new legal definitions that would introduce simplified and cheaper employer obligations. These alternative models seek to broaden the social insurance net without burdening the platform-centered segment of the economy. However, the economic, legal and social rights of "dependent" and "fake" self-employed workers often differ from those of employees—and traditional income-protection measures accordingly fail to afford the same coverage. Asymmetric access to job ladders, careers, and benefits remains a concern in the context of mixed work regimes in which gig work represents only a part of total income.

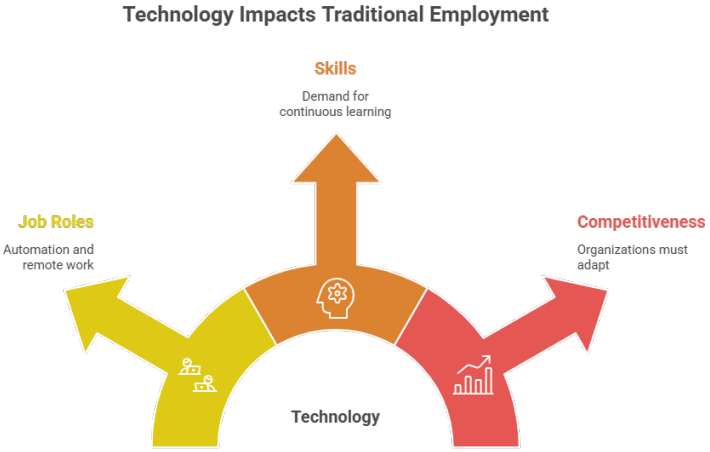

Figure 7.1 Traditional Employment Structures

➢ Employment contracts and workforce segmentation

Classification of employment income into labour and capital components typically rest on the different sources through which income, typically emphasised more so in economic theory than in practice, are earned, in particular the breakdown of the workforce into simply two groups. Moreover, the fact that low-wage industries or the services sectors employ a relatively higher percentage of female workers overtime explains the gender–income relationship of our economy. Indeed, market supply as well as demand plays a crucial role in determining the rates of remunerations through the price for these factors of production; in addition, discrimination plays a role in

determining the lower wages received by women workers. Asymmetric information on the part of both employers and employees, where both parties would not possess full knowledge of the capacities and capabilities of their opposite parties, will also serve to uplift overtime earnings from employment. Such segmentation can also be viewed as an answer to the principal-agent problem, where imperfect information exists. A firm normally would prefer to employ only workers who have a high chance of completing any tasks, whether qualitative or quantitative. This forms the basis of the screening effect, where the workers are not hired together with those of differing level of status and education. An employer prefers employees that are not a mixed blend of high-ability and low-ability workers, as a firm would be willing to offer a higher pay for high-ability workers as compared to low-ability workers, thus performing the first hire of the problem and simplifying the assignment of task by assigning the harder task to the more able agent.

- Employer-employee status and legal classifications

Employer-employee relationships vary across gig roles, driven by contract types, categorization choices, sector-specific norms and regulatory contexts. Several gig jobs—such as ride-sharing—fall within a legal grey area. Ambiguities persist regarding gig workers' employment status: Are they independent contractors or employees? The latter classification may grant entitlements like minimum wages, approved working hours, social security benefits or enhanced safety measures. Separating workers from employers can narrow decision-making power and weaken collective bargaining influence. Most platform-based offerings are categorized as economic services, granted limited—if any—rights: labor laws typically don't extend to such economic agents. Yet ongoing platform–worker negotiations have yielded contextual changes. In California, Proposition 22 defined gig workers as independent contractors but only partly fulfilled minimum wage, benefits and rights criteria. Similar rules have emerged in Australia. European Union legislation emphasized safe working conditions and direct contacts between platform operators and workers but refrained from mandating employee status. In contrast, the United Kingdom has ruled that drivers and couriers qualify as workers and are thus entitled to minimum wage

and earned leave. These shifts underscore the potentially greater social protection available when governments address the legal status of non-traditional work.

- Wages, Benefits, and Job Ladders

While empirical assessments of wages and job ladders for mixed work arrangements are still developing, the available evidence suggests that the comparative pay differentials often identified between non-standard workers and full-time, permanent workers do not pertain in the same manner to more hybrid arrangements. Contracted platform workers with a regular traditional job often earn more than their sole employed counterparts, as their second job may boost overall earnings or encompass higher-paid niche activities. Such people also appear to be more engaged in formal jobs that entail pay scales pegged to professional or union-negotiated levels, unlike pure-platform workers, who are more concentrated in low-skill service-sector tasks characterized by significant price competition and absence of an effective minimum wage. A different picture emerges when the focus shifts to employee-type roles with gig or platform characteristics, as these contracts regularly offer weaker protection in areas such as pension savings and sick leave. Access to benefits is also mixed. In pay-as-you-go systems, gig commuters usually have to make contributions based on their labour income and do not earn pension entitlements on non-worked maternity or parental leave periods. Commitments made by firms are often weaker than in standard employment due to need for agility and fluidity, low-cost service delivery, asset-light models and investments in technology for customer self-service and fulfillment. These incentive structures imply employer risk shifting onto the labour force, which deepens rent gaps, discourages labour participation and leads qualified workers to pursue alternatives that may not involve joining an insider/traditional service sector job ladder.

7.4 SKILLS REQUIRED IN THE DIGITAL ECONOMY

The digital economy requires workers to develop both technical and non-technical skills. Technical skills include digital literacy, data handling, online communication, platform use and basic knowledge of digital tools. Non-technical skills such as adaptability, problem-solving, time management, communication and self-discipline

are equally important. Since digital technologies change rapidly, lifelong learning has become essential for workers who wish to remain employable and competitive. Digital platforms are changing the very nature of how tasks are accomplished. They facilitate work being dispersed to both workers and firms in completely new ways and are thus making place and time arrangements more flexible, sometimes facilitating work from anywhere. Indeed, distributed work for certain tasks has allowed commercial enterprises to open up markets in countries or regions that previously provided limited services but now can do so for parts of the world that are far away. COVID-19 further accelerated the shift toward flexible remote work, especially among highly skilled workers in non-routine tasks that can be efficiently performed online. Increases in commuting costs, pollution, road congestion and urban housing prices are prompting discussions about allowing workers to reside outside of the immediate vicinity of the workplace. At the same time, many workers are also reconsidering and adapting their place of work in light of the increased adoption of new digital tools for collaboration. These changes and their underlying causes are leading to a dispersion of highly skilled workers and the characteristics of the local labor market. The demand for highly specialized skills remains elevated, and thus the productivity associated with these capabilities is positive even for locations peripherally located in relation to large urban centers.

- In-demand competencies and lifelong learning

Low-, middle-, and high-level jobs that many workers perform are increasingly defined by digital tasks and media rather than by working with people, processes, or things. Demand for technologically advanced and high-end services continues to grow. Most organizations—while worried about digital talent shortages—are not concentrating their investment in these areas. Competencies remain the central driver of income growth, complemented by physical capital accumulation at the top end. In-demand skills are often not technical. For most businesses, the key competencies are increasingly shaped by non-routine problems and communication and management capabilities. Demand is for adaptable workers capable of lifelong learning—quickly and repeatedly acquiring new skills as career paths and business requirements shift—

and with the socio-emotional capabilities to work effectively with others. Neither companies nor education systems are delivering this needed adaptability and lifelong learning at scale. The urgency of policy-makers' preoccupation with skills is driven not simply by the historic scale of skill requirements but by the pace of change. The number of skills growing at scale continues to rise. Skill-building trajectories are still being established at the global level. The positive impact of employer-required certification on application rate is countered by the lower match quality of remote work and the associations with flagged opportunities. Industries from the ground up that are absorbing large pools of workers—building, agriculture, services—remain primarily concerned with physical skills for medium-level activities. In advanced economies, the task of certificate-based skills is decentralizing from national bodies; at the same time, the process flow remains unaligned across different levels of supply networks and between markets of different types and levels of risk.

- Certification, credentialing, and standardization

Work-based skills standardization and certification, especially within private sector skill-centered organizations, have emerged as a strategic response to overcoming skill mismatches and boosting labor market mobility. Employers seek candidates with the right mix of specific foundational, technical, and higher-order skills required for specific jobs, while individuals want to pursue skills training to enhance labor market outcomes. Various national and regional efforts are underway to create competency frameworks and promote the certification of competencies acquired in both formal and non-formal sectors. The standardization, certification, or credentialing of skills remains, however, largely limited to specific sectors or industries either at national or regional levels. The skill demand review kick-started by the AI and digital economy, covering the period up to 2026, has also pointed to the need for a more proactive approach to nodal competency building in the digital sector with a view to minimizing skill mismatches. In several instances, necessary actions that would relate to standardization of certification and demand-supply gaps either at the total, specific sector, or regional level have also been mapped.

- 2024–2026 skill development trajectories

The skills required in the digital economy are undergoing change. Demand for several skills (e.g. engineering skills, programming, and software development) is projected to grow rapidly in the coming years. Adaptability to change and the ability to acquire new skills continue to be in-demand worker attributes. Demand for problem-solving and creative skills, especially in the context of economic digitalization, is increasing. But while there is strong demand for the skills of a relatively small share of high-skilled, high-paying occupations, upskilling alone is insufficient as a strategy for ensuring strong productivity growth across the labor market. The rates of supply growth for these in-demand skills appear to be insufficient to satisfy demand. Certification, credentials, and what constitutes a skill are evolving rapidly. Skills in non-cognitive social and emotional areas are increasingly in demand by employers. Employers express concern about the relatively weak supply in certain skill domains. What is required to address this unmet demand for skills? There are also some skills that remain deeply important but can be taken for granted. The implications for 2024–2026 skill-development trajectories in curriculum design, primary education, and training systems are, however, profound. What these trends mean for the nature of digital skills and for what skills are needed across five domains remains a key policy question.

7.5 LABOR RIGHTS AND JOB SECURITY ISSUES

Gig workers often face income instability because their earnings depend on demand, platform rules, ratings and availability of tasks. Many do not receive benefits such as health insurance, pensions, paid leave or unemployment protection. Since they are often classified as independent contractors, they may not have the same legal protections as regular employees. This raises important questions about fairness, worker security and the responsibility of digital platforms. As a result, non-standard workers are more likely to lack insurance coverage or access to social protection. The absence of insurance and benefits rich enough to compensate easily for joblessness can make it hard for individuals to weather short spells of inactivity, let alone prolonged unemployment. Moreover, in the absence of such a cushion, the prospect of

job loss may deter individuals from quitting, even when their jobs are of low quality. Short-term contracts create a de facto need to keep searching for work even when out of a job, for the loss of income will be immediate. In addition to issues related to job quality, rights, and benefits, the extent of workers' bargaining power is also at stake. Non-standard work arrangements raise questions about collective representation and whether, in the absence of a common employer-employee relationship, workers have the ability to combine their efforts and seek better working conditions. The challenge is to foster forms of collective organization that protect workers' interests while maintaining the flexibility inherent in platform-based work. Addressing such concerns is not straightforward, as neither labor laws—originally designed for a different era—nor unions, which maintain a predominantly industry-level focus, are easily adaptable to non-standard work situations. The absence of a common employer, and hence an employer to bargain with, complicates representation efforts in cases where powerful platforms exert considerable market power. The result is a unique blending of both formal and informal work setups; addressing the rights and protections associated with traditional employment thus remains a work in progress.

- Income volatility and social protection

Income fluctuations tend to be stronger for those engaged in gig employment relative to non-gig workers, and income sources are more diverse for freelancers and contributors across creative industries than those relying on remote jobs that essentially replicate the office-based structure. Employment models predicated on temporariness generate gaps in pension, health, maternity and family support coverage—similar to those of other functions filled on a temporary basis. Access to these benefits tends to be strongest for workers hired full-time and not through third parties, yet contributory schemes covering sickness, maternity, paternity and retirement remain scarce in developing Asia, especially in low-income economies. In some cases, the absence of employer involvement comes at a price; non-contributory schemes are usually characterised by low coverage, inadequate payments or limited duration. Income protection during periods of illness, maternity or incapacity remains elusive for the vast majority of the workforce in many countries, including higher-

income ones, and yet social protection systems did not concede defeat during the pandemic. In many economies, the trade-offs between economic security, mobility and equity have taken centre stage, and these underlying tensions are reflected in the changing contours of labour market supply in both formal and informal work. In emerging economies, more momentary or recurrent income-generating activities, albeit often associated with poverty conditions, have coexisted with other forms of work that lead employees from one position to another without substantial gaps or fiscal protection. Large portions of the workforce employed in temporary or non-standard positions exhibit a heightened sense of insecurity, and income volatility emerges as a stark characteristic of the worker experience.

- Bargaining power and representation

For many individuals engaged in platform-based work, the absence of a conventional employer-employee relationship raises questions about negotiating power and collective representation. Mismatches in supply and demand often underpin sporadic earnings, engendering economic instability that may be cushioned by social protection schemes. However, bargaining power is reinforced in demand-driven contexts, such as labour shortages in certain sectors, creating opportunities for higher earnings and improved working conditions. In sectors where the volatile nature of income is well recognised, informal groups or forums are being established to facilitate discussions and shape opinions. However, collective representation by labour unions remains infrequent due to regulatory limitations regarding campaign funding, stipulations on union credibility or civic leadership announcements. Impediments also stem from legislative frameworks governing minimum wage, licensing fees, working conditions and health and safety standards—notably absent in casual work arrangements—thereby precluding collective negotiations involving firms. Consequently, those working through platforms lack coverage by trade unions or employer associations. Globally, there appears to be no marked upward or downward trend in union representation and density among workers engaged in a wide variety of non-standard employment. Direct relations with platform owners have also tended to inhibit unionization. Notwithstanding, established unions are looking to expand their reach

into non-standard forms of work. Examples of organised attempts to forge relationships with platforms include membership certification, group discount services, personal development opportunities and financial security enhancements. Nevertheless, some platforms are resisting such partnerships due to opposing interests or are pursuing solo alternatives.

- Safety, rights, and workplace protections

Income volatility, limited access to social protection and lack of benefits are pervasive vulnerabilities among gig, freelance, remote and other newly emerging workers. Workers in the platform economy appear to be particularly badly affected. In 2021–2023, two-thirds of respondents in the International Labour Organization (ILO) World Poll indicated that they would not be able to cope with an unexpected expense of a few hundred dollars: 3.3 billion people were unable to cover essential needs. Freelancers reported inadequate safety and security provisions far more frequently than traditional employees. There is also evidence of substantial levels of income insecurity, financial stress and mental ill health. Despite a growing interest in health and safety within the gig economy, workers in these types of arrangements may be exposed to increased health-related risks: they bear primary responsibility for their safety and health at work, lack necessary resources for managing health and safety and find it more difficult to comply with health and safety regulations. Indeed, protection, safety and labour rights in the gig economy remain unclear. National labour laws were not designed for this new form of work, posing great challenges for workers engaged in these activities. As a result, they may be losing the rights and protections traditionally linked with employment, with implications for their safety and health.

7.6 POLICY RESPONSES TO GIG ECONOMY CHALLENGES

Policy responses to challenges arising from the expansion of gig and platform work have emerged. Some governments are evaluating traditional labor regulations to cover non-standard work forms, while others are adopting regulatory frameworks tailored to specific workers. A growing number of countries are contemplating reforms that offer greater protection to workers who have been classified as self-employed or independent contractors while preserving the flexibility associated with gig jobs.

Measures to improve social protection and workers' rights in the gig economy include portable benefit schemes that allow gig workers and freelancers to consolidate contributions from multiple jobs, thereby enabling access to pensions and health insurance at levels equivalent to full-time employees. Economies that prioritize skill development and invest in research and education to ensure equitable digital transitions are projected to fare better by creating higher-quality jobs that embrace digital technologies and by upskilling existing workers to participate in the new economy.

- Regulatory approaches and classification reforms

Regulatory approaches to non-standard and platform-based work differ widely across countries, often reflecting traditions in labor law, industrial relations and welfare. In some economies, gig work has been embraced and deregulated entirely, whereas in others it remains tightly controlled. Legal frameworks in the European Union, Canada, New Zealand and the UK are evolving in response to increased recognition of the rights and needs of gig workers. Most countries, including advanced economies, have expanded or introduced social protections like minimum wage guarantees or occupational health and safety provisions. In several instances, governments have supported social models providing portable benefits that follow workers rather than employers. Additional policy initiatives facilitated the identification of skills in demand, prepared workers for online freelance or remote work or improved digital infrastructure. Legislators are reassessing whether digital platforms classify workers correctly and comply with existing labor regulations. The application of traditional worker classification tests is particularly challenging in the context of technology-mediated, temporary and location-specific work. Gig assignments often involve aspects of entrepreneurship, such as risk sharing and the use of one's own capital, which need to be adequately weighed. Some courts in the United States and elsewhere have opted to create a hybrid model, whereby workers are not classified as employees but are entitled to at least some benefits, including minimum wage guarantees, paid sick leave and health and safety protections. In other countries, labor laws are being

amended to redefine the worker category entirely, while still acknowledging the special circumstances of gig work.

