Data, New Technologies, and Global Imbalances

Beyond the Obvious

Georges Kotrotsios

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To those who do their best to bring beauty to life,
and to those who bring beauty to my life:

Yoann, Myrto, Stefi.

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PREFACE

THE 3 AS

Αξιοπρέπεια, Αλληλεγγύη, Αρνηση: three Greek words, which translate to dignity, solidarity, and refusal. It was the summer of 2013 or 2014, in Chalkidiki, northern Greece. Vassilis Papakonstantinou, since the mid-seventies a living legend of Greek rock music, was giving a concert, to the applause of his young (and less young, including me) fans. Then, at the end of the concert, he explained the three *A*s, his three *A*s—which we need, according to him, if we are to make our society liveable. I am really grateful for having heard, from this great person, these simple, impactful words, these three *A*s. Myself, I would change the last A to another word: Αμφισβήτηση. This means "doubt". I believe that Αμφισβήτηση — constructive doubt, my third A—is vital to our efforts to build upon the past while, when necessary, circumventing concepts that block our path on our journey to the achievement of dignity and solidarity, all in the context of the disruptive, technology-driven changes society and the economy are currently undergoing. Whatever the last A is, it has to do with how to achieve the two first *A*s.

Beyond any specific analysis that this book attempts, beyond potential ways to balance imbalances, the first two *A*s, dignity and solidarity, are the beacons we must not lose sight of.

When imbalances between regions of the world, nations, individuals, and—I dare to use the term—"classes" of people (though I believe that "class" today has a very different meaning than that conveyed by its original Marxist definition) increase at a rapid pace, keeping dignity and solidarity in mind are keystones in the maintenance of a sustainably liveable society. The reasons for global (and local) imbalances go well beyond the impact of technology and science. But science and technology are playing an increasingly important role, as we are here to extensively discuss.

I wish to thank the people who provided valuable stimuli to the thoughts expressed in this book: First, my boss, Mario El-Khoury, for having created over the years, in the place where I spend my professional life, an environment conducive to open, stimulating discussion and analysis, as well as for his own rigorously analytical approach, which proved really valuable to my putting together the thoughts expressed in these pages. Olivier Parriaux, Professor Emeritus at Jean Monnet University, Saint Etienne, for long and valuable discussions on the political aspects of this analysis. My former colleague Aline Bassin—now an economics correspondent at the Swiss daily *Le Temps*—with whom I debated aspects of technologies and resources. Dave Brooks, who helped correct this text, provided invaluable help, always asking the difficult question regarding the meaning of my words, which itself pushed my thinking even further. And last but by no means least, the three people with whom I share my life: my two kids, Myrto et Yoann, and my wife, Stefi, who—through their love and patience—allow my brain to wander beyond the limits of the everyday.

Chapter 1

Introduction

Prior to the Industrial Revolution, wealth was—at least for the vast majority of people—directly linked to agriculture and the ownership of land: the more land a person, family, or society owned, the more domesticated animals this person, family, or society could support, and the more crops they could grow. Commerce and artisanal production were both based firmly upon raw materials, often the direct outputs of agricultural activity. War and related looting were, of course, another important source of wealth, as was the control of commercial roads. But again, in the majority of cases wars targeted the occupation of land in order to facilitate agriculture and access to commerce. This was a Malthusian (Malthus, 1798) society. Land ownership was a *casus belli*—a cause of, or sometimes a justification for, war.

What the Industrial Revolution changed was that machines were now able to produce wealth, since they could replace work, both agricultural and artisanal. In the industrial world, the accumulation of capital in the form of industrial machines became an additional source of wealth. Machines were (and still are) a multiplicative lever that enabled their owners to accumulate wealth at a faster pace, and more efficiently than an owner of land alone. As we transitioned from one world to the next—from the Malthusian to the industrial—wealth accumulation mechanisms changed radically.

The advent of the industrial world led to a decrease in the importance of agriculture, while increasing the importance of raw materials, either as inputs for the aforementioned machines (e.g., cotton, metals) or in the form of the energy required by those machines (coal, fossil fuels, nuclear fuel, and more recently renewable forms of energy, including hydraulic power, wind power, and photovoltaics). Land ownership remained a *casus belli*—as previously, in terms of agricultural resources (as was the case during World War II with the conflict between Germany and the USSR (Francopan, 2017)), but increasingly in terms of access to resources. The decrease in the importance of agriculture and the artisanal proved, in fact, to be extremely significant: agriculture currently constitutes less than 2 percent of the GDP of Western countries.

Today we are entering a new world: the data world. A new form of wealth is being added to all the previous forms, and that form is data. In this new world, data (and technologies that create and process data) is the factor that is changing wealth accumulation mechanisms and human societies' modes of competition in a completely new way, a way that we are only now starting to understand. The resulting impact is difficult to evaluate and goes far beyond the creation of certain large companies. It has to do with a redistribution of wealth between persons and between areas of the world. It also has to do with the extraction and accumulation of wealth. Land is becoming less important than it was in the Malthusian world or the industrial world, and is therefore less a reason for war. Wars are becoming increasingly commercial, and data is part of the weaponry, as well as part of the loot. Wealth extraction and accumulation are also changing. Increasingly, consumers are trading (or to be more precise, giving away) their wealth (i.e., their data) in return for services, including access to social media or search engines. To obtain all these data, adequate tools and resources are needed, and the interplay between three elements—resources, which have existed since the Malthusian world; manufacturing, initiated by the Industrial Revolution; and the digital technologies of our new, data world—is deepening, and shaping the world of today.

Of course, the challenges faced by human societies, both today and tomorrow, go well beyond the realms of science and technology. They have to do with ourselves, our relation to each other, and our relation to the environment, built or natural. These challenges are societal, economic, environmental, and political. They remain, however, strongly dependent on the accelerating pace of scientific inventions and technology-induced innovation, and the pace at which these challenges are changing is, thus, unprecedented.

To illustrate this in a more concrete way, I would like to take you on a journey back four centuries in time. In the late sixteenth century, the Dutch discovered how to use wind power to saw wood. The sawing of wood was important for the shipbuilding industry. Thanks to their invention, the Dutch were able to replace human power with wind power. The result? The acceleration of the shipbuilding process: a task that previously took six months now took only weeks. The seventeenth century was a century of Dutch global domination. Of course, technological innovation was not the only influential factor, but it was essential.

Wind power, associated with shipbuilding knowledge, created a competitive advantage of specialization, as theorized a century later by Adam Smith. The Dutch model, which we just examined, is a classical process of economic growth based upon technological innovation. Did it lead, however, to the same type of growth that we are experiencing today?

In the closing years of the last century, technology, IT, electronics, and robots replaced the human factor. This model was, in terms of its basic economic mechanism, very similar to the Dutch model of the seventeenth century: accelerating productivity.

So, what had changed between the end of the sixteenth century and the end of the twentieth? The answer to this question illustrates precisely the difference between the industrial world and the Malthusian world: productivity has increased, not only thanks to machines but also due to the accumulation of immaterial assets such as data (and algorithms); and wealth exists not only in the form of classical assets, which accountants—for example—are used to dealing with, but also in the form of data, which we cannot manage appropriately with our current accounting practices. The next question is, what is different today compared to the end of the twentieth century? The answer? The creation today of increasingly large amounts of data and the use of these data in the digitalization process. Such vast amounts of data can only be created because we have a convergence of factors. Today we are able to rapidly manufacture high-quality, affordable digital systems; we can access high-bandwidth communication networks that allow us to transmit data; we have at our disposal powerful computers equipped with high-performance algorithms that can store and process all these data; we have all accepted a common interaction protocol, the Internet.

The presence of these large amounts of data enables mechanisms that create innovation in a radically different manner. Further, the presence of data and these novel innovation mechanisms act in a different way on human societies and economies, transforming the way they function by disrupting processes. These transformations also change the way that industry produces, and as a consequence the way that technology develops.

Personalized health, the smart city, and the autonomous car are often-quoted examples of the evolving role of technology, industry, and the economy. The impact of this evolution can, however, appear in unexpected places in our societies. Gender differentiation is just one example. According to Lausanne's IMD Business School, in India men buy three times more than women over the Internet. We are not, here, judging this fact as either good or bad, simply presenting it as an indicator of differential gender behavior. Effects of gender-differential behavior certainly exist in other parts of the globe and in other domains, due—in particular—either to limited access to IT infrastructure or to gender-related discrepancies with regard to education.

A topic close to that of gender-differential behavior is birth control and the emancipation of women. These are, at first glance, far removed from technology. Throughout history, the practice of birth control has been more or less empirical and often quite random. Today, a sophisticated wristband—a kind of smartwatch—offers a precise indication of where a woman is in her fertility cycle. Is this good or bad? Can this technology be used widely, all over the world? These questions are open to debate. What is not debatable, however, is that the technology is here and has been commercialized, and that it has the potential to contribute to our efforts to meet societal challenges—even those as difficult to grapple with, a priori, as gender discrepancies or birth control—doubtless in both high- and low-income countries.

Leaving the domain of societal challenges behind and looking at environmental challenges, we see that issues such as arable land (which has a direct impact on food availability and quality) and water scarcity and control are becoming critical. Today, one third of arable land has been degraded by overexploitation: only precision agriculture can help humanity provide enough food, as we stand on the cusp of a world in which we will be asked to sustain nine billion individuals. Satellites with smart (hyperspectral) cameras, associated with smart terrestrial devices, can drive such precision agriculture. Robots with smart vision are being used more and more widely to optimize plant care and harvest agricultural crops. What does this mean? It means a change in agriculture as a process, and in value chains and the very jobs of those people who create the element that answers our most basic need—food.

We can also observe disruptive changes happening in an entirely different domain, that of the value chain of energy production and distribution: the logistics of energy generation by centralized nuclear and thermal plants are changing rapidly, giving way to a mix of centralized and decentralized energy production and usage systems that in turn require complex digital systems that allow real-time control and optimization.

In yet another domain, half of the world's freshwater flows across the borders of at least two countries, making the potential for disputes very real.

For two-thirds of these cases[1] there is no cross-border management system. Obviously, only mobile, sturdy, easy to deploy and use electronic devices can enforce fair monitoring. And it is not only the economy that is concerned here. Water is expected to be another *casus belli* in the decades to come. Proper quantitative monitoring can form a common basis of understanding, and a starting point for discussion. So, the challenge of water resource monitoring is not only environmental, but also political.

Societal and political issues closely related to the evolution of technologies are evident in our daily lives. According to the World Bank, average per capita wealth in OECD countries is more than 50 times higher than that in low-income, non-OECD countries.[2] Worldwide,[3] the "top" one percent (in revenue terms) of the population earns two times more than the "bottom" 50 percent. In Europe, the "top" 20 percent (in terms of assets) of the population earns five times more than the "bottom" 20 percent.[4] This discrepancy is continuously increasing. Is this only due to technology and to the growing role of data? Certainly not, but the complex interplay of the delocalization of the manufacturing industry and the increasing power of capital, particularly when that capital is interconnected with digital assets, is nevertheless an important factor, and one we will discuss below. And this discrepancy is also, at least partially, the cause of political and social unrest, including large migratory movements from poorer to richer areas of the world, or unrest within the same geographical area, the latter variety having a very recent example in the "yellow vests" (*gilets jaunes)* movement in France.

In the chapters that follow, we will try to analyze the mechanisms behind the role of technologies in these changes, along with these mechanisms' potential impact.

In "Technological Trends, Industry Trends, Impact on Society, and the Evolution of the Economy", the mechanism of accelerated, mutual interaction between technology trends, industry trends, and societal as well as economic

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[1] IMD International Institute for Management Development. "Access to water", IMD Global Signals, 2020 Edition. For more information on IMD Global Signals: https://www.imd.org/research-knowledge/global-signals/environmental/.
[2] https://openknowledge.worldbank.org/bitstream/handle/10986/29001/97814648 10466.pdf, page 45.
[3] wir2018.wid.world/files/download/wir2018-full-report-english.pdf, page 13.
[4] IMD International Institute of Management Development. "Rising inequality", IMD Global Signals, 2019 Edition. For more information on IMD Global Signals: https://www.imd.org/research-knowledge/global-signals/environmental/.

impact will be addressed, and the various interconnections and mutual interplays discussed. It transpires that all these interactions are growing in intensity: Everything in our economic and social lives (and also our political lives) depends on technological evolution and interactions. On top of this, these interactions are not only growing in intensity, they are also becoming more complex and evolving more rapidly. The main message is that private and public stakeholders need to take these interactions—these increasingly important factors—into account when it comes to public and private policy making. Understanding them is a first step.

In the following chapter, "Data and Resources", we address the question of the often invisible role of resources such as energy, place, and bandwidth in our world. And if there is one resource that we cannot omit from our discussion, it is the human resource, which is the subject of the chapter "The Human Factor in the Digital Age: The Manufacturing Environment". Here we will avoid addressing topics often covered by works appearing in the bibliography (such as, for instance, those covered in Rifkin's *The End of Work* (Rifkin, 1995)) concentrating instead on changes to working environments.

The chapter that follows, "Comparative Advantage and Geographical Economic Clusters", addresses the impact of technologies, in particular digital technologies, on the formation and the competitiveness of ecosystems, and on the risk of creating vast disequilibria that can only be addressed when adequate attention is paid to the processes of policy making and policy implementation. The importance of increased interaction—and on fairer terms—between the public domain and the private domain is also highlighted.

The sixth chapter looks at "Data, a New Form of Capital" and at how data capital can accelerate the creation of imbalances. Perhaps one of the chapter's most important messages is that we no longer live in a world where capital cooperates with and competes with labor: today we have a triangle between capital, labor, and data capital. And data capital disrupts the traditional coexistence of capital and labor, creating a completely new economic and social landscape.

In the final chapter, "The Path Forward", we present a number of disruptive proposals. These include the taxation of data, creating a (legal and regulatory) global governance mechanism for digitalization, and modifying the dominant culture of national state governance to incorporate a new, more entrepreneurial spirit.

The common theme of these different analyses is that technology is impacting resources (human, material, and immaterial) at a faster and faster pace, leading to the creation of disequilibria, whether these be geographically concentrated or geographically spread. If we fail to pay sufficient attention to these disequilibria and to the question of resources, our societies may disintegrate.

CHAPTER 2

TECHNOLOGICAL TRENDS, INDUSTRY TRENDS, IMPACT ON SOCIETY, AND THE EVOLUTION OF THE ECONOMY

Technology and society: Their changing relationship

Major technology trends, industry trends, and societal and economic evolution today form a complex puzzle. An understanding of the evolution of each of these elements and its impact on how this puzzle evolves can be useful with regard to the puzzle's overall optimization. When seeking to obtain such an understanding, an important tool is an analysis of the mutual interaction of these elements.

Given the ever-increasing importance of technology in the shaping of the societal and economic landscape, such an analysis can make a valuable contribution to the elaboration of measures that can mitigate potential societal or economic imbalances, maintain overall sustainability, and promote opportunities for better living.

To advance toward such an analysis is useful as it enables us to try to create a conceptual basis for the aforementioned mutual interaction, even if that conceptual basis cannot be either exhaustive or generally accepted.

We can visualize this proposed conceptual basis as existing on **three levels** that are parallel to one another: the technology trend level, the industry trend level, and the level of societal change. These levels interact with one another via a form of chain—a kind of imaginary arrow that traverses them. This arrow is bidirectional: as much as new technologies enable new industrial trends and impact society, societal changes require industry to follow, which in turn means new, adequate technologies.

At a high level we can state that all of today's major technological developments relate to one or more of three major **technological trends;**

namely, new manufacturing techniques,[5] digital technologies, and technologies related to resource generation, management, and access.

Technology trends are at the origin of the creation of **industrial trends**,[6] which can themselves be categorized into three groups: new manufacturing paradigms, digitalization, and the complexification of products and value chains.

In turn, industry trends impact societal evolution and create new economic effects. And both society and the economy are closely linked to politics and the environment. For brevity in the present analysis, when using the terms *society* and *the economy* we understand them to incorporate, if only as a backdrop, politics and the environment—politics as a regulator and the environment as a constraint and boundary condition. These three levels are schematically illustrated in Figure 2-1.

There exists a continuous interaction and **convergence** between technological trends. This convergence happens in multiple ways, as we will detail below. It accelerates and strengthens the chain of interaction between technology, industry, society, and the economy. A new key factor that has emerged over recent years is data. Its presence is the result of the intense digitalization of our economy and society. Data is also the oil that lubricates all these interactions, resulting in them both accelerating and strengthening. This acceleration and strengthening of interactions, in turn, allows the creation of even more data, in an upwardly spiraling mode.

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[5] For the sake of simplicity, biological processes that create new types of medication or even newly emerging artificial (human) organ technologies can be categorized as new manufacturing techniques

[6] Here, the words *industry* and *industrial* are understood to comprise all value creating economic activities, including those taking place outside of the secondary sector (i.e., manufacturing). Thus, service provision, for example, is included.

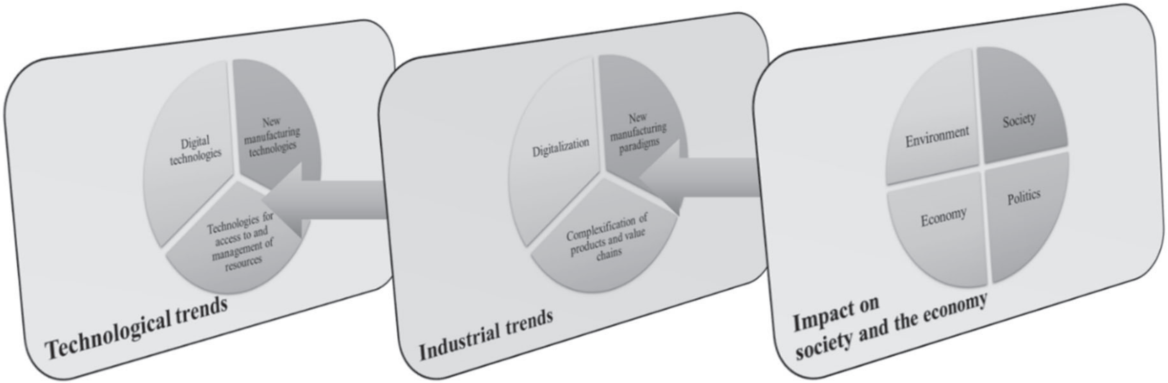

Figure 2-1. The accelerating evolution of technology in the form of its three key trends is having an increasingly strong effect on the way industry (including service provision) operates, which in turn creates rapidly evolving changes in how the key elements of our lives—society, the economy, politics, and the environment—function. We can observe that this effect is becoming stronger as time passes

Our analysis below is structured to follow the aforementioned logic: It starts with an analysis of technology trends, followed by a description of convergence mechanisms. Then, industrial trends are illustrated as are impacts on society and the economy. The mechanisms that link these three levels are discussed in depth. The focus then moves to the role of data in interactions, before the impact of these mechanisms on the sustainability of societal and economic change and the potential types of measures that society and the political milieu could adopt to support economic, societal, and ecological sustainability conclude this analysis.

Technological trends

The first step of our analysis is to try to understand the trends behind the big evolutionary changes in technology that are today commonly accepted as mainstream and involve technologies that are widely expected to mature further. These are diverse, and include the dominance of artificial intelligence, 3D manufacturing, 5G and 6G communication technologies, alternative energy, robotics, biotechnologies, artificial organs, augmented and mixed reality, the Internet of Things (IoT), quantum computing, augmented reality and related usages such as personalized health (which includes printed organs and vital sign monitoring), smart cities, and autonomous vehicles. Our first target, then, is to identify these "big rivers"—the **technology trends** that are the common denominators of all the aforementioned topics and that, today already, inundate our lives.

These underlying "rivers"—these technological trends that seem to carry with them everything in their path—can be gathered together into one or more of three big lines: digital technologies, new manufacturing technologies, and technologies that allow the generation of, access to, and optimization of resources.

Digital technologies

The term digital technologies includes all Internet and networking technologies but also extends further, including all technologies that allow the extraction of data and their transmission in digital form across communication networks. The information that we want to extract, copy, transmit, and process is in the vast majority of cases analogue at the macroscopic level, varying continuously (e.g., temperature, weight, light intensity, and color measurement). Every single device that is used to measure analogue information and transform it into digital form and then process it, store it, display it, and communicate it—still in digital form—is part of what we call digital technology. Today, such devices are everywhere. For example, 40 percent of the value of the average automobile is in the form of digital technologies, including sensors, geographical positioning systems, electronic driving controllers, and many other elements. Airplanes fly controlled by digital devices and systems. Factories are controlled by digital devices and systems. Household appliances such as refrigerators, ovens, and autonomous vacuum cleaners are controlled by digital devices and systems. And, of course, these are only a few examples. These individual devices, operating at the "edge" of electronic networks are the "things" of the Internet of Things (IoT)—the dimension of the Internet that is going to operate without human intervention. The IoT is only the natural extension of the Internet, an extension that humans will, of course, continue to feed with valuable digital information in the form of text and numbers, photos and videos.

Whatever we refer to today as artificial intelligence is also an example of digital technologies. Artificial intelligence comprises the very advanced algorithms that can replace basic human operations. It is expected that such algorithms will, in the future, be able to manage more and more complex functions.

Robots are "simply" complex mechanisms that can, today, carry out actions commanded by simple algorithms. Soon such algorithms will become more and more complex. But at some point more and more complex algorithms become artificial intelligence, which in turn becomes more and more evolved. Artificial intelligence, as it evolves, will be increasingly able to make decisions currently made by people or organizations, or at least give very precise information to people and organizations, allowing them to make these decisions while reducing uncertainty to the minimum.

Other technologies that can be categorized as digital include the upcoming applications of quantum communications and quantum computing, based—as their name suggests—on the quantum behavior of particles. Based on these "weird" phenomena, extremely powerful computers and communication systems are expected to become reality. Such computers will be able not only to perform calculations at previously unimaginable speeds, but also to run new families of algorithms that we are yet to conceive of.

New manufacturing technologies

Manufacturing technologies allow the realization of tangible “objects”. These can be in the realm of what has been manufactured for many years, but with better quality and more features (automobiles, telephones, or watches), but they can also be new objects with as yet unseen functionalities and performance, such as smart objects (e.g., smart sensors or actuators), processors, robots, bio-medication, artificial organs, flat displays, or more efficient solar cells. Robotics and sensor and communication techniques—in other words, digital technologies—allow the very existence of such devices in forms that are reliable, and available at a commercially acceptable price and in a reasonably small form.

In turn, these novel objects allow manufacturing techniques to become faster, more reliable, interconnected (to improve logistics), efficient (to optimize cost and yield), and easily reconfigurable (to create customizable, versatile projects). Without digital technologies new manufacturing techniques could not be employed. From the opposing standpoint, the digital world cannot exist without real “things” that we can use. In today’s world, the one cannot do without the other.

For reasons similar to those for which digital technologies should not be mixed up with the digitalization of the economy and society, we need to be extremely careful to avoid mixing up manufacturing technologies with the changing manufacturing paradigm, which we shall encounter below. The latter is an industrial trend, while manufacturing technologies are technology trends.

To illustrate the continuous evolution of manufacturing technologies, let’s focus on a novel example: additive manufacturing. The concept is simple; the results can be remarkable. Additive manufacturing is the natural continuation of “classic” manufacturing. Additive manufacturing is the process of adding material to create monolithic and often complex forms. This can “simply” happen by heating and melting powders in a specific point in space, using a precisely positioned laser beam.

Despite the simplicity of the method, or perhaps because of it, the consequences of employing additive manufacturing can be significant. Additive manufacturing systems can be cheap because the necessary equipment is quite simple, and often inexpensive when compared to the complex machinery required for mass produced, “classically” manufactured goods. What does this mean? It means that individuals can buy one of these additive manufacturing systems. This means that each individual will—although, of course, we are stretching this logic to the extreme—be able produce his or her own goods, such as footwear and clothes, at home and at will. This ability may have a deep impact on manufacturing. The structure of the manufacturing industry itself might be modified. In some cases, instead of buying goods the consumer will be buying designs for goods, which she or he will be able to modify at will. Of course, it is currently inconceivable that mass-produced goods will cease to inundate markets, but additively manufactured goods will coexist with them.

