PART I
Introduction

> The future is already here, it's just unevenly distributed.
>
> (William Gibson)[1]

Although digital technologies seem to have reached every corner of the economy, there is actually quite a bit of variation with respect to the degree of digitalization. Therefore, digital transformation continues to upset firms, industries, and markets around the globe. The pace of change continues to be rapid and relentless. This book helps you learn from the past and ongoing processes of digital transformation to predict and facilitate future transformation. You will see that the only constant in digitalization is change. The first part of the book introduces the key concepts of digital business innovation, digital disruption, and communication networks, which underpin the deeper analyses of the digitalization of organizations and markets in later parts.

[1] *The Economist*, 2001. Retrieved from www.economist.com/business/2001/06/21/broadband-blues in August 2022.

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1 What is Special about Digital Business Innovation?

> Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road.
>
> (Stewart Brand)

Innovation is about change: *the introduction of novelty into an economic system.* Managing any type of economic or organizational change is challenging because its effects are usually uncertain and affect participants unevenly. Managing technological change requires a heady cocktail of creativity, flexibility, and perseverance in the face of novelty and turmoil. In this chapter we explore the special features of digital innovation of new businesses, digital business innovation. **Digital business innovation** deals with *improved technology-based business models for information and communication* – core elements of all economic activity. Furthermore, we look at the long-term patterns of technological change and notice how digital technologies arise from the combination of electronics and instruments and lead to new kinds of technologies that accelerate invention activity itself.

One might think that every business is digital business. It is difficult to imagine any economic activity that does not rely on information and communication technologies for their basic functions. Even the most traditional local services such as restaurants and construction companies market and coordinate their activities using websites, computerized booking and scheduling systems, and digital payment systems. At a minimum, a plumber or an electrician has a smartphone to communicate with clients using its call, text, and email functions, even if much of their marketing might still take place using word-of-mouth and the work itself is still based on manual skills and "analog" (as opposed to digital) knowledge. However, digital labor markets such as TaskRabbit and Fiverr are digitizing the job matching process even for these manual trades!

However, not all digital business is equal; some firms are more digital than others. We can distinguish general users of information and communication technologies such as local services and traditional manufacturing and service firms from businesses significantly enhanced by digital technologies[1]. The latter include financial institutions, credit rating services, online retail, and even airlines that all operate in the physical world ("bricks and mortar" as these businesses were called

[1] President's Council of Advisors on Science and Technology Report to the President and Congress: Designing a Digital Future (2010). Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf in August 2022.

during the first internet boom) providing concrete, offline services to people and client organizations. However, their organizational effectiveness and innovation are often significantly reliant on digital technologies that enhance their ability to communicate, coordinate, carry out transactions, collect and analyze information, and make informed decisions. This uneven distribution of digital technologies allows us to examine the most highly digitized business organizations and activities and extrapolate to areas that are probably yet to adopt the most advanced technological solutions. This book intends to help speed up the dissemination of useful digital technologies through business innovation.

In 2015, the most digitized industry was the information and communication technology sector itself – not surprisingly – and agriculture was the least digitized.[2] However, industries such as wholesale trade, utilities, and finance were also quite highly digitized whereas retail trade, hospitality, and health care were surprisingly far from the frontier of digitization, leaving room for new services to enter and offer rapid digital transformation.[3] Just a few years later, digital agriculture started to take off. The extent and rate of digitalization thus varied significantly by firm and industry, often for competitive and strategic reasons.

1.1 Origins of Digitalization

This book will primarily focus on the innovation strategies of dedicated communication and information technology businesses. These organizations are, at their core, built on digital information and communication networks. They offer information products and services or create communication networks for their customers and users. Products and services of such purely digital businesses include digital content and media, communication networks, software, computing services, and so on. These types of service companies have been leading the transformation into a digital society, and by studying how they function, we can shed light on the issues that will affect digitization of businesses that are currently only digitally enhanced or general users of digital technologies.

An interesting boundary object of our study of digital transformation are businesses that provide services offline but at their core define and operate themselves as digital platforms. Boundary objects translate and connect different social and economic worlds. McAfee and Brynjolfsson (2017) called such services Online-to-Offline or O2O services: online information and communication systems support the search, coordination, and matching necessary to provide offline services. They

[2] McKinsey Global Institute (2015). Digital America: a tale of the haves and have-mores. Retrieved from www.mckinsey.com/industries/high-tech/our-insights/digital-america-a-tale-of-the-haves-and-have-mores in August 2022.

