Social Classes and Political Order in the Age of Data

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By

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To the three generations of people to whom I owe so much:
my children, Myrto and Yoann, to my wife Stefi,
to my parents Maria, Kostas.

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ACKNOWLEDGMENTS

As a child, I dreamed of inventing new types of ships, cars, airplanes, and lasers (a word new and magic at that time). As a teenager, I dreamed of doing research and, to be honest, I had only the vaguest idea of what research meant. Life was kind enough to give me what I dreamed of and I have been doing it for almost 40 years now. The journey has been incredible, beautiful, but also filled with disappointments and mistakes, some of which I have learned from, and some of which I have not, unfortunately... Among these learnings, perhaps one of the most important is that, in today's world of science and technology, cooperation is the key word: learning to work with others, to build on mutual complementarities, both as a professional and as a human being, is the only way to have an impact on society and the economy, outside of our word. I tried to apply this learning, in all my endeavors.

There was only one exception: this book; at least that's what I thought and what I tried. My ambition was to craft original reflections on the radically new challenges raised by the intrusion of data in our lives. When I started writing it, I felt like I was in a kind of meditative process, trying to fix my own ideas and discover unseen patterns. Certainly, when I was typing on my computer keyboard, I was alone, isolated from the world, alone with my thoughts. However, very quickly I realized that all these ideas that were emerging and flooding my laptop screen were not my own, but rather the results of countless interactions with scientists, engineers, industrialists, diplomats, politicians, colleagues and partners, small diamonds that shone through everyday discussions. These discussions have been going on since the beginning of the formation of this new Age, the Age of Data, the heart of this book. These interactions were never about writing a book. It was more often about spontaneously discussing one topic or another, trying to understand what we are doing with our technology, where we are going, why we are doing it. It happened that all these discussions slowly and unconsciously distilled ideas, concepts, patterns that, in preparing this book, I tried to streamline, to make them coherent and clear. It is almost impossible to mention all the names of the people with whom I had these stimulating exchanges.

They were colleagues from my own workplace, CSEM, one of the major Swiss Research and Innovation centers; colleagues of our academic partners of EPFL, research centers, Swiss (EMPA, PSI, IDIAP or the Wyss center) or foreign (as the Fraunhofer, CEA, VTT, TNO, DTU); economists; parliamentarians and diplomats; administrators for research and innovation, Swiss and foreigners; journalists. While I try not to forget anyone, for these open and constructive interactions, I would especially like to thank Olivier Parriaux, Prof. emeritus at Saint Etienne University; Dr. Mario El-Khoury, former CEO of CSEM, Dr. Yves Depeursinge (†) and Prof. Hans-Erich Hintermann(†), former division heads of CSEM and visionaries who contributed to its success today; Prof. Dr. Hubert Lakner, director of Fraunhofer IPMS research institute and former speaker of the Fraunhofer Association for Microelectronics; Dr. Xavier Comtesse, former director of the western Switzerland branch of the think tank Avenir Suisse; Mrs Marieke Hood, executive director of corporate affairs at Gesda, the Geneva Science and Diplomacy Anticipator; my colleagues at the executive board of the European Association of Research and Technology Organizations (EARTO) between 2009 and 2018 and in particular Muriel Attané, secretary general of this association; Mrs Aline Bassin, head economics correspondent at the Swiss daily *LeTemps*; Dr. Bahaa Roustom, my deputy for more than eight years, when I was a member of the CSEM's executive committee; Dr. Benoit Dubuis, president of the Swiss Academy of Engineering Sciences (SATW); Dr. Thomas Skordas, deputy director general, at the DG Connect, European Commission; Dr. Laurent Herault, vice president for European Affairs and fellow at CEA-Leti; Dr. Laurent Mallier, former director of CEA-LETI (French research and innovation center) and executive vice president at ST Microelectronics,and last but not least Dr. Matthias Frey, former head of science and technology at the Swiss embassy in Tokyo.