Clothes and footwear are only two examples. Food is another example of a potential 3D-manufactured good, in this case biological and organic in structure. And if one can produce biological structures, why not produce organs—hearts and livers, fingers and skin? And this is precisely where we are heading. Additive manufacturing methods alone are not enough, but such methods will most probably play a key role in the building of biological structures such as human organs, which will change medicine disruptively. The implications surpass our imagination.

Since new livers, kidneys, or lungs can be produced, why not new *types* of livers, kidneys, or lungs—types that are improved and have other functions? Why not even combine a liver with a kidney, resulting in a new organ that performs the functions of the kidney and the liver simultaneously? And, of course, why not combine the biological with the inorganic in the same organ to increase functionality?

We have not, here, addressed the question of the increasing potential of biotechnology in terms of medication or sensing, only that of disruptive manufacturing. And here resides much of the subjectivity of paradigm choice. Is the manufacturing of organs (or augmented organs) more impactful than biotechnology as pharmacy? Perhaps not. What is more disruptive is the change of the paradigm of our society and our economy. And the choice of that paradigm is, therefore, pertinent. Medication is the evolutionary outcome of what human beings since the time of Hippocrates have been trying to do: have substances (natural or man-made) influence processes, which can be regular processes (so, for instance, aging) or processes that appear unexpectedly (illnesses). The manufacturing of organs is radically different conceptually: it has never happened before. Of course, both regular and known processes will be, potentially, replaceable by the manufacturing of organs. It is not unconceivable that more biological functions will be designed. Such new functions (activated by new types of organs) may include some that can today barely be even imagined. For example, today animal species such as whales and bats have the biological function of localization. Would it be feasible to invent (and manufacture) and implant new human organs that can perform such a function? Or fly-type eyes? Or scent organs that have the sensitivity of those of dogs, or even greater? Or biological organs that produce, directly, digital signals?

Technologies for accessing and managing resources

To begin with let's look at energy. The generation and management of energy, in particular renewable energy, are typically heavily dependent on cutting-edge technologies. The question of energy concerns not only the obvious energy consumers such as transportation, heating, and industry. Even "hidden" heavy users such as electronics can rapidly generate stumbling blocks. Today, the portion of global greenhouse effect emissions caused by digital technologies is approximately 4 percent.[7] In 2030 it may be between 6 percent and 14 percent.[8]

Technologies employed in energy generation and management are essential for both the success and the large-scale deployment of digital and new manufacturing technologies. Who would use a smartwatch that needs recharging every two hours?

The wise use of digital and manufacturing technologies can be a defining factor for the sustainability of our societies. Such careful use of digital technologies could preclude greenhouse effect emissions by a projected 9 percent overall by 2030.[9] Proper use of manufacturing technologies, meanwhile, can reduce the quantity of material resources used in manufacturing processes. Traditional manufacturing removes and subsequently discards, and thus wastes, material during the manufacturing process; additive manufacturing does not.

Energy is hardly the only resource that might be lacking in the decades to come. Other elements or resources that, for the time being at least, we assume will continue to be available in sufficient quantities—including bandwidth, storage space, and computing resources—might be available

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[7] https://theshiftproject.org/wp-content/uploads/2019/03/Executive-Summary_Lean-ICT-Report_EN_lowdef.pdf.
[8] http://www.electronicsilentspring.com/wp-content/uploads/2015/02/ICT-Global-Emissions-Footprint-Online-version.pdf.
[9] https://gesi.org/storage/files/__DIGITAL%20WITH%20PURPOSE_Summary_A4-WEB.pdf.

only at a premium. Today, the number of IoT (Internet of Things) devices are counted in the tens of billions,[10] and their number is expected to increase following a double-digit growth curve. Each one of them is measuring or monitoring and regularly sending information. This tsunami of data will be added to the already existing data streams and information communication channels used by people over the "regular" Internet to transfer photos, video, or text. Some ballpark figures are often quoted and give an idea of the expected orders of magnitude:[11] in 2020, every person on Earth is going to produce—on average—1.7 MB of data per second; over the years that follow, the pace of data creation may well increase at a double-digit rate of growth. Even if these volumes of data can be accommodated in 2020, this situation will not—in terms of storage, processing, and communication—be able to continue forever unless completely disruptive technologies such as quantum computing mature on time. Today, real-world[12] quantum computers are not yet a reality, and the eventual realization of real-world commercial devices is not even a certainty.[13]

Other considerations include the "footprint" of both IoT devices and the computers that will store this growing volume of information. The computing power necessary to process these mountains of data and, of course, the energy required to run these computers as well as to cool them constitute further challenges.

Resources are the basis of, as well as one of the key constraints on, what we need both for manufacturing and for digitalization. Resource access and management is one of the three pillars of sustainability (the other two being economic sustainability and social sustainability, which—as they are not technological trends—we will address at the end of this analysis). Sustainability is key: without sustainability, everything—from ourselves to the environment, society, and the economy—becomes unstable and either explodes or implodes.

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[10] https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/.

[11] https://www.socialmediatoday.com/news/how-much-data-is-generated-every-minute-infographic-1/525692/ ; https://www.ibm.com/downloads/cas/XKBEABLN.

[12] https://www.barrons.com/articles/google-ibm-primed-for-a-quantum-computing-leap-says-morgan-stanley-1503602607.

[13] https://spectrum.ieee.org/computing/hardware/the-case-against-quantum-computing.

So far, we have not addressed other essential resources such as water, food, and conventional fuel (oil and gas). Today, technologies support the extraction, exploitation, production, transportation, management, and distribution of all these resources. Their sustainability is as (if not more) important as that of the other resources discussed above. As they are only indirectly related to specific technologies, however, we can situate them much more comfortably in the fields of the economy and society, which we will discuss below.

Convergence

The three technological trends (digital technologies, new manufacturing technologies, and technologies for accessing and managing resources), and indeed all the technologies of today, coexist and interact mutually. This coexistence is the first step toward convergence, which we will go on to analyze. That convergence is a mechanism that creates an acceleration and a reinforcement of the impact of each one of the technological trends or industrial trends that we are here to address. Convergence happens in different dimensions.

Convergence between disciplines

Convergence occurs between technologies. A well-known case—and example—of convergence is often referred to as "NBIC", which stands for nano-, bio-, information-, and cognition technology convergence. This convergence can be seen in devices and systems that englobe technologies coming from completely different disciplines.[14]

In manufacturing terms, devices that necessitate technological convergence (such as that seen in NBIC) bring about an extremely strong diversification of equipment, infrastructure, and human-resource skills. Since multiple,

[14] One example that illustrates this type of convergence is security that is materialized by the use of micro and nanodevices. Nanodevices are expected to play a future role in protecting people and critical infrastructure from human threats. Efforts to contain such security threats (e.g., chemical, biological, or explosive) will benefit from the merging of both nanoscience disciplines (hard and soft matter) with biology. For instance, the use of specific antibodies encapsulated in nanodevices opens new routes to the multiplex detection of chemical, biological, or explosive agents. Appropriate nanoscale encapsulation allows fast and easy deployment over large volumes while maintaining sensitivity.

very different technologies are needed, the corresponding equipment, infrastructure, and personnel type are both specialized and very different from one technology to another. Equipment and infrastructure tend to be very expensive; people need to have dedicated, high-level skills. Few organizations throughout the world have the financial means to sustain the variety of equipment, infrastructure, and human resources required to cover, for instance, all of the NBIC technologies, with regard either to production or to R&D. Such convergence thus calls for **more complex value chains** that can fulfil all the requirements for products and services that are based on converging disciplines.

Coexistence of research, design, and engineering

Convergence and concurrent engineering can happen between the different phases of design (including material selection and engineering), device manufacturing, testing and feedback/optimization of design and manufacturing, integration of working systems, and functional testing. A reason for convergence between operations such as design, manufacturing, assembly, and testing might be the need for a shorter and shorter time to market at continuously lower costs. Closer and faster interaction all across the innovation value chain will, due to this type of convergence, require **faster, more digitalized processes**.

Coexistence of the real and the virtual

The third type of convergence, and perhaps the most iconic of our era, is that between the real and the virtual worlds. The Internet of Things is the most illustrative example. The Internet itself is the exemplification of the digital, the virtual world. The “Things” (of the Internet of Things) are the exemplification of the real world of manufactured devices. Without each of the two pillars “Internet” and “Things”—digital and virtual on the one side, real and manufactured on the other—the Internet of Things cannot exist. The IoT is increasingly present in our lives, in every respect, from health to entertainment, to transportation, energy, and far beyond.

Today we can have affordable and miniaturized IoT devices because:

- The microelectronics industry is enabling a dramatic decrease in power consumption requirements for the operation and miniaturization of effective devices.
- The energy industry is enabling the scavenging of energy from the environment, which makes possible the optimization of the energy

consumption of novel microelectronic devices, thus paving the way to a steep increase in their deployment.

- Communication technology is making advanced networking techniques—including 5G, but also numerous alternatives such as Lora, Wi-Fi, Bluetooth, and many others—a reality.

Thanks to these capabilities, and specifically their convergence and coexistence, the IoT can exist today, with—at its edges—devices that are quasi-invisible, are produced at very low cost despite the intense customization involved, and are rapidly invading our working and living environments.

Industrial trends

The three technological trends lead to corresponding industrial trends. In turn, industrial trends create a need for these technological trends. Three big industrial trends seem to stand out. The term *industrial* is used here to represent economic activity, and for the sake of simplicity in this text integrates both industrial production and service provision activities.

These three big industrial trends are:

(i) **Continuous change to and adaptation of the manufacturing paradigm**.
(ii) The **digitalization** of a continuously enlarging spectrum of activities.
(iii) The increasing **complexification** of products, processes, services, and related value chains.

A different classification might exist. What is important here, however, is that the very act of seeking such a classification allows us to facilitate the setting up of a conceptual framework and, further, to analyze the relations between the technology trends discussed above and industrial trends, and the differences between technology trends and industrial trends.

To illustrate the meaning of each one of these trends we can cite some examples. For instance, the **digitalization** of health means using digital technologies to make better diagnoses. **Digitalization** in industry means the use of digital technologies to make production more efficient and/or more secure. The digitalization of energy means the use of digital technologies to optimize the production of and commerce in electricity, and so on for all aspects of our social and economic lives.

Concerning **the evolution of the manufacturing paradigm**, we note that these changes were initiated in the second half of the last century (in particular after the oil crisis). Increasing salary costs prompted industrialists to pursue the massive relocation of manufacturing industries previously located in Europe and the United States to Asian countries with lower production costs, mainly because of the erosion of margins (itself a function of wage pressures in Western countries). It is interesting to mention here the dogma of this period—that manufacturing can be geographically split in terms of engineering, on the one hand, and research and development, on the other.

Just ten years into the next century, Europe and the US had understood that this dogma was wrong and unsustainable. Engineering, R&D, and other services (and related jobs) could no longer remain removed from the place of manufacture and therefore started to rapidly shift to those areas attractive for manufacturing, engineering and R&D jobs rapidly moving from Europe and the US to countries with strong manufacturing sectors. As a remedy to this change (which was now going beyond a pure manufacturing paradigm change), Germany was the first to encourage the emergence of Industry 4.0—the digitalization of the manufacturing process.[15]

The ultimate objective of the Industry 4.0 initiative was to increase industrial productivity, thus allowing high-end manufacturing jobs and related service jobs (such as engineering and R&D jobs) to be maintained, and—of course—the wealth associated with them to be retained. This concept quickly extended across the globe.[16] It is feasible now because several of the required technologies are maturing: the IoT, artificial intelligence algorithms, augmented reality, robotics, and—of course—3D manufacturing. Here, digital technologies are also enablers for the evolution of the manufacturing paradigm.

The implementation of digital technologies has enabled frequent and efficient interaction between industrial actors, together with the fast and efficient exchange of data, designs, and images.

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[15] The notion of the digitalization of industry is often perceived differently by different parties. This perception ranges from the digitalization of simple tasks, including, for example, billing, to the total automation of factories or even of the old value chain, including external elements.
[16] The notion of "Society 5.0" was recently introduced (initially in Japan), and implies the digitalization of all aspects of human life.

Complexification is the result of naturally increasing convergences, as outlined above. In addition, the fact that data are being created at an unpreceded rate is adding to complexification. The mere existence of these data enables the creation of value chains that involve, simultaneously, the real and the virtual: products and services tend to coexist in continuous value chains, which are, therefore, becoming longer and naturally more complex. One example of this is our complex and multifunctional smartphones, and the digital services associated with them.

The social and economic impact of industry trends: Scope and evolution

To illustrate the impact that these industrial trends are exerting on everyday life, we can begin with the example of ambulatory personal care for lifestyle and health management. The objective here is to highlight the role of technology trends and industry trends as well as the growing role of technological and industrial trends in our social and economic lives.

Impact on the business world

Today, several diseases, in particular cardiovascular diseases (CVDs) and cancers, are becoming—in societal terms—chronic, particularly in middle- and high-income countries. Cancer is often treated for years and does not cause immediate death as frequently as in the past. A predisposition to CVD is detectable, and CVDs are most often managed and treated over several years. At the same time, and due to an increase in life expectancy, neurological diseases such as Parkinson's disease or Alzheimer's disease are more common, and their treatment is increasing in duration. As a result, health costs are increasing significantly. One of the most promising ways to reduce costs is to treat patients and convalescents outside the hospital, on an ambulatory basis. To this end, prevention and follow-up that can be carried out directly on the person concerned is indispensable. Personal health monitoring solutions include portable electronic devices (such as smart textiles, bracelets, etc.). These electronic devices produce a large amount of data. Data can be passed from patient to hospital, to doctor, and even between several doctors. Artificial intelligence (AI) algorithms can process these data and provide information and advice to doctors and patients. *The generation of large amount*s *of data* by digital devices allows the generation of valuable information after appropriate processing: this illustrates a case of digitalization enabled by the sole existence of digital devices.

In this example, we see a completely new relationship between existing economic actors and that new economic actors are entering the competitive arena. The latter include new companies that produce new types of medical devices and offer new types of services. New value chains and business models are formed in the field of medical care, including—for instance—telemedicine service providers or companies that collect and process these medical data, an example being IBM, with its Watson system.[17]

In parallel, new value chains are also being created at the technological level in order to be able to implement devices intended for ambulatory health monitoring. Such devices include optical components (e.g., green LEDs and lenses and sensors for wrist pulse monitoring), accelerometers (e.g., for measuring the number of steps a person takes each day), chemical sensors and electronics to transform real-world data into bits, microprocessors to preprocess this data, and—of course—communication circuits (e.g., Bluetooth circuits) to transfer the data, for instance to a smartphone. Such devices also include algorithms that are increasingly advanced and complex. The integration of all these elements into systems that can be used by everyone illustrates the increasing complexity of hardware. The creation of new business models and new value chains for components, software, and services, as illustrated by this example, clearly demonstrates the multiple **complexifications** (i.e., of the product, the value chains, and the business case) enabled by the technology and required by the application.

Such products are rapidly upgraded once in the marketplace, requiring new components and software at an increasing pace. Products must be increasingly reliable and less expensive, in particular when used by nonprofessionals. These elements have an impact on the manufacturing industry.

The manufactured products of tomorrow will be multifunctional and will need to get rapidly to market and at a low cost. Cost reduction can result from automation, vertical integration, and efficient access to R&D.

These new types of devices (new in terms of their functionality, form, miniaturization, and cost, as well as in terms of development processes) require radical changes in the **manufacturing paradigm** with regard both to manufacturing processes and to the digital systems that support them. The paradigm is both enabled by the technological trends and is stimulating

[17] https://www.ibm.com/watson-health/learn/artificial-intelligence-medicine.

them. Furthermore, and perhaps more importantly, new professional skills are required.

The densification of interactions between the various actors in value chains in parallel with the requirements on costs, speed, and flexibility have a direct impact on the location of manufacturing units. The creation of **manufacturing clusters** is a direct outcome of these requirements (e.g., Shenzhen for the electronics industry in China, created almost ex nihilo since the last decade of the twentieth century). As previously mentioned, R&D actors have to be geographically close to manufacturing units in order to be efficient and to be attractive to the industry in question, exploiting fast, in situ interactions between manufacturing, engineering, and research. The movement of skilled persons to specific areas and economic growth in some areas and decline in others are the direct economic impacts. Modification of the required skill patterns, and therefore of training and education, are also significant.

The example of health provided here demonstrates the interrelationship between industry trends and technology trends (in particular the trend of digital technologies) and societal or economic impact. More interestingly, improvements in medical technologies are driving further increases in life expectancy and quality of life, which in turn intensify the interactions outlined above.

Several other examples can be helpful to illustrate this increasingly strong interrelationship, which links technology trends, industry trends, and societal (and, of course, economic) impact.

- In agriculture and farming, digitalization can improve efficiency and also create new, more complex value chains (and business models). Satellite platforms with special cameras[18] combined with intelligent ground devices (e.g., crop moisture sensors) can drive precision agriculture.
- In the transportation industry, security, usability, and traffic optimization are vital elements. The recent sad cases of fatal 737 MAX accidents and the subsequent grounding of the model are a clear indicator of the impact of technologies (i.e., the failure of the digital technologies involved to control the aircraft), creating huge

[18] Hyperspectral cameras—that is, cameras that can observe an image at several wavelengths in the visible and invisible optical spectrum (e.g., infrared)—can provide a wealth of information.

risks for an aeronautics giant with a long supply chain and eventually resulting in economic strain on clusters that cover large geographical swaths.

- In the field of energy production, the emergence of renewable energies is closely linked to the change in the manufacturing paradigm (i.e., the relocation of production first and R&D afterward, in this case almost entirely to the Far East). This is heavily impacting the balance of employment between different areas of the globe

Any enumeration of examples of the strengthening of interactions between the three major technological trends, through the three industrial trends, and the resulting socioeconomic impact could run to pages of text. It is virtually impossible to demonstrate this strengthening quantitatively; its presence, however, is beyond doubt. And data play a key role in that strengthening.

Macroeconomic, societal, and economic impact

The dogma of low-cost manufacturing in Asia and high-end R&D, design, and engineering in Europe/the US has proven outdated. Continuous efforts are being deployed in the US and Western Europe to relocate manufacturing. Under the Obama Administration, considerable efforts were made to bring manufacturing activities back to the United States—efforts that continue under the current Administration. European attempts to do the same were initiated under the banner of Industry 4.0, beginning in Germany before expanding, first to include the rest of Europe, and then the world. The objective was to use digital technologies optimally in order to secure production efficiency gains. This increased efficiency would allow production costs comparable with those in areas of the world that have lower labor costs. The same digital technologies that would enable Industry 4.0 would allow better quality, higher yield, and rapid customization. The Chinese government, meanwhile, has launched the program "Made in China 2025". The ambition is clear: to attract green- and hi-tech to a strong manufacturing sector.

Unless these efforts are successful, serious imbalances between geographical zones may appear, which is potentially a lose–lose situation. Today, the results of initial efforts do not seem encouraging. In 2012, former European Commissioner Neelie Kroes[19] set the objective that 20 percent of

[19] https://electronics360.globalspec.com/article/3121/europe-s-ambitious-plan-to-bring-back-chip-manufacturing.

microelectronics components would be produced in Europe, up on the figure of 7–10 percent at the time of her announcement. By 2018, Europe's stake was at only 9 percent.[20] Imbalance is increasing.

The importance of the clustering of manufacturing and high-end technologies (more frequently digital technologies, since this is the basis for advanced research and development) is well understood today by the political milieu worldwide. The impact of such clustering on jobs is more than obvious, since it can create strong geographical inequalities that, if not countered by strong, large-scale political win–win initiatives, potentially create a high-impact lose–lose situation around the globe. Recent import tariff hikes in several parts of the world are a clear illustration of this problematic.

The impact of technology on industry and society: Faster and stronger

The role played by technology in our societies and our economies is growing dramatically. The interactions between the three levels—namely, societal and economic challenges, industry trends, and technological trends—are strong and constantly increasing, defining the evolution of our societies. This increasingly rapid and significant interaction is enabling changes to the very nature of innovation and value creation. The emergence of Big Data is both a result and an enabler of this complex interaction: data creation acts as a mechanism that further increases interaction between the three levels of the complex puzzle discussed here.

What can we conclude from this and what actions should we take? Perhaps the very fact of understanding the situation allows us to see more clearly not only that technologies are influencing business models, but that in turn business models modify the competitive arena by rendering it more complex and by integrating products and services.

Long-standing dogmas need to be reconsidered: The claim that manufacturing can be on one side of the world and engineering and R&D services on the other has clearly been disproven. Adam Smith's theories on specialization do not address the process of innovation, but rather speak of specialization in terms of specific products (or services), and when seen in

[20] https://www.handelsblatt.com/today/companies/semiconductors-european-chip-industry-aims-to-get-back-on-the-map/23582014.html?ticket=ST-22913364-ti4p6JlPBLezLed6gC2C-ap5.

such a light remain absolutely valid. It is the process of technological innovation that cannot be geographically split. The concept of digital innovation hubs recently inaugurated by the European Commission expresses this understanding precisely:[21] each area has its own application-oriented (e.g., automotive, textiles, aeronautics) or technological specialization, but each needs integrated local ecosystems that combine universities, research centers, industry, capital, incubators, and above all the coexistence of secondary and tertiary factors.

A newer dogma is that "data is gold". Of course, data are extremely valuable, but they cannot exist alone; data need technological tools—which are heavily based on hardware—simply to exist, and also to generate value. Data as compared to digital technologies (which are more and more frequently characterized as Deep Tech[22]) seem to be over-appreciated: society and the economy speak about "data" and forget the tools that are needed to get these data. Without digital devices and advanced algorithms (based on digital technologies) data cannot generate value. Further, data seem also to be over-appreciated when compared to resources: without adequate resources (e.g., energy, bandwidth, storage capacity) data cannot be collected and exploited. And we are not even addressing here the huge question of minerals, energy, and water. Certainly, data's role is important, but just and right value needs to be assigned also to the technologies that generate them.

Last but not least, we see that our world is becoming technology dominated, in particular if one takes into account every type of manufacturing (as explained above) including biomanufacturing technologies or if one considers the importance of technologies in securing global access to elementary resources such as food and water. An understanding of the continuous flow of the endless interaction of technological trends with industrial trends and impacts on society and the economy should become central to planning and analysis at macroeconomic (i.e., the political) and economic (business) levels.

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[21] https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs.

[22] One credible definition of Deep Tech, a term that is moving more and more deeply into our vocabulary, is that it encompasses technologies that are based upon intense and excellent scientific or technological R&D endeavors. Not all digital technologies can be seen as Deep Tech: advanced algorithms based upon advanced mathematics or miniaturized sensing devices are Deep Tech; apps for mobile phones are not.