[3] Gandhi P., Khanna S., and Ramaswamy S. (2016). Which industries are the most digital (and why)? *Harvard Business Review* (April 1). Retrieved from https://hbr.org/2016/04/a-chart-that-shows-which-industries-are-the-most-digital-and-why in August 2022.

include some of the most fascinating service platforms of our time such as eBay, Uber, and Airbnb, but also other types of online markets for physical goods and services – homes, shoes, dog walking, grocery shopping, and even furniture. While the designs and details are diverse, these businesses typically live and die by network effects, and the marketplaces become more valuable with scale. Offline marketplaces also exhibit such scale economies to a degree, but online marketplaces do not have any natural size limit and thus can grow extremely large.

Digital transformation is not limited to service industries, even though information-based service tasks are naturally easier to digitize. Concepts such as the Industrial Internet of Things (IoT) and Industry 4.0 draw attention to the digitization of the manufacturing sector, and even the agricultural sector through the efforts gathering momentum under the umbrella of Digital Agriculture[4]. We can call these industry platforms "Offline-to-Online:" dense data from physical transformation activities are collected and digitally transmitted to an information system that allows their merging, organization, and analysis in support of subsequent decision making.

Although the ideas surrounding the IoT are relatively new and seemingly radical, the development and adoption of digital technologies in manufacturing and agricultural production[5] has been long-standing and gradual. Earlier waves of development took place under the headings of automation, systems engineering, and mechatronics. They all concern the application of computers and instruments to measure and manipulate the physical state of a system. Prior to 1970, progress in automation was primarily driven by inventions in mechanical instrument and control technologies, and after 1970, a dramatic switch to electronic instrumentation took place. At the same time, the degree of automation of such systems considerably increased. Since the year 2000, advanced production systems have rapidly adopted wireless communication. Most recently, the combination of the Industrial Internet of Things (industrial data networks) and 5G wireless telecommunications (ultra-fast and high-bandwidth wireless communications) are enabling full digitization and remote operation of production via system-wide "digital twins."

Figure 1.1 illustrates the economy-wide transition from mechanical technologies to electrical and instrument technologies. It depicts technology flows as measured by cross-industry references (citations) in US patent documents. A patent citation is created when an inventor of a new technology cites an earlier invention as the "prior art" on which the new invention is built. If the citation concerns prior art from other fields of technology, it can be interpreted as cross-sectoral flows of

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[4] Kite-Powell J. (2020). Welcome to the new world of digital agriculture. Forbes (April 22). Retrieved from www.forbes.com/sites/jenniferhicks/2020/04/22/welcome-to-the-new-world-of-digital-agriculture/?sh=57608b8d10ce in August 2022.

[5] Bryan, S., Fiocco, D., Issler, M., and Perdur, RSM. (2020). Creating value in digital-farming solutions. McKinsey, October 20, 2020. Retrieved from www.mckinsey.com/industries/agriculture/our-insights/creating-value-in-digital-farming-solutions# in August 2022.