- Social protection mechanisms and portable benefits

The design of social insurance systems in many countries—especially for health, pensions, unemployment support and sickness leave—assumes a traditional employer-employee relationship and is scarcely portable. Such systems need to be adjusted to cover people working as self-employed, quasimployees or contractors at digital platforms, and who are working intermittently, part-time or irregularly. The introduction of "social protection floors", in line with the Decent Work Agenda, can provide basic levels of income support and access to health services for gig and platform workers. However, labour markets are evolving rapidly, and workers will increasingly need to protect themselves against risks associated with income volatility, so that social protection floors are no longer the main or only source of support for those in digital work. The introduction of portable benefits arrangements is one way to tackle these challenges and allow access to benefits that no single employer can or would provide. These arrangements, still being designed, need to be formally defined, especially with regard to who pays for them. In practice, this remains precarious and uncertain: international and regional debates evoke differing employer responsibilities, demand shifts from voiced frustrations related to perceived uncertainty linked to self-employment to an appeal for universal approach made by many trade unions and workers' organisations.

- Public investment in skills and digital infrastructure

Countries across the globe are confronted with the challenges of equipping labor forces with the aptitudes and assets to embrace the digital transformation of the economy. Preparing people for these transformations entails upgrading the skills of current workers as well as fostering meaningful opportunities for youth. However, institutional frameworks, approaches and degrees of investment for skill development differ substantially among countries and regions. Investment in the digital economy and related infrastructure will contribute to skill development for the future. Rising demand for gig work and freelance employment at least partly reflects an absence of

opportunities in the open labor market. Public investment in digital and other related infrastructure, technology-related investment and the development of new technologies can help redress these imbalances. In turn, investment in the right infrastructure will improve productivity and, by providing an enabling environment for business, foster job-creating growth in quality employment. At the same time, public investment and policy measures can influence the type of demand generated and guide the economic structure towards activities that are likely to provide better-quality jobs.

7.7 Chapter summary

The gig economy and platform-based employment have rapidly reshaped modern labor markets, driven by digitalization, technological innovation, and changing business models. Online platforms have enabled new forms of work such as ride-sharing, food delivery, freelancing, and remote digital services, allowing firms to match labor supply and demand in real time. This transformation has expanded opportunities for flexible and on-demand work while simultaneously challenging traditional employment relationships based on long-term contracts and stable workplace arrangements. Freelancing and remote work have become central features of this evolving labor landscape. Advances in communication technologies, cloud computing, and digital collaboration tools have enabled workers to provide services from virtually anywhere, reducing the importance of physical workplace proximity. These trends have particularly benefited highly skilled professionals in sectors such as IT, design, and consulting, while also contributing to greater geographic dispersion of labor. However, participation patterns vary significantly across regions, genders, and age groups, reflecting broader structural inequalities in access to digital opportunities.

The expansion of gig and platform-based work has significantly impacted traditional employment structures. Standard employer–employee relationships are increasingly supplemented or replaced by short-term, task-based, and contract-driven arrangements. While this shift offers firms greater flexibility, cost efficiency, and scalability, it also leads to workforce segmentation, income volatility, and reduced access to long-term benefits. At the same time, the digital economy demands new skill sets, including

technological proficiency, adaptability, problem-solving abilities, and strong communication and collaboration skills, alongside a commitment to lifelong learning.

Despite its growth, the gig economy raises important concerns regarding labor rights, job security, and social protection. Many workers in platform-based roles face limited access to benefits such as health insurance, pensions, and paid leave, along with weaker bargaining power compared to traditional employees. These challenges have prompted governments to introduce policy responses including regulatory reforms, portable benefit systems, and updated labor classifications. Such measures aim to balance flexibility with protection, ensuring that the benefits of digital labor markets are shared more equitably while maintaining economic efficiency and innovation.

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CHAPTER 8

DATA ECONOMY AND DIGITAL TRADE

Data has become one of the most important economic resources in the digital age. Like land, labour, capital and entrepreneurship, data now contributes directly to production, innovation and value creation. The term data economy refers to economic activities that create value through the collection, storage, processing, analysis and use of data. Digital networks allow data to be generated, stored and shared at very low cost. Businesses use data to understand consumer behaviour, improve services, develop new products and support decision-making. Governments also use data for planning, public service delivery and policy implementation. However, the growing use of data raises concerns related to privacy, security, ownership, consent and cross-border data flows. Digital trade increasingly depends on the movement of data across national borders. Therefore, trade agreements are beginning to include rules on data localization, cloud services, privacy protection and digital services. The main challenge is to balance the economic benefits of free data flows with the need to protect personal information, national security and public trust. Data can now be gathered at relatively low cost from a large number of users, stored at low cost and analyzed at low cost and in powerful ways to derive useful information. Yet even as these immense amounts of data are being exploited to deliver services and products, such as recommendation systems and self-driving cars, privacy, ownership and security concerns are being raised about how much of an individual's data or how much of a country's sensitive data is shared or made accessible to third parties, be they companies or foreign governments. Multilayer digital trade agreements are beginning to address these issues, balancing the desirability of joining a global data framework with the political and economic costs of doing so.

8.1 DATA AS A KEY ECONOMIC RESOURCE

Data differs from traditional resources because it can be reused, copied and analyzed repeatedly without being exhausted. A single dataset may generate value for many firms, users and sectors. For example, consumer data can help companies personalize services, improve logistics, detect fraud and forecast demand. However, the economic value of data depends on access, quality, analytical capacity, legal rights and trust. Public, private and nonprofit entities in the modern digital economy create, store, manipulate, analyze and own unprecedented volumes of data. The above processes are funded through payments made by users for products and/or services, where data is provided (directly or indirectly) as the main or an ancillary output. This has led to the emergence of a data economy and innovation in business models through which organizations grow revenue streams by monetizing the data they accumulate. Patterns of behavior and innovation appear across networked organizations analyzing data for new services and products, fueling the creation of new entities and changing the structures of existing organizations. Economists have long recognized the key economic resources of their time. Land, labor and capital were important resources in the era of the agrarian economy; factories, labor savings and scale were vital in the age of the industrial economy. Unlike in physical industries, where acquiring more land or structuring factories differently may significantly affect profitability, data are a key resource in the business environment in which a company operates. Added layers of complexity and uncertainty arise from factors including ownership of data, access to processing capability and market power derived from control of data sets. Data are in their essence a redundant resource, with demand primarily from companies addressing large audiences where consumption is not unit-specific. The accumulation of large volumes of data allows data analysis to identify patterns and derive insights as an ancillary outcome of production processes for users interested in applications sustaining the analysis.

8.2 DATA MONETIZATION STRATEGIES

Data monetization encompasses distinct efforts by firms to exploit data and these initiatives can be categorized into a limited number of models: data licensing

(exploiting data by selling it to others); providing data-as-a-service (DaaS) (data usually embedded in existing or new applications that act as a container); offering analytics products (reporting and visualization of varying sophistication about the firm's data); and facilitating data marketplaces (a trading environment for third-party data providers and data consumers that may or may not belong to the firm). The emerging analysis mainly explores the business rationale behind pursuing these distinct data monetization models, and such a model comparison is described in the table below. It highlights insights about the monetization models by comparing how they differ across critical factors such as revenue potential, production cost and risk. The revenue potential depends on market demand for a firm's data output, whereas the cost of production and risk assessment relies on the effort required to complete the monetization undertaking. Therefore, while the data licensing model is often enabled by core firm data and focused on capitalizing on existing data value, the DaaS and analytic product models require more investment and exhibit greater risk in order to realize scale. In addition to these features, sector-specific consideration themes relating to the governance of the data output and the interplay across the various monetization models enrich the comparative analysis. In particular, recognizing the need to deal with legal and ethical issues around privacy, security and trust; the challenge of limited market size; and the importance of seamless access to external data for enhancing product quality emerges as pivotal for pursuing successful data monetization strategies.

- Data licensing

Licensing data allows an organization to grant specific access rights while retaining ownership and control. Such licenses can take many forms, from unrestrictive to highly nuanced agreements, and are generally more complex than productized offerings such as Data-as-a-Service. License types can include royalty-free licenses, which grant a third party the right to use the data source without further compensation to the data source owner; exclusive licenses, which provide certain access rights only to the licensee; and rights-managed licenses, which permit third-party use subject to restrictions around location, timing, and other factors. Licenses typically specify the

approved use cases for the data, with limitations ranging from allowing only noncommercial use to authorizing the third party to produce derivative works or incorporate the raw data into its own datasets. Pricing may be based on a flat fee or royalties linked to the licensee's revenue from using the data set. Licenses can also define the revenue-sharing percentage for such arrangements. Other important considerations are compliance with terms set by the data source owner, terms of attribution to the data source owner, terms of indemnification of the data source owner, and in some cases, an agreement to advertise the data source owner's data. Lastly, a license may define audit rights and obligations as well as the duration of the license itself.

- Data-as-a-service

Data-as-a-Service (DaaS) is a cloud-based data management solution that provides users with access to data on demand, when and where needed. DaaS abstracts the complexity of data management and helps organizations leverage the power of data quickly and efficiently, while keeping costs low. In a DaaS model, the service provider is responsible for managing the data, including storage, backup, and offering data on demand as a service. Enterprises looking for DaaS offerings can subscribe to the service and choose from a range of service levels that meets their requirements for frequency of data updates, data availability and timeliness, volume of queries or transactions, and so on. DaaS has emerged as a preferred option for organizations looking for a cost-effective solution that allows them to focus their attention on their core operations rather than data management. Externally, DaaS can help organizations combine and analyze data from different sources quickly and at a lower cost. This is because DaaS offers data as a service, complete with optimized and easy-to-understand metadata, controlled access, dedicated application programming interfaces (APIs) or dashboards for connecting different data sources, query processing, and analytics. Customers can explore different aspects of the data and analytics from a single location and gain insights into their data. Organizations can also offer DaaS solutions based on different tiers such that customers only pay for what they consume.

- Analytics products

Analytics products leverage data assets to deliver information, insights, and decision support for internal business units and external clients. Unlike traditional business intelligence solutions, which provide data or visualizations to answer specific questions, analytic products generate predictive models or embedded decision-support applications based on data. Common scenarios include churn or default predictions for customer relationship management, fraud predictions for financial services, and recommendations for retail. Such analytics products should be differentiated from raw data in data licensing or data-as-a-service offers. Yet few firms have been able to realize the potential around analytics products, typically due to lack of dedicated resources for product development, the need for specialized math skills, or challenges in embedding analytics within business workflows. Nevertheless, recent sophistication of the analytic tools market is helping to address some of these barriers. Development time and cost can be reduced by using advanced analytical services that lower the skill level needed to produce a model, by focusing on areas where speed of development and time-to-market are critical, by fostering a regular development rhythm, and by creating a team responsible for easy-to-implement and use products. In some industries, model development can also be integrated into the regular business planning cycle. Further differentiation can be achieved by limiting data access during model development and applying a test-and-learn method. Life cycle considerations also come into play for predictive model products; development costs should be more closely aligned with product revenue generation.

- Data marketplaces

A data marketplace is a simple ecosystem that allows buyers and sellers of data to discover and exchange data. At its core is a data catalog that catalogs the information assets of participating organizations. The marketplace operator maintains a searchable listing, supports appropriate governance mechanisms to ensure compliance with data asset usage policies, and provides the underlying infrastructure for the actual exchange of data. Marketplaces can be internal or external, serve only a select buyer audience, or be open to all. Marketplace data can enhance demand for the data supply and vice

versa. Data assets represent a rich potential supply for a marketplace. Supply-driven marketplaces offer participating organizations another option for monetizing their data assets but such external initiatives can lead to long-term internal consequences if not handled carefully. Supply-driven data marketplaces add demand for data from internal initiatives but data monetization ultimately gets limited by constrained supply. Balancing demand with supply without compromising the main objectives of either market is the ultimate challenge of operating a data marketplace. Data product marketplaces function much like e-commerce platforms. Organizations centralize curated external data, complement their product catalogs with value-added data products from partners, create data product catalogs with tiered offerings, provide a clear value proposition for partners and customers, and minimize marketplace operating costs. Data discovery and purchase activity feed data usage patterns which enable self-serve initiatives with focused governance controls.

Model	Meaning	Example
Data Licensing	Selling access to datasets	Market research data
Data-as-a-Service	Providing data through digital platforms or applications	Weather or financial data services
Analytics Products	Offering reports, dashboards or insights	Business intelligence tools
Data Marketplace	A platform where data providers and users exchange data	Digital data exchange platforms

Table 1

8.3 CROSS-BORDER DATA FLOWS AND TRADE POLICIES

For firms that provide services using data as inputs or that rely on data-intensive services, the absence of market access in foreign territories may directly impact their competitiveness and growth. For other sectors less reliant on international data flows, supply-chain management and productivity can still benefit from cross-border data access. Conversely, restrictions on such data flows can hinder trade expansion in data-dependent sectors. But the enabling effect of international data flows on trade and investment is realized provided that privacy and security risks associated with such

cross-border exchanges are identified, effectively managed, and appropriately governed. Being intangible flows, risks associated with confidential data in transit relate to loss of confidentiality and integrity of data. Effective risk management in turn relies on the degree of trust between countries trading with each other. Hence, measures to build trust between these countries through (i) sound and transparent policies and regulations on data privacy and protection, and security and risk management; and (ii) trustworthy notification and risk assessment processes and also through adequate oversight and supervision play a critical role in enabling safe and trusted international data flows.

- Economic Rationale and Trade Impacts

Economists have long recognised that the world economy is increasingly driven by data. The reliance on data is reflected in the growing investment in digital technologies and their supporting ecosystems (e.g. data storage and processing, labour force skills, digital trade). This investment has been associated with strong productivity gains, particularly in services that support or are delivered over the internet. Data and knowledge-intensive services are the fastest growing segments of trade. Data—and the ability to exchange it across borders—drives inclusiveness and improves productivity across all sectors, enabling businesses in all countries to participate in, and benefit from, trade. Cross-border data flows are increasingly an enabler of international trade. They provide global access to services delivered at a distance, typically with little or no engagement of the service supplier in the country of the user. They construct new business models for the support of trading activity, enabling firms to connect with customers, suppliers, and partners in different parts of the world quickly and easily in a partly automated and machine-readable mode. They permit easy access to larger and richer data sets, helping firms to analyse market opportunities and customer service activities. Indeed, there is evidence that access to such services helps firms that operate relatively locally, perhaps only exporting to adjacent countries, to innovate and develop new products and services that better meet the needs of their customers.

- Barriers, Standards, and Interoperability

Three types of barriers hinder the efficiency and fluidity of cross-border data flows: data localization requirements, incompatibility of technical standards, and lack of interoperability of cross-border data-sharing systems. Data localization mandates that data generated on domestic territory be stored, processed, or managed only within such territorial limits. Such measures can also take the form of bans against outbound data transfers, the deployment of specific digital infrastructure, or even obligations to conduct business through domestic resident authorities. The second source of friction stems from the fact that the technical architectures of data-sharing, data-filtering, or data-access-control systems are developed independently by different countries. Hence trade and investment costs rise, both directly—because organizations must manage, and cope with, a multiplicity of technology systems—and indirectly—because trade and investment negotiations become more complex, and often more time-consuming and costly. A third potential source of friction emanates from the absence of bilateral, multilateral, or regional agreements enabling the transfer of personal or business information across borders while addressing countries' privacy-related concerns.

- Privacy, Security, and Trust in International Data Exchange

Cross-border data flows engage multiple competing interests and priorities with no single universally accepted solution. Regulating the privacy and security of data transfers across borders hinges on the ability of companies in different countries to exchange information while preserving individuals' rights. Companies investing significant resources in data transfer systems seek ways of protecting their own systems while developing managing those of third parties. Trust forms the cornerstone in these efforts and is critical in establishing an optimal balance between privacy, security, and facilitating cross-border data flows. Various parties face distinct challenges in this regard. For users, risk comes from sharing personal information or sensitive data with service providers. Providers face the constant threat of data breaches or information leaks. Governments, on the other hand, face the constant pressure of ensuring that their citizens' private information is adequately protected

while, at the same time, negotiating conditions for granting third parties access to their markets. Establishing sound measures to enable further cooperation among these parties is critical to ensuring successful development of mutual benefit through cross-border data flows. Compliance with existing privacy regulations and privacy risk management measures represent the basic conditions for obtaining access to foreign markets. Beyond compliance, mutual investment in trust-restoring measures is the key in making the regulation of privacy and the prevention of security risks a non-issue in cross-border data exchanges.

8.4 ROLE OF CLOUD COMPUTING IN DATA MANAGEMENT

Owing to the unparalleled growth of data creation, cloud computing is the most suitable model to harness data management capabilities that allow organizations to gather, store, process, analyze and derive insights from data. By encompassing both storage and computing resources, a unified cloud computing infrastructure offers a suite of cloud services enabling organizations to scale their data management functions. The availability of cloud services from diversified providers with global infrastructure environments enhances the operational scalability of cloud data systems, while streamlined support for multi-cloud and hybrid cloud data architectures eases interoperation. While enabling secure and efficient management of data in cloud systems, geo-location of cloud servers also raises key issues. Data sovereignty refers to the jurisdictional ownership of data stored in physical formats in data centers, while data residency represents the geographic location of data storage. Increasingly, data localization requirements are emerging from national regulatory bodies and can lead to the establishment of data silos according to the location of providers as well as consumers. Such requirements may originate from security concerns, economic consideration and the desire to secure political sovereignty. Therefore, understanding the interplay between cloud computing and data sovereignty is critical in determining how cloud computing engenders the safe and reliable flow of data across quantum spaces and geographical fronts.