CHAPTER 3

DATA AND RESOURCES

Why should we make Big Data "smart"?[23]

Today, everybody is talking about data highways, about peta- and zettabytes of data, about high-performance computing and broadband communication. Basically, all these topics refer to Big Data, which means the huge avalanche of "0s" and "1s" that has started to revolutionize our economies and our societies. Big Data is the consequence of the collection of information from many different sources, including computers, cameras, humans, cars, smartphones, manufacturing equipment, written texts, houses, aircraft, and so on. Today, most of this information comes from computers and smartphones, more often introduced by human intervention. This, though, is changing rapidly, and information sourcing from devices—the "Things" of the Internet of Things—and without human intervention will very soon be the core of Big Data. This data can convey many types of information, ranging from positioning coordinates, images and videos, information on human activities, financial information, and aspects of personal identity, to physical or chemical parameters, meteorological information, and information on human transactions or machine interactions. Collecting data from billions of sensors helps us to gather information on human behavior, habits, and emotions, or on the status of machinery (we use the term "machine" here to cover all the non-human sources of information mentioned above). Such knowledge and information are "bankable"—that is to say, they can be sold. Each bit of data can have

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[23] The text of this chapter draws on "How to make big data smart", a white paper initiated under the framework of an alliance that federates four major European research centers (the Fraunhofer Group for Microelectronics (Germany), CEA-LETI (France), VTT (Finland), and CSEM (Switzerland)): the Heterogeneous Technology Alliance—HTA, http://www.hta-online.eu/en/contact.html. The white paper included contributions from J. Hast, A. Maaninen, H. Lakner, A. Grabmeier, J. Pelka, L. Herault, E. Gyorvary, and G. Kotrotsios.

monetary value. Control over Big Data is control over bankable assets and is therefore of the utmost economic interest.

While having, or granting access to, such a tremendous amount of data at no cost appears important in terms of knowledge and economic value, the real price paid by the economy and by society may well be high. The collection, transmission, storage, and processing of data require an ever-increasing amount of resources and energy. It is commonly assumed today that the costs of the resources necessary for these functions (i.e., computing, etc.) will decrease faster than the increase in data volume, while the quasi-infinite availability of resources will be maintained. But in the long run this situation may well change, especially due to energy consumption and communication bandwidth requirements. In addition, the maintenance of privacy and the security of data remain unsolved, growing issues. To illustrate the importance of resources and related challenges, we will take the case of data produced on a massive scale by an increasing number of electronic devices—including sensors—at the edge of the Internet. The case that we will address here is currently referred to as "edge computing", meaning the distribution of the processing of data to near the place of their creation. Edge computing aims to (i) optimize data use in terms of aggregation, uniformity, veracity, and security, and (ii) empower the data owner/user by enabling improved privacy, ownership, and control. Edge computing, by processing data near to the source of their creation, creates "Smart Data" as opposed to simply "data" or Big Data. It can be seen as a parallel route to the collection of raw, unformatted, and unprocessed data from applications (including personalized health, autonomous cars, Industry 4.0, and many others, such as the "smart home" or "smart highway" for example).

In a very conceptual configuration, we illustrate this process in Figure 3-1. Data can be streamed directly from the real world to the cloud, thus creating oceans of data, or what we usually call Big Data.

Alternatively, the smart, local preprocessing of data reduces the amount of data to be transmitted down to only the relevant information ("Smart Data") and helps reduce the energy, bandwidth, and processing power consumption of electronic systems. Furthermore, the smart preprocessing of raw data can anonymize origin, and thus help to ensure necessary privacy.

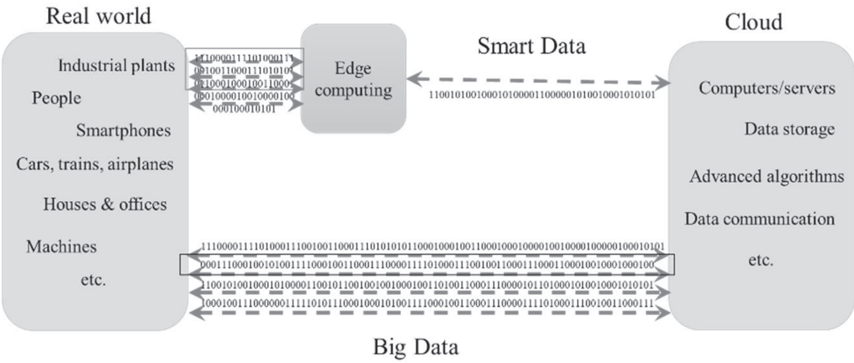

Figure 3-1. Data flow and related processes, from the application to the data aggregator and back to the application.

The objective of the following paragraphs is to introduce the main issues related to resources, a framework concept for the importance of data processing at the local level, side effects that are seen as positive, and—finally—the impact on the economic landscape.

Resource-related issues

An excellent, albeit for the time being imaginative illustration can be found in the novel *The Circle* by Dave Eggers.[24] A young employee of a large social network/Big Data corporation (Eggers is explicit that this is not one of the GAFAs[25]) discovers an enormous cellar equipped with water-cooled servers that store an enormous amount of data. Each server stores videos, photographs, and e-mails from the life of a single individual, charting interactions with family and friends, personal life, and so on, for several years. Even outside of this illustrative (and hopefully only imaginative) case, real quantities of streams of data are indeed already enormous.

In a more practical, actual, real-world example, an autonomous car—with "intelligence" that is not yet close to that of a human brain—today

[24] https://www.theguardian.com/books/2013/oct/12/the-circle-dave-eggers-review.
[25] GAFA: Google, Apple, Facebook, Amazon.

produces from 10 to 100 TB of data per day.[26] [27] If these data were to be transmitted over a network, we would need only a very limited number of cars—so, between 50 and 200—to fill the maximum theoretical bandwidth of a 5G link. It is easy to imagine approximately what amounts of data we would be dealing with if we were talking about a crowded highway, and not just a handful of vehicles. Even more interesting, a simple calculation tells us that the same autonomous car would produce something like thousands of TB of data each year, all requiring processing and storage. This volume of data would require a volume of hard disks perhaps as big as the car itself using today's technology. Considering that data are often backed up at least once if not twice, this illustration with regard to storage space as a resource is quite telling. Following this trend, it is reasonable to extrapolate that in the near future a simple automobile will generate petabyte-level quantities of data every day. Is it also relevant to generalize similar figures for airplanes, buildings, or factories if one takes into account trillions of edge devices? While any effort to discern and calculate such figures somewhat resembles gazing into a crystal ball, we can speak confidently of enormous quantities of data.

The important question here is whether we need all this data. Is it important to communicate, for instance, the whole electrocardiogram or the whole encephalogram of a healthy person, continuously? Should society and the economy allocate low-cost, but nevertheless valuable, resources to storing such probably useless information? Perhaps only the information that the person is healthy is important, and only when a problem appears should the full data series, covering some hours, be required. In another context, but again with regard to an individual human being, the fact that a person has a higher pulse rate and a higher number of potassium ions in her or his sweat can be useful. But it's perhaps even more useful to know that this is happening while that person is running. If, instead, this should be the case while that person is simply sitting, the implications might be more problematic. As can be seen from these two examples, remote medical monitoring does not require all data. Rather, it needs only a limited amount of data, but in the form of information.

In an entirely different context, huge streams of measurements of the vibrations of a turbine do not need to be transferred. When a turbine or

[26] https://www.tuxera.com/blog/autonomous-and-adas-test-cars-produce-over-11-tb-of-data-per-day/,
https://www.kurzweilai.net/googles-self-driving-car-gathers-nearly-1-gbsec.
[27] https://www.wired.com/story/self-driving-cars-power-consumption-nvidia-chip.

power plant is in operation, the key information is that, say, the vibration of the turbine is within certain limits in terms of amplitude and frequency. Thus, only this information needs to be transmitted, rather than every pixel of the vibration pattern itself.

And the same rationale holds good for homes, factories, and cars. Petabytes of data are expected to be generated every day. These data can be transmitted, then stored and processed, including in the cloud. Or alternatively these same data can be processed near the point of their generation, thus becoming a considerably smaller amount of data—carrying only key information—and using much less bandwidth and energy for transmission, much less energy and computing power for processing, and much less physical space for storage. It is also extremely important to underline that such local processing also allows us to control which data are transmitted and which not, and also to control how privacy protection encryption can be optimized—in other words, local processing allows better control of data.

Data: Cost, value, and resources

Today, when data are collected, processed, transmitted, or stored, the incremental cost per byte of information seems marginal; in addition, the availability of resources such as energy, bandwidth, computing power, or storage space is considered infinite. Common wisdom suggests that the cost of computing, communication, and storage resources will decrease faster than data volumes will rise (Scenario A in Figure 3-2, where resource availability increases much faster than data generation), and that these resources' quasi-infinite availability will be maintained. This assumption is debatable, and it may be that a different scenario (Scenario B in Figure 3-2) will emerge. In such a scenario, resources might not be sufficient (or might be too expensive) to accommodate all the data that need to be generated, processed, and stored.

In fact, the situation described in Scenario B (Figure 3-2) is that of the 1980s: computing and communications resources were largely inadequate, and our industries therefore relied on "economizing" with regard to data—so, on the careful use of processor resources, available communication bandwidth, and storage, and on energy management and, of course, space management. With the subsequent exponential increase in resource availability, the collection of all kinds of data and their processing became mainstream. This was a radical change of paradigm, and led to Scenario A in Figure 3-2.

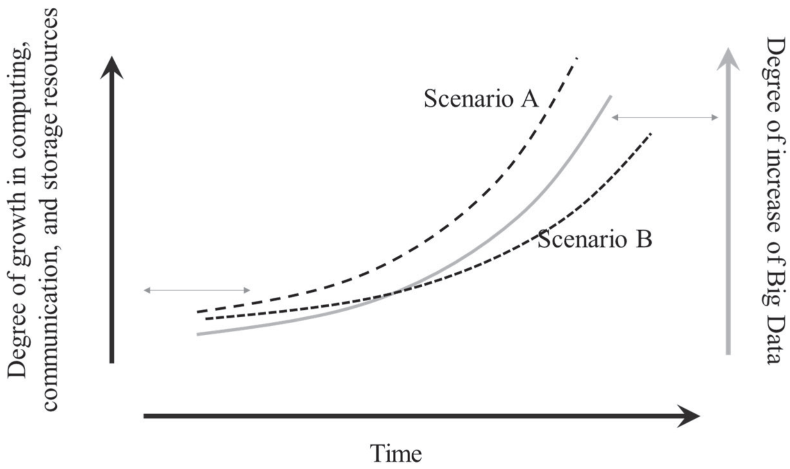

Figure 3-2. Evolution of resource availability in relation to Big Data's evolution.

The question is whether this paradigm change can be maintained. Certainly, the increase in resource availability will continue, and with similarly exponential growth. The question, rather, is whether the growth rate with regard to the data collected is going to be higher (or not) than the growth rate of the availability of resources. In other words, whether we are going to live in a world in which resources are sufficient or not.

If the answer to this question is that data collection will outstrip resource availability—so, sooner or later we will be limited as regards data by resource availability—then the optimization of the data-collection, transmission, processing, and storage chain, and the local processing of data that "edge" computing can make possible (and here we're talking about "Smart Data"), will be a necessary step, even a cornerstone. And even if the answer is that it will not—so, resources costs will fall more rapidly than data generation will rise, and in parallel resources will remain virtually infinite—the question of the relative cost of resources in relation to the value of the data to which those resources are allocated should always be kept in mind.

Seen through this prism, Big Data completely changes its aspect. Resources are optimized, risk (economic and societal) is reduced, and—potentially—benefits are better distributed. Data, at least an important part of data, can remain at their source, and so with their owner. Using Smart Data as an intermediate layer is an alternative to feeding enormous computational infrastructure that can only be owned by a limited number of large and powerful corporations (a question of asset ownership), and this takes us back to the aforementioned novel by Dave Eggers, the main topic of which is precisely data ownership and its impact on the individual. Smart Data drives distributed intelligence. It's like moving from an ultra-centralized form of governance of data to a distributed form. The challenge is enormous and has to do with the question of balancing power between enormous, centralized actors and small, distributed ones.

Energy: A key question

As previously mentioned, the question of resources (bandwidth, energy, storage, and footprint) is increasingly important. With an exploding number of distributed devices in the Internet of Things, the constantly growing number of mobile devices, and the ever-increasing amount of data traffic, bandwidth and energy consumption seem to be the most critical aspects when it comes to future technological development.

As the trend of growth in the number of distributed and mobile devices is not expected to be reversed in the future, one of the key questions is that of energy consumption. Consumption of energy by each individual device that transmits information from the real world to the virtual world should be minimized ("zero-power" or "quasi-zero-power" devices) and data traffic levels should be kept as low as possible. These devices are of paramount importance to the large-scale deployment of edge computing solutions. The reasons for this are simple: batteries pollute the environment; batteries also need to be changed, and to change them one needs monitoring, logistics, and people, which in turn mean higher costs. The good news is that zero-power or quasi-zero-power devices are already plausible and even exist. How have we done this? The answer is twofold. On the one hand, over the years we have seen the power consumption of electronic devices half approximately every eighteen months, meaning that less and less energy is needed for the same operations—digital processing, powering sensors, and communicating (this is the law of Moore, named after the founder of Intel Co., who predicted the temporal evolution of energy, footprint, and the cost of semiconductor devices already several decades ago (the law remains valid even today)). On the other hand, energy scavengers (devices that recover energy from the environment in the form of mechanical energy, thermal energy, or solar energy—the last of which is the most efficient of all energy scavenging methods) allow us to generate all the energy needed to power more recent generations of the electronic "Things" that operate at the edge of networks. It is expected that upcoming electronic devices will be even more energy efficient than the most recent generations of electronic devices commercially available today. Energy scavenged from the environment is starting to allow increasingly sophisticated processing using advanced algorithms, which themselves perform complex functions including, for example, face, gesture, or emotion recognition. Thanks to edge computing, only necessary information is transmitted over—mostly wireless—networks, thus reducing both the energy needed for transmission and the bandwidth required, and consequently precluding any need for resources to be allocated to remote, computationally heavy operations. This is the virtuous circle enabled by edge computing, which in turn is enabled by zero-power or quasi-zero-power devices.

Additional benefits of edge computing

Data veracity

Beyond the open question of resources, as well as that of issues related to privacy, the veracity of data is also becoming a key question. Veracity means how credible data is. The introduction of erroneous data can be intentional and take the form—for instance—of malicious human intervention. It can also be unintentional, occurring—for example—as a result of an untimely hardware malfunction. Erroneous data can be introduced (intentionally or not) once data have been transmitted and processed or stored. Smart Data should include verification-related information. Such verification should be easy to implement. Blockchains seem to be a solution to the challenge of assuring data veracity in the long run. With regard to blockchains, however, we should not overlook the importance of resources, and more particularly the importance of the storage capacity required. Under the current configuration, the information is accumulated in ledgers and distributed in large numbers of electronic copies across networks. If the abovementioned predictions with regard to a single autonomous car are correct, then our worldwide storage abilities—despite prodigious growth in memory—remain questionable. Tomorrow, even a simple object will have an IP (Internet protocol) address. Take the example of a lamp in a home environment. Pushing the logic of the digital world to its extreme, each switching on and off of the lamp is a digital transaction. Following the rationale of the blockchain, every digital transaction should be recorded in an ad hoc ledger—then recopied thousands of times. (The number of electrically and electronically interconnected objects, such as lamps, is extremely high, and itself renders the idea of collecting, transmitting, processing, and storing every transaction a kind of chimera; unless, of course, special types of blockchain are developed to meet this challenge.) Blockchain is, of course, only one possible solution; alternatives exist

The next step would involve physically unconnected objects (e.g., glasses, chairs, or tables) being allocated an IP address. Reflections are underway with regard to allocating IP addresses to such objects (using remote vision systems). What does that mean? It means that any everyday object could, even without the addition of electronics, become as active a part of the Internet as any active electronic device. Under this assumption, it is reasonable to argue that both the quantity of data circulating over networks and the number of transactions to be recorded—possibly in blockchains—will explode, the former attaining large numbers of petabytes. The actual numbers are difficult to forecast, but they are clearly probably extremely high.

Biasing of data is another major question related to data veracity. Polarized (information-wise) or partial data can contribute to the biasing of vital information. Smart Data concepts can improve the traceability and verification of data for several reasons. First, processing the data locally allows one to send to the cloud only what is important. Second, it allows one to "filter" incoherent data (e.g., body temperatures of 45ºC or negative car speeds), which can be produced by momentary errors. Third, important information can be added, such as a source identifier, date, or time. Such Smart Data are closer to being "information" than they are to being simple "data".

Privacy and security of data

Another major concern (again nicely illustrated in the aforementioned novel by Dave Eggers) is the privacy of our data. Can Smart Data provide the solutions to our need for privacy? Is transmitting processed information over a network to the cloud, with elementary control over the type of information to be communicated, a solution to the privacy issue? Most probably edge computing will allow us to create Smart Data, which we have to see as an opportunity: it's a question of negotiating power. By transmitting all data, ownership of those date sooner or later lies with the platforms that collect, accumulate, and process them. The consequence of this is less negotiating power—when it comes to commercial transactions—for the source of those data, and more for the "owner". Strengthening edge computing means better control of the data or information transmitted, which in turn means more negotiating power is invested in the source of those data. It is thought that data will oil the machinery of our future economy, and it therefore has real monetary value. So it's only reasonable for it to be treated accordingly (and this question will be addressed in more detail in Chapter 6—"Data, a New Form of Capital").

In some ways, the very processing of data using local artificial intelligence (LAI) allows data to become Smart Data. LAI goes well beyond classical preprocessing (which engineers refer to as signal conditioning). This opens up an opportunity to anonymize private data, because Smart Data processing happens under local control; Big Data, meanwhile, remains under the control of remote forces, and beyond the means of the initial owner of the data.

Interfacing data to the human

An important facet of Smart Data is the interpretation of information coming from the network in a way that can be understood by a human being. For the first time in history, the quantity of information we can receive is rapidly becoming much greater than the maximum amount of information that a human being can interpret. Machines can manage Big Data; humans can not. Humans can only manage Smart Data. Big Data, then, needs to be processed, presented, and visualized in a form that can be rapidly, efficiently, and effectively interpreted by humans.

Information and data need to be presented to humans in a condensed and concise way for them to be visualized, whether that means images, sound, text, or any other sensorial input, including direct human-to-brain interfaces whether implanted (probably directly on or into the brain) or wearable.

Even when a human being is not involved in the process, as for instance in the case of machine-to-machine (M2M) interfaces, it is important that the devices at the edge of the system correctly prepare the data and emit the right commands to "machines" (e.g., a robotic hand or a hydraulic actuator) by limiting levels of "useless" information. To better illustrate the case, let's take the example of an artificial pancreas. Here, glycose sensors capture information regarding the blood sugar level of the patient. Algorithms evaluate the quantity of insulin that needs to be administered. The insulin is in a reservoir, and a pump extracts the right quantity of insulin. Injection is carried out by devices that are permanently implanted into the patient's body. In this example, the glycose sensor is a "machine"; the pump, which is an actuator, is a second "machine". The term M2M—machine to machine—means that no human intervention is required, from the measurement of the sugar level to the injection of the insulin. The second "machine", the pump, needs to receive only a very simple and clear command. The information extracted by the first "machine", the sensor, and processed by the algorithms needs to be "visualized" by the second "machine" in an adequate manner, so that it can be understood by this second "machine". Of course, this is an elementary example, and M2M may include much more complex interactions, in particular in robots.

Big Data and Smart Data: Data and information

Seen from a completely different angle, one can assert that Big Data is about analyzing the past and the present. The future, meanwhile, is a question for creativity and humanity. On the basis of Big Data, computers can predict. They cannot, however, imagine. And they cannot "think out of the box". This is (and hopefully will remain) the distinguishing quality of humans.

Processing of raw data allows them to become Smart Data by using local artificial intelligence. This type of AI is radically different to the AI that is applied to Big Data. Smart Data processing happens under local control, which means under the control of the person or the organization generating the data. Big Data processing is performed under the control of forces located remotely from the point of data generation and can certainly be beyond the control of the initial owner of the data.

If we try to identify some common denominators among the features of data usage, processing, and exploitation—that is to say, the core of the value-creation process when using data—three important, common characteristics emerge: first, the complexification of value chains, products, and services; second heterogeneity; and third, rapid change rates with regard to technology, products, and services (as we briefly illustrated in Chapter 2). Naturally, the questions of who can benefit from these characteristics, first, and second who can afford to invest in order to be able to benefit spring to mind. In other words, who has the capacity to be interested in, and the opportunity to oversee and possibly master, this complexification and heterogeneity, and at the speed at which this is all evolving? Of course, it is becoming clearer and clearer that highly capitalized structures such as Google, Apple, Facebook, or Amazon (also known as GAFA) can do this. Google's autonomous car, Apple's i-watch, and Facebook's Internet for everybody are illustrative examples of this. In industrial value chains, industrial "giants" are much more likely to have the financial capacity necessary to invest in Industry 4.0 platforms.

Is there any space for additional, different ways of doing things with regard to the implementation of Smart Data—and could these ways include new concepts? Can we implement Big Data-related business models and retain and create value for our intermediate-sized companies or SMEs (small and medium-sized enterprises)? By mastering technologies related to edge devices and edge computing, can the trend of value shifting toward large corporations perhaps be mitigated?

Finally, as previously intimated, the "projection" of Big Data back to humans is of paramount importance. Big Data is the domain of computers, and human beings do not have the capacity to interact directly with it. A way of bridging the common boundary that separates humans from data is therefore required. That interface will provide a bridge between Big Data and real-world situations, enabling the interpretation and understanding of the data delivered by the sensing (sensing that bridges the real world to the digital world) of real-world parameters and—of course—the actuation of ad hoc devices (which bridge the digital world to the real world) when appropriate.

How important are the edges of the Internet?

Although many of the aspects of data veracity, privacy, and interpretation can, as mentioned above, be solved by software—running in some cases on big servers and in other cases locally—the question of hardware must not be neglected. Smart, local preprocessing requires smart sensors and sensor systems, and low- (or zero-) power electronics to cluster and aggregate raw data into Smart Data.

A point of particular interest with regard to the role of hardware is the aforementioned question of privacy and security. Today, it is starting to be widely accepted that all the potential limitations of software have been, or are going to be, resolved. Security holes are going to originate in hardware, another of the last ramparts in the battle for security and privacy. Edge devices are particularly important in terms of their contribution to privacy and security. First of all because they can be customized to the application for which they are used. Protection can be adapted to the application in terms of both hardware and software. To illustrate the role of these devices that operate at the very "edge" of the Internet of Things, applications in personal health provide a useful example. For instance, for the monitoring of the human body, sensors are (and will increasingly be) integrated into and onto textiles, and into eyewear, "smart-shoes", and—of course—wrist-worn smart devices. Needless to say, seamless integration is the main factor influencing user acceptance. Autonomy is part of such integration, and appropriate sensor packaging, including miniaturization, is thus key.

Further, information from a single device is often incomplete; it is usually complemented by information coming from other, complementary devices. A loss of privacy and security in one edge device does not necessarily compromise the security and privacy of the overall system. In addition, such situations are becoming increasingly difficult for "eavesdroppers" to take advantage of, since technology allows for encryption along the entire chain, from the edge device to the cloud. But the importance of the hardware aspect of edge devices goes well beyond "simple" privacy and security.

What else does the advent of the miniaturization of systems mean for industry? Such systems will integrate electronics with sensors, actuators, RF modules, and energy sources. Let's start with the electronics part of these nodes: these devices will continue to use what could be referred to as "classical" microelectronics technologies, and these elements will continue to follow the high volume, very high capital-intensive trend we have seen in industry over the last couple of years ("More Moore").

Although this can also be said for certain sensors—which can be referred to as "commodity" devices and include accelerometers or magnetometers—a second category of devices, which we can refer to as "specialty" devices, will diversify more and more due to the continual fragmentation of market needs (e.g., specific sensors for more exotic needs, including the testing of dedicated industrial environments).

Diversification in ultra-small dimensions calls for the coexistence of disciplines at the nano level, the bio level, the cognitive level, and so on, and ever-more diverse yet convergent disciplines will emerge to fill the growing technological gap. This convergence, in turn, calls for the increased diversification of production equipment, infrastructure, and skills. The combination of several devices, either customizable or mass produced in complex systems, is known as the "More than Moore" trend in the microelectronics industry. Such systems can be either assembled or packaged using advanced technological equipment, as mentioned above.