I wish to express my deepest gratitude to Dr. Anthony Patrinos, who with his unique intellectual honesty brought invaluable, insightful comments to the manuscript, and to my English coach Dave Brooks, who used language as a tool to push me to think more, clarify my thoughts, reveal ideas. And most important of all, my gratitude goes to the three persons with whom I share my life: my two kids, Myrto and Yoann, and my wife, Stefi, who—through their love and patience—allow me the unique luxury of thinking beyond the limits of the everyday

PREFACE

FROM FEATHERS TO DATA

Walking through the small, medieval Swiss city of Murten in early spring 2021 with a friend, like me a Greek immigrant to the Eden of technological innovation that is Switzerland[1], I had a minor "eureka" moment. Nothing to do with the principle of Archimedes; rather, a much humbler, linguistic "eureka." I learned that the German word "*feder*" translates not only to "feather" (as I believed) but also to "spring"—specifically the kind of long, metallic springs, sometimes called leaf springs, that engineers use in trains, buses, and trucks to absorb vibrations. Why was this discovery a "eureka" moment for me? Well, Federnfabrik Schmid, a small company located near Zurich, had been the laureate of a prize awarded each year by my employer at that time, CSEM, to the best respondent to a call for innovative ideas. My knowledge of the language of Goethe being deplorable, I had thought I understood the word "feather," and had never dared to ask about the relationship between the company's name and its principal product. Now though, I got it.

My linguistic achievement, if we can call it that, was minor at best. But it did lead me to reflect on the fortunes of Federnfabrik Schmid, a story archetypical of the tectonic changes we are living through today. The company has, for several decades now, been producing springs. The innovation that won Federnfabrik Schmid that prize was the addition of a small, digital device to these springs. The objective of this tiny device is to measure the aging of the springs. If engineers can monitor how a spring is aging, then it is possible to replace it before it breaks or fails. And breakages and failures of springs normally happen on the road (or on the track) and end up damaging the very vehicle that they are supposed, in the first place, to protect. Engineers call this approach predictive maintenance.

Up to this point, nothing sensational I hear you say. What *was*, I think, sensational was an observation made by Federnfabrik Schmid's director

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[1] The 2021 Global Innovation Index of the World Intellectual Property Organization (WIPO) ranks Switzerland as the world's most-innovative economy for the 11th time in a row.

during a short interview that took place three weeks before my minor linguistic "eureka" moment. He said that the company was considering shifting from being a manufacturing company to being a service provider, from being a company that produces mechanical parts—so, leaf springs—to being a company that provides a service: the service of monitoring vibrations and protecting vehicles. More interesting still, the company's success would, in such a scenario, not be solely due to its manufacturing capabilities, which could certainly remain excellent; success would also be due to the data that Federnfabrik Schmid's engineers would collect and interpret. And the most important element in this entire story is the attitude of the company's director, specifically his open-mindedness and his willingness to change and adapt. What is iconic about this is the same revolutionary change that I seek to place at the heart of this book: the genesis of new social classes[2] due to the existence of data, made rich by the "gold" of data. My message is clear: a revolution is underway, but not everyone has the knowledge, the openness, or the willingness to engage with it. Those who do—those individuals who engage at the genesis of a new social class—are few, but the power of the "gold" they accumulate and possess will revolutionize our societies.

The data revolution did not appear ex nihilo. The technologies that have enabled it to take place have been developing increasingly rapidly over recent decades. Before the turn of the new millennium, however, none of us, including the engineers and the scientists, foresaw the importance of this phenomenon. I, and my colleagues around the globe—each immersed in the world of technological innovation—had our thoughts tuned to the question "À quoi bon?"; or, "What is good about what we are doing?" We asked ourselves what the economic outcome of what we were doing might be, as we developed, day in, day out, tools to improve efficiency and quality of life. But the outcome turned out to involve much more than "simple" improvements in efficiency and quality. Our tools became the foundation of the data revolution. Having not felt it coming, we were all caught up in the "Big One"—the major quake engendered by the emergence of large-scale

[2] As a high-level definition, I use the term "social classes" as a classification of individuals as a function of the source of their revenue (or of the revenue of the individual who financially supports these individuals). In Chapter 2, I will be more concrete about this classification, and its limitations. This classification differs from a classification determined by level of wealth or revenue. I understand the traditional definition of the working class to extend well beyond industrial workers and agricultural workers, incorporating individuals active in the service provision domain, including white-collar workers.

data as a phenomenon. But when that quake hit, we nevertheless tried to integrate it into our work and our lives. But by then already it had a reach well beyond the science and technology community.