- Cloud Infrastructure and Data Architectures

Cloud computing supports data monetization by delivering data management and further technology components as a resource. Devices and data sources collect, generate or transform data, while private or public cloud platforms and environments constitute the backbone infrastructure that data products, services and applications rely on. Substituting these components with cloud resources enables greater scalability, elasticity and cost efficiency. The pay-per-use model and service tailoring afford end-users significant operating leverage. Moreover, cloud service enablers mitigate issues of reliability, security, compliance and perceived costs through stringent security controls, recognized compliance frameworks and third-party audit trails. Cloud data operations cover the storage, processing, analysis and enrichment of data—offered as integrated or stand-alone services at multiple levels of abstraction. These services are further complemented by the supply of data as a service and data marketplaces for direct data consumption. Well-structured, curated and maintained data prepared to meet the specific needs of potential users capture users' attention and serve as the main technology enabler in building and deploying new data-based services or products. Scalability and availability risks can be addressed through the hybrid model, which combines private environments and public facilities on demand.

- Data Sovereignty and Residency

Cloud computing is intimately connected to data sovereignty and residency considerations. Data localization—the placement of data within a specific territory to enable state control—affects cross-border data flows, while data residency assures consumers that data is stored within the territories they care about. Data sovereignty is often understood as the state's ability to assert jurisdiction over data stored and processed within its territory and hence lends credence to data localization demands in authoritarian regimes. Political tensions have led some countries to implement or revive data localization requirements that jeopardize the efficiency of cloud computing services and are therefore economically costly. The benefits of data localization requirements from an economic, technical and security perspective are hotly debated. Locally stored data enable law enforcement to achieve faster response

times, relieve the need for foreign security clearance and avoid the complexities of presenting legal evidence in a different jurisdiction. In this context, the security assurances provided by data residency labels are particularly promising: they allow businesses and consumers to choose service providers based on criteria of their own design, and this privacy-preserving approach is not limited to data resting within a specific territory.

- Security, Compliance, and Reliability

Data security, regulatory compliance and service reliability are primary concerns for organizations shifting to cloud computing. Security encompasses confidentiality, integrity and availability, with multiple stakeholder perspectives. Compliance auditing fulfills legal and regulatory requirements, assuring adherence to controls that safeguard data. Reliability describes a service's resilience to failures, facilitated by backups, redundancy, failover mechanisms and geographic distribution of infrastructure. Third-party cloud infrastructure uses are subject to an increasing array of security and regulatory compliance controls defined by legislation, regulatory agencies and industry standards. Security controls can be tailored to meet specific requirements, while compliance demands are often driven by jurisdictional rules and regulation. The provision of cloud services typically relies on a shared responsibility model, which delineates the division of security responsibilities between the service provider and the customer. Duties attributed to cloud service providers invariably extend beyond those of public cloud environments directly run by cloud service customers. In contrast, the strategic move to public cloud services, which involve outsourcing of the entire technological stack to a third-party provider, offers the highest reduction in security responsibility. Such cloud services are also innovative in that they bundle a diverse array of advanced security controls in an enhanced security-as-a-service offering.

8.5 DATA PRIVACY AND OWNERSHIP CONCERNS

Privacy and ownership concerns arising from data monetization ecosystems can result in the unconsented sharing of data and unwanted intrusions by businesses or government agencies. Addressing these concerns is essential for building a trusted

environment that encourages participation in monetization ecosystems. However, stakeholder perspectives on data ownership differ considerably. Therefore, rights and models governing their realization must be articulated in a well-defined governance framework. Such a framework must also establish essential management and accountability measures, enabling participants to fully exercise their rights while ensuring continued availability, integrity and robustness of the data infrastructure. Data ownership is commonly characterized in terms of these rights: the right to know whose data is being processed, the right to access the data that an entity holds, the right to delete the data, the right to control how data is used beyond its primary purpose and the right to data portability. Data ownership can be viewed from three angles. First, the same primary source of data may generate different data products. For example, individuals generate the data that organizations use for making data-driven decisions. Similarly, the same AI model deployed by two different organizations may produce different predictions for a single input. Second, digital platforms do not own the data they process but merely serve as custodians. Given the asymmetry between data subjects and data controllers, digital platforms are expected to analyze data for the benefit of data subjects and not merely for maximizing their profits, which will usually be at the expense of data subjects and society at large. Third, data serves as the lifeline of many organizations that have invested significantly in it. Without proper safeguards, these organizations may suffer so-called data entrailments if their data is shared or used without their consent and knowledge.

Ensuring privacy while enabling data stakeholders to monetize data products is indeed a daunting task, Balancing privacy protection with data monetization remains a complex and challenging task. Apart from the problems inherent in achieving a balance between privacy and monetization, the lack of transparency in data monetization activities and the ambiguity associated with the resulting data products make the use of privacy-preserving data monetization mitigators extremely difficult and, in many cases, even impossible. Nevertheless, various privacy-preserving techniques, such as differential privacy and federated learning, have been proposed to address these challenges. Although these techniques can help mitigate privacy

concerns, any reduction in privacy protection will reduce usability and the intended effects on increasing participation will also be lost.

- Rights, Ownership Models, and Consent

Established privacy rights and requirements reflect the core idea that an individual owns their data and that data monetization should not undermine individuals' data privacy or ownership rights. Pricing, consent structures and reporting requirements should thus support and protect data privacy and ownership. Data monetization involves using an individual's personal data for financial gain. Individuals should be compensated for enabling such activities, thus establishing a user-centric distribution right that reflects the data product life cycle. Data subjects should therefore receive a share of revenues generated from their personal data for privacy-sensitive data-driven services. A proactive and predictable approach to remuneration mechanisms is also needed, especially for minors, as well-designed systems can create new job opportunities while turning data privacy into a source of passive income.

Ownership rights and models related to data privacy are also gaining traction. The concept of ownership already exists in the physical world and is currently being extended to data. However, many data protection regulations do not assign ownership of an individual's privacy-related data for privacy-preserving purposes; instead, they usually establish only a right of access and use in favor of the data subject via consent policies. Nevertheless, a reciprocity-based data transaction model is required to turn the data ecosystem into a sustainable service. Ideally, data subjects should own their data and thus be able to decide what data to share. Even with ownership rights, consent is needed to process an individual's personal data according to existing data protection regulations. This emphasizes transparency and providing information about the processing operations and their purpose. Real-life examples reveal that organizations do not control consent management, as they need to collect data and machine-learning algorithms to conduct business activities. Consequently, organizations need a new technology to streamline consent management, which usually requires the consent of multiple parties, such as data subjects, third-party data holders and analytics service providers.

- Privacy-Preserving Techniques and Transparency

Privacy-preserving techniques, such as anonymization and cryptographic approaches, mitigate privacy risks but often require concessions on data transparency and auditing. The ability to trace data throughout its lifecycle relies on a privacy-preserving design that balances the trade-off between privacy and usability dimensions across all participating stakeholders. Consent mechanisms strive to increase transparency around data usage and dissemination by allowing stakeholders to specify a set of desired and undesired usage conditions; deviations from the consent condition prompt the need for user-facing consultations. Privacy-preserving anonymization techniques and transparency-enhancing directions support the disclosure of private communication. Nevertheless, privacy risk assessments and auditing processes must sufficiently capture the risk level to user privacy and trustworthiness while remaining usable and useful for the actors at the origin of the data-sharing process. Several privacy-preserving transparency mechanisms examine privacy risk analysis with the privacy risk certification process for cloud service providers used by data owners. Transparency controls can strengthen auditing and accountability; consensus across actors can be achieved by mandatory onboarding of users at the data provider side only.

- Accountability and Auditability

Accountability and auditability are key to the success of privacy-preserving frameworks. Governance models in which data owners curate the shareability of their data should be preferred to passive frameworks relying exclusively on consent. A data monetization ecosystem is proposed that hinges on audit and control procedures assuring data sharing is in accordance with users' preferences. Targets for data operator accountability and auditability, and potential procedures to meet these targets, have also been identified. Data trading and sharing without proper control and oversight may easily lead to abuses. A natural way to exert such oversight is for the users/owners of the data to have a formal role in the decision process, especially since they are the ones being affected by possible undesirable use of the data. Hence, adding users' preferences as an additional criterion for data sharing appears to be a valuable

feature for accountability and auditability. Indeed, users' control over services like Facebook, Uber, AirBnB and similar platforms could easily have prevented many of the negative uses that have affected these applications. The proposal to treat data sharing as a trade exchange can be extended to a broader accountability and auditability framework in which the shareability of the data may be curated by the data owners and/or other interest groups or third parties constituting an authorization authority. This implies that sharing can occur only if the data users' conditions are satisfied. Such conditions may be specific for a single user or a group of users with similar preferences. Consequently, the resulting governance model is more accountable than a passive framework tailored exclusively on the data owners' privacy preferences.

8.6 DIGITAL TRADE AGREEMENTS AND FRAMEWORKS

The economic and legal foundations of international digital trade agreements encompass not only services and cross-border data flows, but also interconnections between services, cloud computing, data exchange and the free flow of personal data. Misalignments between digital trade provisions and privacy regulations or data policies can obstruct the use of cloud services. Compliance with trade obligations—whether in bilateral, plurilateral or multilateral agreements—may require cross-border data flows, data storage outside national borders or data processing for fulfilment in a third country. Cloud computing enhances security, compliance and reliability, but the incorporation of such services into digital trade frameworks faces complex challenges.

Key provisions in digital trade agreements address the conditions affecting cross-border data flows, the provision of cloud services and the localization of data storage and processing. Recognizing these requirements can help companies identify compliance obligations and plan corresponding measures. The negotiation and implementation of the trade provisions examined in this section may also yield practical lessons that benefit the broader agenda of data localization versus the free flow of information.

- Economic and Legal Foundations

Scholarly and trade-related literature addresses the foundations that enable digital trade and related agreements. Such work also examines direct provisions pertaining to cloud computing and cross-border service delivery, as well as those that indirectly influence these, such as regulations governing cross-border data flows. The analysis clarifies how cloud enablement and the adoption of Cloud Service Providers (CSPs) affect compliance with and the cost of meeting digital trade commitments. Scholarly analysis classifies the legal foundations for digital trade into four groups: the premises that underlie digital trade, provisions that directly regulate cross-border data flows, provisions for CSPs and services and supporting trade facilitation measures. Collectively, these determine the digital economy's capacity to operate on a GVC basis. Cloud computing's attributes facilitate the delivery of data-related services on a globally distributed basis, although exploitation of these advantages also requires specific regulatory alignment. Such alignment concerns specifics related to data localization placed in trade agreements as well as broader substantive compliance issues in the area of data privacy.

- Provisions Affecting Data Flows and Cloud Services

Digital trade agreements shape the global landscape for services and commerce. Examining key agreements reveals provisions that guide countries toward compatible approaches to data flows and cloud services, encouraging coherence and minimizing compliance burdens for businesses. However, implementation remains a challenge, as highlighted by recent case studies involving large-scale trade deals. Provisions in major trade agreements often acknowledge the importance of cross-border data flows, seek to remove restrictions and clarify their interplay with data protection. The Comprehensive and Progressive Agreement for Trans-Pacific Partnership endorses free data movement for businesses, notwithstanding the risk of data breaches, and encourages the adoption of cloud services. The Regional Comprehensive Economic Partnership is similarly focused, prohibiting data localization requirements except under specific conditions and promoting reliable cloud services. In services-sector agreements, preserving the benefits of digital trade underpins commitments to

eliminate data-transfer restrictions, while the African Continental Free Trade Area Agreement underscores the need for data protection without hindering trade.

- Implementation Challenges and Case Studies

Data governance policies in major jurisdictions are at different stages of development, requiring careful handling to ensure rules supporting trade in services do not hinder the adoption of cloud computing and related services for enterprises. Both the United States and China are currently developing a more elaborate set of cloud and data-related service rules. In the United States, the Digital Services Act and related initiatives take a first step to establish a coherent service trade-focused governance model for the digital economy, while also addressing a wider economic agenda, with the Federal Trade Commission looking at online marketing practices. Content and services hosted or delivered to users in specific jurisdictions require greater visibility and accountability. For China, the order establishes a file-cataloging scheme for public, important private and cross-border data, monitoring of critical information infrastructure provider data, a content security administrative system, cybersecurity review and data outflows mechanisms regulating commerce lanes, networks and partners. The Digital Trade Service Agreement, currently being negotiated by the United States and partners, is one of the first regional groupings looking to develop a coherent governance framework for digital and services trade and investment flows. Other regions and agreements also require careful attention. The RCEP Data Free Flow Agreement is a key 10+6 initiative to establish a coherent legal underpinning for digital service trade throughout the broader Asia-Pacific region, one of the fastest growing markets in both e-commerce and digital products and services. The agreement is pioneering the first steps toward developing coherence among these important trade flows while also recognizing the equally important flow of data through cloud and other digital service infrastructures.

8.7 Chapter summary

The data economy has emerged as a central pillar of modern economic systems, positioning data alongside traditional factors of production such as land, labour and capital. In the digital era, data is generated continuously through online interactions,

platforms, devices and services, making it one of the most abundant and valuable economic resources. Organizations across public, private and non-profit sectors increasingly rely on data to drive decision-making, innovation and competitiveness. As a result, data has become foundational to economic growth, reshaping industries and enabling new forms of value creation in the digital economy. Within this evolving landscape, data monetization strategies have become essential for firms seeking to convert raw data into economic value. Businesses employ multiple models such as data licensing, data-as-a-service offerings, analytics products and data marketplaces to generate revenue from data assets. These strategies vary in complexity, investment requirements and risk exposure, but collectively reflect a shift toward data-driven business ecosystems. However, the monetization of data also introduces challenges related to governance, transparency and ethical use, particularly when personal or sensitive information is involved.

Cross-border data flows and trade policies play a crucial role in shaping the global data economy. As digital services expand internationally, countries are increasingly integrating provisions on data movement into trade agreements while balancing concerns related to national security, privacy and economic sovereignty. Restrictions such as data localization laws can influence the efficiency of global digital trade and affect the scalability of cloud-based services. Consequently, policymakers face the challenge of designing frameworks that facilitate seamless data exchange while protecting legitimate regulatory interests. Cloud computing serves as a critical infrastructure supporting the data economy by enabling scalable storage, processing and analysis of large volumes of data. It allows organizations to access advanced computational resources efficiently, facilitating innovation and global service delivery. However, the expansion of cloud-based systems raises significant concerns regarding data privacy, ownership and control, especially when data is stored or processed across multiple jurisdictions. In response, digital trade agreements and international frameworks are increasingly being developed to regulate data flows, harmonize

standards and ensure secure, transparent and equitable participation in the global digital economy.

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CHAPTER 9

DIGITAL DIVIDE AND INCLUSIVE GROWTH

The internet has become an essential part of modern life. It supports education, banking, shopping, healthcare, employment, communication and access to public services. However, despite the rapid expansion of digital technologies, many people remain excluded from the digital world. Some lack internet access or digital devices, while others do not have the skills, confidence or relevant content needed to use digital services effectively. This unequal access to digital technologies is known as the digital divide. It affects educational opportunities, employment prospects, income generation and social participation. People who remain offline often miss opportunities for learning, job searching, entrepreneurship and access to government services. Therefore, bridging the digital divide is essential for achieving inclusive growth in the digital economy. They feed augmented inequalities in the availability and therefore use of information, services and business opportunities, which in turn affect growth prospects for poorer groups. Given these asymmetries, any failure to address them would tend to detract from the demand-side dimension of inclusive growth. But addressing this pent-up demand is difficult, because being offline is not just about access—many are offline by choice, for varying reasons.

9.1 CONCEPT OF DIGITAL DIVIDE

A comprehensive conceptual framework for the digital divide captures its determining drivers, mediating factors and outcomes. Four main drivers—access to ICT resources, the affordability of those resources, the capacity to use them effectively and the quality of the infrastructure behind them—shape digital access and use. The digital divide refers not only to the gap between those who have internet access and those who do not. It also includes differences in the quality of access, affordability of

services, availability of digital devices, level of digital literacy and ability to use online resources meaningfully. Therefore, digital inclusion requires more than physical connectivity. It requires affordable internet, reliable infrastructure, relevant digital content and the skills needed to use technology effectively. Together with the quality of the governance that supports these aspects, they determine the level, nature and volume of digital engagement in society. Digital engagement—whether e-learning, e-skills development or online job-search activity—is expected to affect education, employment and income outcomes. A logic model represents the presumed linkages between these elements. Access, affordability, digital literacy, infrastructure quality and governance quality are interlinked factors in the analysis of the digital divide. Growing volume of digital engagement is posited to improve education and employment outcomes, thereby increasing income. The logic model also lays out a set of targeted intervention points for research and policy attention—strategies that can be expected to close the digital gap in society and so enhance the well-being of children, youth, women and poor people more generally.