Impact on the economic landscape

Big Data is going to flood our everyday lives. The inclusion of a layer of processing at the edge of the Internet of Things—that is to say, the process of creating Smart Data—is an important step in our optimization of the use of resources. Such resources include storage capacity, bandwidth, energy (processing, cooling, and the transmission of information), and storage space. This layer can bring about a number of positive side effects, including improvements in data veracity and uniformity, increased privacy, and better interpretation of data.

Smart data as a result of edge computing may empower both the individual and smaller organizations such as SMEs. Controlling the flow of data could allow SMEs and intermediate-volume companies to mitigate the shift of power toward large corporations, and could therefore help maintain some form of equilibrium. This can be good for privacy too, which in extreme cases could, in the future, also mean for the privacy of our very thoughts. Edge devices could also be useful as data verifying and formatting tools, thus enabling better decision-making processes and allowing the owner of the information to decide what is transmitted to the cloud and what is not.

Smart Data can also be seen as the local transformation of data into information. Edge devices are key in this respect, and are versatile and complex, mirroring the multi-disciplinarity required for their realization. We can therefore confidently extrapolate that, in a world incorporating Smart Data, capabilities would be sourced in a more balanced manner from different economic and industrial clusters, which could in turn source different parts differently, therefore contributing to a leveling of demand across global industrial ecosystems. Indeed, it is obvious that direct Big Data collection, transmission, and processing will coexist with edge computing, which will produce Smart Data as a complementary flow to raw, Big Data. This coexistence will certainly prove positive, as a greater diversity and degree of specialization of systems and devices requires economies that are highly diversified and networked, and that are based upon multiple technological foundations.

The point at which humans will no longer be able to interpret Big Data will sooner or later be passed. Adequate data processing at the local level—or, "local artificial intelligence"—will be necessary to enable the appropriate filtering of information. This process is also valid for simple actuators that need to act at the end of a complex process of consolidating multiple sources of information.

The Smart Data layer and associated edge devices and edge computing are perfectly adapted to industry's transition to the digital economy. They can help us to better harvest benefits while using fewer resources, and at the same time can contribute to more balanced growth thanks to an increased need for more diversified skills, industrial traditions, infrastructure, and equipment.

CHAPTER 4

THE HUMAN FACTOR IN THE DIGITAL AGE: THE MANUFACTURING ENVIRONMENT

The human and the machine: Rethinking the relationship

There is no shortage of essays, discussions, conferences, or books that address interaction between the human and the digital world. There is, however, one aspect of human activity that is particularly illustrative and interesting to address: the manufacturing environment. It is interesting because it is situated at the crossroads between the changing manufacturing paradigm (which itself operates in the framework of continuous ecosystem competition) and digitalization (which both influences and is influenced by the changing manufacturing paradigm).

Today, the penetration rate of the "machine"[28] in the manufacturing process is increasing at an exponential rate. The performance, the functionality, and the complexity of each "machine" is rapidly increasing. The fact that more and more machines coexist with one another further accelerates the growth of performance and functionality, while increasing the complexity of the overall manufacturing system. Further, individual "machines" and overall systems are becoming increasingly flexible. This fast and radical change is already modifying the role of the human. What are humans' expectations, and how will they fit into this rapidly changing manufacturing paradigm?

This question can be approached from a multitude of angles. The first is societal—so, in terms of jobs and of extra-professional impact. The second is the interaction of each human with his or her professional environment—an interaction and an environment that themselves are changing radically (and are going to change even more radically) with the introduction of digital technology tools, including robots, the Industrial Internet of Things

[28] "Machine", here, means everything that helps humans with regard to the manufacturing process—from large machines to robots to sensors to computers.

(I-IoT), vision systems, high bandwidth networking, simulation tools, and devices that allow a person to be "augmented", including mixed reality glasses, exoskeletons, or mind-to-machine interaction systems. The third angle is the legal. What will be the changes to the legal responsibilities of humans and corporations as a function of the introduction of new tools that intervene and modify the human response? Last but not least, we can approach the question from a fourth angle, which has to do with the human as a part of the business system and with the relative empowerment of the individual worker, the respective roles of human and machine in data collection, the impact of such data collection on the human being, and changes to business models in the manufacturing environment.

We will try to address these questions in the form of a short but holistic overview, all the while attempting to understand what this means for the integration of the human in the manufacturing environment, as that environment rapidly evolves.

Society

People as employees of manufacturing corporations are facing a radical change in the way they are integrated into and evolve in companies, the economy, and society. The first, certainly well-addressed, aspect of this change is the shift in the skills required of people. It seems almost unnecessary to illustrate this: Manufacturing (and, more globally, industrial) sites need increasingly dedicated IT capabilities. In the past, a worker who had to operate a lathe needed to know how to do so. Today, the worker who operates a numerically controlled lathe needs to operate the IT system that controls the lathe and, of course, to understand the functioning of the lathe. And the same is true for any machinery for any type of production, ranging from automotive, aeronautics, and shipyards to pharma, chemicals, or food. Obviously, the degree of automation is not the same for each type of industry: several industries remain heavily human dependent; others not. For instance, the microelectronics industry has a considerably higher level of automation than the raw material transformation industry. In addition, within many industrial sectors there is strong differentiation between companies in terms of their implementation of digital technology. Such differentiation, in turn, means differentiation with regard to which specific skills are required from employees. And it is SMEs that are often lagging behind in this respect. Differentiation in the degree of digitalization implemented between industrial sectors, as well as between small and large companies, results in a broader spectrum in terms of the skills required from employees. If we were to focus on blue-collar jobs alone, we would see that in some cases more "traditional" skills are required, that in others more digitally enabled skills are asked for, and that in others still both skill types are necessary.

The demand for new type of skills leads to the question of where and how these skills are to be acquired. Technical schools or technical universities have trained young people in late adolescence or post-adolescence. Today, this kind of system is no longer viable since workers need to acquire new skills continuously. A window of opportunity for creating new structures and methods for lifelong training and education adapted to the continuously evolving environment is now opening.

This lack of the skills required by industry fuels unemployment. And that unemployment impacts those closer to retirement age more than it does young people. "Robotization" and automation amplify this trend, because—globally—the overall number of blue-collar manufacturing jobs is decreasing. And even if we postulate that jobs lost to robots and automation are going to be replaced by other types of jobs, jobs that create greater added value (and therefore pay higher salaries), it is probably not the blue-collar workers that are suffering from this transition that are going to get those new jobs. A large percentage of them will therefore remain unemployed, and for longer periods of time.

Another societal impact of the transformation of blue-collar jobs is the expected increase in rates of telecommuting. Service provision is relatively apt for this mode of working; telecommuting for manufacturing jobs, meanwhile, has until recently been unthinkable. This, however, is ready to change. Blue-collar telecommuting can, for example, simply involve the replacement of certain on-site operations by equivalent remote operations. So, for instance, the replacement of in situ monitoring by tele-monitoring—a one-to-one replacement. Today, we associate the maintenance of a manufacturing plant with inspectors who periodically check in situ processes and equipment. Over time, however, a significant portion of this inspection process will be replaced by sensors that continuously monitor and communicate the status of machinery. Again, this is a one-to-one replacement. But this time around, it means the replacement of a blue-collar inspector by technology. The function of the monitoring remains the same, albeit at a lower cost and at higher levels of precision.

One novel development that is proving disruptive in today's world of manufacturing is the creation of digital twins of individual machines or even entire manufacturing plants. A plant's equipment and infrastructure can now be fully simulated using computer models. What does this mean? First and foremost, it means considerable gains in time and reductions in cost for companies. Machinery downtime can be properly planned for when a simulation shows that maintenance is needed. Second, and with particular regard to human resources, we are seeing work shift from blue-collar inspectors to white-collar software engineers. And these engineers can perform a considerable portion of their work by telecommuting.

In the future, it is very likely that we might observe a more radical change in the production mode. The act of making things can potentially simply be displaced from a traditional manufacturing environment to the home. As an example of such a radical transition, we might see the serial production (i.e., unit-by-unit production) of small-scale series of devices that can be produced at home using 3D manufacturing. This trend is coherent with the shift—observable today—from mass manufacturing to mass customization, and in some cases to personalized manufacturing. The production of certain medical devices nicely illustrates this trend: hip prostheses, for instance, are now being produced according to the specific morphology of the individual patient, as imaged by medical tomography. We are not, of course, going to produce hip prostheses at home. But a number of goods that can be personalized to the needs of the individual (with respect to morphology or personal taste—so, for instance, footwear or glasses) or to the configuration of the built environment (so, for instance, a house's architectural structure) could be produced at home, based on basic designs fine-tuned by the individual user to suit his or her specific needs. This trend is even transforming the very nature of commercial relations, converting the user into a manufacturer–user. Though the nature of this transformation may, at first glance, be difficult to grasp, it is the natural extension of what we have already seen with regard to service provision, where individuals reserve their own flights and hotel rooms on the Internet (now an everyday practice), thus converting themselves from simple users to users–travel agents.

A very probable evolution of overall working conditions that the individual as employee is going to see over the coming years is an increase in free time due to the potential reduction in work time. Such a change is merely the result of increased productivity. In this situation, we are probably going to have two types of people with more free time on their hands, and this trend is apparent not only in the manufacturing sector but also in the sector of service provision. The first type is people that have sufficient financial resources to get by without working, thanks to regular incomes or accumulated cash. For these people, more time will mean more leisure and cultural activities, which in turn will mean more human interaction and, thus, greater business opportunities. The second type is people that do not have the necessary skills to find a job. For these people, more free time might mean greater stress levels, and certainly a need for further training.

The working environment

The augmented person

Working conditions and the working environment in the manufacturing sector are changing very rapidly, not only thanks to the digitalization of processes and the creation of digital twins—as described above—but also in terms of the way blue-collar employees work.

One important trend is the transformation of "normal" workers, over time, into "augmented" workers. What, in this context, is the meaning of "augmented"? Let's look more closely at this with a concrete example. In a large manufacturing plant a worker needs to repair a complex piece of equipment—say, the electronic control element of a turbine. Traditionally, this worker would approach the machine equipped with nothing more than her or his tools and a manual, empowered by training and experience to carry out the repair. For more complex, modern machinery, the manual might be found on an electronic device such as a tablet computer. The repair operation is dictated either by the worker's experience or by a careful reading of the manual, or of course by a combination of both. In the years to come, it is highly likely that this worker will approach that same machine, but this time he or she will be wearing mixed reality glasses that supply, in real time, both advice and details of the series of actions that need to be performed. This might be automatized (automatically guiding the worker through the sequence of actions required), or perhaps performed thanks to real-time interaction with a remotely based specialist or specialists. The benefits of such a setup will be enormous, in terms of both repair efficiency and operational downtime. And there will be other benefits in terms of the safety and security of the repairperson, the machinery, and society in general—particularly in potentially hazardous circumstances such as the need to repair critical infrastructure (e.g., electrical powerlines or nuclear reactors).

Looking a little further into the future, visual tools such as special, smart eyewear will be used, not only to exchange visual and acoustic information but also to control equipment and machines. The same methods and technologies used by pilots of today's military aircraft to control the orientation of their aircraft or the locking on of targets, and eventually the launching of munitions, will—while currently still extremely costly—be used by the workers of tomorrow to control and interact with machinery, in particular expensive machinery. Of course, such a scenario rests on the assumption that today's military technologies will become much less expensive over time—but that particular assumption is a reasonable one. Today already, functions such as capturing iris movement or gaze direction can be performed on miniaturized, potentially low-cost devices. Such functions may be a basis for the interaction between the person, through eye movement, and the exterior world. Obviously, for simple maintenance operations such interaction is unnecessary. In potentially high-impact cases however (e.g., where high cost or safety and security questions are involved), such tools may prove invaluable. Think, for instance, of situations in which rapid and precise responses are required—a sinking ship, or the repair of a large turbine. In the long run, more extensive use of such solutions will make possible further improvements in productivity, and thus, in turn, decrease personnel needs.

Smart eyewear, as briefly outlined above, is a means of intuitive communication between a worker and a machine, based upon real, existing technological tools. Today, these tools are expensive, but their cost can and will decrease. The next step—which seems utopian (or dystopian) today—is the direct brain-to-machine interface. Today, the use of electroencephalograms in a noninvasive way and on a moving person can't be called reliable. It seems reasonably acceptable to consider, however, that in a time horizon of 5–10 years this technology will *become* reliable, usable on a large scale, and sufficiently affordable to be introduced on the manufacturing floor.

The notion of the augmented is not limited to the interaction of repairpersons with machines, to the provision of visual support, or—in what some today might consider a more farfetched scenario—to brain–machine interfaces. For example, the strength of a person can be mechanically reinforced. Exoskeletons can be employed to reinforce a person's muscular structure. This can increase the capacity of an individual to carry a load, allowing a person to work at multiples of his or her unaided capacity. In productivity terms, this means improvements in a number of jobs that require muscular strength. In security terms, this might mean an increased capacity to handle unexpected loads and being better protected should an accident occur.

All these technologies are simply illustrations of the upcoming revolution of the augmented person. They lead us inevitably toward increased productivity, increased security, a change in the skills required of workers, and reductions in our need for human resources. The response from the economy and society should include increased and lifelong training, and measures to improve time management, both for active workers and inactive individuals.

Needless to say, this kind of revolution will not be implemented overnight. Its gradual introduction will, logically, begin with larger, wealthier companies. But over time it will spill over to medium and then small manufacturing companies. Such a gradual introduction will—as we will discuss below, in Chapters 5 and 6—play an important role in the creation of structural imbalances, which will appear naturally because of the nature of the adoption of the technological innovation.

Humans and robots on the manufacturing floor

The coexistence of people and robots in the manufacturing environment is, today already, a reality. In the previous subsection we—very briefly—addressed issues such as man–machine interfaces and the related evolution caused by technological tools; one view of this change has been detailed above, with our discussion of the augmented worker. But this is not the only evolutionary trend at work here. A number of questions remain open with regard to interaction between and the coexistence of humans and robots in the manufacturing sphere. Security is one of them.

So far, and with the technology currently at our disposal, the question of security seems to have been mastered and the number of accidents has been limited to a level widely deemed acceptable. This is certainly due to the ability of currently available technologies to master a limited number of robotic devices, most of which are stationary. The manufacturing plants of tomorrow will require a considerable increase in the numbers of robotic devices used. And a number of these robots are expected to become mobile. The coexistence of humans and an increasing number of robots, some of which are mobile, is expected to raise the degree of risk. The most typical risk is that of collision; but this is not the only risk. Inadequate cooperation between robots might lead to errors that create harmful environments for any humans that are called to interact with those robots. So, for instance, errors in a chemical plant could create an unforeseen gas leakage, which could be harmful for anyone working in the vicinity. Of course, particular care will have to be taken to address this kind of risk. Our technological mastery of risks so far seems to indicate that this issue is going to remain under control. Technologies currently reaching maturity and being developed for use in autonomous vehicles can, and will, be implemented in mobile robotic devices too, and are expected to improve security on the manufacturing floors that humans and robots will increasingly share.

Legal and ethical questions

The ethical choice faced by those programming robots will certainly be the following: Should a life-threatening risk emerge, which element will be our priority? This ethical question can already be seen with regard to autonomous cars: If an autonomous vehicle finds itself in a situation where it can only protect the life of an individual by sacrificing the life of another individual, which individual should be "saved", and which "sacrificed"? The driver, or the pedestrian? And if there is a choice between two pedestrians, what will the decision criteria be? Similar dilemmas will play out on the manufacturing floor.

Another obvious question of that of legal responsibility: In a case of damage to material property or human life (for the latter whether that "damage" is fatal or "merely" leads to injury), where does the legal responsibility lie? This question is only the tip of the iceberg. Imagine an erroneous action of a robot that manufactures a product that itself causes material damage or injuries to a human being. This could, for example, be a robot that produces an autonomous vehicle—a vehicle that goes on to cause damage or injury. Besides their legal aspects, such questions also have a purely ethical element, and they are yet to be properly addressed by society.

Independently of legal responsibility with regard to robots—briefly discussed above—the potential incursion of machines into the personal lives of those workers with whom they share the manufacturing floor raises further ethical and legal questions. Information on personal interactions between humans, including for example informal discussions, which might include an exchange of personal information, can be recorded. How can human workers be certain that robots are not working to hidden agendas set by their owners or their manufacturers? So, for example, how can human workers be certain that the owner or the manufacturer of the robots they are working with is not spying on them or monitoring their every action moment to moment, going beyond monitoring for valid business purposes such as the maintenance of good manufacturing practices in a factory environment?[29] And, even if workers are not being spied on, how can we manage the *perception* of being spied on? Recall the reaction of people who avoided talking to one another—and worse—because one of them was wearing Google's famous eyewear. The reason? Precisely the fear of being monitored or recorded.

The risk of being spied on or hacked in the highly sophisticated digital environment of the manufacturing floor is both perceived and real. A machine, a fellow worker, or a manager could do it (or be suspected of doing it). The manufacturing environment is even more sensitive than other environments—including the home environment or the professional services environment—because of its complexity, composed as it is of numerous machines, including location sensors, vision systems, and microphones (usually employed for vibration monitoring). Under normal conditions, these functions combine to produce a meaningful image, for instance of the functioning of a turbine. The same data could, however, potentially be used for spying on or hacking the individual worker. The collection and combination of data from the manufacturing floor is very useful, for security for instance or for preventive maintenance. But as manufacturing operations are much more complex and use far more elements than a single computer, tablet, or smartphone—the everyday interfaces between the average employee and the digital world—it seems reasonable that that average employee might feel potentially subject to spying or hacking, even if in reality that spying and hacking is not taking place.

At a later point in time, robots—which will have become increasingly intelligent—may no longer be respecting priorities established by their designer or manufacturer, either because neither has foreseen some specific situation (and the autonomous vehicle offers us many excellent examples here) or because, at some ultimate stage in robots' development, they are following their own priorities. The film *2001: A Space Odyssey* presents a quite nightmarish—and possibly prophetic—vision of such a scenario: a machine taking control away from a human. Several intermediate steps need to be taken, each increasingly encroaching on the free will and decision-

[29] In the context of increased quality requirements, the location and activity of workers is already monitored. In pharma, for instance, it is quite normal to know which worker has performed which operation. This is considered good manufacturing practice.

making power of the individual, before we find ourselves in this, one of many possible futures.

Business questions

Rapidly increasing levels of digitalization (meaning also automation and digitalization) on the manufacturing floor have numerous potential business impacts with regard to productivity. They also have possible impacts with regard to power and control. Larger companies can benefit from a greater potential for economies of scale than can SMEs. Larger companies' motivation to invest is higher than that of smaller companies: investment that delivers even small gains in terms of cost or productivity promises significant advantages when scaled up. Larger companies also have a greater *potential* to invest as they usually have deeper pockets, along with easier access to financing. It therefore seems quite reasonable that the degree of digitalization is higher in larger companies. This mechanism may help create a virtuous circle for larger organizations: the more productive they become, the more digitalization they want and the more they can invest in digitalization (of course, seen through the eyes of SMEs this is a *vicious* circle).

The more a manufacturing company becomes digitalized, the more powerful its position with regard to its workers when it comes to negotiations. A company that has more digital tools (e.g., robots or sensors) can more easily automatize production, and therefore lay off employees. This can happen to blue collars on the manufacturing floor, but also to service personnel. Further, a digitalized company can more easily subcontract services that it considers "nonessential"; here we can cite the massive use of subcontracting services to replace in-house Human Resources services. When we compare larger corporations to smaller companies, or SMEs, we clearly see that larger companies have a greater motivation and capability to invest in digital technologies. The motivation is that the scale effect of financial returns on investment is more pronounced than it is for an SME. The capability is greater because of the availability of cash or credit lines, on the one hand, and on the other the capacity to justify the hiring of specialized personnel who can plan and perform new digital processes.

The fact that larger corporations have the motivation and the capability to digitalize their processes faster, combined with the fact that digitalized companies have more negotiating power with regard to their employees, means that there is a quite understandable trend among the human workforce to be employed by smaller organizations. (This argument certainly holds true for both manufacturing companies and service companies.) This means that the distribution of the workforce can reasonably be expected to change, shifting the center of gravity of employment more and more toward small and medium-sized enterprises. Jobs at small companies can reasonably be considered to be more precarious, mainly due to the fragility of smaller organizations, in particular under the increasing pressure of the data- and technology-driven economy. We can, then, reasonably conclude that the transition to an increasingly technology- and data-based economy is globally increasing the precarity of jobs.

The increased digitalization of the manufacturing floor is de facto imposing structural changes on the role of human capital in the manufacturing environment. These changes can be observed in terms of societal impact (including aspects of training and skills), the integration of humans into a manufacturing floor that is more and more dominated by machines, legal and ethical concerns, and evolution with regard to negotiating power and the distribution of the workforce between large and small companies.

If we also take into account the relative empowerment of larger companies as compared to smaller organizations due to digitalization, we can, then, expect human manpower to be placed under increased pressure (The relative empowerment of large companies is also strengthened by another factor, detailed in the chapter “Data, a new form of capital”—the fact that larger companies can more easily collect and better use data.)

Perhaps the most important outcome of these changes is that the way humans work is changing. But the way people live, are trained, negotiate, and—even more broadly—are integrated into their working environment is also changing radically. Any effort to try to stop this transition would be illusory, meaningless even. Rather, employees and employers, workers and citizens, need to better understand these issues and to prepare for what is to come.

CHAPTER 5

COMPARATIVE ADVANTAGE AND GEOGRAPHICAL ECONOMIC CLUSTERS

Specialization in manufacturing today: Reality or chimera?

The fact that manufacturing industries have been delocalizing[30] since the end of the "Glorious Thirty" (1945–70) is no secret. French journalist Herve Kempf outlines the mechanisms nicely: An increase in workers' negotiating powers pressurized profit margins. To protect profit margins industry delocalized to areas with lower personnel costs. The idea was to keep high-end services (in particular engineering services and R&D) and relatively small-scale production of a high added value and/or high complexity in Western countries.[31] This was a twentieth century interpretation of nineteenth century theories of comparative advantage. Comparative advantage was no longer a question of manufacturing different types of products in different places around the globe, as had been the case in the past, but one of the geographical splitting up of different types of activities—manufacturing, services, engineering, and so on. Paul Collier puts it in more concrete terms: Europe, the USA, and Japan specialized in knowledge industries; East Asia in manufacturing; South Asia in services; the Middle East in oil; Africa in mining.

The transformation described in the works just cited (and in other works referred to therein) did indeed take place. Jobs moved to East Asia and this increased unemployment levels in the West. According to a report prepared by a High-Level Group (HLG) prompted by the European Commission,[32]

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[30] Manufacturing industry delocalization is still occurring, if at a slower pace, in parallel to a new wave of delocalization to lower cost areas, as for instance from coastal, higher cost areas of China to inner China or countries such as Vietnam.
[31] With the term "Western" here we refer specifically to the US, Europe, and Japan.
[32] HLG-KET (Key Enabling Technologies High-Level Expert Group) Final report, http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail

manufacturing job numbers in Europe were reduced by 14 percent between 2003 and 2008—so, by 2.5 percent per year. The very same report recognized a previously unidentified mechanism associated with the growth of several East Asian companies (at least at the time of the report's preparation, in 2011), which we can summarize very briefly here. First, these companies acted as commercial resellers, which allowed them to accumulate important amounts of capital and to grow considerably. Then, in a second phase, these same companies used their accumulated capital to acquire manufacturing facilities and skills and became manufacturers for Western brands. Third, such companies created their own brands based on their own manufacturing capabilities. Finally, to maintain their branding capabilities they developed strong R&D capabilities, which allowed them to create new products. In other words, manufacturing jobs clearly attracted and also helped to create engineering and R&D jobs.