The data quake hasn't subsided. It changed and is still changing our way of thinking. It changed and is still changing my peers' way of thinking. It changed and is still changing the way the economy works. It changed and is still changing the way our societies function. Contemplating such fundamental transformations pushed me to try to understand the interactions between technologies, industry, society, and the economy. I aligned the ideas in a book—*Data, New Technologies, and Global Imbalances: Beyond the Obvious*.[3]

I thought that my ideas were complete. I finished the manuscript I had prepared, by writing its preface. While doing so, almost instinctively I added a passage about social class. The passage reads, "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." For months after the manuscript was finished, this sentence kept coming back to me. In particular the parenthetical part, "*though I believe that 'class' today has a very different meaning than that conveyed by its original Marxist definition.*" I tried to understand whether there was something more profound in the meaning and implications of this passage than a simple observation of a framework. This began as simple curiosity. My basic idea and my questions were straightforward and based upon two arguments. The first was one of the conclusions drawn in my book. Data and technology are accelerating, at an unpreceded speed, the interaction between technology, industry, society, and the economy. This interaction has always existed, but now the pace was growing exponentially. The second argument was new: data is a new type of capital, and a new factor in the production of wealth.[4] As such, data creates both

[3] Georges Kotrotsios. *Data, New Technologies, and Global Imbalances: Beyond the Obvious.* Newcastle upon Tyne: Cambridge Scholars Publishing, 2021.

[4] With the terminology "production factor," I signify assets, tangible or intangible, that create economic value. Machines, equipment, and infrastructure are production factors, because when used properly can create new products or services; these are tangible assets. Money also, since it can be invested in buying the above assets or in hiring personnel. Human labor that produces economic value is a production factor. I will also use technology as a production factor. In this context, the real production factor is the know-how associated with each specific technology. For me, know-how

new opportunities for wealth creation and unknown risks. New opportunities (so my argument goes) lead to the creation of new social classes. The emergence of new social classes generates novel interactions between classes, including those classes that have long coexisted. These new interactions challenge our political institutions—in other words, they challenge order. Risk, meanwhile, sets the boundaries within which social and economic interactions occur. And we need to understand all these mechanisms. And that effort to understand might unearth the germs of ideas that—carefully nurtured and cultivated—empower us to adapt these mechanisms for the greater good of society. These thoughts were new for me. Combined, they form the central theme of this book.

I am not a social scientist. Neither am I an economist or a political scientist. And I experienced intense apprehension about the prospect of navigating in completely unfamiliar waters to which people far more qualified, experienced, and knowledgeable than I dedicate their lives. There was (and there is), however, a big "but" appended to this feeling of apprehension: I have had the opportunity to observe tectonic changes, and from a privileged position. I owe that privileged position to my 40 years of immersion in the world of R&D, the very enabler of the revolution that is currently taking place. That environment has shaped the ideas that I express here. The winds, tides, and ripples of technological change impact those ideas too. My "privileged position" is thus both a weakness and a strength of my analysis. My alternative, perhaps even naïve or simplistic way of reasoning will nevertheless take us off the beaten path, and I hope the route we take will see us contribute, even if in only a modest way, to the reflection we need to engage in as a society.

Writing my previous book felt more comfortable, because I was setting out ideas that had been matured for years by myself and my peers. Those ideas concerned the interplay between technological trends and between industrial trends, and the influence of data as a new form of capital. Now, as I embarked upon for me uncharted waters, trying to understand new production factors' consequences for society, like the navigators of old I needed some kind of instrument to help me—a kind of optic through which to observe the past and what technology has meant over the years for societies. I would then, with the help of this optic—my temporal telescope, if you will—be able to distill *something* from the past that was repeating itself, and that something would relate technology and society to one another. I am, of

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means the widespread knowledge and availability of the required machinery for producing and using technology at an affordable cost.

course, not the first to engage in this pursuit. Since Herodotus, and more intensely since the eighteenth century, the question of what the past means for the future has been a central focus of historical thinking. For me, however, the question is a little more specific and perhaps a little simpler: What happens to the economy and to society when a new production factor (currently, data) emerges? Observing the past might help us to identify recurrent patterns and to answer this specific question. Winston Churchill wrote, "The farther back you can look, the farther forward you are likely to see." Unfortunately, our view as we peer through our temporal telescope at the past is often blurred. Historians and social and political scientists identify and combine artifacts, creating theories of the evolution of the economy and society. But the farther into the past we look, the fuzzier the image becomes, because these artifacts are less well preserved or their context is relatively less well understood. Interpretation, therefore, becomes more challenging.

In my world, the world of physicists and engineers, we already use telescopes to probe the past. Telescopes allow us to inspect the depths of the Universe and to measure with precision. We have observed microwave radiation,[5] the relic radiation that proves theories elaborated by the brilliant minds of physicists, confirming the existence of the initial event that created our Universe, the Big Bang. We have also observed the oldest and most distant portions of the Universe.[6] Telescopes have revealed nebulae[7] of interstellar material, never imagined fifty years ago and of incredible beauty, delivering to us the secrets of our Universe's past. These observations, and many more, allow us to verify, modify, or dismiss scientific theories and to develop a deterministic understanding of at least some of the elements involved in the evolution of the cosmos.