Figure 9.1 Digital Divide

9.2 URBAN AND RURAL DISPARITIES IN DIGITAL ACCESS

Urban–rural disparities strongly influence digital infrastructure availability and use. Urban centres tend to have substantially better quality and density of fixed-line telecom infrastructure for voice and data. Gaps exist in mobile broadband coverage

too; cities have greater, earlier roll-out of 4G, while its implementation in less densely populated areas, especially in the North-East, has been slow. Moreover, use of telecom services for internet access is limited among both urban and rural users. In urban areas, low broadband subscription costs do not fully translate into affordability for lower-income households. As a result, large segments depend primarily on mobile subscribers for internet services. The rise in mobile broadband usage in rural areas, however, has led to a narrowing of disparities: rural mobile broadband subscriptions per 1,000 persons are now close to 80% of comparable urban levels. This trend is driven by increasing affluence, penetration of low-cost smartphones and improved availability and affordability. Yet, high monthly costs relative to incomes limit the use of mobile broadband for many rural households. Against this backdrop, the effects of digital access on growth and inclusion are of pressing policy concern, given persistent inequalities across many dimensions. More broadly, the impact of digital access on education, employment and income poses a question: Is it simply a by-product of growth or a precondition for sustained inclusive growth? Empirical evidence increasingly suggests that the former is more likely to promote long-term development with rising inequality. Access to the internet during schooling years, for example, is positively associated with college completion, college quality, job search success, employment in higher-wage industries and higher wages. Furthermore, beyond basic internet access, faster-speed connections that enable complete internet usage can promote long-term growth. Evidence by Atal and Das also reveals that increased internet access on both production and demand sides has a positive effect on labour productivity. It is therefore no surprise that countries with a higher proportion of individuals using the internet tend to have greater lending rates and income-per-capita growth rates.

9.3 IMPACT ON EDUCATION, EMPLOYMENT AND INCOME

Digital access has a direct influence on education, employment and income. Students with access to the internet can use online learning materials, attend virtual classes and develop digital skills. Job seekers can search for employment opportunities, prepare applications and access training programs through digital platforms. Workers with

digital skills are also more likely to participate in knowledge-based and higher-income occupations. However, people without reliable internet access or digital skills are often excluded from these opportunities. This exclusion can deepen existing inequalities in education, employment and income. Therefore, digital inclusion is not only a technological issue but also an economic and social development priority. Improved quality and lesser risk of job loss during a recession following strong economic growth support persistent positive effects of better internet access. Employment growth during the past decade has been concentrated in knowledge-intensive sectors and occupations, suggesting that higher digital skills improve the probability of occupying such positions. A sizeable increase in average productivity during the pandemic provides further support for the positive impact of digital skills on worker productivity. Econometric estimates for India establish not only a robust positive correlation between digital access and income, but also evidence of causality. These estimates suggest that the reduction in the rural–urban income gap due to improved digital access has the potential to be a key driver for India's long-term growth. The elasticities relating to money-metric measures are large, indicating that the impact of a temporal reduction in the rural–urban digital access gap on the rural–urban income gap is likely to be persistent. Such persistent reductions in rural–urban income inequality would also be expected to feed back positively into long-term growth.

9.4 GENDER AND SOCIAL INEQUALITIES IN DIGITAL ACCESS

Gender and social inequalities intensify the digital divide. In many developing countries, women and girls have lower access to smartphones, computers, internet connectivity and digital training than men. Social norms, household responsibilities, safety concerns and limited financial independence may further restrict their digital participation. Similarly, marginalized communities, persons with disabilities and low-income households often face barriers related to affordability, accessibility and language. Addressing these inequalities is essential for ensuring that digital transformation benefits all sections of society. Connection gaps remain in most regions of the world, usually concentrated in rural areas where people are older, less

educated and poorer. In addition to gender, other factors such as ethnicity and disability also affect access to and use of Information and Communication Technologies (ICT). While the pandemic accelerated the digitization of various sectors, the accessibility of goods and services associated with this process still raises concerns. Smartphone ownership is not widespread among the poorest, and only half of people from the poorest background used the Internet in 2022, compared to more than 90% of those in the richest segment. These inequalities constitute a significant barrier to digital inclusion. The limited adoption of ICT in emerging economies reinforces existing inequalities and curbs educational opportunities, especially for young women and girls. For young women, the lack of access to a laptop or support from parents limits their chances of participating in online learning and even distance university courses compared to their male peers. Young people from less privileged backgrounds are less likely than their better-off peers to attend university and are at increased risk of dropping out. Nevertheless, policies based on the availability of connectivity and resources, and on courses to strengthen digital skills, boost young women's participation in online learning and reduce the educational gap with young men.

9.5 GOVERNMENT INITIATIVES FOR DIGITAL INCLUSION

Various government policy initiatives aim to address inequalities in digital access. First, there are government policy instruments that explicitly promote digital inclusion. Second, digital inclusion forms a strategic priority in national government agendas. Third, the information and communication technology sector is witnessing a sharp rise in public and private investments in infrastructure and services. Fourth, a variety of digital literacy and skill-building initiatives are being undertaken. Fifth, mechanisms for monitoring, evaluation, and accountability have been developed to foster effective implementation and delivery. Governments employ a range of policy instruments to encourage digital inclusion. Notable approaches include affirmative actions in universal service obligations for telecom providers, provision of subsidised access devices, establishment of mobile phone service networks in remote and inaccessible locations, special discount for public schools, state-funded training and support for

teachers, and expansion of community service centres. Recognising the complex nature of the challenge, authorities seek to converge efforts related to digital access and digital skills, ensure synergy with other educational initiatives, establish partnerships with stakeholders, and create a reliable data framework for policy planning.

- Policy instruments and strategic priorities

A wide array of policy instruments and interventions is available to address the problem of digital exclusion. The government has articulated a strategic priority to achieve universal availability, affordability, and accessibility of digital services. The use of universal service obligations for network rollout in uncovered areas, along with demand-side subsidies for less affluent households and communities, has played an essential role in mitigating urban-rural disparities. Policy initiatives focused on incentives for infrastructure sharing, security, and appointment of an independent regulator have enhanced competition in the mobile segment. Systematic investment in infrastructure to underpin broadband growth has included substantial public investment in fiber deployment as well as directing additional resources toward expanding mobile broadband coverage. Growth in broadband connectivity has been further catalyzed by programs to provide low-cost 4G services in underserved locations. New policy initiatives are also emphasizing universal access to affordable broadband services as a key driver of socio-economic development. Digital literacy and capacity-building programs increasingly constitute key components of policy initiatives hinging on growth in user demand and skills. Initiatives have recast digital literacy programs in schools and higher education institutions, focused on skill development in the training ecosystem and leveraged public-private partnerships to meet the demand-supply mismatch.

9.6 STRATEGIES FOR BRIDGING THE DIGITAL GAP

Wide-ranging strategies are necessary to close the gap in access to digital technology. Klaus Schwab, founder of the World Economic Forum, stated, “The best way to prepare for this revolution is to be a part of it.” The results of the COVID-19 pandemic illustrated the urgency of overcoming lack of access to networks, computers

and software. Professor Glen Ellison of MIT highlights the importance of getting many more people onboard for society's digital economy. Schwab emphasizes the significance of expanding talent pools and increasing women's participation in development. The greatest barriers to employment in developing countries relate not only to lack of education but also to lack of technology, and Ellison identifies the creation of sufficient jobs as the most important issue in these economies. Unions in several places have also played a role, promoting access for women and disadvantaged minorities in societies where computer networks are a source of advancement. Nationwide government programs in the United States, for example, have created low-cost access to computers and the Internet for low-income households. The growing understanding that access to digital technology breeds performative efficiency has resulted in parallel initiatives in several countries, notably initiatives to supply Internet access to all schools. Moreover, to keep pace with expansion, government educators have begun to sense the urgent need for creativity in developing and updating a rich library of learning resources suitable for school-age children and youth.

Bridging the digital divide requires coordinated action from governments, educational institutions, private companies and civil society. The following strategies are important:

1.Expanding broadband and mobile internet infrastructure in rural and remote areas.

2.Providing affordable internet services and low-cost digital devices.

3.Strengthening digital literacy programs for students, workers, women and elderly people.

4.Creating local-language digital content and accessible platforms for persons with disabilities.

5.Supporting schools, colleges and public libraries with internet-enabled devices.

6.Encouraging public–private partnerships for digital inclusion.

7.Ensuring online safety, data privacy and user confidence.

9.7 Chapter summary

The concept of the digital divide refers to the unequal distribution of access to, and effective use of, digital technologies such as the internet, computers, and mobile devices. This divide is shaped by differences in infrastructure availability, affordability, digital literacy, and governance quality. While digital technologies have become central to education, employment, healthcare, and economic participation, large segments of the population remain excluded. As a result, the digital divide has emerged as a key barrier to inclusive growth in the digital economy. Urban–rural disparities are one of the most significant dimensions of the digital divide. Urban areas generally benefit from better digital infrastructure, higher internet speeds, and earlier adoption of advanced technologies such as broadband and 4G services. In contrast, rural and remote regions often face limited connectivity, higher costs, and lower service quality. These infrastructural gaps are further reinforced by income differences and lower digital literacy levels in rural populations, restricting their ability to fully participate in digital platforms and services.

The digital divide has profound implications for education, employment, and income distribution. Limited access to digital tools reduces educational opportunities, especially in online and distance learning environments, and weakens job search efficiency in increasingly digital labor markets. It also restricts access to high-skilled and better-paying employment opportunities, thereby reinforcing income inequality. Gender and social inequalities further intensify these effects, as women, marginalized communities, and low-income groups often face additional barriers to digital access and usage. Governments and policymakers have introduced several initiatives to promote digital inclusion and reduce the digital gap. These include subsidized internet access, distribution of digital devices, expansion of broadband infrastructure, and digital literacy programs. Despite these efforts, significant challenges remain in ensuring equitable access across all population groups. Bridging the digital divide requires a combination of infrastructure development, affordable connectivity, skill

enhancement, and targeted policy interventions aimed at ensuring that digital transformation leads to inclusive and sustainable growth.

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CHAPTER 10

REGULATORY FRAMEWORKS AND DIGITAL GOVERNANCE

The digital economy is shaped by emerging technologies such as artificial intelligence, blockchain, cloud computing, autonomous systems and digital platforms. These technologies create new opportunities for innovation, trade and economic growth. At the same time, they raise concerns related to privacy, cybersecurity, consumer protection, competition, data ownership and ethical use. Digital regulation refers to the laws, policies, standards and guidelines that govern digital activities. Digital governance is broader and includes the role of governments, international organizations, private companies and civil society in shaping the rules of the digital environment. A strong regulatory framework is necessary to build trust, protect users, promote fair competition and support responsible innovation in the digital economy. The primary actors include states, which establish public governance frameworks, and international organizations, which create rules and principles. The regulatory framework involves the use of policy instruments—laws, standards and guidelines—for the achievement of specific goals. A well-functioning regulatory framework is essential for a digital economy to support market integrity, provide sufficient protection for consumers, promote competition and stimulate innovation. In general, the core principles of regulation include fairness and justice, social and economic welfare, sustainability and simplicity. Although regulation entails costs for society and possibly introduces obstacles to competition and innovation, adequate regulatory methodologies can build a foundation for the digital economy. Applying the principles and objectives of regulation to the digital economy highlights the reasons why regulation is crucial for its functioning. Specifically, the features of the digital market indicate the need for regulation in various sectors.

10.1 IMPORTANCE OF DIGITAL REGULATION

Regulation of the digital sector is fundamental for its functioning and development. A range of market failures mean that unregulated markets are unlikely to deliver the best outcomes for consumers or society as a whole, justifying efforts to make markets work better. Well-designed regulation can also enhance competition by setting the ground rules fairly for all market participants, including large incumbents and newer, smaller entrants. Well-designed regulation helps digital markets function fairly. It protects consumers, prevents misuse of data, reduces cyber risks and encourages competition. At the same time, regulation should not be so strict that it discourages innovation or prevents new firms from entering the market. Therefore, digital regulation must be risk-based, proportionate and flexible. Research and experience show that taking consumers' interests seriously and protecting their rights leads to better outcomes, including driving increased innovation by helping build and maintain consumer confidence in a digital economy. Similarly, although increased automation and greater interconnectivity present new risks, it has never been more important for innovation still to proliferate, for resources to be invested productively and for firms to be viable. Achieving these objectives requires striking the right balance between fostering innovation and ensuring consumers are protected and their rights respected. Various high-level principles guide digital market regulation: regulation should be risk-based, proportionate, unintrusive and targeted only at cases where action is needed; regulation should mitigate risks and foster innovation in such a way that resources for investment and innovative opportunities for new, smaller market entrants are not harmed; regulation should, above all, focus on ensuring that smaller and newer entrants can compete fairly with existing market participants while still allowing such participants the means to recover their investments and innovate. Not all regulatory interventions addressing these goals will apply in all digital markets.

10.2 DATA PROTECTION AND PRIVACY LAWS

Data protection and privacy laws regulate how personal data is collected, processed, stored, shared and deleted. These laws are usually based on key principles such as consent, purpose limitation, transparency, proportionality and accountability. They

also provide individuals with rights such as access to their data, correction of inaccurate data, deletion of data and objection to certain forms of processing. However, implementing privacy laws is complex. Businesses must balance the need to use data for innovation and service delivery with the responsibility to protect individuals' privacy. Cross-border data transfers create additional challenges because countries may follow different privacy standards and enforcement mechanisms. This is particularly the case in regulatory models that are broadly similar to the General Data Protection Regulation of the European Union (EU) and that have been adopted or are in the process of being implemented in other jurisdictions. The effectiveness of these frameworks in achieving their goals, especially in view of the associated compliance burden, is a valid concern for policy-makers and industry alike. Moreover, there are different routes for the cross-border transfer of personal data, each with its merits and shortcomings. Though these routes are often seen as equivalent, one also has to consider the different protective levels for privacy in the relevant jurisdictions, the legality of implementing the considered approach and the actual uptake. The enforcement mechanisms available under data protection frameworks, including sanctions, are of course also indispensable to the actual realization of the aforementioned principles. Only a handful of jurisdictions have imposed truly significant sanctions for GDPR infringement; hence these penalties cannot yet be seen as an important driver for compliance. Nevertheless, they remain a relevant concern for businesses and serve as a clear reminder to national regulators that deterrent sanctions can be imposed when warranted. International police cooperation in the field of data protection has also received attention in the context of enforcement and the fight against criminality. Cross-border transfers of personal data are a vital component of today's global economy, and companies have to be able to rely on the agreements in place if they want to seize business opportunities in the respective markets. Data protection frameworks induce costs for businesses and otherwise affect operations, and some jurisdictions have even considered the sheer volume of requests for expressing interest in a Privacy Shield-like agreement.

10.3 CYBERSECURITY POLICIES AND FRAMEWORKS

Cybersecurity policies define the structure, controls, and governance required to mitigate the risk of cyber threats and are integral to overall risk management, being emphasized by developments in digital regulation, including the EU Cyber Resilience Act and Data Security Act. The GDPR explicitly mandates that data processors and controllers implement appropriate technical and organizational measures to ensure the security of data processing. E-commerce, banking, and other sector-specific legislation introduce additional security requirements, while companies in sectors critical to EU economies must apply security measures in compliance with the NIS Directive. Cybersecurity has assumed a highly propulsive regulatory role, with policy frameworks mandating layered and risk-based mitigation of cyber threats, thereby implementing the now-prevalent concept of defence-in-depth across a myriad of diverse sectors.

The core concepts that underpin a cybersecurity policy framework include:

1. Risk Management: Organizations must adopt a risk management methodology centered on prevention and preparation. Such analysis must incorporate threat intelligence and it would be prudent for organizations to seek outside expertise that has experience in conducting similar assessments for organizations of a similar size and complexity.

2. Defense-in-Depth: Security Controls must be deployed in layers to provide redundancy and protection against a variety of threats. Protecting against every possible threat with a single control layer is impractical, and any such controls that are deployed must be expected to fail at some point. Therefore that failure must not compromise the confidentiality, integrity or availability of systems, data or the organization as a whole.

3. Incident Response: Organizations should have a documented process for the management of detected security incidents and must test that process at least once a year (or more frequently, based on risk assessment and threat intelligence).

4. Recovery Planning: Organizations must adopt a plan for the restoration of systems and services that are compromised by a successful incident.

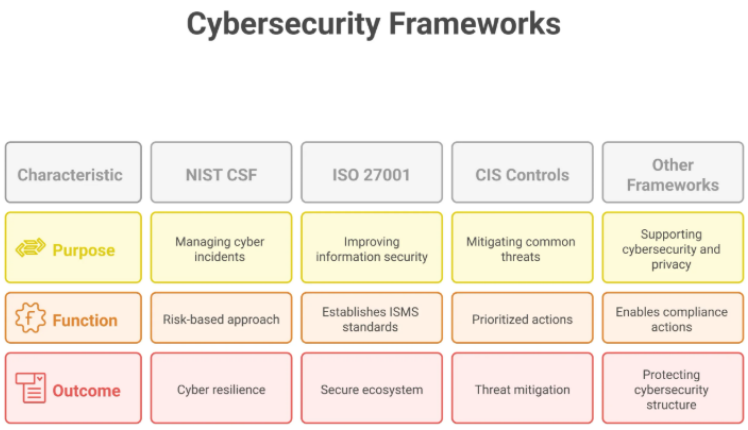

Figure 10.1 cybersecurity frameworks

10.4 ROLE OF GOVERNMENTS AND INTERNATIONAL BODIES

Within nation-states, the primary role of digital regulation lies with governments, which retain the sovereign power to legislate, issue executive orders and develop national policies and frameworks in consultation with relevant stakeholders. While the trend towards digital sovereignty has witnessed regulatory fragmentation and the imposition of conflicting rules, an understanding of the economic and technological rationale for harmonized regulation is growing. Digital services regulations, for instance, aim to increase diverse-content availability and user safety; when designed carefully and with appropriate safeguards, they can facilitate trade by reducing trust frictions. Global companies advocate regulatory convergence to minimize compliance costs; regulators also express support for mutual recognition, given that fundamental principles of privacy protection and security are increasingly shared. Regulatory convergence mitigates conflicts of laws, eases compliance costs and promotes consumer welfare. International organizations—such as the United Nations, the Organisation for Economic Co-operation and Development (OECD), the World Trade Organization (WTO), regional blocs (e.g., the European Union, the Association of Southeast Asian Nations), and the G20—play key roles in establishing norms, recommending guidelines and facilitating international cooperation for effective

global governance. Capacity building, the provision of aid and technology transfer increase the ability of developing and least developed countries to regulate effectively.