What is the impact of this mechanism? What Collier refers to as the "knowledge industry in Western countries" is not functioning as expected: the skills that were expected to bring value to Western economies are rapidly moving closer to manufacturing centers, which accentuates actual—and potentially future—unemployment in Western countries. "Knowledge-based" jobs shifting to East Asia might, in the long run, also impair the innovation capabilities of the West and therefore hurt its potential for growth. This risk is more relevant for Europe, which has lost a more important portion of its manufacturing industry.

Industry 4.0: From European remedy to global industrial trend

The HLG report spelled out clearly the mechanism with respect to job losses related to the transition of "knowledge-based" jobs to manufacturing centers and therefore away from Western economies and in particular Europe. And the maintenance of manufacturing capabilities was an obvious remedy. But how to compete with lower wages? The answer was by replacing more and more humans with machines. This—very simple—idea was, of course, not new. It had started with the introduction of industrial robots some decades earlier. What *was* new, however, was the urgency of the situation. And that the necessary technologies were maturing and

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offering new opportunities. And this was particularly the case with what we, today, call digital technologies.

German Chancellor Angela Merkel stated clearly a political willingness regarding “the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry.” This is Industry 4.0.

A briefing to the European Parliament then clearly elucidated this vision,[33] using very concrete technological terminology to clearly set out what was essential if the Industry 4.0 concept was to succeed: ICT to digitalize information and integrate systems; cyber-physical systems; embedded sensors; intelligent robots; 3D-printing devices; wireless and Internet technologies; simulation and modelling; vast quantities of data; cloud computing; augmented reality.

The wording of this September 2015 parliamentary briefing parallels other rapidly evolving technological innovations, beyond those it explicitly mentions. First, the Industrial Internet of Things (I-IoT)—the Internet that allows machines to talk to each other. I-IOT needs two key components: (i) smart “things” that translate the physical world’s parameters into digits and are sometimes referred to as cyber-physical systems, and (ii) wireless and Internet technologies (Wi-Fi, Bluetooth, Lora, 4G and now 5G, and the many other communication methods that support the Internet). Second, the creation of digital twins—that is, the digital representation of real factories, machinery, and/or equipment in a computer, in which each individual system or component is represented digitally and the whole operation of the real factory or of machinery is also represented digitally. Third, the extensive use of artificial intelligence, which uses the aforementioned “vast quantities of data” (i.e., what we understand as Big Data)—collected at the factory or from machinery or equipment—to analyze complex situations.

In stark contrast to what usually happens following political declarations, these very concrete words have, today, become reality: the juxtaposition and parallel exploitation of several of these techniques is being used to improve productivity, quality, and security in factories and industrial equipment.

Returning to the start of this strand of our analysis, we can see that the rationale of Industry 4.0 was to relaunch industrial activity in Europe. Jobs

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[33] http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568337/EPRS_BRI (2015)568337_EN.pdf.

would be maintained and/or even created in manufacturing by the repatriation of industry to the continent, thus allowing a balancing of the secondary and tertiary domains. It is no longer a question of specializing in "knowledge-intensive" jobs alone (as was thought when the industrial delocalization wave hit); today, Western economies' stakeholders (in particular those in Europe and the US) understand that the objective is rather to maintain the entire chain—"knowledge-intensive" jobs, manufacturing, and, of course, services—locally.

The sustainability of comparative advantage

We can certainly understand Industry 4.0 as the willingness of Europe's industries and political leadership to relocate industry back to Europe (the same happened in the US) as a reaction to the fact that nothing can hinder the rapid delocalization of secondary domain jobs, in particular knowledge-intensive jobs, to any place in the world. But it happened that, equally, nothing could hinder the implementation of similar initiatives in other parts of the world. And this is what occurred, thanks to clear political incentives, in particular in East Asia's emerging giant, China. The 19th National Congress of the Communist Party of China (in 2017[34]) adopted "Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era". Its 14-point basic policy includes two important points:[35,36]

- Adopting new, science-based ideas for "innovative, coordinated, green, open and shared development" (point no. 4).
- Coexist well with nature, with "energy conservation and environmental protection" policies, and "contribute to global ecological safety" (point no. 9).

Which, in other words, says that China is no longer the factory of the world, but is now the factory of the world strongly supported by science-based innovation and knowledge-intensive jobs: this is "the factory of the world +"—a balanced combination of "knowledge industries" and manufacturing.[37] This means that the Industry 4.0 initiative did not bring a

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[34] https://en.wikipedia.org/wiki/19th_National_Congress_of_the_Communist_Party_of_China.

[35] "19th Party Congress: Xi Jinping outlines new thought on socialism with Chinese traits", *Straits Times*, October 18, 2017.

[36] "His own words: The 14 principles of 'Xi Jinping Thought'", BBC Monitoring, archived from the original on 28 October 2017.

[37] The strength of this balanced system (which includes industry and "knowledge-

specific comparative advantage to Europe, since it spilled over rapidly (and naturally) to the rest of the world.

Where, then, is the specialization and comparative advantage of each area of the world that was theorized over two centuries ago? Are those theories still valid today? And if so, how can they be interpreted?

In the eighteenth century manufacturing was about specialization per geographical area; today, the world has changed. Among others, three factors are adding complexity to this concept:

a. Products and services converge. When products can be manufactured in and shipped from anywhere in the world, services can—by definition—be local.
b. Products themselves—from automobiles to phones to washing machines—are becoming more and more complex. And when this happens, they need more and more sophisticated subsystems and components.
c. The increasing importance of the role of technology in every aspect of our lives suggests that comparative advantage is (and will probably remain) closely related to the presence of technological excellence.
d. The sufficiency of resources—in other words, resource sustainability—is a boundary condition.

It is, then, straightforward to test whether the comparative advantage of each area of the globe is not its specialization, but its capacity to fluently integrate technological innovation in various "traditional" industries (so, industries such as agriculture, finance, resource extraction, medical, etc.). If the latter hypothesis is correct, then mastery of the processes of technological innovation becomes the key skill when creating and maintaining comparative advantage.

The nature of innovation processes is universal and does not differ from one part of the world to another: the same processes (with minor differences) are valid in the Bay Area, in Tel Aviv, in Shenzen, or in

based" jobs) is also bolstered by the control of resources. For the sake of brevity and the focus of our argumentation, we do not address here the case of "resource extraction". The importance of control over strategic resources—including, for instance, lithium for batteries—itself merits a substantial chapter, which would add an extremely interesting geopolitical control dimension to the entire question, but lies beyond the scope of this short analysis.

Lausanne.[38] Going one step further, one might speculate that due to the global uniformity of these processes one of two outcomes can be expected. The first is that there will be a global "winner"—an area or a cluster that differentiates itself from all others, achieving global dominance and therefore creating large imbalances in economic power, which in turn can create societal and economic instability. A variant of this outcome is that there will not be only one "winner", but certain areas/clusters that become "winners"—a kind of concentration of those who master excellence in technological innovation into specific areas/clusters that compete with one another, each with small differentials that translate into small comparative advantages. One can express both these variants as a kind of "oligarchy of innovation". Once more, the subject of imbalances (and their consequences) remains an open question. The second possible outcome is a simultaneous raising to a comparable level of more and more of the areas of the world that use these technological innovation processes. This would mean increases in productivity, and we could describe this as a "democratization of innovation". (Of course, the word "democratization" is, here, used metaphorically, and means a spreading of the mastery of the capacities concerned across as large a spectrum of clusters as possible.)

It is worthwhile noting that such a process is being attempted today in Europe, with the preparation of the upcoming 9th framework R&D program Horizon Europe/Digital Europe; the creation of European "Digital Innovation Hubs" (E-DIHs) seems to be an attempt, at least at the European level, to move in this direction.

In the next subsection we will try to understand the factors that can influence the creation of comparative advantage.

Factors key to technological comparative advantage

As society and the economy evolve, the mechanisms that influence the gaining of comparative advantage change naturally and continuously. These mechanisms are increasingly influenced by technology,[39] but not by technology

[38] This statement is not absolutely true. For instance, the provenance of the capital employed (private or quasi-state) or the innovation support mechanism in play (so, support from a public innovation project or in the form of public procurement) may differ considerably from country to country. The basics of technological innovation processes remain, however, the same throughout the world.

[39]https://www.satw.ch/en/blog/how-technological-and-industrial-trends-impact-on-society-evolution-and-the-economy/.

alone. The first important influencing factor that does not depend on technology is tradition, meaning industrial tradition.

To illustrate tradition's role, let's take Europe as an example. Today, Europe boasts strong industrial sectors in fields such as automotive, aeronautics, pharma, and microelectronics, each with their respective clusters. And, of course, we are not being exhaustive here. Sometimes these clusters were created centuries ago (chemistry and textiles for instance), sometimes more recently (automotive, microelectronics, and aeronautics). They are geographically delimited, occurring in specific areas. They harbor strong ecosystems with all the necessary innovation actors, from universities with specialized faculties to research centers and subcontractors. Currently, there is a systemic effort underway to structure and reinforce these clusters and their innovation potential in the framework of the upcoming R&D program Digital Europe, including the creation of the aforementioned Digital Innovation Hubs (DIHs)—industrial clusters, reinforced by digital technology and related ecosystems, that include, ideally, all the necessary innovation actors, both public and private.

To illustrate in greater detail the question of tradition we can look at the pharma industry. Pharma is a legacy of the chemical industry. The chemical industry is a legacy of the textile industry. Europe's textile industry flourished at the time of the Renaissance, and still has strong clusters in certain areas where the Renaissance began (Gent and Tuscany included), despite the massive delocalization of textiles to the Far East. Returning to pharma, despite high wages in Switzerland, Germany, and France, very important clusters exist in all three countries. The same is true of the intermediate link between the textile industry and pharma—the chemical industry, which saw strong growth in the nineteenth century. Despite pressures on the chemical industry's profit margins, large manufacturing facilities still exist in Europe; pharma maintains both manufacturing and very important R&D activities on the continent.

But tradition is not enough when one is seeking to maintain a monopolistic comparative advantage. Life science clusters have been created in Europe. Similar clusters have, however, grown elsewhere in the world, if much more recently. For instance, the powerful life science cluster in the Boston area is evidence that, in this market at least, barriers to entry built upon tradition and roots have not enabled European pharma to keep competing clusters from entering the arena.

Public incentives and/or significant private investment can rapidly enable the creation of new clusters. Examples are numerous, but three in particular are highly instructive.

The first is the creation—almost ex nihilo—of a civil aeronautics industry in Europe. Despite its lack of tradition in this domain and the presence of a well-developed tradition in the USA, during and after WWII Europe was able to close the gap and become competitive. In a present-day development, we observe the rapid growth of a Chinese aeronautics cluster based in Shanghai.

A second example is the shipbuilding industry. From the starting point of geographical centers in northern Europe (since the era of Dutch and British sea domination), activity rapidly moved—within a period of mere decades—to Korea (the Busan area, with the epic creation of shipyards—again, ex nihilo—in the late 1970s and 1980s), and slightly later to China (while this same industry had been maintained in Japan). Public incentives and strong private entrepreneurship were at the origin of this fast and radical change in the business landscape.

A third example can be found in the domain of electronics, where several cases are illustrative, including the microelectronics industry in Taiwan and South Korea (the latter a country that in the 60s was on the verge of collapse) and—most revealing of all—the transition of Shenzen from a fishing village in the 1990s to a world-dominant cluster (as of today, one-fifth of all the smartphones in the world are produced in the Guangdong area).

Beyond tradition and public incentives and private entrepreneurship, another factor is important for the creation of comparative advantage today: a large—initial—addressable market. It is, indeed, much easier for a new business to start up in a large market where standards, culture, and the ways in which buyers think are quite uniform. The best and most illustrative example here is the fast growth of the "Internet industry", in particular the e-commerce industry in the USA: the GAFAs. It is doubtful whether e-commerce would have enjoyed the same success without (a) the opportunity to address the same culture (with regard to advertising and market acceptance), (b) product standardization, (c) uniform practices regarding product-centralized logistics (storage and distribution), and (d) avoiding the difficult process of border crossings. This argumentation is further reinforced by the case of the Chinese electronics market, and in two ways: observe (a) the notable difficulty of GAFA to penetrate this market (and this is not only the case for search engines), and (b) the impressive growth of indigenous national leaders such as Alibaba and WeChat.

Comparative forces for dominant clusters

Tradition, public incentives and entrepreneurship, and a large addressable market seem to be the factors that contribute to certain clusters' dominant positions. These forces sometimes converge and sometimes compete, and contribute to the creation or annihilation of clusters.

Tradition tends to stabilize a cluster and strengthen its roots; incentives to reinforce clusters but more often to create new ones. A large addressable market for incumbents tends to contribute to clusters having a more stable position (see, for instance, the tradition of the automotive industry in the USA); in some cases, however, such large addressable markets act in completely the opposite manner and allow the creation of new clusters with disruptive technologies (so, for example, the electric car—this time in China—and possibly the hydrogen-powered car). The case of the hydrogen-powered car is highly illustrative of the need for an addressable market. It is clear, today, that the most environmentally friendly type of vehicle (even more so than the electric car) is one based on hydrogen fuel cells. What hinders deployment? The answer—beyond the inherent risks of hydrogen—is logistics and production costs. If a company wants to product hydrogen-based vehicles, it needs to follow[40] the cost-of-manufacturing curve (the inherent physics clearly allow for a motor that can be at least as cost effective as the internal combustion engine). To follow the cost-of-manufacturing curve the company needs to produce on a large scale. Large-scale production requires fueling logistics: owners of hydrogen-powered vehicles living in, say, Belgium need to be able to refuel their vehicles in Germany, France, the Netherlands…. The concept of a large addressable market means, in this example, that a country or a cluster of countries needs to (1) define common standards for vehicles and for refueling, and (2) commit to building refueling infrastructure (and, here, public incentives come into play).

Internationally, clusters with comparative advantage coexist and compete for dominance. Dominance, at the end of the day, contributes to the economic well-being of their stakeholders. Stakeholders include economic stakeholders, the state (including its citizens), and politicians (whose

[40] Initially, production costs are high for any manufactured good. But with experience and volume, the cost per item produced decreases dramatically.

political longevity depends significantly on the well-being of their constituents). This is, of course (and fortunately), not a zero-sum game: competition creates opportunities and new businesses. The world is not, however, that angelic. Despite not being a zero-sum game, significant disequilibria can be created: the important delocalization of facilities for (and jobs in) manufacturing (first) and knowledge-based (second) jobs that the Industry 4.0 initiative tried to combat is a concrete example of this.

A shift of comparative advantage from one area of the globe to another is subject to the aforementioned forces. But the pace at which these shifts are taking place is increasing fast, despite mounting barriers. Important parameters accelerating the speed of change include the mobility of human resources (in particular of educated/skilled human resources), the mobility of capital, and the instantaneous availability of information. On the opposite side of this equation, important parameters that tend to slow down the pace of changes in comparative advantage include increasing barriers to entry and the availability, locally, of innovation stakeholders. The first of these—barriers to entry—is easy to understand if one takes as one's example the exponential cost increases experienced by a factory that moves from producing the present to the next generation of microelectronic chips (comparing, say, the 65 nm generation to the 22 nm generation). The second parameter is also easy to understand. Comparative advantage is becoming more and more synonymous with technological advantage, which requires solid technological innovation capabilities and experience: scientific excellence, technology development, knowledge transfer abilities, and the availability and capacity of venture capital, as well as a stable entrepreneurial climate and conditions.

Which future?

Between the factors that define the evolution of comparative advantage (i.e., tradition, public incentives and private entrepreneurship, and access to a large market) there is continuous cooperation and competition, which drive the dominance of one cluster or another. The—changing—relative weight of these factors defines the dominance of clusters and creates the potential for continuous shifts in dominance. The presence of industrial tradition tends to root the dominance of a cluster in a specific area (as in the case of the pharma industry (see above)). Public incentives can either anchor the dominance of a cluster (the aeronautics industry in the US is an example, in that particular case involving extensive public procurement) or create new clusters (for instance, in the same industry—aeronautics—in Europe; or, at least, US industry has claimed that this is the case). Private entrepreneurship can, in theory, operate worldwide. Geographical areas with experience in managing this process—so, for instance, the Bay Area—have, however, a clear advantage. The importance of a large initial market is underlined by, for example, the case of Alibaba in China.

The struggle for comparative advantage is, today, intense. The list of "winners" in this struggle can and will change rapidly, and we will end up with one of three possible futures:

i. A limited number of clusters and areas that are the technology innovators. As of today, these are situated along three axes in the US (the Bay Area, Boston, and—to a degree—Texas), in certain areas of Europe (including London and Berlin, and Switzerland—the last of these number one in innovation worldwide for ten years now), and in Israel, Taiwan, Singapore, and South Korea, as well as—and at an accelerating pace—China's Shenzen area and Shanghai area. These areas would dominate, through their technological leadership, the innovation process. It is important to point out that among them we can differentiate between two categories: (a) those that are purely technological (as in Taiwan, around microelectronics manufacturing) and (b) those that are technology platform-based.[41] The latter sub-category refers to clusters that encompass large companies that master technology and collect large amounts of data. In the remainder of our analysis, we will mean this sub-category when we refer to technology clusters.
ii. A larger number of application-oriented hubs focusing on their own respective applications (e.g., automotive, aeronautics, smart textiles, medical, pharma, space…) with the appropriate level of technological empowerment (which, as previously mentioned, is an explicit focus of the European Commission, as embodied by the Digital Innovation Hubs of its upcoming Digital Europe R&D program). Such centers would have a specific flavor (e.g., automotive or aeronautics), but their shared characteristic would be that they cover two ecosystem dimensions: the innovation ecosystem (with all the related stakeholders,

[41] Typically, in the Bay Area (GAFA and related organizations) or China (Alibaba or Tencent). Also, public organizations that collect large amounts of behavioral data using advanced facial recognition techniques—as is the case, for instance, in some places in China—or corporations that use techniques such as those once used by Cambridge Analytica. Finally, companies that collect data with the objective of using them to feed artificial intelligence algorithms, whose objective can be decision-making support or even—simply—decision-making.

from academia to industry, including the necessary financial means and technology management capabilities) and a supply chain for the production of subsystems (despite the fact that supply chains are global).

iii. Of course, and most probably, a combination of both of the above.

It is clear that path (ii), or path (iii) with a strong component of path (ii), would be optimal with regard to reducing interregional imbalances, since each would create more opportunities, and exploit pre-existing industrial tradition.

For an illustrative example of the struggle between paths (i) and (ii), above, we need look no further than the watchmaking industry. Watchmaking has been deeply rooted in Europe, in particular in western Switzerland, since the sixteenth century. A strong foundation, from low-cost electronic watches to high-end luxury timepieces—a healthy pyramid—has ensured that a region populated by barely two million people is responsible for exports that account for around half of worldwide revenues in the watch sector. Even since 2015 (approximately when smartwatches started to appear), the powerful cluster has continued to grow, based upon a well-defined (in localization terms) industrial sector (case (ii), above). The smartwatch was created, in less than half a decade, by a technology company, Apple, that itself generates practically one-third of the revenues of the entire Swiss watch industry: a clear illustration of case (i), above. Today, the Swiss watch industry continues to sell well in the luxury segment, but in the low-cost segment competition is ferocious and that "healthy pyramid" has been eroded. The sharp increase in sales of smartwatches clearly demonstrates how it is possible to shift dominance, very rapidly, from one cluster to another, and from one path or future to another—possible futures (ii) and (i) above, respectively.

What is a certainty is that the struggle for dominance through comparative advantage will intensify. And the main reason for this is the increasing role of technology in the evolution of the economy and the transformation of society, globally.

Is it possible to influence the race for dominance and to favor one or the other path? The answer is certainly yes. Firstly, and starting today, consideration of technology should be placed higher on the political agenda: failure to do so will lead to a failure to take correct strategic decisions, both in countries and in specific regions. The question of the fluidity of the dominant positions of clusters should also be actively considered: clusters that are dominant today might become mere followers tomorrow. Giving close and due consideration to the factors discussed above—namely, tradition, public incentives and private entrepreneurship, and finally addressable markets—is vital. Of these factors, tradition cannot be changed. Addressable markets, however, can—in the long run—through the establishment of international agreements (e.g., NAFTA) or more structured configurations such as the European Union.

And while we have previously cited public incentives and private entrepreneurship as one, combined factor, it will also pay to assign significant importance to these two elements' coexistence and interaction. Private entrepreneurship can be cultivated, and above all supported, by fair and sustaining policies. And such policies can be a part of public incentives. Without public incentives, private initiative with regard to any cluster is probably doomed to failure. But public incentives are not—and should not be—limited to the purely financial. They may also be regulatory, educational, or environmental, or take the form of ecosystem creation, or many other forms that cannot be enumerated and explored here given the limited scope of this brief analysis. And to be able to offer these incentives, the public domain requires robust finances. Such a condition can be put in place if the public domain is regarded as a respected partner of private entrepreneurship. This can mean, among other things, the fair return of a portion of the financial gains of the private sector to the public sector; meaning, in turn, that the public domain does not suffer unduly from the risk taking of private entrepreneurship. This is a visionary, entrepreneurial public domain possessed of strength, flexibility, and leadership, not an ultralight, risk-absorbing administration that transfers business risks to society, nor an old-fashioned, sclerotic regime.

Private entrepreneurship can, meanwhile, generate huge benefits for investors. But focusing purely on the criterion of financial gain is a self-defeating approach. It leads to the accumulation of wealth and power in specific areas and clusters, which in turn means enormous imbalances and consequent social unrest, both of which damage the business environment. Close collaboration and careful formulation of policy, along with mutual respect between those managing public and those managing private investment, is the only way to build a long-term win–win situation with regard to comparative advantage.

The very foundations of the roles of the public domain and of the private domain and their interrelation are drastically changing, and in the future their paradigms will be transformed. The public domain needs both the flexibility and the leadership skills of the private, alongside its own commitment to society, to be able to reap the benefits of technology and disseminate them among all those individuals that make up society. In other words, it must be able to act as a fair partner, which not only bears the cost, but also enjoys the profits, and is able to use those profits to create conditions appropriate for the flourishing of clusters. The private domain, meanwhile, needs to go beyond Friedman's dogma that the company's focus is exclusively its shareholders—while this is analytically perfect, in the more and more rapidly changing future it will prove socially unsustainable.

The public and the private sectors: The need for a change

Economic clusters flourish within specific geographic areas and produce jobs and value. Their dominance over competing clusters can create more jobs and more well-being in human communities that live in those same geographical areas. Dominance can, however, shift rapidly from one cluster to another, meaning from one area to another. This is due to unprecedented mobility, including mobility of persons and—much more significantly—mobility of capital. Dominance can, with increasing rapidity, be built or eroded. The efficiency of a cluster depends on its dominance (or lack thereof) of the international scene. New clusters can be created quickly.[42] Clusters can be technology platform- (e.g., social media or Big Data-based artificial intelligence) or market/application-based (e.g., automotive, textiles, microelectronics). The second type is based on a more or less long industrial tradition. Technological platform clusters by their very nature tend to operate in a quasi-monopolistic, "winner takes all" manner, creating a kind of "technology oligarchy". Application- or market-oriented clusters can be more diverse in geographical terms and therefore allow for a more homogeneous distribution of wealth.

The dominance of a cluster depends precisely on the presence of tradition, public incentives and private entrepreneurship, and addressable markets. And new clusters can be created seemingly from nothing provided the two last factors are strong enough. This despite the fact that new clusters

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[42] Who could have imagined 30 years ago that the small town of Shenzen would become a world-beater in the electronics sector? Or foreseen the transformation of South Korea from a quasi-bankrupt state with an impoverished population in the 1960s to today's flourishing economy?

face higher and higher barriers to entry because of the increasing complexity (and therefore cost) of technology.