An imaginary, temporal telescope that probes the past and the evolution of societies is, however, an infinitely more complex instrument. To illustrate why, let us compare natural science to the social sciences. We can begin our comparison with the very basics. Natural sciences are deterministic, at least in the vast majority of cases. Things become a little more complex at the level of subatomic physics, but for the sake of simplicity let's stick to the classical natural sciences. In any well-defined, deterministic system, output

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[5] NASA, Wilkinson Microwave Anisotropy Probe, *WMAP 9-Year Results Released,* https//:wmap.gsfc.nasa.gov/news/index.html.

[6] W. M. Keck Observatory, *Oldest Galaxy Protocluster Forms 'Queen's Court,* https//:keckobservatory.org/oldest-protocluster/.

[7] Consult, for example, the website of the Hubble Space Telescope: https//: hubblesite.org or, more recently the Jeff Webb Space telescope: https://webb.nasa.gov/content/multimedia/images.html.

is precisely predictable for a given input condition. A handheld calculator is a relatively straightforward engineered system: inputting “1” and “1” and asking the system to sum these inputs will always result in an output of “2.” A space shuttle is also an engineered system, albeit a much more complex one. The input is (in an oversimplified form) the thrust of the launch motors. The output is (again oversimplified) altitude, speed, angle, temperature, trajectory, and other conditions. In our engineered system the space shuttle, we also have a control system, because there is a feedback mechanism. Sensors that measure the output influence the input (the thrust of the motors, for instance) and correct the output. Robots can also be, or merely contain, control systems.

History is the science that allows, or at least should allow, us to understand the “engineered systems” of societies, economies, politics, and eventually individuals. But engineering and history, when viewed as “control systems,” have essential differences. We can credibly claim that three factors stop history being as deterministic as engineering. And these factors hinder us from looking with certainty into the future. First, the “input” parameters (humans and the environment) have characteristics that are infinitely more complex than the most complex engineering control systems. Engineers build their systems to accept a limited number of input parameters. In human history, meanwhile, the number of input parameters is quasi infinite. They can include such factors as the behavior of a single, individual human and that of this individual’s natural environment, which can comprise geography, climate, fauna, flora, and natural occurrences such as earthquakes, and—as we have recently learned to our bitter cost—ultra-small living “things” such as viruses. The second factor is that it is not only the “inputs” of the system that change its “output.” The system itself changes, and its input parameters are also part of it. Humans and the environment are the “input,” but are also the system’s constituent parts. Third, the elements that constitute the past of the system are recognizable, but only partially, since time has left its destructive mark on them. The farther we look into the past, the less readily we recognize the system’s inputs and component parts—humans, and the environment.

Take, for example, the following events. At the dawn of twentieth century, shortly before Easter 1901, a Greek sponge diver found a shipwreck close to Antikythera, in Dodecanese. He brought back to the surface a box with a strange, metallic “thing” inside. One year later and archaeologists had understood that it was a gear, a device to transmit mechanical movement. But it took half a century until Derek J. de Solla Price understood that it was a mechanism for predicting solar and lunar eclipses, the movement of the sun and moon, and that of five planets[8] In sum, this strange, metallic "thing" was a computer, if an analogue one. Time erases so many things and hands us so many unanswered questions: Why was this miracle of engineering, perhaps the first analogue (i.e., non-digital) computer, lost? Was it the only one of its kind? What were the thought processes that gave birth to it? While we are (we think) able to understand the physical mechanism, despite its obvious complexity and the fact that certain parts are surely missing, what we cannot understand is the social and economic environment that brought its beauty and ingenuity to life, and the reasons for its disappearance.

Returning to the main thread of our argument, our objective here is to understand the trends that link technology and society. Are the words of Heraclitus, Greek presocratic philosopher of the 6th century BC, "τα πάντα ρεί"—so, "everything changes"—always true? Does everything change? Can we not find certain very elementary common denominators that have always manifested themselves throughout the evolution of our societies? If so, these irrevocable patterns could help us navigate the aforementioned uncharted waters. The same Heraclitus was saying that there is an underlying stability in continuous change, "the hidden harmony." [9]Permit me to propose a first such common denominator: every change in a production factor induces changes in the social classes present in an economic system.