Diverse regional and multilateral cooperation initiatives address cybersecurity across the full cycle from strategy and policy through capacity development to resource-sharing. Nevertheless, underinvestment remains a concern, especially in least developed countries. Although private-sector participation is crucial, direct government involvement in emergency preparedness and recovery activities is essential for critical infrastructure resiliency.

10.5 CHALLENGES IN GLOBAL DIGITAL GOVERNANCE

Global digital governance faces several challenges. Digital technologies develop faster than legal systems, making it difficult for governments to respond quickly. Countries also differ in their approaches to privacy, cybersecurity, data flows, competition and online content. These differences create regulatory fragmentation and increase compliance costs for businesses operating internationally. Another challenge is the tension between national sovereignty and the global nature of the internet. Data, digital services and online platforms often cross borders, but laws are usually enforced within national territories. Therefore, international cooperation is necessary to address cybercrime, data protection, misinformation, digital taxation and platform accountability. The process of developing digital regulation and governance calls for an appraisal of the prevailing regulatory regimes and how adequately they protect society's bordering interests. Of increasing concern is whether the rapidly growing digital environment can be adequately governed, not only to prevent a crisis of domestic but also international consequence but also to facilitate protection in the face of rapid technological evolution. Anomalies in existing paradigms (particularly those developed within national jurisdictions) seem self-evident, especially when distinguished from a bottom-up approach in which risk itself drives regulation. Instead, a top-down analysis highlights four aspects of the governance of the digital realm from which specific governance decisions flow: the need for a strict division between national security objections and infringement of civil liberties; the dangers posed by coercively derived information and supply chains; the still-nascent but fast-developing

governance of emerging technologies like artificial intelligence, edge-computing and the Internet of Things; and the cross-border flow of digital information, especially related to privacy. Even where there is international recognition of such issues, regulation and enforcement remain frustrated by the respective dynamics of globalization and national sovereignty. The Internet serves as a particularly potent example of such divergence. On the one hand, many—perhaps most—users perceive it as a sanctuary for unfettered, often unregulated and sometimes illegal or dangerous speech. At the same time, national governments and their agencies are equally cognizant of the Internet's potential for advancing domestic security, with many focusing on both the data privacy of their citizens and on the potential for data manipulation across jurisdictional boundaries; some have begun to attempt to coerce compliance with national legislation with sanctions attached to the use of domestic markets.

10.6 BALANCING INNOVATION AND REGULATION

An optimal approach aligns regulation with underlying risks and acknowledges desired outcomes and governance levels. The principles of proportionality, subsidiarity and evidence-based policymaking thus serve as valuable touchstones for the design of effective regulatory frameworks. A proportionality-based approach analyzes the risk being mitigated, the cost of the proposed regulation and the risk of under-regulation as well as that of over-regulation. An equally considered application of a subsidiarity-based approach foresees layers of governance responding at the level best suited to do so. Finally, an evidence-based policymaking stance requires solid data to determine the right response, where the ex-ante expectation and ex-post evaluation of a regime is based on the best empirical evidence available at the time. Regulatory sandboxes allow regulators to adapt their approaches more quickly, adaptive regulatory regimes are targeted at fast-moving technologies and sunset clauses form part of the attempted earlier responses to the ascendant tech giants and potential anti-competitive consolidation in digital markets. However, the strictures of the broader context must continue to be acknowledged. In addition, while such approaches may enhance relative competitiveness and attractiveness in the near term,

attracting business at the expense of other jurisdictions may ultimately be a zero-sum game. International political consideration must therefore explicitly seek to prevent regulatory divergence while also recognizing the necessity for accommodating local variation.

10.7 Chapter summary

Digital regulation forms the backbone of a secure, trustworthy, and well-functioning digital economy. It establishes the rules, laws, and governance mechanisms required to manage emerging technologies, digital markets, and online services. Effective regulation ensures market integrity, protects consumers, promotes competition, and encourages innovation. At the same time, it must remain flexible enough to accommodate rapid technological change while maintaining fairness, transparency, and accountability across digital ecosystems. A major component of digital governance is the development of data protection and privacy laws, which define how personal and organizational data is collected, processed, stored, and shared. These frameworks emphasize key principles such as consent, purpose limitation, transparency, and user rights including access, correction, and deletion of data. Alongside privacy regulations, cybersecurity policies and frameworks play a critical role in safeguarding digital infrastructure, ensuring resilience against cyber threats, and maintaining the confidentiality, integrity, and availability of data systems.

Governments are central actors in shaping digital regulation through legislation, national policies, and enforcement mechanisms, while international organizations such as the UN, OECD, WTO, and regional blocs support cooperation, standard-setting, and policy alignment. However, global digital governance faces significant challenges due to regulatory fragmentation, conflicting national interests, and rapidly evolving technologies. Issues such as cross-border data flows, jurisdictional disputes, and inconsistent compliance requirements complicate coordinated governance efforts. Balancing innovation with regulation remains a key policy challenge in the digital era. Over-regulation may hinder technological progress and competitiveness, while under-regulation can expose societies to risks related to privacy breaches, cybersecurity threats, and market monopolization. Therefore, effective digital governance requires a

balanced, risk-based, and evidence-driven approach that supports innovation while ensuring protection, inclusivity, and long-term sustainability in the global digital economy.

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CHAPTER 11

SUSTAINABILITY AND GREEN DIGITAL ECONOMY

Digital technologies play an important role in promoting sustainable economic development. They support efficient resource use, environmental monitoring, smart infrastructure, renewable energy management and climate-related decision-making. At the same time, digital technologies also create environmental concerns through energy consumption, greenhouse gas emissions, electronic waste and the use of scarce materials in hardware production. The green digital economy focuses on using digital technologies in ways that support environmental sustainability while reducing their negative ecological impact. It seeks to balance technological innovation, economic growth and responsible resource use. Therefore, countries must adopt policies that encourage energy-efficient digital infrastructure, green computing, circular economy practices and sustainable digital innovation. These two opposing views lead to a discussion of how digital technologies can best contribute to sustainable economic development. The role of digital technologies in a green growth strategy is development-oriented, emphasizing the economic and social benefits associated with the adoption of such technologies in developing countries. The discussion focuses on three main aspects: how the digital economy can improve the performance of traditional sectors in a more resource-efficient, cleaner and lower-carbon economy; digital innovation for sustainable development; and how policies toward a green digital economy can help countries pursue the dual objectives of reducing the consumption of natural resources while sustaining long-term economic growth.

11.1 ENVIRONMENTAL IMPACT OF DIGITAL TECHNOLOGIES

Digital technologies depend on physical infrastructure such as computers, smartphones, servers, data centres, networks, satellites and electronic components.

Their environmental impact occurs throughout the life cycle, from raw material extraction and manufacturing to use, maintenance and disposal. Electronic waste, greenhouse gas emissions and the use of rare earth materials are major concerns. Therefore, digital sustainability must consider both the operation of digital systems and the environmental cost of producing and disposing of digital devices. Physical substrates of digital technologies include end-user devices and the infrastructures that enable service delivery, comprising data centers, fixed-wireless and mobile networks, satellites and the embedded carbon in software. Hardware manufacture and disposal incur the greatest environmental impact, especially greenhouse gas emissions, electronic waste and resource use. Two-thirds of predictions for future growth in the digital economy's overall footprint concern production and decommissioning and are therefore related to the materials and energy embodied in computing products rather than their direct operation. Research uncertainty about this connection is growing, drawing attention to the environmental consequence of scarce and toxic resources such as rare earth elements. The impact associated with the operation of devices, transmission of signals and overall use of the technology portfolio, although smaller and declining, remains significant. All the life-cycle assessments point to the relatively small share of the energy consumption of the growing use of digital technologies, especially the internet, relative to conventional fossil-fuel burning activities such as coal-based generation. Nevertheless, it is still significant on a global scale. The operation of digital technologies requires energy, and the supply of data entails an ever-growing share of electricity in all producing countries. This technology share in energy consumption is rising with increases in energy intensity, especially with an increase in relative energy use of data centers. This higher energy intensity of computing cannot be matched by the current efficiency gains. A growing share of the global energy supply of carbon-free sources can therefore address this increase in the absolute energy use of digital systems.

11.2 ENERGY CONSUMPTION OF DATA CENTERS

Data centers belong to a critical branch of the ICT ecosystem, supporting a vast range of digital services. They account for about 1% of worldwide electricity use, yet

demand may rise to 3% by 2030. Energy intensity is comparatively high, and efficiency remains an issue of both economic and environmental concern. Data-center operation involves energy-consuming hardware and management processes that determine the ratio of energy consumption to user load, as well as the demand for cooling. The computing load can be highly variable but is generally increasing, and overflow or peak demand for the electricity grid is often severe. A significant share of data-center energy is consumed by older, less efficient hardware. Deployments that stress response times reduce energy efficiency per unit data output. The fastest systems must process back-up loads quickly when input surges, remain hot in order to hold the least ready-time, and have dedicated circuits supplying peak sector demand. A further problem for efficient operation lies in the cooling system. An internal temperature differential above minimal levels cannot be tolerated by most computer hardware, and hence cooling energy often dominates total data center energy consumption. Achieving full cooling efficiency is problematic, and chiller systems that waste energy by maintaining unnecessarily low coolant temperatures continue to be common. Improved management practices and PUE technologies enable considerable efficiency gains using standard chilled-water cooling systems.

11.3 GREEN COMPUTING PRACTICES

Green computing refers to the design, use and disposal of digital technologies in an environmentally responsible manner. It includes energy-efficient hardware, optimized software, virtualization, cloud resource optimization, low-power devices, responsible e-waste recycling and the use of renewable energy in data centres. Green computing can reduce electricity consumption, lower carbon emissions and extend the life cycle of digital devices. Green computing refers to the energy-efficient design, manufacture, operation and disposal of computers, peripherals and supporting systems. Principles emphasize energy efficiency throughout the complete computing lifecycle. Techniques that directly reduce energy consumption during system operation include selecting, deploying and configuring energy-efficient hardware; optimizing software code; and using resource schedulers to control execution on multiprocessors. Important strategies include efficient algorithm design, software virtualization and

low-power operation of peripherals such as displays, disk drives and network interfaces. Power consumption can also be reduced using low-power modes, networked peripheral management and low-power operating systems. Other approaches focus on energy-efficient operation of key computing systems, especially data centers. Best-practice guidelines address the design and operation of data centers; benchmark standards such as Power Usage Effectiveness (PUE) and Data Center Infrastructure Efficiency (DCiE) quantify efficiency. The next layer above computing devices is the data center. Data centers are consolidation points that house large numbers of servers, storage systems and networking devices. Best-practice design principles enhance data center efficiency: proper cooling to minimize the energy overhead, virtualization to reduce the number of physical servers required, modular construction for low-capital overhead, reuse of surplus energy and a debate about the relative merits of liquid versus air cooling.

- Energy-Efficient Computing

Energy-efficient computing encompasses practices and strategies that help minimize power demand without compromising on service quality. The three main approaches—systemwide hardware choices, software optimizations and operating-system mechanisms—have different organizational scales, scopes and methods of achieving low power consumption. The guiding principle of green computing is to maximize energy efficiency, and various benchmark standards assess equipment and management efficiency. In data centers, the design of cooling systems, building form, virtualization and consolidation ratios, modularity, energy reuse, operating temperatures and liquid cooling setups affect power usage. The Power Usage Effectiveness (PUE) and Data Center Infrastructure Efficiency (DCiE) ratios quantify and evaluate the efficacy of data-center energy-resource utilization. A growing number of products are designed to use less energy. At the level of hardware components, the major suppliers proffer multi-core processors that split workloads across several execution units, thus reducing chip-level switching power. On the software side, code profiling and optimization, workload scheduling, virtualization overhead and greedy-service-development practices help reduce the computation and

memory footprint of applications. From the perspective of operating systems, taking advantage of sleep modes minimizes energy usage for idle devices.

- Sustainable Data Center Design

Electricity generation and consumption account for significant portions of global greenhouse gas emissions. Data centers are among the most power-hungry infrastructures, consuming as much as 3% of global electricity with PUE values greater than 2.5. As such, they present an attractive target for energy conservation initiatives, and the following design principles address major consumption categories.

Cooling is by far the largest contributor to data center electricity use. Vereinigte Staaten government studies have shown that raising operating temperature and humidity levels by a few degrees significantly reduces cooling demand. Several other options exist for lowering cooling loads. Virtualization lessens the amount of equipment in service and allows more efficient use of cooling sources. Consolidation in larger data centers enables free cooling techniques, using outside air directly or indirect water-side economizers to reduce chiller loads. Modular designs and energy reuse utilize large infrastructure loads to reduce cooling needs. Liquid cooling can also lower cooling costs compared to conventional air cooling, though the relative simplicity and safety of air tend to favour its use. Once cooling loads have been minimized, the equipment itself represents the next logical target. Cooling loads typically dominate for low-utilization data centers, and deployment of virtualization and free cooling techniques permits cost-effective provision of high-utilization centres with minimal cold-aisle control, raised floors or even hot-aisle containment. In such installations, the RC, DCiE and PUE values of the operating facility may provide excellent benchmarks for the selection of server components. While the idle load of servers remains as much as 70% of their maximum load during production use, operating systems have only spawned network login and file access programs at time intervals of many minutes or even hours; strategies to shut down computation and control servers when not in actual use would thus seem advantageous. The core objective of low-power software is to minimize the overall external power drawn by the system while satisfying the requirements of the application users.

- E-Waste Reduction and Responsible Lifecycle

E-waste generation has reached alarming levels and is expected to exceed 100 million metric tonnes annually by 2025. A triangular approach is needed to reduce its volume: stopping its accumulation by avoiding obsolescence, extending collection for recycling and recycling effectively. Industry support for take-back schemes has grown, but challenges remain in hazardous materials stewardship and in ensuring that the economic gains from e-waste recycling are shared with stakeholders at the bottom of the pyramid. Lifecycle stewardship offers another approach and can engage consumers, but policy initiatives may also be necessary. Digital technologies can provide support in these areas. E-waste consists of discarded consumer and professional appliances and, increasingly, of entire ICT systems. It has been defined by the United Nations Environment Programme (UNEP) "as one of the fastest growing waste streams ... with ever-larger quantities and ever-shorter lifetimes." A combination of demand-side and supply-side initiatives is needed to reduce the generation of e-waste. Demand-side initiatives focus on the minimization of hazardous materials used in the manufacture of electronic devices and the design of easy-to-repair and recyclable devices. Manufacturers should also adopt circularity principles, including design for refurbishment, remanufacture, disassembly and upgradability. Supply-side initiatives focus on improved collection and recycling approaches. The recent growth in take-back schemes offered by producers is commendable but needs to be directed toward emerging economies and communities at the bottom of the pyramid, where the economic incentives for e-waste collection and recycling are underdeveloped.

- Software Efficiency and Resource Optimization

Optimal software development is key to delivering performance-proportional services while minimizing the underlying resource consumption. Development practices that utilize efficient algorithms and programming paradigms, such as low- and high-level parallelism, are essential to reducing the compute and memory footprints. Optimization techniques should cover all software components, including middleware and network services, while addressing issues such as mismanagement of resources

that amplify the overhead of virtualization. Cloud management systems should include functionality to efficiently allocate and release resources. Finally, to minimize the input-output and ransomware impacts, embrace the trade-offs of lean coding practices, which promote short and efficient development. With the growing reliance on cloud services, the demand for service scalability has induced large data clouds composed of the physical infrastructures of multiple service providers. But the on-demand nature of cloud computing and the bursty traffic inherent in most services make effective resource provisioning a tough challenge. Because over-provisioning leads to resource under-utilization and waste, the resource scheduling employed by a cloud management system can significantly influence the energy consumed by a cloud; yet little attention has been paid to the overhead introduced by this additional layer. Although recent techniques for deploying virtual machine instances on a data cloud, as opposed to reserving individual hosts, can significantly reduce energy consumption, the scheduling algorithms and the order of deployment remain crucial for minimizing total energy consumption.

11.4 ROLE OF DIGITAL TOOLS IN SUSTAINABLE DEVELOPMENT

Digital tools are powerful enablers of sustainable development. Through platforms for environmental data collection and monitoring, digital twins of natural systems and open data portals, digital technologies support applications in resource management, climate service enhancement and preparation for extreme events. Addressing data quality, interoperability and usability is essential for realizing these benefits. Digital tools also help bridge the digital divide. While there is a risk that widening inequalities could accompany digital transformation, adoption strategies that support digital inclusion, affordability and accessibility can secure equitable outcomes. The development of sustainable digital solutions is further accelerated by collaboration among the public and private sectors as well as innovation communities. These dynamics support the creation of an enabling environment for sustainable growth in digital technologies and services. For resource management, it is important to establish decision-support systems that leverage real-time or near-real-time data to underpin efficient operations. Such systems can take different shapes depending on

the domain of application and may include, for example, predictive maintenance dashboards for industrial systems; demand forecasting and supply chain management tools for addressing bottlenecks; or dashboards for monitoring at-risk populations and predicting future displacements linked to climatic events. Resource-oriented decision support is further enhanced by scenario analysis informed by digital twins of the physical system being managed or past data that quantitatively explore the trade-offs associated with different intervention strategies.