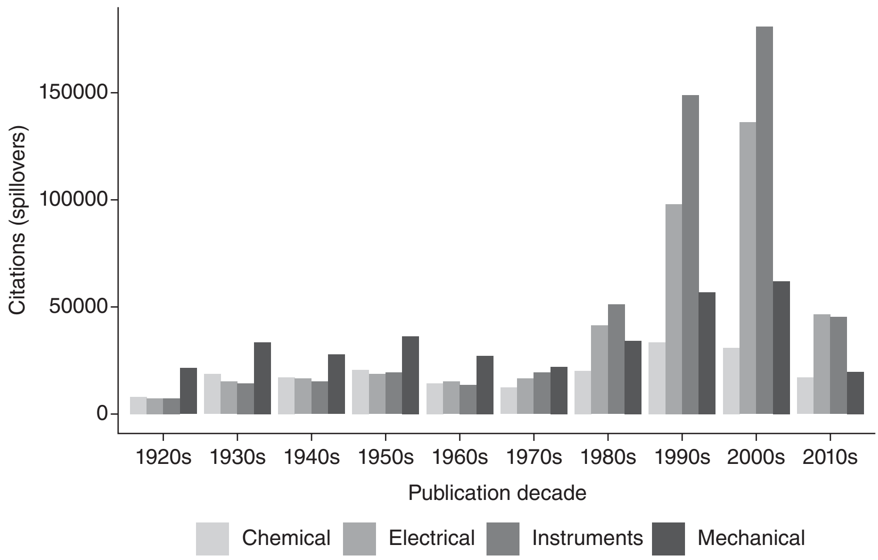

Figure 1.1 Total cross-sector technology flows by field and decade as measured via patent citations
Note: After the 1970s, electrical technologies and instruments became widely adopted in other technology sectors, suggesting large-scale dissemination of these technologies. This illustrates the widespread adoption of electronics, such as computing and communication technologies, and associated instruments, in all sectors of the economy.
Source: Koutroumpis, Pantelis, Leiponen, Aija, and Thomas, Llewellyn D.W. (2020). Digital instruments as invention machines. *Communications of the ACM 64(1): 70–78.*

technology that are spurring additional invention in the recipient industry. Thus, up until the 1970s, mechanical technologies were dominant in influencing invention activities in other fields. After the 1970s, electrical technologies had a much greater impact on invention in the US economy. However, it is interesting that instrument technologies had an even greater impact on other technology fields. If we look more closely within the sectors of electrical and instrument technologies, we will find that it is primarily computers, communication technologies, and control instruments that have had such outsized impact on technological change in other fields of the economy. Together, these three technology fields have driven the rapid and ongoing digitization, automation, and networking of the economy since the 1970s.

1.2 What are the Challenges of Digital Business Innovation?

We define **digital business** as any business that in its core processes is dependent on information and communication technologies to deliver products and services, usually information products or communication services. By **digital**, we mean information and communication that is reduced to (binary) computer code and that can be processed and transferred using computers and communication networks. We particularly focus on the impact of the internet and other communication networks that have enabled extremely high connectivity of social and business relationships. The societal value of information depends very much on the connections through which it is shared.

Innovation involves the creation of novelty, and novelty is difficult to define beforehand and usually uncertain to achieve. Creation of novelty through technological or business invention necessitates a creative step. In an R&D or new business development project the team can define some desirable goals or specifications, such as faster computing performance, but the more ambitious the project, the more likely that the specified goals are not reached. As a result, a radical innovation project such as an order of magnitude increase in microprocessor speed will be very risky. Such attempts to change the future are fundamentally unpredictable and unquantifiable.[6]

Innovation might be faced with both technical and market uncertainty. **Technical uncertainty** concerns whether the technical goals of the project can be reached. For example, the creation of a faster microprocessor requires packing more transistors on a chip that operates on ever-higher frequencies. It is not known at the start whether it is feasible to continue to shrink the manufacturing process beyond single nanometers, or whether there will be scientific discoveries enabling higher frequencies despite their power consumption and heat production.

Market uncertainty concerns whether the commercial goals of the project can be reached. While there has been seemingly relentless appetite for faster computing speeds, during the transition to mobile computing, demand actually shifted significantly toward chips featuring lower power consumption. Battery life is a key performance issue for mobile devices and speed may often be secondary. As a result, Intel's very fast processors lost much market share to ARM's RISC designs that are much more energy-efficient. Market uncertainty can derail even very successful incumbents.

Furthermore, in digital markets for information and communication products, user behavior constitutes another challenging source of uncertainty. **Behavioral uncertainty** can be viewed as a subclass of market uncertainty. When information and communication technologies are used within social groups, it is very difficult to predict what unintended consequences emerge through that process of social construction. **Social construction of technology** entails social interactions among users of technology, and interactions between users and technological artifacts that, jointly, influence how people interpret, adopt, and use the technology in their everyday lives.[7] Unintended consequences can be positive, such as innovative practices that enhance the value of the product, or negative, such as behaviors that reduce the value of the product for everyone. An example of a positive behavioral effect might be the emergence of "memes" as a popular and highly

[6] Knight, F. (1921). *Risk, Uncertainty, and Profit*. Boston, MA: Hart, Schaffner and Marx.