At this point, it is interesting to return to the beginning of the present strand our analysis. The European dream of re-localizing industry—based on the foundation of Industry 4.0, which itself was supported by a combination of all the four factors mentioned above, which were expected to act synergistically—has proven unattainable. It remains, however, a very interesting case. This dream proved unattainable because the key technologies upon which the implementation of Industry 4.0 was supposed to be based were not unique to Europe; strong private entrepreneurship (in the US) and public incentives (in China[43]) accelerated the building of technological clusters that have tended to dominate industrial clusters. In this way, the expected comparative advantage factor that would lead industry to relocate to Europe disappeared.

The roles of the public domain and the private domain are changing rapidly, and those active in each need to exercise a certain degree of introspection. This would enable each to acquire improved social responsibility. It would also enable them to work together in a more intertwined manner, developing the synergies necessary if sustainable societies are to be created and maintained in a world that is becoming more and more technology oriented. And such a revitalized relationship might even be the foundation upon which to radically change the governance of our societies, adopting modes never seen before—modes adapted to today's rapidly changing conditions.

Strength, flexibility, and leadership in the public domain are key enablers for the empowerment of healthy private entrepreneurship, and support access to large market pools making it possible to exploit existing industrial tradition (or to build up new "traditions" when and if necessary), which means more balanced and uniform growth across the globe.

Such strength, flexibility, and leadership can be only sustained if built upon the foundations of a fair return of a portion of the gains of the private domain to the public domain, and of balanced risk taking. If we lack these qualities, we will be promoting the dominance of technological platform-based clusters, and in the process will bring about a kind of cluster

[43] In the US, meanwhile, the two elements interact, with private entrepreneurship being significantly leveraged by public procurement.

"oligarchy" that will, itself, drive global imbalances that will prove unsustainable.

CHAPTER 6

DATA, A NEW FORM OF CAPITAL

Data, a new factor in the economy

Science and technology have always played an important role in the evolution of human societies. The case of the Industrial Revolution is a clear illustration of this fact. They are not, of course, the only important factors. Ideas, geographical factors, climate, or even accidents of history have also played key roles in the evolution of societies.

Today, a new factor can be added to this list: data. Data are the product of today's technological tools, which we can call "digital technologies". Data also shape the world around us, in a trend that is commonly referred to as "digitalization". This trend is apparent in every aspect of our lives, ranging from our personal environment and health to transportation, energy generation and management, and industry.

Today the role of science and technology is more important than in the past. And digitalization is an influential factor in this change. Digitalization both impacts society and improves efficiency and productivity in existing processes. It also creates impact by introducing completely new processes, generating disruption in traditional businesses. There is a continuum, from technology through industry trends to societal and economic challenges. These three elements are approaching one another and their mutual interaction is becoming ever stronger. This interaction is bidirectional: not only does technology create disruption in the economy and society, this disruption creates a need for new technologies. Digitalization plays a key role in accelerating the interaction between the three aforementioned elements of the continuum: technology, industry, and the economy and society.

Impact on novel innovation mechanisms: The role of data

At the end of the last century computing, electronics, and robots replaced the human factor with regard to improving productivity in almost every sector of the economy. This model was, in its basic economic mechanism, the acceleration of productivity by replacing older elements (irrespective of whether these were human or machinery) with new, more productive ones (Figure 6-1). Technology (or technological innovation) was "simply" the process of making this mechanism more efficient.

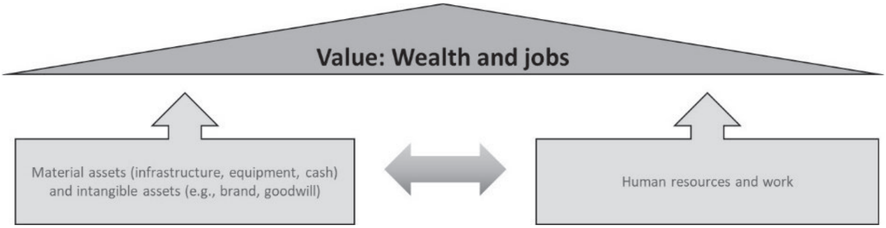

Figure 6-1. Up to very recently the key to value creation was the coexistence (cooperation and competition) of assets and human work. Technology can improve the efficiency of each of these two pillars.

What is different today compared to the end of the twentieth century (and all periods before) is the creation of an increasing amount of data, made possible by the rapid manufacture of intelligent electronic devices of ever-increasing complexity. The Internet creates, communicates, and collects data on a daily basis—including our photos, messages, answers to questionnaires, and web searches. This is the "classic" Internet. In addition to the classic Internet, the Internet of Things (IoT) collects data that are not generated by humans but by "things"—so, for instance, by smart sensors that read from machines, from ourselves, from our environment, or from our vehicles and homes. Data from the Internet and the Internet of Things are transmitted over powerful fiber-optic networks to giant servers, which store and process them to generate information and knowledge. The term Big Data is used to describe the tsunami of all these bits, which flow from both the classic Internet and the Internet of Things. In addition to the exponential growth of the classic Internet, the growth of the IoT—even more tremendous—is expected to lead to trillions of devices surrounding us, creating data flows that rapidly overtake those of the classic Internet, generating unknown quantities of bits. At the end of the chain, the data processed will allow informed decisions to be taken without human intervention, or provide valuable information, allowing humans to make better decisions. Artificial intelligence (AI) is a decision-making process that involves the sophisticated processing of data and allows improved and accelerated decision-making. AI can reside on large supercomputers, which can be far from the point of action. AI can also reside locally, when adequately engineered for embedding in the devices that are at the edge of the IoT. All these elements are the basic components and the backbone of digitalization.

While data are being, thanks to digital technologies, created at such an unprecedented pace, is such attention to digitalization, in terms of its economic impact, justified? Are we not living in a process where the machine "simply" replaces the human and where capital competes or cooperates with human labor, as illustrated in Figure 6-1, in a "business-as-usual" manner? Or are we living something more fundamental, something that is no longer an evolution but a radical paradigm shift?

We have been hearing every day for several years now that "data is gold" or that "data is the oil of the twenty-first century". The simplest reasoning tells us that since data are a form capital they are part of one of the two pillars of value creation, as illustrated in Figure 6-1, above—the "capital" pillar being the one that includes material assets (infrastructure, equipment, and cash) and intangible assets (e.g., brand and goodwill).

The question we must ask ourselves is whether the nature of this capital, the capital constituted by data, is the same as that of classic capital—that is, capital that consists of buildings, equipment, infrastructure, and/or other physical assets, or intangible assets such as brand value or intellectual property. The answer is: not really. Data do indeed constitute a form of capital, but of a nature different to that of conventional capital. Data is, then, a new form of capital. The main difference between "data capital" and classic capital is ownership. The latter, by its nature, generally belongs to a single organization or person at any one time. In contrast, data can be accessible to several people and organizations at the same time. Data is not always someone's property, but access to it provides essential information and data itself is thus de facto similar to property, but with multiple owners. Information, knowledge, or human creations that are present on the Internet may have an author, but knowledge and intellectual stimulation is common to all. For instance, information about a person's location, for example as a result of a shared photo or a GPS locator, is usually held by a multitude of people, including that person's friends, enemies, colleagues, and commercial competitors, as well as numerous electronic platforms. This type of capital, "data capital", cannot be compared directly to classic capital.

The difference in nature between classic capital and "data capital" is having a huge impact on the economy and its evolution. Today, "data capital" intervenes in the interaction (which can be cooperation or competition) between classic capital and work and modifies it. If used properly, “data capital” can be a lever both for classic capital and for work. It is more than obvious that this cannot be the case equally for all types of work: value created by the work of an economic analyst or a computer scientist, for instance, is much more likely to be leveraged by data than is the value of work produced by a construction company (Figure 6-2).

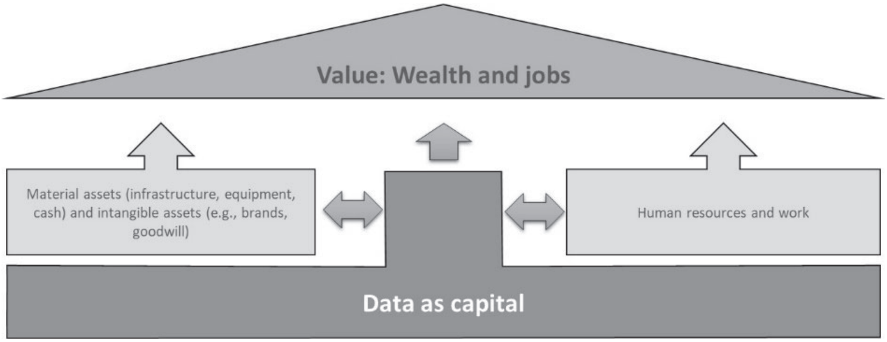

Figure 6-2. The advent of capital allowed the creation of a new pillar in the value creation mechanism. Data is a kind of capital that creates value but also leverages material and intangible assets as well as human work. The expected outcome value is much bigger.

“Data capital”, by its nature, is accessible to (and often de facto, as argued above, belongs to) several people or organizations simultaneously. Further, data, being more fluid by nature, are more easily accessible to users. The nature of “data capital”, therefore, makes it possible to bypass conventional commercial and societal links and bridges. Today’s simplest examples are Bitcoin, which envisages bypassing established structures such as banks, or, similarly, blockchain technology, which is thought to be able to replace contracts and many other concepts that the economy and society are familiar with and that we consider as established. Today, companies capable of building virtual bridges (and shortcuts) can and do dominate international trade, and sometimes even master politics. The difference between the twentieth century and today is that the speed of “construction” of these virtual bridges is infinitely greater than that of any material construction.

We stated above that access to data is possible for several persons and/or organizations simultaneously. One can, however, argue that, on the one hand, the ease of access to data and, on the other, the effectiveness of such access can be different, as a function of (1) the size of the organization that accesses and uses the data, and (2) that organization's nature.

The leverage effect of "data capital" is most effective when that capital belongs to a large organization such as a large commercial company. When a large company and a small company—the latter an SME (small or medium-sized enterprise)—access the same amount of information, the large company has a de facto advantage. The reason for this is that the multiplier (i.e., the "data capital") multiplies a larger value (i.e., the classic capital) in the form of material assets in the case of a large company than it does in the case of a small business; therefore, by definition the result of such a "multiplication" is larger.

In addition, there is a second reason why large companies have an advantage when using "data capital" compared to smaller companies. Large companies have the ability to accumulate data from a wider range of sources (text, images, data from different sensors) than small companies. There are many reasons for this. The first is that large companies have more access to the resources necessary to build huge databases. These are human resources but also material resources (e.g., IT resources, access rights). The second is bargaining power. In a value chain, an SME is often obliged to collaborate with a large company. Imagine an SME that manufactures switches for automobile doors: without an integrator that manufactures automobile doors, the SME cannot function. In the "classic" world the company sold automobile door switches. In today's world, the SME continues to sell the same switches, while continuously sharing its data (and probably its problems), which enriches its larger partner ("data capital") and consequently modifies the power ratio between the two. The existence of almost total transparency, brought about by the exchange of data, also makes it possible to observe potential problems (for example, in the SME's production processes), which makes the SME's commercial negotiating position with regard to its larger partner (in our example the integrator of automobile doors) weaker.

It is reasonable to conclude that data are much more useful for large organizations than for small ones. A large structure has two inherent advantages: (i) large organizations can more easily collect and access data and thus build up a larger capital base, and (ii) through the multiplier effect, they can produce a greater leverage effect on their physical capital. Hence the increasing risk of creating imbalances and concentrating power.

This simple, mechanistic effect induces greater market dominance by larger economic structures, particularly data-based platforms. Thus, large structures have a competitive advantage, solely because of their volume. Large structures whose main business is related to and/or leveraged by data are in an obviously advantageous position vis-à-vis large structures that are not in a data-related business (e.g., construction) since the latter do not profit from this leverage effect.

New mechanisms as sources of societal imbalances, and of opportunities

Imbalances and opportunities

The global economy and the global distribution of wealth are both closely linked to access to advanced technologies. The Internet industry has created[44] wealth of a value of no less than USD 8 trillion. However, more important than the value of the wealth created is how that wealth is distributed.

Silicon Valley's entrepreneurial culture has enabled Big Data companies to flourish, accumulating not only data but capital. These include not only the famous—GAFA—but many others, such as Airbnb or Uber, which in turn touch many others still, which in turn play a part in every sector of the economy and society, fueling the increasing domination of this particular region. Intuitively, there is nothing to prevent the further expansion of this established dominance, with its roots in both a geographical area and a segment of the population (highly qualified; very entrepreneurial) that is, of course, unrepresentative of the vast majority of the population—even in this one geographical area. The expansion of these companies seems to indicate that although geographical specialization was initially present, the profile and level of training of different regions is ultimately the driving force behind growth. The very high incomes of the people involved in this adventure—whether that takes the form of the salaries of executives, stock options, or venture capital—show precisely the importance of the leverage effect of data ownership. It is highly unlikely that such income gaps will prove sustainable, particularly when compared to the stagnant incomes of segments of the population that are not benefiting from this wave.

[44] https://amp.theatlantic.com/amp/article/247963/.

According to the World Bank, average per capita income in OECD countries is more than 50 times higher than in non-member countries. In Europe itself, the share of the population whose incomes are rising by 20 percent is five times greater than the share that is falling by the same percentage. It can be seen that this gap is constantly increasing as a function of time.

It is highly likely that the widening income gap[45] and unemployment are, at least in part, the cause of political and social unrest. Such unrest can be expressed through significant migratory movements between the world's richest and poorest regions. Another type of unrest, this time occurring within one geographical area, comes from fractions of the population suffering from this widening gap—as demonstrated by the "yellow vests" (*gilets jaunes*) in France. This widening of gaps is potentially unsustainable.

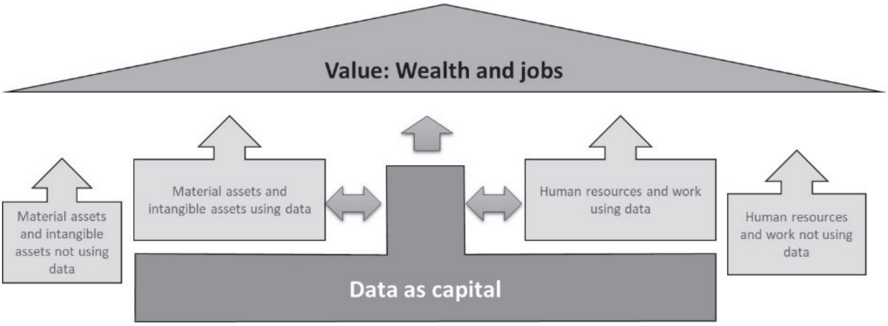

Figure 6-3. Data as a form of capital that can leverage assets and human work cannot be universal.

Some assets and some forms of labor cannot, by their nature, profit—or can profit but not to the same extent—from data (e.g., the local grocery store profits much less from data than does a big bank). Value continues to be created without the use of data, but it becomes more marginal and less sustainable and competes on unequal terms (Figure 6-3). This can potentially create unsustainable inequalities.

From another point of view, it can be observed that the fluidity of "data capital", which is much more mobile than material capital, makes it possible

[45] Income differences, here, refer to differences between rich and poor countries, and also between categories of the rich population and categories of the poor population in the same country.

to create opportunities in places around the globe provided that human resources are properly trained. This is a factor that can, subject to the availability of resources, contribute to a better income balance between geographical areas of the world. Two interesting examples that illustrate the offshoring of "data capital" creation are India's Bangalore region and Mongolia, the latter favored for the mining of cryptocurrencies such as Bitcoin.

These two illustrations indicate that human capital can be formed elsewhere and imported into a place of production. However, the proximity between training, research, and innovation is very important, even in a world dominated by data. Clusters such as Silicon Valley or the Boston area in the US are proof of this. In general, the education and training of resources is an important factor in attracting value creation to a geographical location (in addition to other framework conditions such as political stability and infrastructure availability, and others that we will not address in detail here). It is also important to note that the availability of quality education and training is generally highly dependent on both the wealth of the individual and the family and their societal background and on the geographical origin of human resources: world regions with a good education system—more often developed countries, therefore—remain favored.

Manufactured products—all along the value chain—generate data and/or enable opportunities for data analysis, artificial intelligence, and hardware; this, simply, is the concept of Industry 4.0. Value chains and products become more complex as several basic functions interact to produce data: data collection, cleaning and formatting, preprocessing, and communication. To make the whole system sustainable in the long term, resource sustainability (e.g., energy) must be taken into account, which is rarely the case today. The continuous increase in the demand for data acquisition, communication, processing, and storage implies a continuous increase in the demand for resources, including energy, bandwidth, and storage space. So, what does it mean when we make products and processes more complex? A simple web search for popular product value chains, such as that of the iPhone, illustrates that even individual value chains cover the entire planet. Digitalization and complexity lead to a globalization of products, and so to a tendency to equalize differences between geographical areas while maintaining the advantage of qualified organizations and people who master specific parts of the production process, all widely geographically distributed throughout the world.

We have seen that the momentous changes in our lives, both present and future, are being increasingly influenced by digitalization. Digitalization has its origins in the huge potential created by digital technologies—the Internet of Things, robotics, artificial intelligence, advanced manufacturing technologies, and simulation technologies. The possibility of manufacturing ultraminiaturized smart devices that operate with very low power consumption, together with networking and communication technologies, allows us to envisage ubiquitous smart devices. The IoT is the backbone of digital technology; without it no digitalization can take place. High-power computing, artificial intelligence, and Big Data processing allow data collection to exert impact—to have a real commercial value—on the one hand, and to leverage value (which is a new phenomenon), on the other. We identify data-based capital ("data capital") as a leverage effect—a multiplier effect and not an addition effect—that acts on cooperation or competition between "traditional" capital and "labor". Data owners, especially the largest companies, which can collect and use data, are clearly in an advantageous position. The presence of data also has an impact on the global distribution of both industrial and data production capacities.

The sustainability of the evolving innovation landscape

With regard to digitalization, we note that specialization is essential, but that it is probably not socially viable due to growing income and wage gaps. The mobility of data and the complexification of value creation processes act as mitigating factors, at least geographically, with the tendency to better distribute wealth across geographical areas, but not necessarily between individuals (where core competencies are the deciding factor). It is, however, understandable that specific skills are required and that these specific skills are not necessarily mastered by the majority of the population.

Our societies must position the cursor in the right place between two paths if they are to optimize the advantages of these paths' impact and above all avoid any economic divide. The first of these paths is to let the "invisible hand of the market" balance all forces and hope that the complexification factor will allow manufacturing to take place with a greater focus on work and that the riches of digitization will be distributed fairly. The second is to give a clear direction to the market, through either incentives or regulation. Upon the second of these paths we find the new law on GDPR in Europe, along with various legal frameworks regarding data access, the framework being much more liberal in, say, the United States than in Europe or Japan. The creation of international initiatives with strong political support, such as Industry 4.0 in Europe or Forchungsfabrik Mikroelektronik in Germany, can act as a stabilizing factor if they can operate in a flexible way and without significant administrative costs.

While positioning that cursor in the right place, we should not forget that to the old equation of labor and capital we must add a new form of capital—data, which plays a multiplier and an accelerator role with regard to the old equation. A leverage effect can be both a positive accelerator and a destabilizing factor. We are all responsible for verifying the validity of these reflections, identifying the role and potential impact of technology and data, and bringing this information to society.

Economic mechanisms can only be channeled by political decisions—that is, by creating appropriate legal frameworks and adequate economic incentives. Such political decisions can, however, de facto be applied to well delimited (and limited) geographical regions or countries, even while the economy is global and data flows at the speed of light around the globe. But local enforcement of legislation in a small or medium-sized country or region (even one with a strong economy, such as Switzerland or Germany) cannot have an impact at the global level. Policy measures, applied through law, can only have an impact when the regions to which they are applied are large enough to have a significant influence on international trade. The recent GDPR legislation is the embodiment of a unilateral effort by the European Parliament, which has been able to create a global framework to channel the impact of digitalization. The time that has passed since the implementation of the GDPR is not sufficient for us to be able to draw conclusions with regard to its effectiveness. On the other hand, it suggests a potential way, in parallel with possible incentives, to optimize the impact of megatrends and make them economically and socially sustainable. Local measures (legislative or incentive) are not sufficient to contain interregional imbalances: legal frameworks between regions and countries must be compatible and as far-reaching as possible.

The legal measures and incentives mentioned above are tools to help us position the cursor in the right place between the two extremes:

i. Full freedom, which will allow mechanistic effects due to "data capital" (with the risk of uncontrolled economic imbalances between people of the same region and between regions).
ii. Full control by public authorities, which can be exercised by legal means or incentives.

It is important to understand the role of digitalization and the digital technologies that enable it—at the intersection of technological change and the challenges faced by society, the economy, the environment, and also politics. It is as important to understand how these technologies' impact is increasing, and their mutual and catalytic role in the emergence of data. When we understand this, it will be easier for our economies and societies to position themselves through political means, whether legislative or incentive, at the level of nations and supranational structures.

The monetization and taxation of data

The emergence of Big Data is both the result and the enabler of a complex interaction between technological evolution, industry trends, and societal/economic impact. This increasingly rapid and strong interaction enables changes in the very nature of both technology and the value creation process.

The key effect is that data achieve real monetary value. They become capital, "data capital". Data capital's nature is different from that of capital as we traditionally know it. This type of capital is a new element in the usual interaction (whether cooperation or competition) between classic and work capital. By its nature, it plays a leveraging role, a multiplier role, first toward traditional capital and then toward those actors who have technological knowledge, and therefore also with regard to labor, and in particular those people, regions, and structures (private or public) that have access to scientific and technological education. Thus, data capital radically modifies competition and creates new forces that can potentially unbalance incomes between geographical regions and population groups. Education and training are becoming the dividing factor—the digital divide separating regions of the world and their peoples. Right now, significant imbalances are being created. And the speed at which this is occurring does not seem to be sustainable. The question that governments (or clusters of governments, such as the European Union) must ask themselves is whether they should intervene, and—if so—in what way (legislative or incentive), and also in what geographical context.

What becomes evident from the above analysis is the existence of two antagonistic trends: On the one hand, the ensemble of mechanisms that seem to influence value creation and leverage due to data, as detailed above, create opportunities for flexible and fast-moving individuals and organizations, when conditions (capital, training, business environment) allow. On the other, significant imbalances are created. To mitigate these imbalances the overall economic and societal environment needs framing. Framing requires the consensus and action of important economic (large companies) and political (large countries, or associations of countries, such as the European Union) actors. The capacity for impact is directly proportional to the economic weight of the constituent parts: the bigger they are, the more impactful their actions can be, whether they be legislative- or incentive-based. A last point, which lies between legislative- and incentive-based approaches, is the processing of "data capital" as financial capital: the taxation and banking of data are aspects that require a dedicated analysis. What if every MB stored were treated as wealth, every MB acquired as revenue? How much value should be assigned to data flow or storage, as revenue and capital, respectively? Who should assign that value? And should that value be measured in bits or in terms of information? While these questions are beyond the scope of this short text, they certainly need to be addressed soon.

Chapter 7

The Path Forward

Technology is not neutral

In our previous chapters we outlined the fact that digitalization—as a trend in the industrial landscape—is a new phenomenon in our world. It influences societies and economies. And, in turn, is influenced by them. So, a new phenomenon it may be, but isolated it is not. It exists because several technologies are currently reaching maturity, in particular those that allow the extraction, processing, transmission, and storage of data. These are also the newest of our manufacturing technologies, and they allow us to manufacture—at convenient cost, to the required dimensions, and with the desired performance—devices that can take on the aforementioned functions with regard to data. At the same time, the resources (including energy, bandwidth, and storage space) needed for these processes to work seem, for the time being at least, sufficient for our needs. All these technologies—digital technologies, manufacturing technologies, and technologies that allow us to generate and manage resources—are the bases of industrial trends such as digitalization.