- Digital Platforms for Environmental Monitoring

Digital platforms enable resource efficiency and climate mitigation by supporting environmental monitoring, modeling and management. Geo-spatial and crowd-sourced data, environmental sensors and simulation models are assembled in distributed, interoperable frameworks that drive data-driven decision making. Their widespread adoption remains contingent on addressing data quality and interoperability as well as ensuring cost-effective visualization and insight generation. Environmental monitoring and modeling are central to effective resource management. Decision makers must possess a thorough understanding of the current state and associated trends to allocate resources efficiently and pinpoint hotspots of progress or concern. Monitoring, modeling and visualization are rarely packaged together within a single platform; digital twins require extensive investment and are typically organized around specific sectors. A comprehensive system spans several sectors and scales, integrating simulation models, real-time sensor networks, local knowledge bases and citizen science observations, with a focus on data quality and gap-filling.

Figure 11.1 Digital Tools in Sustainable Development

➢ Data-Driven Decision Making for Resource Management

Data-driven decision making encompasses all major aspects of resource management. It should integrate models that capture resource interdependencies, dashboards that present essential indicators, predictive analytics that identify risk and service level abrogation likelihood and scenario analysis that inform corporate, regional and national transformation pathways. Such tools provide means to incorporate forecasts of future demand into resource management thus enabling preemptive action to avoid service level disruption. Consequently, their design and deployment, mainstreaming, scaling-up and affordability are crucial issues. Having models that capture resource interdependencies is essential for data-driven decision making. Such models can take many forms—from simple relationships to complex simulations based on physics or operations research—but shared representations linking various resources on a common platform or data portal offer the most comprehensive view and enable complex analysis. Interdependencies matter because service level disruption in one resource can have cascading effects on others, typically exacerbated by increasing exposure to natural hazards. For instance, water supply disruption can impair energy generation (hydropower, thermoelectric) and food production (irrigation, cooling), while energy supply disruption can impair communication networks and key services (e.g. hospitals, transport). Dashboards that provide key indicators for decision makers

address the urgent need to cut through the barrage of data available and focus on what matters. They support decision making at various levels, from local to national to corporate, and at various time scales—monitoring of service level and risk status, campaign management, triggering of crisis-mode actions and performance assessment. Predictive analytics extend the horizons of decision making and offer the tantalising prospect of enabling avoidance of supply disruption. Use of forecasted demand also matters since resource provision capacity typically adjusts only over the long term, whereas demand needs to be managed proactively. Such integration can improve risk mitigation but is rarely done at present. Data-driven decision making should incorporate regulatory aspects rather than solely focusing on resources for which robust management models exist. Such models are often complex, data intensive, costly to develop and subject to scepticism. Consequently, regulation can also help stimulate an appropriate resource management response such as ensuring diversity of suppliers for critical components or services. Such strategic aspects, however, typically require more long-term planning and consideration of a broader set of decision variables than is possible with either operational or tactical management.

- Digital Inclusion and Equitable Access

The democratization of technology is a hallmark of the digital economy, yet access barriers and inequities remain substantial worldwide. Digital technologies serve as important enablers of sustainability; however, the costs associated with deploying these technologies as well as the costs of using and operating them remain significant across many societies. Affordability, universal access to digital network services and digital literacy are critically important for maximizing the potential for sustainable impacts across sectors of the economy. Therefore, the inclusion of all groups in society in relation to the development and deployment of digital technology and services must be a priority throughout their lifecycle. If access to digital technologies focuses predominantly on those who can afford them and who gain a competitive advantage in using them, the efforts of their development and deployment may serve to exacerbate social and economic inequities. The broader social and economic inequities present in society can also influence how digital technologies and resources

are deployed and used, how access to them is obtained and by whom, and the impact that their use has on society and the environment. Investments in digital technologies by the private sector are driven by the expected returns on investment and serve their interests—that is, pursuing high profit margins on proprietary software, producing mobile phones with short lifespans and leaving the risks associated with the use of technology to the user. Such responses may not expand markets, particularly where economic conditions are weak, but rather only bring about the refurbishment of existing technologies and their transfer to lower-income user groups. Consequently, the sustainable use of digital technology resources by such groups may only be of secondary consideration for their private providers. Public policy plays a key role in establishing and sustaining an appropriate ecosystem of incentives and demand patterns to secure broader inclusion of developing countries and disadvantaged sections of society in the digital economy and to enable the sustainable use of digital technologies.

- Innovation Ecosystems for Sustainable Outcomes

Sustainable innovation outcomes in any economy result from the strengths of diverse actors and their resources interconnected into desirable structures and processes. The product–service systems discussed earlier enable ecosystem innovations; the emphasis here is on public–private partnerships for sustainable outcomes and open innovation mechanisms that harness heterogeneous assets. Public agencies can initiate and lead pilot projects and provide resources to lower risk for market and technology-development investments by the private sector. Consumers, firms and municipalities are developing and operating sensing networks for a variety of environment-monitoring and improvement tasks. Data from these deployed and dedicated sensors complement remotely sensed data of varying fidelity and spatial and temporal resolutions. Open data portals facilitate the assimilation of disparate environmental-data sources and their effective use by various stakeholders. The quality of the incoming data, tools to visualize these multidimensional data sources and the incorporation of citizen-science data remain challenges for the further development of

information and decision-support systems, yet they also present substantial opportunities.

11.5 CIRCULAR ECONOMY AND DIGITAL INNOVATION

Digital tools can support the circular economy by improving product design, tracking materials, supporting reuse and recycling and enabling sharing platforms. Modular design, standardized components and upgradable products can reduce waste and extend product life. Platforms for sharing and collaborative consumption, such as car-sharing and equipment-sharing services, can also increase the use of existing resources and reduce unnecessary production. Digital innovation enables new circular modes of production and consumption by promoting product-as-a-service and other service-based business models, by facilitating remanufacturing, repair, refurbishment and recycling through resource tracing and re-acquiring technologies, and by providing a technology infrastructure for new sharing and collaborative consumption platforms. The ability to pay per use or share a product rather than own it is often the most effective way to minimize its material footprints. If an item can replace many others—cars, drills and packaging are common examples—conventional ownership models viscerally consume an order of magnitude more materials than necessary. Nevertheless, business models offering product-as-a-service or other sharing or collaborative consumption models have so far only been widely adopted for relatively high-utility items that are expensive to buy but cheap to maintain and have short periods of unused downtime. Most people still own the clothing, furniture and kitchenware they use for only a small fraction of their lifespan, and most business-to-business capital goods are still rented only infrequently relative to their lifespan. For many low-cost high-volume products enabling new consumption models can be expected to yield no direct reduction in overall material demand. The concept of product-as-a-service therefore entails only partial ownership, encompassing long-term leasing arrangements with the manufacturer responsible for maintenance and support or trade-in agreements. The other key element is durable design: in categories such as sport shoes and heavy clothing where durability and reparability are strongly inversely correlated with assiduity of care, the productivity gains from a PaaS model can be

undermined by purchases by large leasees who make the swap for aesthetics and have very little need for the functionality.

- Product as a Service and Longevity

Products designed with longevity in mind and placed into products-as-a-service (PaaS) or service-oriented models have the potential to reduce materials throughput and waste creation associated with new production. Businesses can access products in a PaaS model without having to purchase, finance or manage them. Bundling products with services creates ownership shifts in favor of suppliers along with incentives for longer product life, improved maintenance management and upgrading during use. Product offerings based on product-as-a-service principles can create new business opportunities and better align economics with sustainability goals. Service-oriented models that have been announced include Walt Disney's 100-year rental of custom-manufactured and maintained costumes for local productions, Hitachi Rail's leasing of urban transit trains that it owns and maintains, digital items sold as licenses rather than ownership by streaming providers, and automotive subscription services. Virtual products (like software) are naturally PaaS offerings where consumption and reproduction can occur at near-incremental cost without material burden. Nevertheless, PaaS offerings must be scrutinized to ensure that they foster positive environmental performance. One possibility is that PaaS could displace thin ownership during use (for example, moving from ownership to timesharing when not in use) but that limited-time rentals could drive more intense usage that drives higher throughput (for example, a camera rental service). Another is the potential for repeated short-term rents to generate the same footprint as ownership.

- Resource Recovery and Reuse through Digital Technologies

Digital technologies are critical for planning and execution of resource recovery and reuse, from waste stream and value recovery analysis via recycling technologies to material tracing for assurance. Digital twins and item-level traceability tools facilitate recovery at end-of-product life. Technology advancements provide cost-effective, efficient and sustainable approaches for unmanned recovery from readily accessible waste streams. Digital platform ecosystems provide a comprehensive solution to

facilitate the recovery and reuse of decommissioned products beyond products and road exhausts. Each platform's traceability database is integrated at the core of operation to enable advanced analysis on resource demand-supply matching, cost-benefit evaluation on resource recovery, evaluation of recycling technology options, automated sourcing coordination for resource recovery and monitoring of accessibility toward achieving a net-zero objective. The platform facilitates recycling in unattended mode and provides an efficient information-connection point to enable a wide range of handling approaches (including central handling by dedicated recyclers, decentralized handling by volunteer organizations, and community-and-individual-led mobilization). Data-driven optimized strategies on unused and abandoned retirement are comprehensively integrated into a digital platform ecosystem to reduce both capital cost and environmental impact during the establishment of road infrastructure lifecycle. AI-enabled exploration and positioning of land mines, active digital accelerator monitors of human activities, and unmanned testing and recovery of abandoned and unused resources via drones and robots, robotics-assisted modulization of land mine testing and resource recovery, and unmanned restoration of prohibited area environment during land mine test-exploitation stage-oriented digital platform ecosystem represent a systematic solution enabled by digital technology and paradigm-shifted design.

- Design for Remanufacturability and Upgradability

Digital technologies support the transition to a circular economy by enabling collaborative platforms, resource recovery solutions, product-as-a-service strategies, service-oriented models, and design for remanufacturability and upgradability. Concerning the latter aspect, remanufacturing is defined as a process that restores a product to its factory specifications or better, thus expanding the product lifecycle. Durability, support for reception and reconstruction, and disassembly capability are key factors that facilitate remanufacturing. Meanwhile, upgrading permits product enhancement without full replacement and maintains market value post-upgrade. Digital design tools can underpin both remanufacturability and upgradability by enabling modular architecture, standardized interfaces, and the use of separable

components that will in turn facilitate reuse in future generations. Product design is fundamental to implementing a circular economy; thus, addressing the reusability, recyclability and upgradability of products is crucial. Policy schemes and regulatory frameworks increasingly emphasize these aspects, and consumers assign material value to remanufactured or refurbished items. The effective design of a remanufacturable product must consider not only remanufacturing costs, cycle time and quality but also the remanufacturing volume and the corresponding production and selling prices of new and remanufactured products. Consequently, it is important to optimize the design for remanufacturability during the product development stage.

- Platforms for Sharing and Collaborative Consumption

Shared-use platforms have gained considerable traction because they allow greater utilization of the same physical objects, leading to reduced material throughput as well as reduced waste generation. Some well-known examples include systems for car-sharing and bike-sharing, but the potential of such solutions extends much further. The sharing of goods such as power drills, consumer appliances, camping equipment or even clothes is often not only more convenient for consumers but may also be more cost-effective, provided that necessary alignments in maintenance timing and intermediary services throughout the usage cycle can be organized. Nonetheless, supporting and building trust in sharing relationships can involve considerable social costs and sometimes even adaptation of operators to allow platform licensing and usage for non-business goals. Designing platforms that support collaborative consumption can also be more complex than merely designing sharing systems, as they must enable cooperation among groups of users with sufficiently similar needs, working schedules and geographic proximity. Such collaborative solutions can include, for instance, the joint acquisition of different undesired items and the joint provision of services such as cleaning or home care, often facilitated through highly localized networks supported by social media.

11.6 POLICIES FOR SUSTAINABLE DIGITAL GROWTH

Policies for sustainable digital growth should encourage green investment, energy efficiency, responsible e-waste management and sustainable innovation. Governments

can use standards, tax credits, grants, subsidies, certification schemes and public–private partnerships to support green digital transformation. Regulations should be transparent and predictable so that businesses, especially small and medium enterprises, can comply without excessive cost. Environment-related requirements may also include international, supranational and national standards, certification schemes and compliance procedures adopted under sector-specific legislation such as EUTR Recital. Regulatory compliance costs are particularly relevant for small and medium-sized enterprises with limited resources for bearing compliance burdens.

- Regulatory Frameworks and Standards

The demand for sustainable digital solutions is accompanied by calls for green digital regulations, standards, compliance requirements and certification schemes. Harmonizing cross-border policy implementation enables greater protection against green digital market fragmentation and the development of a level playing field. The introduction of minimum requirements and standards for products and services relevant to the digital economy is an essential part of any pathway toward sustainable digital transformation. Even before the COVID-19 pandemic, private investments in green digital solutions were lagging behind public funding. A supporting regulatory framework, aligned incentives and appropriate funding mechanisms strengthen the business case for such investments. These can take various forms including performance-based funding, tax credits, grants, equity and loan guarantees, indirect tax exemptions or rebates, subsidies for green technologies and investments in science, technology and innovation systems, infrastructure and skills development. Reducing the risk of capital loss also encourages private investors to commit. Green tax reforms can create the necessary funding space for public investment and can be designed to improve equity and social acceptability.

- Incentives for Green Digital Investments

Economic instruments address market failures that hinder the adoption of green technologies and governments provide substantial financial support to stimulate digital investments that accelerate climate action. By considering capital expenditures alongside operational costs, businesses can make better resource-allocation decisions.

Digital technologies are relatively new and taxation schedules should be updated to reflect their evolving use to enhance sustainability. Incentives that stimulate investments are differentiated into tax credits, grants and guarantees. Tax credits allow investors to deduct a specified percentage of investments from their taxable income. Grants provide upfront financing for capital costs while guarantees cover part of the investment, lowering loan costs for users. Attracting private investments and financing innovative green initiatives requires low-cost capital—directly or indirectly—through subsidies for research and development projects or tax credits for priority fields such as digital transformation. Financial support is most effective when directly linked to the environmental performance of investments. Moreover, conditional subsidies that reward efficiency are more successful in promoting climate-friendly activities than unconditional subsidies. For instance, funding for green school buildings can be tied to ambitious energy-performance standards that surpass minimum compliance thresholds. Support focused on industrial electrification has higher marginal returns when linked to smart grid readiness. Performance-based funding with annual budget ceilings has proven particularly effective in scaling up the use of green data centres to support climate research, adaptation and mitigation.

- Accountability, Transparency, and Reporting

Regulatory requirements at the national or local level often mandate disclosures relating to company operations or production processes or their impacts on the environment or society. These laws, intended especially for risk management and to help protect investors and other stakeholders, are increasingly animated by concerns over broad public goods issues such as climate change and biodiversity loss. Reporting frameworks, standards and compliance requirements exist for many of these areas of interest. Multi-jurisdictional companies face numerous challenges in navigating these especially in connection with cross-jurisdictional operations. Alignment and harmonization can help lower the compliance cost burden and enhance data comparability. Incentives are also being explored to recognize and reward those companies that go beyond compliance in their disclosures. Accountability and transparency mechanisms aimed at ensuring that private resources deployed for green

digital transformation are indeed being used for that purpose often seek to hold corporations accountable for the impact of their operations and products on society and the environment. Given the information asymmetry between corporations and stakeholders, the policy objective is to bridge this gap through appropriate disclosures. Expanded stakeholder engagement and participatory mechanisms at different levels can also help strengthen accountability and trust especially when coupled with decentralized monitoring and verification systems. Quantitative indicators and self-reporting should be complemented with audit trails and disclosure for its use. Recognizing the inherent tension between a government-dominated audit trail and the spirit of a decentralized, self-organized process, some have proposed a decentralized approach to reporting in which businesses publish audits without third-party validation.

- Collaboration Across Sectors and Jurisdictions

Collaborative mechanisms across sectors and jurisdictions are essential for realizing sustainable digital transformation. Such mechanisms may take various forms including collaboration among multiple sectors of the economy across various jurisdictions, concerted action in specific priority areas, cross-border public–private partnership initiatives, engagement of complementary sectors, alignment of market forces and economic incentives and shared-sector focus. Multi-sector collaboration within the same jurisdiction supports joint action that is difficult for the individual sectors to achieve without mutual agreement. Collaboration among jurisdictions may occur in response to similar pressures from local weather events, natural disasters or seasonal changes. The creation of regulatory and technological frameworks at the national and regional levels can facilitate these actions. Policies or regulatory frameworks governing the actions of the telecommunications or energy sectors can induce or incentivize the services that other sectors require for operational sustainability. Support for digital innovation platforms and ecosystems can lead to innovative collaborative consumption offerings in the transport and building sectors. Support for life-sciences technology and research can lead to new diagnostic, peptide and vaccine solutions that advance application across sectors, and partnerships across

at least four sectors are needed to support the operational sustainability of fresh food supply chains.