[7] See, for example, Bijker, W.E., Hughes, T.P., and Pinch, T., eds. (1987). *The Social Constructions of Technological Systems*. Cambridge, MA: MIT Press.

engaging form of user-generated content. A negative example might be the rise of racist or extremist user groups that may tarnish the reputation of otherwise neutral digital services. Behavioral uncertainty is particularly high in information and communication technology-based services because these technologies display exceptional **generativity** – they are capable of spawning additional innovations.[8] A considerable part of innovation strategy involves the management of all types of uncertainty.

1.3 Why are Information and Communication Technologies so Critical to Economic Performance?

In 2010, the United States President's Council of Advisors on Science and Technology stated that digital technologies are key drivers of economic competitiveness and crucial to achieving policy priorities in energy, transportation, healthcare, education, and national security; they accelerate scientific and technological discovery in nearly all other fields; and are essential to achieving goals of open government. By 2020, the US government's top science and technology priorities included 5G telecommunications, artificial intelligence, advanced manufacturing, autonomous transportation, cybersecurity, privacy, and quantum information science, in addition to priorities related to health, energy, and the environment. A very large part of Science and Technology policy had thus become digital policy. Even after 50 years of rapid innovation, the fast pace of technological change continued in digital industries. There was a constant churn and evolution of information and communication technologies, and early-stage technologies often took more than 10 years to become productive and widely adopted in the economy. The sheer pace of technological improvements continued to be more rapid in digital industries than in many others.

Digital technological advances have translated into unprecedented business innovation opportunities. A comparison of the 10 most valuable companies in the US economy in 2020 and 2000 reveals the tremendous dynamism of the digital economy. In 2000, oil, pharmaceuticals, retail, and banks along with general manufacturing were the dominant industries, although the economy was experiencing the first internet boom with the expansion of the networking infrastructure (Cisco) and the dominance of "Wintel" desktop computing (Microsoft + Intel). Vodafone was busy building the global 3G wireless networks. Oil was still at the top in 2010, but by 2020, the number of digital companies in the top 10 had doubled, with Amazon, Alphabet, Alibaba, Facebook, and Tencent representing a new type of a digital service company that was only invented in the late 1990s and early 2000s (see Table 1.1). These digital services were translating technological advances in information and communication into very large-scale business activity.

[8] See Zittrain, J.L. (2006). The generative internet. *Harvard Law Review* 119: 1974–2040.

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Table 1.1 The world's most valuable companies by stock market capitalization, 2000–2020

Ranking	2000	2010	2020
1.	General Electric	PetroChina	**Microsoft**
2.	**Cisco**	Exxon Mobil	**Apple**
3.	**Exxon Mobil**	**Microsoft**	**Amazon**
4.	Pfizer	ICBC	**Alphabet**
5.	**Microsoft**	**Apple**	**Alibaba**
6.	Wal-Mart	BHP Billiton	**Facebook**
7.	**Citigroup**	Wal-Mart	**Tencent**
8.	**Vodafone**	Berkshire Hathaway	Berkshire Hathaway
9.	**Intel**	General Electric	**Visa**
10.	Royal Dutch Shell	**China Mobile**	Johnson & Johnson

Digital companies in bold.
Note: Although digitalization was well under way in the year 2000, non-digital companies dominated the process of value creation until the 2010s. During that decade, digital platform companies grew to an unprecedented global scale and became powerful forces in their markets and broader economies.
Source: Retrieved from https://en.wikipedia.org/wiki/List_of_public_corporations_by_market_capitalization#2020 in August 2022.

Perhaps the most fundamental reason for the dominance of digital businesses in the economy was that information and communication technologies were driving the economy because they facilitated very basic and critical functions of the economy and society, and they were **General Purpose Technologies**: applicable in all parts of the economy.

Fundamentally, all decisions and actions we take depend on the sequence of:

$$\text{Communication} \rightarrow \text{information} \rightarrow \text{decision} \rightarrow \text{action}$$

Communication and obtained information influence everything we do, from looking for a job or a restaurant, to business decisions about market entry and product design, to societal decisions about voting, health policy, or even war and revolution. Thus, when communication technologies make it easier to access relevant information or coordinate with others, we will make more or better decisions that lead to different courses of action. Think about this sequence the next time you make a purchase decision. What were your sources of information and what was the network of communication you relied on to make the decision?