In our conceptual framework, discussed in Chapter 2, it is important to distinguish between technology trends and industrial trends. Data technology is a technology trend; digitalization is an industrial trend. Digitalization exists because data can be created, and at a rapidly increasing pace. Digitalization is the entirety of activity based upon the existence of data. Data exist because we need to observe the real world and, in some cases, to control it; each bit of data carries information that is related to the world. Data exist because we can extract them, which means transforming images, text, writing, or measurements into bits, bytes, gigabytes, petabytes.

Digitalization, as an industrial[46] trend, is also closely interlinked with the other industrial trends—that is to say, with new manufacturing paradigms

[46] It is, perhaps, worthwhile reminding the reader that our reference to "industry" and "industrial" encompasses both value-creating activities in the manufacturing

and the complexification of products, services, and value chains; it impacts them, and is influenced by them. All these three industrial trends together influence our societies and economies. Inversely, the evolution of our societies and economies influences these industrial trends. This interaction is accelerating and increasing in strength. Digitalization, beyond being part of the processes operating through these complex interactions, is also an accelerator of these same processes.

We are familiar with the idea that technology is neutral, and that its impact depends only on how it is used. But this traditional view has become untenable: technology, by its nature and in its complex interplay with industry, the economy, and society, is no longer neutral. By its nature it favors specific parts of society and the economy. Thus, it contributes to the creation of imbalances. And it is important first to understand this, and second to start identifying and implementing mitigation mechanisms.

Digitalization mechanistically creates imbalances. By "mechanistically", we mean without the intervention of human will; in other words, these imbalances are created due to the nature of the evolution taking place with regard to technology trends. These imbalances are driven by the nature of data and by the digitalization process. Further imbalances appear between different parts of the globe. Still further imbalances appear within individual geographical spaces, manifesting themselves in the workplace, in society, and in the economy. What has changed compared to the past is first that the interactions driving these imbalances are operating more rapidly and are more intense, and second—and perhaps more importantly—that all of these imbalances are not only the result of human activity, but also occur mechanistically due to the very nature of data. Data acts as a new form of capital, which earlier, in Chapter 6, we referred to as "data capital". By its nature, data capital favors the owners of conventional capital (i.e., material assets, cash, and intangible assets such as brand value or intellectual property), again as discussed in Chapter 6. Data capital, without any human intervention either political or economic, mechanistically favors (i) larger organizations[47] over smaller ones, and (ii) organizations that can use data

domain and activities that are heavily influenced by manufactured products. So, for instance, we consider the whole "farm-to-fork" value chain as industrial activity—including the optimization of production using satellite technology and robots, mechanized extraction, information technology (IT), monitored transportation, industrial transformation, and IT-based logistics.

[47] By "organization" here, we mean a large spectrum of organizations, including corporations, clusters of corporations (which may take the shape of formal or

over organizations that cannot (or can, but to a lesser degree). So, for example, a social network is favored over a local grocery store.

Digitalization also creates imbalances between digital platform-based technological ecosystems (e.g., the ecosystem present in the Bay Area), on the one hand, and industrial ecosystems (e.g., automotive, around, for instance, Nagoya—or "Toyota City"—Munich, or Detroit; or aeronautics, around Toulouse, Birmingham, or Hamburg), on the other. Digitalization also creates imbalances between small companies and large companies, since it modifies the nature of work—not only by bringing about job losses due to automation but also structurally. Finally, digitalization can create imbalances between the private and the public sector. And these imbalances are growing as time passes, and at an increasingly fast pace, as we discussed in Chapter 2.

The impact of imbalances

We make the axiomatic assumption that growing imbalances can damage social stability and the well-being of individuals, at least for the majority of the population.

Where might limitless evolution and greater imbalances take us? What do they mean for our societies? One can argue that one possible result might be that we move more rapidly toward a wealthier, fully capitalistic society. The last forty years since the neoliberal revolution of the 1980s have demonstrated that this is, indeed, one possible aspect of one possible future reality.[48] But these same influences led to stagnant real revenues for a significant part of the population—the part with the lowest incomes. And the size of this group as a proportion of the overall population is also growing over time. At the same time, the gap between higher revenues and lower revenues is steadily increasing. Thus, new imbalances are created within individual nations, as well as between nations.

These increasing imbalances might be the source of increasing unrest in years to come. This has, historically, very often been the case. Unrest has, over the years, expressed itself in various ways. One recent example is the

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informal trusts), countries, associations of countries such as the European Union (EU) or the Association of Southeast Asian Nations (ASEAN), and any other type of organization with economic interests.

[48] https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2018&start=1961&view=chart.

"yellow vests" (*gilets jaunes*) movement in France. Staying with the color yellow, but reaching back much further into history, the "yellow turbans" movement in China in 184 AD—born precisely due to economic imbalances—made a significant contribution to the fall of the Han dynasty. Another expression of unrest is the large migratory movements—partly due to wars, partly to economic imbalances—that we are seeing today. And migratory movements can create further unrest in recipient countries. Another expression of unrest caused by imbalances can be war. The extreme rigor of the punitive measures visited on Germany by the Treaty of Versailles created significant poverty and was widely perceived as greatly unfair with respect to the German nation. And this was one of the key reasons for the rise of national socialist dominance in the country, which in turn had catastrophic and all too well-known consequences. During World War II, Nazi Germany's invasion of the Soviet Union was—among other things, and irrespective of the element of simple human ambition—a quest for *Lebensraum*, meaning "living space", which included a place from which to secure food resources: resources perceived to be at risk due to the severity of the aforementioned Treaty. The target was the Ukrainian plains, since it was assumed that sufficient food could not be produced within Germany's borders.

In the past, the redressing of imbalances has been expressed in the form of revolution, including the French and the Russian Revolutions, or the revolutionary movements of 1848. Those segments of the population who found themselves on the wrong side of imbalances were closely involved in each, but did not necessarily drive these movements. Rather, they were instrumentalized by charismatic leaders. The success of such movements was often mixed, and this was the case for all the aforementioned examples. Re-equalization and redress have also occurred involuntarily, and more peacefully (although not necessarily with less damaging consequences), via inflation (e.g., the period following the First World War or the financial crisis of the 1930s). These, of course, are only examples, and not an exhaustive list of ways in which imbalances have been redressed and re-equalized. And these processes played out either with the explicit objective of reducing economic imbalances (as was the case for the revolutionary movements cited) or spontaneously as a result of economic changes (as was the case for inflationary periods). That economic imbalances very probably create catastrophic social phenomena seems a reasonable assumption.

Indeed, in the cases mentioned above, the corrective phenomena at work (revolutions, wars, high inflation)—whether employed deliberately or not—had catastrophic effects. They emerged at moments in which imbalances were so strong that maintenance of the status quo was, or seemed, impossible for large parts of the population—in particular the parts with lower revenues and fewer resources to live on. Today, we have enough data and the necessary tools to be able to identify trends in our economies, including and in particular the buildup of imbalances. It is even claimed by scholars[49] that with the data processing capabilities at our disposal today we are in a position to explain and even predict major events, though this claim invites further study and analysis. Here then, we have identified an important factor in the acceleration of certain imbalances, a factor favoring unequal competition between ecosystems globally, the more or less favorable impact of technologies—and digitalization in particular—on companies of different types (in terms of business type and in terms of volume type), and the different levels of influence exerted by the public and the private sectors: the increasing interaction between technology, industry, and the economy, and the creation of a new type of capital, data capital. This new type of capital produces real financial value and also mechanistically influences the workings of the economy, both upstream and downstream. By "upstream", we mean the creation of new economic mechanisms. With "downstream", we refer to the development of new technologies. But there is also an upstream and a downstream impact on the role of people, including on their personal lives and working environments, both in manufacturing and in services, both every day and from a long-term perspective, as we outlined in Chapter 4.

Technology's advance simply cannot be stopped, and there is no reason for it to be, since if properly used, it can bring about well-being and progress. And the same is true for technology's interrelationship with our societies and economies. The objective of our analysis here is to identify means to mitigate the imbalances generated by this advance, with the aim of having our societies and economies optimally profit from the evolution currently underway.

Optimizing the impact

The first point to be made here is that the growth of data technologies—a clear and distinctive technology trend—cannot take place without those technologies that are also advancing within the two other technology trends

[49] https://aeon.co/essays/if-history-was-more-like-science-would-it-predict-the-future?fbclid=IwAR3GDlnLLkTaPRwkHJfUshgg1Q6hj1iqQsdbKRGjcBgkqNJadT3_pG0XyXc.

we outlined in Chapter 2. In a similar manner, the industrial trend of digitalization cannot exist as a single, isolated phenomenon. Economists tend to believe that the owners of data and of data-related platforms are the central players in the economy as it is evolving today. This premise is erroneous. Data extraction, transmission, processing, and storage simply cannot happen without other technologies and without access to resources. Data cannot be extracted without sophisticated hardware, whether this hardware is a computer, a camera, a smartphone, an autonomous vehicle, or increasingly "smart" devices, the last of which will be customized for each specific application, meaning for sensing and monitoring in our homes, our cities, and our factories, or even on mountains and in rivers, lakes, and seas. As we discovered in Chapter 3, smart systems are becoming key elements in the interaction between the real world and the virtual world. Practically all the systems that surround us can become smart, by the addition of adequate sensing, actioning, data-processing, and communication capabilities, as discussed in detail in Chapter 3. From cars to houses, to roads to ships and beyond, data cannot be transmitted without sophisticated wireless networks and efficient fiber-optic links. Data cannot be stored and processed without powerful computers. And—of course—for all these computers, networks, smart devices, cameras, et cetera, energy is needed, bandwidth is needed for transmission, and space is needed for hosting on powerful servers. Digitalization, then, cannot exist as an isolated phenomenon. And the supposition that those who control data control the evolution of our economies and societies should absolutely be challenged. The importance of this observation cannot be overstated. And traditional industrial ecosystems need to understand the importance of their heritage and of their industrial, technological, and scientific background in order to affirm their value.

As discussed in Chapter 5, the fact that those organizations that have data and digital technology-based platforms have—by using the lever effect inherent in the nature of data—accumulated huge amounts of cash puts them in a dominant position compared to the competition, including compared to other industrial companies. The evolution of the market value not only of each of the GAFAs but also of numerous other digital technology platforms over the last 15 years is an excellent illustration of this. This has had an impact on the strategic control of technologies and resources and on international competition between two types of ecosystems, traditional industrial ecosystems and digital technology platform-based ecosystems. This competition is evident in the efforts of large, platform-based companies to acquire—organically by growing competencies internally, or through acquisitions—certain capabilities of traditional industries. This is perfectly illustrated by Google, in the form of its progress in the automotive industry with its autonomous car or its efforts with regard to Google Glass—each an example of internal, organic growth—but also in the form of acquisition, which more accurately describes its activity in the smartwatch field given its acquisition of Fossil.[50]

History has seen fit to distribute the various competing ecosystems unevenly across the globe. And the fight for dominance can create enormous imbalances between geographical locations. Today, we recognize that ecosystems have very often been developed thanks to, or at least supported directly by, national policies; this has been the case, for instance, for the ecosystems of the aeronautics and space industries. It is important to stress here that it is extremely difficult to identify ecosystems, recent or less so, that have *not* been encouraged to grow by support expressed via public domain policy decisions. Of course, such policies have, over the years, taken different forms, including public procurement.

As outlined above and detailed in Chapter 6, the nature of data capital, which acts as a lever, means that the amount of cash accumulated by technology platforms (and related ecosystems) is huge. The forces—including economic—in play are enormous. Only large structures have enough resources to face up to the economic power of some of these technology platforms. To wield comparable economic influence one needs, today, to deploy colossal efforts, and these are only possible if one is the size of a nation. Only nations have the economic (and legislative) power necessary to intervene and attempt to rebalance these disequilibria. This might mean state interventionism, and related policies that can be considered Keynesian in nature. Policies that may be applicable today, however, differ considerably from traditional Keynesian policies applied in the past. The debate regarding the respective merits of Keynesian and of laissez-faire liberal policies is not new. And at various points since the modern economy began to take shape up and until today one or the other have been considered optimal and have been applied. What seems to be necessary today is a post-Keynesian approach where the state not only intervenes, but also participates as an active economic actor. Perhaps this idea requires further explanation. And to begin that explanation, it may be useful to provide an example that illustrates the case of traditional Keynesian interventionism. And what better example than the New Deal, implemented in the early 1930s by President of the United States Franklin

[50] https://www.cnet.com/news/googles-40m-purchase-of-fossil-tech-was-for-hybrid-smartwatches-report-says/.

D. Roosevelt to relaunch the national economy following the stock market crash. In this classic application of the Keynesian approach, the state created jobs by building highways and engaging in large infrastructure projects. The cost was huge. But the state had the means necessary to sustain this policy, high taxation rates being, under the circumstances, politically acceptable.

Today, meanwhile, things are different as one has to take into account the huge and growing sovereign debt of the vast majority of industrialized countries. And it is certainly clear that to have the economic power necessary to apply policies that can credibly redress rapidly worsening imbalances, a nation needs to be financially robust. Of course, this statement is true for technology-induced imbalances, but also for imbalances caused by any other factor or combination of factors. The nature of the imbalances caused by technology differs only because of the unprecedented pace at which technology is evolving.

At the time of writing, taxation rates of the levels experienced in the period between the two world wars seem politically implausible. Further, the national debts of the larger economies in the world, with some exceptions, are very high[51] and these nations would therefore find it difficult to take on even greater debt. We can conclude that, on the one hand, states need to be financially sound if they are to take the measures necessary to rebalance competition between ecosystems—and in particular between the two types of ecosystems, industrial and digital platform-based—as well as all other disequilibria. On the other hand, meanwhile, states will find it difficult to deploy such measures because taking on more debt seems a catastrophic course to embark on and raising taxation rates appears politically unrealistic. The only possible path out of this dilemma—and what we, here, are calling a post-Keynesian approach—involves states acting as entrepreneurs. This, in turn, implies that the state should reap a fair reward for the risk it takes on. The case of bank bailouts during the global financial crisis of 2008 is a classic illustration of such risk taking: inordinate levels of risk undertaken in the financial sector drove the whole economy to the edge of the precipice. Huge amounts of taxpayers' money were then spent—in the best case in the form of loans—on saving private interests. Was this risk taking by states (employing taxpayers' money) properly valued at the price of bonds? Similar scenarios have played out over the

[51] A good reference measure for what can be considered "high" or "low" in terms of national debt (as well as deficit) can be found in the Maastricht criteria set for those European countries bound to employ the euro as their national currency (see https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A12012E%2FTXT).

years with the automotive and other industries. Financial mechanisms such as convertible bonds would have made it possible for states to garner fairer rewards. Not, of course, in the name of covering the inevitably higher costs of their heavy administrative structures, but rather to enable them to reinvest these rewards with the aim of maintaining greater balance with regard to their deficits. And, more importantly, to allow them to implement the necessary policies—financial, regulatory, or legal—that would enable them to better control the forces that create imbalances in the first place, whether those be in a context of international competition or within their own national borders.

It is important to clearly differentiate the ideas proposed here from those that underpinned the planned economy that operated behind the Iron Curtain from the end of World War II to the fall of the Soviet regime. The point to stress here is that we are proposing entrepreneurial behavior from the state—in its role as the representative of its taxpayers—that is radically different from that observed in a planned economy. Rather than the state as planner, this is the state as entrepreneur. Obviously, the role of entrepreneur and the role of creating and maintaining an environment appropriate to business are to be undertaken by separate structures within the state.

How can this be made to work? A detailed answer to that question would involve a comprehensive economic analysis that is beyond the scope of the present study, and would require both the synchronized efforts of multidisciplinary teams and strong political will. However, certain guidelines that seem straightforward can be spelled out here, taking us beyond the simple principle of fair reward for risks undertaken. First and foremost is that the planning of national economic policies needs to take into consideration all of the interactions between technological trends, industrial trends, and societal as well as economic evolution described in Chapter 2, and this on an ongoing rather than a periodic basis. Such interactions are not collateral effects; rather, they are central economic and societal phenomena that can potentially radically change forms of national economic governance. Second, the economic structures that take the aforementioned risks need to be governed in a manner that is independent of the central state itself. The independence of central banks is an illustration of how this type of setup could function at the operational level. Different types of profiles are required to run an entrepreneurial endeavor (whether we are talking of a private or of a public structure) than are required for the running of a state. Separate administrative structures and individuals with appropriate profiles should therefore undertake the challenges faced by the entrepreneurial branch of the state—that is, the branch that takes the risks, but also reaps the rewards. The return on these risks goes back to the sovereign treasury. Third, the financial returns garnered by such an independent structure should be reserved for use as a means of facing up to and redressing long-term structural imbalances between ecosystems, and not to cover everyday, "normal" expenditures. These three guidelines seem to constitute the basic lines around which one could build tools that could be used to mitigate long-term imbalances between ecosystems in different parts of the globe.

Taking a "traditional" industrial ecosystem as an example is an interesting way of illustrating how the mechanisms of a strong state could operate to protect such ecosystems from the threat posed by digital technology platforms. The core idea is to build upon the forces of tradition—developed over decades, in some cases over centuries—strengthening these forces and adding layers of intelligence and smart devices that allow "traditional" products and services to be adapted to the new, digital world. We presented earlier, in Chapter 5, a concrete example that spoke volumes—that of Switzerland and the smartwatch. For the case of the risk-taking state, we need look no further than the bailout of the automotive industry in the US in 2008—a clear case not of competition between ecosystems but of a "classic" industry-saving effort by the public authorities, with US government financial support coming to the aid of that industry. In such scenarios, there is the option of providing support either in the form of loans with bank-type interest rates or loans that take the real level of risk into consideration in their interest rates, or alternatively the option of lending money in the form of convertible loans.[52] With the first option (loans with low interest rates; so, bank-type loans) the state would take the risk but not reap the fair reward if the venture were successful. In the second (the case of convertible loans) it would take, if the venture were successful, a fair reward. And that reward would allow reinvestment in education, R&D, or infrastructure-building projects.

When required to "invest" astronomical amounts in bailouts (so, for example, the bailout of the financial industry), even a government as powerful as that of the US has only a limited amount of funds that remain

[52] Convertible loans are—usually short-term—debt that can be converted to equity. The mechanism is used to finance start-ups, and to finance entities whose value is difficult to evaluate at the point at which a loan is issued. For start-ups, it is often too early to estimate value; in a bailout situation—where the market is battering the value of the company that requires saving and that value is thus highly volatile—the same is true.

for investment in education and research. If the risk taking of the state were rewarded fairly, however, this amount would become more consequent. The choice could then be, if once again we take Switzerland as our example, between investing in creating new ecosystems to compete with the established Bay Area digital platform clusters and building on and adapting and improving on, for example, the country's traditional precision engineering and watchmaking cluster by creating—based on the cluster's traditional skills—the smart systems that are key for the digitalization of the economy and society, a topic discussed in detail in Chapter 2. Or, of course, a combination of both. The decision on where to position the cursor and which choice to make is clearly political. But it is important that such a decision be taken based on a thorough understanding of the mechanisms governing competition between ecosystems, and those mechanisms' dynamics.

The individual and the corporations: The economic power of data

As a next step, we will focus on understanding the role that the nation state might play, not in supporting local ecosystems but rather in supporting the individual. To do so, we need to understand the real economic value of data. And here, a helpful parallel is the cash used in venture capital (VC) investments. The money invested via VC is often characterized as "smart money". There is a reason for this. This particular type of money is made available in a specific context, which includes VC knowledge of how to grow start-ups. The same money but without the accompanying knowledge-driven advice would be much less valuable, and this is why entrepreneurs are ready to give up larger parts of their companies to investors when this "smart money" is involved. The same amount of money invested by a person or organization *without* the added value brought by VC is less valuable, which is reflected in the smaller stakes that non-VC investors take in the equity of any given start-up. Like money, not all data—even if they are equivalent in "size"—have the same value for a specific person or a specific organization. For instance, my buying preferences might be extremely valuable to an e-commerce company. Data on my health status may be of less interest to this same e-commerce company. Both sets of information can take up precisely the same number of gigabytes, but context contributes more than size to their value, and the same information can thus have a different value for different types of company. For an insurer or for a telemedicine company information on the status of my health would probably be considerably more important than it would be for an e-commerce company. And if we compare our insurer to our telemedicine company, the insurer would certainly place more value than the telemedicine company would on knowing the effort that an individual client is making to improve his or her health: practicing sport and in which manner, body weight and its evolution, smoking habits and their evolution.

In the example of the insurer and its clients, three main elements are of interest: First, information aggregated from several insured individuals. Second, mathematical models that—based on this information—can forecast the real cost of the insured individual. And third, data regarding the company's own operational expenses. An insurer can make a more adapted offer (and therefore expose itself to less risk in financial terms) if it has information on my health status and if it has access to that information continuously. This decrease in risk has an economic value. The insurer can thus decrease its costs with regard to the nominal cost of insuring an individual, and can pass that cost reduction on to its clients in the form of a reward for those clients (who are also the information providers) for the information provided (and, in some cases, also for clients' sporting, health-promoting activity). In this configuration, the only party to this bilateral contract (i.e., involving the insured and the insurer) that has all the information concerned is the insurer. The insured person has neither the data nor the technical knowledge necessary to verify the fairness of the margins the insurance company can apply. The only regulation mechanism is the market itself. But market forces only work when the market is transparent. And in this case, it cannot be. The only way to ensure fair negotiations between these two parties is for each to share its information with its counterpart. But this is not feasible, since sharing information would deliver the insurer's commercial secrets to its clients, the insured. And even if an insurer did agree to share its data with its clients, its processing and use of that information are so technical in nature that the average insured individual would not be in a position to process the information and judge whether the provider's pricing is, indeed, fair.

User syndication [53] is a means of understanding and reinforcing the value of data. User syndication could deliver this currently lacking negotiating power to the citizens of the digital economy, in a very similar way to that in which cooperatives acted in the period immediately following World War II. In today's world, any form of user syndication has the potential to increase users' negotiating power, because by bringing data

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[53] By "user syndication" we mean any aggregation of the efforts of isolated users with the aim of securing a stronger negotiation position for those users, in this particular case a stronger negotiation position via-à-vis digital technology platforms.

together it creates more data capital. The larger the syndication, the larger the data capital accumulated, and the more powerful the negotiating position of the syndicated vis-à-vis digital technology platforms (in the above example, the insurance company). Then, by applying the mechanisms outlined in the literature (as we will discuss in a little more depth below) it becomes possible to inform the individual user (in our example, the insured individual) with regard to the value of the data he or she provided in the context of a specific contractual agreement. Syndication, then, makes it is possible to achieve greater balance with regard to the de facto power of service companies.

With regard to insurers, a very delicate point is the question of knowledge of the biological, hereditary data of insured individuals. While beyond the scope of the present work, the ethical aspects of this question are more than obvious. What we can point out here is that when we strengthen the negotiating position of the individual—thanks, say, to user syndication—the individual sees his or her position with regard to privacy issues reinforced, including those issues centered on hereditary biological information.

Another interesting feature of data as a specific type of capital is its ability to potentially be common property, assuming of course that the data provider and the data owner allow this. Let's introduce another, more concrete example. In the case of social media or e-commerce applications, the individual user freely provides information regarding his or her tourism and commercial interests, trips, political preferences... (the list is not quite, but almost, endless). This information is collected and sold to third parties that exploit it, often for the purposes of targeted marketing or even for political purposes (here, the case of Cambridge Analytica is illustrative). This process creates imbalance mechanistically, since the company can aggregate the data it has collected (or bought).[54] It is easy to understand that the information has more value (i) because it is aggregated, (ii) because it is sold to the appropriate buyer who can extract value from it, and (iii) because only the specific aggregator in question has that information. It is precisely the last of these points, point (iii), that is vital to address here: while information may belong to several parties, it belongs only to one single aggregator. This fact allows this aggregator to extract greater value from the information, and therefore creates significant imbalances vis-à-vis the

[54] For the sake of simplicity, we can apply the term "aggregator" to social media e-commerce companies; clearly though, any company or organization (including the state) that can collect sufficient amounts of data can be considered an aggregator.

individual. Allowing individuals access to several aggregators is a potential way of reducing the importance of the secrecy of data. This works because a large part of the value of data for a specific aggregator comes from the fact that the data are accessible only to this aggregator and are this aggregator's "secret" alone. If data, anonymously or not, are accessible to more aggregators or more users, their value is reduced, as is the lever effect for one, unique aggregator—the effect thus being distributed across all parties that have access to the data.