11.7 Chapter summary

The sustainability and green digital economy explores the dual relationship between digital technologies and environmental outcomes. While digital technologies contribute significantly to economic growth and innovation, they also generate environmental concerns through energy use, electronic waste, and resource consumption. This chapter highlights how digital transformation must be aligned with sustainability goals to ensure that technological progress does not come at the cost of environmental degradation. It also emphasizes the need to balance innovation with responsible resource utilization in the digital era. A major focus is the environmental impact of digital infrastructure, particularly the high energy consumption of data centers and supporting networks. As global data usage continues to grow, energy demand from cloud computing, storage systems, and communication networks is rising rapidly. This creates pressure on electricity systems and contributes to greenhouse gas emissions. At the same time, awareness of these impacts has led to increased attention on green computing practices, including energy-efficient hardware, optimized software design, virtualization, and low-power system operations.

Digital technologies also play an important role in advancing sustainable development. They support environmental monitoring, resource management, and climate change mitigation through data-driven systems, smart infrastructure, and real-time analytics. In addition, digital innovation enables circular economy models by promoting product-as-a-service systems, resource recovery, recycling, and extended product lifecycles. These innovations reduce waste generation and improve resource efficiency across industries, contributing to more sustainable production and consumption patterns. To support a green digital economy, governments and institutions are implementing policies that encourage sustainable digital growth. These include regulations on energy efficiency, incentives for green technologies, and frameworks promoting responsible e-waste management and carbon reduction. International cooperation and digital governance frameworks further support the alignment of

environmental goals with digital transformation. Together, these measures aim to ensure that digital development contributes positively to long-term ecological sustainability and inclusive economic growth.

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CHAPTER 12

FUTURE TRENDS IN THE DIGITAL GLOBAL ECONOMY

The future of the digital global economy will be shaped by rapid advances in artificial intelligence, blockchain, Web 3.0, smart cities, digital public infrastructure and virtual economies. These technologies are transforming the way individuals, businesses and governments create value, exchange information and participate in global markets. Digital transformation is no longer limited to specific sectors. It now influences trade, education, health, finance, governance, public services and social interaction. As economies become increasingly digital, policymakers must prepare for new opportunities as well as new risks. These include cybersecurity threats, labour market disruption, inequality, data governance challenges and regulatory fragmentation. The digital economy encompasses economic activities that use the Internet and related information and communication technologies (ICT) as the primary means of economic activity and exchange. The digital economy thus sits on top of the world economy, supporting trade in traditional physical goods as well as services and supporting all types of (digital or non-digital) economic activities by the providers of education, health, finance, insurance and so on. The entire global economy is being enabled by everything and everyone going digital, supported by the digital trade ecosystem. Therefore, the digital economy can also be thought of as the development of all economic activities going digital via a digital infrastructure, largely a mobile platform, across business-to-business, business-to-consumer, government-to-government and government-to-business and consumer segments.

12.1 EMERGING TECHNOLOGIES SUCH AS AI, BLOCKCHAIN AND WEB 3.0

Emerging technologies such as AI, blockchain and Web 3.0 are expected to redefine the structure of the digital economy. AI can improve productivity, decision-making, public service delivery and innovation. Blockchain can support trust, transparency and decentralized transactions. Web 3.0 may create new models of ownership, participation and digital exchange. However, these technologies also raise concerns related to regulation, privacy, ethical use, misinformation, financial risk and social inequality. Addressing emerging technologies on the timescale of adoption will be more difficult, as the character of AI and related fields will change over time—not least because they are under development partly by private actors and in a race for commercial advantage. Responsibility for these technologies does not reside easily in existing institutional frameworks. Two rapidly evolving technological domains—AI and blockchain—are considered in detail; reference is made to Web 3.0 and the metaverse as well. The main focus is on the opportunities and hazards associated with AI. The first-mover advantage in consumer applications such as chatbots, agents and automating creative activities is believed to provide a limited time window for regulation, with the risks associated with potential behavioral manipulation and societal division receiving growing attention. There is a risk that the desire to be a world-leader in these novel applications may mitigate controls and regulatory enforcement rather than strengthening them. Future risk factors apply to areas closer to military applications, where regulatory frameworks may need to remain on a reduced-time horizon for exploration and use.

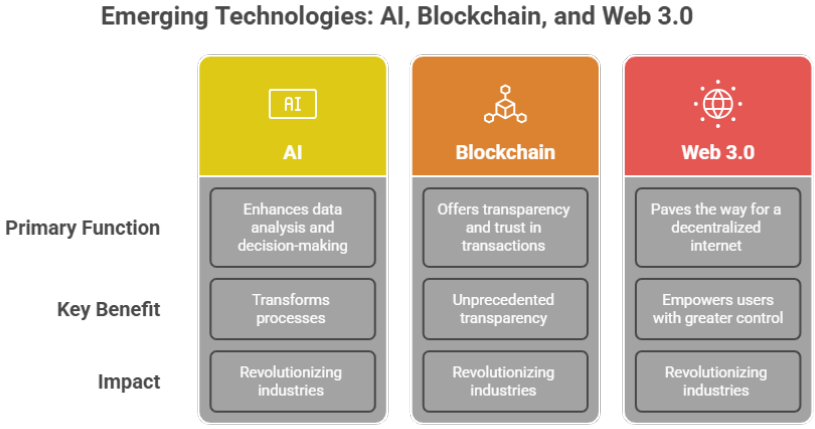

Figure 12.1 Emerging Technologies

➢ Artificial Intelligence: Opportunities and Risks

The impact of emerging technologies constitutes the first group of digital-era attributes. The most transformative of these are generally considered to be Artificial Intelligence (AI) and digital infrastructures such as the blockchain and the so-called Web 3.0, along with the metaverse and associated virtual economies. They are described here primarily in terms of their opportunities and risks—wherever possible, a simple matrix approach is adopted, but other dimensions are also relevant and discussed in the respective sections—and then in terms of their governance implications. AI is likely to enormously increase the efficiency and productivity of many industries, but at the same time accelerate labour market dislocation and put employment under threat. It has the potential to enhance public good service provision—in education, health and the delivery of government services—at lower cost. It also opens up new opportunities for support for the disabled and for an ageing population, which increasingly require advanced economic and welfare support systems. Such systems can be underpinned by AI-based supervision, abuse detection and fraud prevention, and can scale up demand for public service provision. AI can both enhance defence and increase its risks. At the same time, it raises serious ethical, reliability and legal questions, in areas ranging from data bias (and bias in algorithms based on it) to liability issues regarding harm caused by autonomous machines and weapons.

- Blockchain and Web 3.0: Trust, Decentralization, and Compliance

Blockchain technology lies at the heart of the emerging Web 3.0 paradigm. It allows the reliable decentralized storage of data and hosting of services that can exert trust between parties without the need to rely upon trusted intermediaries. Such third-party intermediaries handle sensitive data and are responsible for assuring its correct use, putting the global economy and individual users at serious risk when they fail or are compromised. Decentralization can therefore reduce cyber risk and greatly increase resilience. Yet, the decentralized nature of blockchain-based services also poses significant difficulties for law enforcement and regulatory oversight, which work to ensure stability, safety and security in the real economy and digital world. Policymakers are thus faced with the challenge of fostering an environment where the use and adaptation of blockchain technology can enable trust without intermediaries while ensuring that relevant services can nevertheless be appropriately supervised. The correct approach towards enabling the adoption of blockchain technology while simultaneously maintaining public safety and governance will differ from country to country and even from sector to sector. In fulfilling this challenge, innovators and governments will have to adopt a modus operandi of close cooperation and engagement. Regulations devised in isolation will lead either to very low developmental uptake or to massive disruptions and public harm.

12.2 GROWTH OF METAVERSE AND VIRTUAL ECONOMIES

The metaverse and virtual economies may create new opportunities in entertainment, education, digital commerce, virtual workspaces and social interaction. Digital assets, virtual goods and blockchain-based ownership systems may support new forms of value creation. However, the long-term economic impact of the metaverse remains uncertain. Issues related to intellectual property, taxation, consumer protection, digital identity, privacy and speculative investment require careful policy attention. Once it has become common to live significant parts of daily life in virtual universes, the question of whether and how a virtual economy can grow has been raised in earnest. Central to this formulation is the capacity of virtual places to ensure so-called virtual “economic gravity”, i.e. the ability of individuals to live off the trade and services

originated entirely within the virtual economy. Other developments in online places are also likely to condition how commercial activities develop and operate, now and in the years to come. Artworks are being digitally reproduced with such ease that a proper business for physical works seems doomed. Those who create, reproduce, sell, buy and collect artworks are investing time and money in ways that demonstrate strong bonds with the product—even if they cannot ascertain that the universe's rules will continue to reward them in the future. The conditions that rules lending value to any virtual work (for example, exclusivity) may well be served by the establishment of moves toward establishing and enforcing intellectual property rights in these online places. To develop a copyright-like capacity to control the use of specific works.

- Economic Structures in Virtual Environments

Recent discussions around the metaverse highlight its potential to host virtual economies spanning entertainment, commerce, education and civil engagement. These virtual economies can generate value and support monetization within the gaming and social-media industries, although questions remain about their interconnectedness and size relative to real-world economies. Platforms such as Meta frequently describe their undertaking as an "economic" one, potentially referencing their economic responsibility and interest in stimulating economic participation via a virtual economy. What should actually be understood as a metaverse or metaverses continues to evolve, even if specific pointers toward what is being built have begun appearing in the domain of digital worlds and infrastructure developments—building blocks necessary for constructing connected immersive 3D environments. While the graphic details represent more classical elements of digital economies in real environments, the metaverse discussion hints at plausible new structures for virtual environments where user-generated content, digital goods and even financial and property markets can simultaneously support different parts of their economic dynamics as they transform from games into social worlds. NFTs have also taken root in gaming, and the idea of player-owned economies in gaming has evoked much interest, even if they frequently devolve into token and speculator bubbles, microtransactions and unpleasant pay-to-win schemes. An adjacent energy may have been present in early discussions of the

"creator economy" and blockchain networks that sought to reduce the fee dependency of platforms by creating better economic environments for content creators.

- Intellectual Property and Monetization

Virtual environments are becoming increasingly popular and integrated with the daily lives of significant portions of the population. This opening, in turn, offers new opportunities for both creators and companies. Non-fungible tokens (NFTs), among other technologies, allow digital works to be sold as if they were unique, providing creators with a mechanism for recognizing their investments while providing companies with the opportunity to monitor and regulate the sale of digital copies of their products on these platforms and benefit financially from the works of artists who use their digital assets. Initially, discussions about NFTs revolved primarily around their novelty, although without sufficient understanding about their sustainability or utility. In addition to the environmental concerns related to the classic proof of work deployed in some blockchain networks, such as Ethereum, the criticism of NFTs was also directed towards the formation of speculative bubbles around specific digital assets. Recently, however, the conversation has shifted to analyzing the actual use cases in the digital economy and within the metaverse and assessing their legal regulation, particularly in the fields of intellectual property, tax and money laundering legislation. As mentioned above, NFTs enable the sale of digital works as unique and original copies but also allow the owner to retain the right to copies that remain identical to the originals. This mechanism is important for companies as it prevents their digital products from losing value due to unauthorized mass reproduction and allows for the control of these productions by the right holder, who can prohibit the dissemination of copies of their work that he deems unacceptable or that he wants to distance himself from. In both cases, the creator or right-holder can establish a royalty mechanism for secondary sales. Discussions about NFT taxation can be approached through several angles, including money laundering regulation and VAT/GST.

12.3 SMART CITIES AND DIGITAL PUBLIC INFRASTRUCTURE

Smart cities use digital technologies to improve urban planning, transportation, energy use, public services and environmental management. Digital public infrastructure,

including connectivity networks, data platforms and digital identity systems, can support more efficient and inclusive governance. However, smart city development must also address privacy, cybersecurity, affordability and equal access to services. Without inclusive planning, smart cities may widen existing inequalities. Cities are at the forefront of climate change and digital transformation, and winning the race for urban sustainability and resilience will be central to humanity's long-term well-being. Guided by ambition, investment and planning, smart cities that embed digital public infrastructure can offer enhanced connectivity, service delivery and data governance for all. The same infrastructure can support cutting-edge urban digital trade, enabling the equitable and efficient transmission of data across borders and reducing barriers to trade in digitally enabled services. Climate change adaptation is becoming an increasingly urgent priority for governments, and its impacts have direct repercussions on security, health and economic prosperity. Urban areas will bear the brunt of this challenge: cities become heat islands, need to cope with extreme weather events and are exposed to sea level rise. Despite these growing risks, cities are still responsible for the majority of greenhouse gas emissions, with the main culprits being energy production, transport and industry. The quest for urban sustainability will thus rely on reducing energy demand both in buildings and through efficient public transport, as well as the clean electrification of transport and industry. However, investment in advanced technologies and digital innovation will not be sufficient to ensure long-term adaptation, and consideration needs to be given to physical and social infrastructure.

- Urban Sustainability and Resilience

Sustainable and resilient urban growth is a pressing challenge in an increasingly climate- and disaster-vulnerable world. Emerging digital technologies could help plan, design and manage cities, transportation activities and their infrastructures. Urbanization also creates opportunities for locally adapted circular economy solutions. Digital twins, spatial data infrastructures that combine real-time data with simulation capabilities for different urban sub-systems, promise improved predictions of urban processes; yet their practical implementation depends on appropriate completion of

foundational digital public infrastructures. Global cooperation is needed to set standards for safe and responsible implementation of smart city solutions, especially those combining large-scale data collection with artificial intelligence's predictive power. Cities should also actively promote usage of their service-delivery infrastructure by socio-economic actors in the real and virtual worlds alike.

- Connectivity, Data Governance, and Service Delivery

Smart digital public infrastructures underpin initiatives to harness information technologies for urban sustainability and resilience. Although improvements to roads, transport networks and other traditional infrastructure remain crucial, many cities are allocating increasing budgets to develop better digital public goods and services. The aim is to support technology-driven solutions to the complex socio-economic and environmental challenges facing urban centres in a digital era. The appropriate choices for the underlying network structure vary by context. The EU's investment in a dedicated satellite communication network aims to support connectivity in remote regions. Data is a key element in the digital age, giving rise to the adage of the era being dominated by the triad of "connectivity, data and algorithms". For smart cities, the availability, use and sharing of digital data is essential not only for government services and business development but also for ensuring that the potential benefits of digital innovation can underpin improvements in quality of life across different segments of urban residents. Management of data flows and governance instruments—encompassing not only infrastructure architecture but also regulation and design of services—determine whether digital technologies contribute to urban inclusiveness and resilience or widen existing societal inequality. Expanding connectivity in urban areas is a key part of many cities' infrastructure development plans. Many cities are rolling out, or investing in, fibre-to-the-home and 5G networks, and have defined accommodation priorities that express a preference for regulating networks open to all service providers and not being invested in by public authorities. Providing a network where more than one operator can supply services reduces monopolistic behaviour and offers customers a choice of payment structures. Where such conditions are not met, there is greater metropolitan pressure to ensure affordable

digital solutions for all. These physical layers need to be supported by data architectures and digital-enabled services that allow citizens to receive collective benefits from the digital era.

12.4 FUTURE OF GLOBAL TRADE IN A DIGITAL WORLD

Digitalization introduces new modalities of trade and supply chain interactions, affecting established patterns of production, service provision and consumption. The resulting shifts in patterns of comparative advantage and competition are not necessarily consistent with existing business models or seen as economically beneficial. New trade rules are considered to facilitate secure data flows and the cross-border provision of services, especially for small and medium enterprises. Additionally, the increasingly digital nature of global supply chains raises questions of resilience and safety. Not surprisingly, therefore, the focus of digital trade discussions has widened beyond trade facilitation. Building on the various dimensions reviewed, the following policy considerations emerge. Digital trade imperatives. Rules facilitating secure digital trade flows and transborder data exchange will increasingly be seen as vital for the economic success of countries in a digital era. In particular, ensuring that the potential benefits of digital trade are made available to small and medium-sized enterprises and to developing countries will require specific attention. Recent initiatives in this area—at both the regional and global levels—provide a useful starting point, but much remains to be done. Moreover, the cross-border provision of digital services is becoming a factor in the international competitiveness of many economies. Whether it is in the area of professional or telecommunications services, action is needed to open up markets and ensure that the opportunities offered by the digital economy can be exploited.

- Digital Trade Rules and Cross-Border Flows

Data are rapidly becoming a major trade and investment asset. However, existing trade agreements do not cover the international movement of such data. With digital technology generating new ways for companies to access world markets, build their supply chains and optimize production and distribution processes, a new approach to trade negotiation is needed. Current frameworks need to adapt and set new rules for

existing trade in services and virtual trade. To breathe life into the WTO, nations should aim for agreements limited in coverage but carefully constructed to match the specific requirements of the digital economy. Rapidly growing cross-border movement of goods, services, finance and people through the Internet promises major gains for all countries. However, the expected benefits will not be realized automatically. For many countries, protecting and managing risks is more important than gaining opportunities. The digital economy creates an era of global trade, with a shift from national to virtual trade. But many government policies, especially in developing countries, are still focused on national trade, leading to inefficiencies and missed opportunities. Sustainability, privacy, fairness and security are vital for making the most of this shifting trade environment. The current Global Trade Analysis Project global computable general equilibrium model is not able to evaluate trade in bits; this must await a new data-trade framework. However, trade needs go far beyond bits. The e-goods need classified and maintained; trade in services needs rules and prudent regulatory openness; and trade in people needs nurturing. A new data-trade framework would naturally lead to a data-trade report card, listing major actual and potential data trade flows and assessing priorities for action. Such an assessment can match the supply-side computation of data flows with the need for new data-trade rules.