For example, upon buying a new phone you might first explore which phones your peers use by connecting with them in a social network. You might also search and visit comparison websites that write reviews of the latest products. Armed with the recommendations and technical information you would perhaps search for specific products from multiple websites, or use comparison shopping services to locate the best price. Only after that might you visit a specific retail store to purchase it. There is a whole ecosystem of information and communication about products and prices, and a single retailer will have limited control over the information available about their products in this communication network. However, if any of the elements of the information ecosystem are missing or deficient, your ability to optimize your decision may be compromised.

Information and communication technologies might also be called "**Invention Machines**."[9] They accelerate scientific progress by making the process of discovery and technological development more effective. As highlighted by the disproportionate importance of instruments in the process of invention (see Figure 1.1 above), the collection, analysis, and application of data and information are critical for the creation of new knowledge or new technologies. Consider the massive effect of the microscope on the biological sciences. Without such optical instruments, scientists wouldn't have been able to discover cells, proteins, genes, molecules, atoms, or microbes. The microscope revolutionized many areas of science, particularly the medical field, but it also facilitated environmental sciences and engineering. It enabled the development of modern medicine and new materials. The microscope is thus not only a general-purpose technology, applicable in a wide range of industries and technological fields, but also an Invention Machine that accelerated discovery and enabled subsequent inventions. Instruments are technologies that facilitate the collection and manipulation of information that then enters the processes of communication and transfer, decision making, and action. Technologies of information collection, retrieval, and communication are so critical to society and economic activity that their improvements and evolution will shape the very structure and functioning of society.

In today's economy, various computers and communication devices are the primary "instruments" and carry out much of the data collection. When people interact in social media, use mobility apps on their phones, drive around in a connected car, or browse webpages with the intent to buy something, they leave behind a digital trace that the providers of digital services collect, aggregate, analyze, and use for decisions and actions. Additionally, various sensors of physical activity also operate as instruments. Such sensors can detect the state or motion of a physical object. For example, sensors embedded in an engine can measure direction, motion, temperature, or vibration of the engine or its parts. Wirelessly connected sensors can then transmit the data to a remote computer that can analyze and potentially autonomously or with human help make decisions and act to modify the engine operation.

Considering the long-standing and massive economic, societal, technological, and scientific impacts of information and communication devices, we can speculate

[9] See Koutroumpis, Pantelis, Leiponen, Aija, and Thomas, Llewellyn D.W. (2020). Digital instruments as invention machines. *Communications of the ACM* 64(1): 70–78. Retrieved from https://dl.acm.org/doi/fullHtml/10.1145/3377476 in August, 2022.

that when data and analytics are networked at scale, very significant technological and economic changes follow, too. We saw such massive and disruptive impacts from the global adoption of the internet, and we can similarly begin to assess how the digital connectivity of physical objects and activities via the Internet of Things will influence scientific and economic progress in the coming decades.

KEY IDEAS

- Information and communication are critical for decision making.
- Digitalization changes how people and organizations find, collect, analyze, and communicate information.
- Rapidly evolving information and communication technologies influence the speed and direction of scientific discovery and technology adoption.
- Instruments, computers, and communication networks create the Internet of Things that promises to bring about a new wave of innovation in the economy.

DEFINITIONS

Behavioral uncertainty concerns user behavior when adopting new technologies and makes it difficult to anticipate how users react to and engage with new digital products and services.

Digital refers to information and communication that is reduced to binary code and that can be processed and transferred using computers and communication networks.

Digitalization refers to the social and economic processes of *adoption* and use of digitized data, artifacts and processes by individuals, organizations, and societies.

Digital business is any business that in its core processes is dependent on information and communication technologies to deliver products and services, usually information products or communication services.

Digital business innovation deals with improved technologies for information and communication that are designed to enable new forms of economic activity.

Digitization is the technological process by which analogue or physical artifacts and processes are *transformed* into digital or digitally-enabled artifacts or processes.[10]

Generativity is the capacity of technologies to spawn (generate) additional innovations.

General Purpose Technologies facilitate and accelerate very basic and critical functions of the economy and the society, and they are applicable in all parts of the economy.

Innovation is about change: the introduction of novelty into an economic system.

Invention Machines are General Purpose Technologies that accelerate scientific progress in many different fields by making the process of discovery and technological development more effective

Market uncertainty makes it difficult to assess whether the commercial goals of the project can be reached.

[10] Gradillas, M. and L. D. W. Thomas, “Digi-what? Distinguishing digitization and digitalization,” Unpublished Working Paper, 2021.