Governance in the digital world

The legal tools that societies employ to provide a framework for the use of data operate in national contexts, or alternatively in the context of groups of countries such as the European Union. The introduction of the GDPR[55] by the European Union is a clear illustration that such tools can be powerful and force business models to change. For instance, under the GDPR, companies acting as digital technology platforms have been forced to locate their servers in Europe. The very essence of the legislation appears to have been developed with the rigors of international competition firmly in mind. Normally, competition is a healthy mechanism that makes possible the creation of value for all players. But the introduction of data as a new parameter that transforms business models is also changing the nature of competition itself. Competition is beneficial if the market is transparent and the rules are the same for all players. This is not the case today for several aspects of the economy that are based on data. The reason for this is dual. First, due to the lengthening of value chains, transparency is becoming more and more difficult to ensure. Second—and also due to their lengthening—we are experiencing a significant internationalization of value chains. For hardware, components, and subsystems the legal framework can be different from country to country, but export rules, standardization, and regulation developed over decades allow for sufficiently smooth commercial exchange; intellectual property rules have also existed for centuries and have evolved with similar smoothness. The same cannot be said, of course, for legislation on data ownership, standardization, or privacy, since the relevance of "data"—as a unique concept shot through with its own particularities—is very new. Thus, the application of legislation currently in force seems to approach matters from a "classical" standpoint on privacy, rather than from the standpoint of data. The implementation of the GDPR,

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[55] EU legislation for data protection (https://ec.europa.eu/info/law/law-topic/data-protection/eu-data-protection-rules_en).

meanwhile, clearly shows that this type of legislation can have an impact, and not only within the borders of the countries that create it and pass it into law.

Algorithms and software (e.g., graphic user interfaces or software controlling mechanisms) are often proprietary, and in most cases are a company's core strength—Google, of course, is the iconic example of this. Communication protocols are regulated by international standardization bodies, and the importance of the level of standardization achieved through international cooperation in this area cannot be overstated. Two examples illustrate this perfectly. Europe was able to thrive in the market for mobile telephony and dominate that sector only because all countries agreed, around the end of the 1990s, on a common standard; and today, all of us have short-range communication because the Bluetooth standard was agreed upon at the turn of the millennium. These common rules have been made possible by the work of internationally recognized standardization organizations such as IEEE[56] or ETSI,[57] which have acted as catalysts for the general acceptance of Bluetooth and other standards.

Homogeneity of the legal and reglementary framework seems an important objective for the years to come. The governance of data should also be global. Internationally agreed rules allow commerce in products and services, either on bilateral bases or multilateral bases, or even under World Trade Organization rules. Internationally recognized organizations allow a homogenization of standards that permits products to function throughout the world: the telecommunication standards of IEEE, for instance, allow Wi-Fi systems to operate worldwide, meaning that a smartphone works equally well in Europe, Asia, or the Americas. Why not take the same, internationalized approach with regard to data?

As we have discussed, data is capital—a new form of capital that exerts even more leverage and is even more powerful than the classical form of monetary capital, and that is already today highly mobile and international. It is no longer plausible for the world economy to grow in a balanced manner in the long run while we have different rules from country to country with regard to the use of data. Rules on data privacy vary between countries; rules governing the ownership of data too. Even where supposedly uniform

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[56] IEEE (ieee.org) is the world's largest professional association for engineers (initially electrical and electronic engineers, which explains the three *E*s); standardization is one of its most important activities (https://standards.ieee.org/).

[57] https://www.etsi.org/.

rules—such as the GDPR—exist, their application can differ from country to country and from company to company. The GDPR is, however, a first attempt at a move toward global legislation with regard to data. And its extension to global governance is of major importance. The GDPR is, though, only one step on this road. Other aspects need to be homogenized, including the ecological impact of data, and data's economic value, both of which will be discussed below. Such homogenization would facilitate the exchange of data as an element with intrinsic economic value, and strongly empower the data-based economy. An organization similar to the World Trade Organization, but for data, could play an important role in the homogenization of rules.

The transparency of data capital

How can we mitigate the imbalances brought about by data? As discussed, their causes are multiple, and are basically rooted in the nature of data itself. Today, the idea that the ownership of data is one of the most important factors influencing growing imbalances is becoming a widely held belief. The solution to this problem should also take the same element—that is, the nature of data itself—as its foundation. So, for example, the problems caused by ownership of data may be resolved by a system of shared ownership of data, as by its very nature data can belong to several people or organizations simultaneously. This is a kind of user syndication, a concept we introduced earlier. And possible solutions are, indeed, beginning to emerge. Michael Kwet[58] outlines a number of them, including ideas on antitrust proposals, the creation of a social networking commons, and social media decentralization, adding his own proposal, which takes the form of "digital socialism". In brief, the antitrust approach focuses on the breaking up of previous mergers and acquisitions; the social networking commons approach has, at its heart, legislation that guarantees open data, and infrastructure that belongs to its users, while algorithms would be open source; and the social media decentralization proposal aims at a set of interoperable social networks based on free and open-source software—Kwet cites, as a concrete example, Mastodon, which is already operating on this principle.

José Parra-Moyano, Karl Schmedders, and Alex Pentland meanwhile, propose a data exchange, building upon the idea that "[d]ata exchanges are

[58] https://www.aljazeera.com/indepth/opinion/fix-social-media-introduce-digital-socialism-200512163043881.html.

platforms that have the permission to gather, curate and aggregate data from many different sources (companies, universities, funds, banks, individuals, etc.), in order to allow third parties to gain insights (knowledge) from these data. Data exchanges are a layer between the individuals or organizations owning data, and the third parties." Without stating it explicitly, the idea of a data stack exchange is implied.

These observations are just a taste of the ideas popping up across the globe about two of the most important ways in which technologies cause imbalances—ownership of data and the secrecy surrounding the ways in which data are used by digital technology platforms. Information is valuable to a company precisely because only that company has it. Secrecy and ownership are thus walls that these platforms raise up to protect what they consider to be their assets. Despite the fact that these "assets"—their users' data—could, and in some cases should, be shared outside of these protective walls, for the benefit of the users who provide these data and of society in general.

We can draw a parallel here to the theory of capital markets: capital markets can only be efficient if they are transparent. The same, of course, is true of any type of market, including the market for data as a new form of capital. There is a significant difference, though, between these two forms of "transparency". When we refer to transparency in a capital market, we understand it to mean the availability of all information concerning tangible and intangible assets—the credibility of a company, its management, products, services, etc.—as they appear in a "classical" balance sheet, to all potentially interested stakeholders. When we speak about transparency in a market for data as a form of capital, we mean access to the data itself, which means access to data as a form of capital *is* capital. Access to data capital, then, potentially leads to the value of data being distributed between all the actors that can use it, including the source of the data itself.

The question that remains, then, is what practical means are necessary to bring about this transparency with regard to data. This particular question is highly multi-faceted, and any path we potentially embark on will need careful prior examination, and fine tuning along the way. The proposals outlined briefly above (such as a data exchange or common data access) seem to lead in the right direction. Another—alternative or additional—idea would be the creation of a publicly available data bank. Such a bank could be very similar to that discussed by Michael Kwet. The contents of this data bank could be distributed among servers, creating a kind of distributed database that could operate as a blockchain. The main difference between this proposal and those summarized by Kwet would be the source of the data: for the data bank, data would be provided not by digital technology platforms but by the platform users who generate data and provide them to these platforms.

To illustrate this principle, let's take the example of the social networks. It is quite reasonable to consider that users' data (photographs, comments, articles, etc.) are—by their very nature—public, either broadly or in the sense of being accessible to at least a limited number of individuals. These data are transmitted over telecommunications networks, and displayed by and accumulated on the servers of the social networks. It seems technically feasible that the same information be copied to a publicly held data bank with contractual conditions regarding terms of use.

As a consequence, the photos, texts, and messages shared on a given social network would not be available to this one social network alone; they would also reside in the data bank. Access rights to this data would have been decided upon by the platform user—so, the originator of the data—her or himself, designating some data as available to everyone, other data as available to only a limited number of people or organizations, and still other data as available to no one. With regard to anonymity, the platform user would decide what data is made available anonymously and what is made available in an identifiable manner. This proposal, then, would not require the digital technology platforms to share their data (which understandably would be a very difficult objective to achieve); rather, it would empower their users—who are simultaneously the providers of that data—enabling them to make their data publicly available in a manner governed by rules that they themselves have defined. The idea is to base this transition—from data only being accessed by certain digital data platforms to access for a community of users and companies—not on enforcement carried out by large, powerful corporations, but rather on the empowerment of users.

The operation of this kind of data bank requires two components: First, infrastructure and skilled support personnel. Second, the consent of the user or of the aggregator. There is no technical reason why the requisite infrastructure and support personnel cannot be put in place. The infrastructure needed to host data from large numbers of individuals would, of course, be extremely significant (in terms of computer memory, which of course impacts the footprint, space required, and energy needs); and the personnel required to operate and manage both these computing installations and the data concerned would be just as significant. Access to data for third parties could be established on a fair commercial basis, following methods described in the literature. Such a setup would demand significant investment. But if data were—for example—to be taxed, a fair return on that investment could be guaranteed.[58]

Can data be taxed?

An additional means of mitigating the imbalances we have identified is the redistribution of value across society through taxation. Today, taxation is applied to capital (i.e., assets) and revenues when individuals are concerned, and to capital and earnings when it comes to corporations. A company's earnings have required the employment of both labor and capital, but also—of course—the use of data capital. And as earnings are taxed, this use of data is also taxed. This thinking, though, is based on an assumption: that the data are of the same nature as regular sources of wealth, labor, and physical assets (intangible assets, including brand value, fall into this same category). In our previous analysis, however, we revealed that data capital is a different animal. First, and in contrast to labor and materials, data capital has been acquired for free, or—if we wish to be a little fairer—as a reward for services rendered to the individual user (including, for example, the provision of search results or social networking services). This, though, is not a fair trade, and we have two arguments to support this assertion: First, comparing the value of services to that of data is beyond the abilities of the individual user—she or he simply does not have the technical knowledge necessary to carry out such an evaluation. Second, the individual user does not have the necessary negotiating power—the services in question are offered on a take-it-or-leave-it basis, and "taking it" entails agreeing to unreadable, or at least largely unread, contracts. The premise that data have the same value as capital or work is thus, in our opinion, incorrect. And each should, therefore, be taxed at a different rate. Data, after all, exert a stronger leverage effect than capital, and thus logically have to be taxed at a higher rate than capital. A practical solution to this challenge would be to apply relatively simple econometric models in order to identify which part of the added value of a corporation is due to the value of data in the form of data capital. Companies whose operations are entirely based on data would then be taxed at higher rates. Establishing the precise differential taxation rates is, of course, a topic that goes well beyond the scope of the present analysis.

The next question, then, is whether we can separate the value of data from the overall value of a corporation, on the basis of publicly available information such as earnings, revenues, and number of employees. Economic models[59] that target the separation of the value delivered by each specific value-creation element (i.e., labor, capital, and data capital) are starting to appear in the literature. If these models prove successful, it will then be possible to tax data separately. In such a scenario, an international governance structure for data—as proposed above—could play a particularly significant role in efforts to preclude the creation of further imbalances. Such a structure could, in addition to its legislative role, recommend or even decide on the level of a differential (differential with respect to capital- and labor-based revenues) tax for data, in order to compensate for the aforementioned leverage effect.

One final, vital point that needs addressing concerns not the value but rather the cost of data—cost in the sense that goes beyond the cost of the smart devices required and the nominal cost of the resources needed for data extraction, processing, communication, and storage. Data have an ecological footprint that, currently at least, is barely considered. As we have already pointed out, the overall contribution of digital technologies to the greenhouse gas effect is in the order of 4 percent, and this figure is expected to rise to somewhere between 6 percent and 14 percent by the end of this decade. And it is precisely the cost of this impact that will require consideration. The state, in its role as final arbiter in the matter, can aggregate the value and the costs of digital technologies and tax data at a different level than that at which normal earnings are taxed. By doing so, the state would be recognizing the unique nature of data. The aforementioned upcoming models[59] tell us that it is, indeed, possible to evaluate the contribution that data make to earnings, based on readily available information on the labor and capital involved, which, for any given company, can be ascertained by a simple reading of the P&L and balance sheet.

[59] José Parra-Moyano and Karl Schmedders. "The liberalization of data: a welfare-enhancing information system". University of Zurich working paper series/ Department of Economics (2019).

CHAPTER 8

CONCLUSIONS

In this book, we have tried to understand the multiplicity of mechanisms associated with the increasing role that technology and data are playing in our industries, our societies, and our economies. We have encountered several elements that are creating imbalances at an increasing rate and have also identified certain paths that lead toward the mitigation of these imbalances, targeting the even growth that could ensure an optimal future for society.

The question is how we can use the evolution of the interactions between technology trends and industry trends to improve our economies and societies *in globo*, and not only at the corporate level. The first step is to understand these mechanisms, the interactions between trends, the influence on the human, and the influence on the planet, and to understand how value is created. This was the subject of Chapter 2. The second step—to propose ways of analyzing the impact of technology trends on public policy planning—is of paramount importance.

It is clearly vital to come up with measures to mitigate the impact of digitalization on the competition between industrial ecosystems, as outlined in Chapter 5. Empowering the public domain and allowing it to act in an entrepreneurial manner would be a meaningful step in this direction, despite the fact that this proposal seems to run contrary to the common "wisdom" in all that concerns today's economies. Our proposal regarding this act of empowerment means creating a branch of the state that acts as an entrepreneur. And this model is already being applied today, in the shape of certain sovereign wealth funds. Which means that this mode of operation has been proven to be, at least to a limited geographical extent, feasible. We believe that this is the only way of empowering individual states to compete in this gigantic, global game of the dominance of industrial ecosystems.

The word "public" needs, perhaps, further attention and definition. "Public" is often synonymous with the "public" authorities of individual nations. Economic value chains have, however, become increasingly global and complex, and in many cases policy planning requires international consensus. As digitalization further extends the global scope of value chains, policy planning measures with regard to mitigating the imbalances thus created must, in their turn, become more global in nature. International governance, possibly global governance in a manner similar to that practiced by the WTO (World Trade Organization), is one option, and we believe that it could be an important step toward mitigating transnational imbalances. Legislation regarding data privacy, ownership, and perhaps taxation, as discussed above, could be in such an organization's remit, at least in the form of recommendations that would then need to be translated into individual national legislation.

It is said that a knowledge of history can prevent errors being committed. This, of course, is true. But in each era, changing conditions—evolving from the past—have led to history repeating itself, but not exactly. Today, however, the changes happening to framework conditions are much more radical than ever was the case in the past. The pace of change is unprecedented. This is true of the pace of growth in our populations, the pace at which pollution is increasing, and the pace at which we are exhausting natural resources. And it is, of course, also true of the pace at which technology is changing. The emergence of data as a social and economic factor is an unparalleled event. As Yuval Noah Harari points out, we find ourselves at a point of radical change in the paradigm of authority, with authority shifting steadily from the human to the machine, the latter—using algorithms and collected data—taking over the decision-making process.

An understanding of the ensemble of technological trends as a mutually interacting system is of key importance, as is an understanding of the increasing and accelerating interaction between technological trends, industrial trends, and their impact on society and the economy. The role of the state as a post-Keynesian entrepreneurial actor that—rewarded fairly for risk taking—could thus support traditional industrial ecosystems needs to be understood, evaluated, and where possible encouraged. A powerful and caring state could also prepare the individual for the challenges particular to the working environment of the upcoming digital world.

Fresh ideas on how to mitigate harmful imbalances by using the nature of data itself are on the way, and include user syndication and data exchange. These ideas' driving force is to allow open access to data, and they should be supported by legislation, both national and international. The idea of creating a data bank that collects all the data that users voluntarily make public completes these approaches. The interesting thing is that this last approach can be applied by any individual user who produces data and provides it to digital technology platforms, and it does not require access to the databases of these platforms.

Imposing a differential tax on the value created by data—based on the premise that data are a particular form of capital—may appear unrealistic at a first glance. We are, however, on the verge of being able to estimate, using appropriate economic models, the value created by data. And beyond the *value* of data, we are beginning to obtain indispensable information on the additional ecological *costs* of data.

Applying these fresh ideas, new approaches, and newly available knowledge will require the involvement of multidisciplinary technical teams composed of engineers, economists, and legal experts, particularly as the concepts outlined here need to be fleshed out. Strong political will also be necessary if they are then to be implemented in everyday life.

This entire analysis does not claim to offer solutions. Our objective has simply been to highlight points we consider important and to raise awareness of them among scholars, politicians, scientists, and engineers, as well as the broader public. Our wish has been to indicate potentially helpful directions and be clear and frank that they require strong political consensus—certainly at the national and multinational levels, and perhaps at the international level too. In doing so, we hope to have contributed a modest stepping-stone to the road we need to build, and then to take, if we are to achieve and sustain our common well-being.

Afterword

This book is an attempt to analyze the evolution of the relation between society, the economy, and technologies. This analysis is based on observation of how the interactions between these three elements have evolved to date. As that evolution pursues its course, the validity of the analysis presented here should be cross-checked, and its conclusions confirmed or amended.

The last lines of this book were written during the rising tsunami of the 2020 coronavirus pandemic in Europe. Some months later it is tempting to try to understand the reactions of society to the threat of the virus and how those reactions relate to technology.

Society's reaction to the pandemic is as convincing an argument as any for the presence of the reinforced degree of interaction and multiple convergences addressed in Chapter 2. As I write, several vaccines are in phase three clinical trials. Another has been approved by the authorities of the Russian Federation, although doubts have been raised as to its safety—a point on which I do not feel competent enough to express an opinion. Never in human history has civil society been able to command such a rapid reaction from the scientific community. And the development of potential vaccines has not been science and technology's only fast and effective contribution to fighting the pandemic.

In diagnostics, serological tests to detect antibodies in blood have been developed at an unpreceded speed. Antibodies develop in the human body either as a reaction of the infected individual to a virus or thanks to vaccination. New techniques for antibody detection are delivering results with improved sensitivity at an increasing speed. Experimental techniques are being developed for detecting antibodies in saliva, which will further facilitate diagnostics by improving usability.

Beyond biochemistry-based diagnostics, infrared thermometry had already been broadly adopted during the H1N1 crisis of over a decade ago (at least in some Asian countries, including Japan). Today it is being used to identify coronavirus infections in people. And newer, non-invasive methods for the early detection of coronavirus are also becoming available. Wearables developed for other purposes are now being tested for employment in such early detection,[60] continuous monitoring in the home providing an opportunity for the early pinpointing of possible infections. Here, there is, of course, a potential for imbalance between economies or individuals who can collectively or individually afford high-performance wearable systems and those who can not.

Automatized manufacturing techniques (and a lot of hard work) allowed ventilator manufacturers to rapidly ramp up production to satisfy the steep increases in demand. In parallel, technological knowledge has been used to radically cut production costs and develop, within a very short time, a low-cost ventilator.[61]

As far as traceability of the virus is concerned, digital technologies have been applied in various countries, in some cases delivering excellent results thanks, in part, to their early use.[62] Data and algorithm exchange, meanwhile, has been limited. The transnational tracing of infections by countries exchanging data and possibly exchanging algorithms (and, of course, related good practices) might have reinforced and accelerated our reaction to the virus. An international body to regulate—or at least discuss in depth and around the same table—the use of data, as proposed in this book's final chapter, would only have been beneficial. The existence of such a body would not only have helped with regard to traceability and scientific research, it could also have played a role in limiting the influence of the conspiracy theories that have proved so damaging to our fight against the pandemic.

The economy also reacted rapidly, using ad hoc digital technological tools. It is almost redundant here to mention the rapid expansion of videoconferencing as a tool for business. But what *is* important is that business processes have been adapted to the digital tools used. Which is a neat illustration of precisely what was described in Chapter 2—the growing level of interaction between society, the economy, and technological tools. It is also important to highlight that if COVID-19 had appeared 10 years ago, the economy's capacity to operate under lockdown would have been

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[60] avawomen.com/press/liechtenstein-study-aims-to-help-combat-coronavirus-pandemic/.
[61] https://www.ukrinform.net/rubric-society/3054858-ukraine-switzerland-to-work-on-production-of-lung-ventilators.html.
[62] https://www.theguardian.com/world/2020/apr/23/test-trace-contain-how-south-korea-flattened-its-coronavirus-curve.

much weaker. Increased need for videoconferencing has improved the quality of existing products to boot.

Less familiar to the general public is digitalization's impact on manufacturing. Robotization and automation make possible increasingly remote operation in manufacturing, product characterization, maintenance, and packaging, in particular in industries that produce advanced technological goods, such as the semiconductor industry or bio-pharma. The pandemic has led to the increased use of equipment and infrastructure that either reduce the need for human infrastructure or completely preclude it. Large corporations are implementing the concept of the "digital twin", virtual factories that simulate the operation of manufacturing plants. The development of digital twins began years before the pandemic. Manufacturing companies equipped with digital twins and with advanced automation systems and robotics are better placed to maintain their operations under the stresses and strains of "lockdowns" than would have been possible 20 or even 10 years ago.

Here, once more, the question of imbalances raises its head. Not every company can apply such methods. The initial investment required for an advanced degree of automation and robotization or for digital twins means that today only a handful of large organizations can afford these kinds of advanced tools. SME's find themselves excluded. Similarly, automation is generally more adapted to larger organizations.

The reaction of states, in particular those that make up the European Union, demonstrated the importance of transitioning to a post-Keynesian mode of operation. The European Union debated for weeks before agreeing to an unpreceded support plan for the relaunch of its economy. During these debates, it was the state and not the private sector that took responsibility for restarting that economy; the dogma of the "invisible hand of the market" was not considered the main driver for the relaunch. The member states' decision is courageous, but at the same time public debt—already at unsustainable levels for several European countries—has increased still further. To address this requires the kind of entrepreneurial state discussed in Chapters 5 and 7—a state that not only bears the costs and the risks of new technological developments, but also benefits from the economic value created by technology.

Artificial Intelligence algorithms are already being used in the design and development of vaccines or therapies for COVID-19[63], with *data* acting as leveraging capital (as mentioned in Chapter 6) to facilitate research in this area. It is worth, however, asking: what benefits could we have achieved if we had had the large-scale exchange of data during the development phase, and could this have potentially accelerated or improved the efficiency of the research involved? Understandably, pharmaceutical companies' need for return on their investment means that a certain level of confidentiality is required. On the other hand, the European Commission has invested billions of Euros into research related to the novel virus. It seems reasonable that the Commission could demand an open data policy, at least between companies whose research it has financed. Would such an approach benefit citizen by rendering vaccine or therapy development more efficient thanks to the pooling of valuable resources—human, technological, and data?

Whatever happens in the years to come, technology and data have been widely used to combat the global risk posed by the coronavirus, unfortunately maintaining—and even accentuating—already existing imbalances. Here's hoping that our societies will have the wisdom to face the pandemic's various challenges intelligently and to fight it rapidly and efficiently, and will relaunch their economies in a way that avoids those imbalances that, in the long run, can only be harmful. Here's hoping that our societies, independently of the pandemic, will take the measures necessary to employ science and technology—and in particular the new, groundbreaking digital technologies—in the service of an existence that is sustainable, at once economically, ecologically, and socially.

[63] https://www.sciencedirect.com/science/article/pii/S1871402120300771

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