- Supply Chains, Automation, and Competitiveness

Evolving trade structures reflect the shifting economic landscape, raising uncertainty about the future of the global supply-base. The adoption of emerging technologies can boost productivity and competitiveness across all sectors, but it requires careful coordination with other policies in areas such as education, training and trade. Inadequate attention to these aspects creates risks that countries may lag behind. The high-level group notes that while robotics, 3-D printing and Artificial Intelligence hold great promise for both advanced and developing economies, these technologies also create new challenges, in particular for the workforce, with skills and education becoming more important than ever. Investment in digital public infrastructure, including availability of adequate data sets, is vital for full and equitable seizing of potential opportunities. Innovation in these technologies is therefore not simply a

matter for private enterprises pursuing business opportunities; it is also a strategic investment domain requiring public sector foresight, policy and funding. With ever-greater emphasis being placed on services, the quality of 'low-tech' services provided by micro and small enterprises is also an important factor for growth and competitiveness in trade in value-added.

12.5 ECONOMIC RESILIENCE IN A DIGITAL ERA

Economic resilience in the digital era depends on secure infrastructure, skilled human resources, strong institutions and adaptive policy systems. As governments and businesses become more dependent on digital networks, cybersecurity becomes a core part of national and economic security. Countries must strengthen critical infrastructure, develop cybersecurity skills, improve crisis-response systems and build resilient digital supply chains. The increasing pervasiveness of digital technologies and the evolution of economic structures have impacted the risks and vulnerabilities of economies. The potential for cyberattacks on critical infrastructure networks, the dependence of governments and businesses on these systems, and the level of preparedness in dealing with crises are now critical for economic resilience. In addition, the various dimensions of digitalization—including inclusion, workforce capabilities, regulatory balance and innovation policy—interact in shaping the capacity of economies to absorb and respond to sudden external shocks. The Cybersecurity and Critical Infrastructure paradigm focuses on strengthening cyber-resilience through policy responses tailored to risks in specific economic sectors. Cybersecurity incidents are now recognized as one of the most dangerous risks for business and activity and cloud computing presents the main vulnerability in terms of lost assets. The original factor determining cyber-resilience is the availability of workforce skills. Furthermore, governments have a key responsibility in protecting national critical infrastructure. While education and health systems should implement universal measures, the transportation field needs to focus on the security of surface transportation and the financial system should concentrate on the security of automated clearing houses. Enabling rapid recovery is paramount.

- Cybersecurity and Critical Infrastructure

Digital technologies underpin virtually all sectors of modern economies, exposing them to cyberattacks at an unprecedented scale. Whether vulnerable due to malicious behaviour, software bugs and flaws, human error or equipment failure, loss of cybersecurity in any one organisation can bring a wider service deficit, and the interdependence of digital infrastructure means shockwaves can run through a whole economy or across borders. Cyberattacks are already posing real risks to the national and economic security of many countries. Yet the collective capacity of the region's countries to mitigate cybersecurity risks is weak – starkly illustrated by the COVID-19 pandemic, during which certain borderless cybercrimes flourished. As the region's economies invest heavily in digital transformation, the resilience of their core digital infrastructure will have to be strengthened. Critical information infrastructure and operations technology teams should prepare and plan for different types of cyber risks, such as insider threats, skill shortages, technology dependency, vendor management weaknesses, cloud service security shortcomings and attacks on operational technology. Cybersecurity simulation exercises need to move beyond the critical infrastructure sector into the services economy. Countries should consider both mandatory cybersecurity requirements and incentives for smaller firms. To address the region's skills shortages, partnerships should be formed between academia and industry, while governments and business associations should promote awareness of the value of careers in cybersecurity.

- Digital Inclusion and Workforce Transformation

Digital skills training and education have advanced significantly in recent years, yet digital usage patterns reveal diverse vulnerabilities by age group. Young people report high levels of digital anxiety, while older adults with lower levels of digital involvement cite a lack of digital skills as a barrier to use. Education and training systems must prepare students and young people for the new digital economy. Rapid technological change may outpace skill development, necessitating investments in retraining and upskilling for workers displaced by automation. Consideration must be given to both the skills needed for jobs being created and the types of jobs that are

likely to remain in demand. Digital supply shocks resulting from external shocks like the COVID-19 pandemic, the war in Ukraine and the resulting global energy crisis have led many governments to re-evaluate the resilience of their economies. The spillover effect of past shocks is reflected in supply bottlenecks in numerous sectors. Many companies are now trying to build resilient supply chains that can withstand geo-political tensions, move towards sustainable forms of production and increase their provisioning for future pandemics and other local and global shocks. The need to keep climate change under control, learn lessons from the COVID-19 pandemic and reverse the growing trend towards greater geo-political tension also reinforces the need to move to more resilient cyber-secure supply chains.

12.6 PREDICTIONS AND STRATEGIC DIRECTIONS FOR POLICYMAKERS

Digital-era benchmarks reveal uneven change across the globe and across economic and social sectors. Within these technological and structural changes lie distinctive opportunities and risks. On the positive side, innovation—driven by emerging technologies, digital infrastructures, and global connectivity—offers possibilities for more effective public services, as well as improvements in productivity, employment, trade and infectious disease detection and response. On the negative side, economic dynamism, job retention, trade relationships and equity are all at risk from fragility in cyber- and physical security. Addressing these threats alongside regulating the emerging technologies shaping the economy and society is an important policy agenda. The stakes for humanity could hardly be greater. A review identifies new priorities for policymaking and related areas of public investment that require careful thought. Policymakers have long supported technological innovation in the private sector through financial backing and investment tax incentives. As the pace and scale of change accelerate, the importance of public investment is rising across many dimensions. Policymakers must do more than stimulate private investment in new technologies; they must also actively invest in next-generation digital public support infrastructure. These cyber and physical systems will be the foundation for society, the economy and politics in the decades to come and can be pivotal for environmental and

social sustainability. The technologies underpinning a specific phase of the economy are enormously capital intensive and often have limited rivals or substitutes. Careful planning and foresight by public agencies are therefore essential to ensure these investments are made intelligently and at the right scale.

- Innovation Policy and Investment

To seize opportunities, mitigate risks and foster resilience, governments should invest and incentivise businesses to advance foundational areas of innovation relevant to critical developments. For artificial intelligence systems, these areas include algorithms that are fundamentally interpretable, explainable, controllable and verifiable, as well as systems that integrate reliably with the human touch. For blockchain, the main areas include technologies that enable scalability, truly trustless (rather than trust-minimising) security models and compatibility with existing legal and regulatory requirements. For economic activity in the metaverse and other virtual environments, the areas involve linguistic and cultural translation at scale, realistic avatars and forms of behaviour and novel inputs (e.g. sensorimotor interfaces) that complete the traditional senses in effective virtual presence. More generally, investments should help make government budgets more efficient and effective, support the development of communication technologies that will meet the needs of better connected people and things, and secure vulnerable parts of key economic infrastructures and systems of participation and engagement. At the same time, efforts are needed to encourage business—especially in more traditional sectors—to invest in their digitalisation, to move to the level of sophistication required for the digital business ecosystems that are emerging, and to meet future skill needs.

- Regulation, Ethics, and Accountability

With the advent of emerging technologies, the nature of innovation and future of business have raised intricate regulatory challenges with an impact across the technological spectrum. Autonomy and sophistication have changed the way technology interacts with human societies and the need for regulation in accordance with ethical standards has become urgent. There are certain spheres of technological development, such as the metaverse and such applications of AI, that raise new ethical

questions about confidentiality, criminal exploitation and virtual property creation, rendering the concept of the traditional state obsolete. Governments and international organisations are looking to connect regulation of the digital world with human rights and ethical principles; these broad rules should outline the limits and objectives of innovation but not hinder curiosity in exploiting emerging technology. Compliance using Blockchain and Web3 technology has the potential to provide near real-time visibility and assurance on the legal, tax and regulatory aspects of every digital trade. For some stakeholders though, the focus on compliance has evolved into a debate around its interpretation. Some nations promote a compliance-by-default strategy, while others consider it an active requirement.

- International Cooperation and Standards

Technological developments increasingly transcend national borders and have evolved to a level where they pose external shocks to economic and social systems. The Internet, for example, has shifted how humans interact and changed established customs and relationships, yet it remains a set of standards rather than a structured system. Although the technology's far-reaching economic and business implications were foreseen, the international trading and economic systems were arguably poorly prepared for the upheaval that came with the digital era. Policymakers must not only take advantage of continually emerging technologies but also head off their potentially harmful effects. To maximize the benefits while limiting the drawbacks, a whole-of-government approach is needed to shape these technologies through appropriate political incentives and regulation. International cooperation and agreement will remain necessary to achieve this goal. Cybersecurity and privacy breaches are critical concerns for individuals, governments and the business community. In a globalized digital economy, digital trust—or its absence—represents an opportunity for innovative business and an equally significant risk for enterprises. Cybercrime has many facets, including fraud, hacking, money laundering and violation of privacy. Addressing these issues requires cooperation across home and host countries and local and foreign enterprises for regulations and best practices in the digital sphere that ensure legal certainty and eliminate loopholes.

12.7 Chapter summary

The future of the digital global economy is being shaped by rapid technological advancements and the increasing integration of digital systems into economic, social and governance structures. Emerging technologies such as artificial intelligence, blockchain and Web 3.0 are redefining how information is processed, how trust is established, and how value is created and exchanged. These technologies are not only transforming traditional industries but also creating entirely new digital ecosystems that operate across borders. As a result, the global economy is becoming more interconnected, data-driven and platform-centric, requiring new models of governance and policy coordination. At the same time, the growth of the metaverse and virtual economies is opening new frontiers for economic activity. Virtual environments are evolving into spaces where users can engage in commerce, education, entertainment and social interaction, often supported by digital assets and blockchain-based ownership systems. Parallel to this, smart cities and digital public infrastructure are transforming urban governance by enabling real-time data usage, improved service delivery and more efficient resource management. These developments collectively point toward a future where physical and digital environments are deeply integrated.

Global trade is also undergoing significant transformation in the digital era, with increased reliance on data flows, digital services and platform-based commerce. Traditional trade models are being reshaped by the digitization of supply chains, automated systems and cross-border digital transactions. However, this shift also raises concerns about cybersecurity, regulatory fragmentation and unequal access to digital infrastructure. In response, economic resilience is becoming a central priority, with countries focusing on building adaptive systems capable of withstanding technological disruptions, cyber risks and global shocks. For policymakers, these changes demand forward-looking strategies that balance innovation with regulation and inclusion. Strategic directions include fostering digital infrastructure investment, promoting international cooperation on standards, and ensuring equitable access to emerging technologies. Policymakers must also anticipate long-term shifts in labour markets, governance systems and economic structures driven by digital transformation.

Ultimately, the future digital economy will depend on how effectively governments and institutions can harness innovation while ensuring sustainability, resilience and inclusive growth.

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Index of key terms

Economic Globalization

Edge Computing

Electronic Payments

Economic Integration

Enterprise Resource Planning (ERP)

E-governance

E-wallets

Economic Digitization

Ecosystem Innovation

Energy-efficient Computing

Elastic Computing

F

FinTech

Financial Inclusion

Freelancing Economy

Fourth Industrial Revolution (Industry 4.0)

Firm Productivity

Flexible Work Models

Forecasting Models

Fraud Detection Systems

Fiber Optic Networks

Financial Digitalization

Fiscal Policy (Digital Context)

Future of Work

Functional Innovation

Financial Data Analytics

Firm-level Digital Adoption

G

Gig Economy

Globalization

Green Economy

Gross Domestic Product (GDP)

Global Value Chains (GVCs)

Governance Frameworks

Government Digital Services

Growth Analytics

Geospatial Data

Green Computing

Digital Governance

Global Trade Networks

Growth Models

H

Human Capital

Hybrid Cloud

High-speed Internet

Human–Machine Interaction

Hyperconnectivity

Heuristic Algorithms

Human Resource Analytics

Hybrid Work Model

High-tech Industries

Human-centered AI

I

Internet of Things (IoT)

Innovation Ecosystem

Information Economy

ICT (Information and Communication Technology)

Industrial Automation

Inclusive Growth

Intelligent Systems

Internet Infrastructure

Innovation Diffusion

IT-enabled Services (ITES)

Industry 4.0

Information Security

J

Job Automation

Job Displacement

Job Creation (Digital Sector)

Just-in-Time Production

Joint Ventures (Digital Economy)

Java-based Systems

J-Curve Effect (Productivity)

Job Polarization

Jurisdiction in Digital Trade

JSON Data Structures

Job Matching Platforms

Judicial Frameworks (Digital Regulation)

Job Flexibility

K

Knowledge Economy

Knowledge Management

Knowledge Sharing Platforms

Key Performance Indicators (KPIs)

Knowledge Workers

Knowledge Capital

Knowledge Diffusion

KYC (Know Your Customer)

Knowledge-based Systems

Kernel Systems

L

Labor Market Dynamics

Logistics Management

Learning Algorithms

Local Area Networks (LAN)

Labor Productivity

Lifelong Learning

Low-latency Networks

Lean Digital Systems

Learning Management Systems (LMS)

Legal Frameworks (Digital Economy)

M

Machine Learning

Mobile Economy

Market Digitization

Microtransactions

Multinational Corporations (MNCs)

Mobile Banking

Metadata

Metaverse

Manufacturing Automation

Monetary Policy (Digital Context)

Market Analytics

Mass Customization

N

Network Effects

Neural Networks

Natural Language Processing (NLP)

Network Infrastructure

Net Neutrality

Network Security

Non-traditional Employment

Nano Technology

Network Optimization

New Economic Models

Network Externalities

Node Computing

Neural Data Processing

Network Scalability

New Media Economy

O

Online Platforms

Open Innovation

Outsourcing

Omnichannel Retail

Open Data

Online Marketplaces

Organizational Transformation

Operational Efficiency

Open-source Software

Online Education Platforms

On-demand Economy

Optimization Algorithms

Online Payment Systems

P

Platform Economy

Predictive Analytics

Privacy Protection

Public Policy (Digital Economy)

Payment Gateways

Peer-to-Peer (P2P) Networks

Productivity Growth

Process Automation

Personal Data Protection

Platform Governance

Public–Private Partnerships (PPP)

Programming Interfaces

Price Optimization

Platform Innovation

Procurement Digitization

Q

Quantum Computing

Quality of Service (QoS)

Query Processing

Queue Management Systems

Quantitative Analysis

Quick Response Systems

Quantum Encryption

Quality Assurance (Digital Systems)

Query Optimization

Quantitative Finance

Queue Algorithms

R

Robotics

Remote Work

Research and Development (R&D)

Real-time Analytics

Regulatory Frameworks

Risk Management

Retail Digitization

Resource Optimization

Revenue Models (Digital Platforms)

Re-skilling Workforce

Robotic Process Automation (RPA)

Resilient Supply Chains

Recommendation Systems

Regulatory Technology (RegTech)

Renewable Digital Infrastructure

S

Smart Cities

Software as a Service (SaaS)

Supply Chain Digitalization

Social Media Economy

Security Protocols

Startup Ecosystem

Sustainable Development

Smart Manufacturing

System Integration

Service Economy

Shared Economy

Scalability

Simulation Models

Secure Transactions

T

Technology Adoption

Total Factor Productivity (TFP)

Telecommunication Networks

Tech-driven Innovation

Trade Digitization

Tokenization

Technological Disruption

Transaction Costs

Tech Startups

Trust Frameworks

Tech-enabled Services

Teleworking

Technology Transfer

Tech Policy

Transparency Systems

U

Ubiquitous Computing

Unified Payment Interface (UPI)

User Experience (UX)

Urban Digitalization

Universal Internet Access

Usage Analytics

User Data Protection

Unstructured Data

V

Virtual Economy

Virtual Reality (VR)

Value Chains

Venture Capital

Virtual Platforms

Value Creation

Virtual Workspaces

Voice Recognition

Virtual Banking

Value-added Services

Virtual Collaboration

W

Web 3.0

Wireless Networks

Workforce Automation

Web-based Services

Wearable Technology

Work-from-home Models

Web Security

Workflow Automation

Wireless Communication

X

XaaS (Everything as a Service)

XML Data Structures

X-Factor Innovation

XBRL (eXtensible Business Reporting Language)

Xen Hypervisor

X-Analytics

XaaS Models (IaaS, PaaS, SaaS)

X-Optimization Techniques

X-Data Processing

Y

Yield Optimization

Youth Digital Employment

Yottabyte Data Scale

Yield Management Systems

Youth Entrepreneurship

Y-axis Growth Models

Year-on-Year Growth (YoY)

Youth Skill Development

Yottascale Computing

Yield Forecasting

Youth Innovation Programs

Y-linked Data Models

Young Workforce Analytics

Z

Zero Marginal Cost

Zero Trust Security

Zettabyte Economy

Zoning Regulations (Digital Infrastructure)

Zero Downtime Systems

Zonal Data Centers

Zero-latency Networks

Z-score Analysis

Zero-based Budgeting (Digital Projec

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Modern Economic Trends
in a Digital Global Economy

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