The case of the birth of fiefdoms is illustrative. In the Middle Ages, the mastery of armoring knights mounted on horseback—mastery that required significant support personnel—contributed to the creation of the feudal system.[10] Each of these "horseback fortresses" needed support workers and backup horses if they were to remain operational and functional. The armor itself was also costly. If an individual were to afford this equipment and personnel and these horses, he needed money. To get money, one needed to control taxes. Control of taxes, and therefore control of land, shifted from the king, who was happy to profit from these mobile fortresses and the protection they afforded him, to the knights. And the fiefdom system was born.

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[8] Tony Freeth and Alexander Jones, *The Cosmos in the Antikythera Mechanism,* ISAW Papers 4 (February, 2012) (nyu.edu); https://dlib.nyu.edu/awdl/isaw/isaw-papers/4/; *The Antikythera Cosmos* - YouTube, https//: www.youtube.com/watch?v=1ebB0tyrMa8

[9] Philip Ellis Wheelwright. *The Presocratics.* New York: Prentice Hall, 1966.

[10] Peter Watson. *Ideas: A History of Thought and Invention, from Fire to Freud,* New York: Harper Perennial, 2006.

So far so good for our use of our temporal telescope and our perusal of history. We just have learned, by observing our past, that technological dominance has long been a significant factor in the fight for political dominance: city struggling with city, kingdom with kingdom, fiefdom with fiefdom, empire with empire, nation with nation, and political system with political system. Scientific discoveries led to technological innovation, allowing individuals and groups to expand into broader territories; any loss of control over technology, meanwhile, limited one's ability to maintain control of one's territory. When the Hittites lost the secret of iron production, their dominance waned. The Byzantines, meanwhile, were able to maintain, for more than one thousand years, Constantinople, as a border between Europe and Asia, and to resist, among others, the dazzling Arab expansion. One of the ingredients of this success was their mastery of an incendiary weapon, Greek Fire (ὑγρὸν πῦρ). There were, of course, other ingredients, including the geographical positioning of Constantinople, its formidable walls, and last but not least the admirable administrative capacities of the Byzantine Empire. But technology was a major factor.

In each of these three cases—the birth of the fiefdom system, the waning dominance of the Hittites, and the millennium of success enjoyed by the Byzantine Empire—mastery of technology played an essential role in the game of dominance played out between warlike actors, whether they were kingdoms, fiefdoms, empires, or nations. Technology also facilitated dominance within each individual system, thus creating stratification within societies. The first technological revolution was the agricultural revolution. It made possible a surplus of crops. Surpluses could be, should be, and were reserved to be used in the future to mitigate bad harvests and the threat of famine. Crops became wealth, and accumulated crops became accumulated wealth, in other words, capital. The guardians of such surpluses were, de facto, the guardians of capital. And when controlling access to capital presented a temptation too strong to resist, the temptation of becoming the owner of the capital, these guardians of capital became the first priest-kings. Thus, the technology that made the agricultural revolution possible had enabled the birth of a political system. It was not the first time this has occurred, and it would not be the last. Indeed, it is a persistent pattern in the evolution of societies.[11] Mastery of the horse allowed the Aryans to conquer the region we know today as Punjab, and to install the four-level social system of Brahmans, warriors, artists, and farmers.

[11] John Keegan. *A History of Warfare.* London: Vintage, 2004.

Of course, technology has not been the only factor to influence the evolution of economic, societal, and political systems. The development of the compass, gunpowder, and paper by the Chinese each impacted, in distinctive ways, different societies in different parts of the world. Printing techniques using mobile metal elements were introduced in Korea more than two centuries before Gutenberg began printing in Europe. So why did printing then develop much more rapidly in Europe than it did in Korea? Undoubtedly not due to the limited number of characters that make up the European language alphabets. Unlike Chinese, and contrary to common belief, the Korean alphabet, the Hangul, has only 24 characters, comparable to the number of characters of the Latin alphabet. Thus, other factors were at play.

Geography and climate, for example, have always played an important role, and the literature on the subject is rich. Jarred M. Diamond[12] addresses the geographical dimension of the dissemination of technology, revealing how east–west transmission proved easier than north–south transmission; Tim Marshall, meanwhile, assesses past, present, and future geopolitical factors through a geographical lens.[13] And David Landes's *The Wealth and Poverty of Nations*[14] is an excellent starting point for the interested reader. Even pandemics have played an essential role. Pandemics changed the flow of history at the time of Pericles and of Justinian, and during the late Middle Ages, when the Black Death decimated Europe's population.[15] Several authors have pointed out a change in economic relations between classes after the Black Death dramatically reduced the European population in the fourteenth century. Diamond's book has as a central theme the role of germs in the decimation of the pre-Colombian American population.[16]

Yuval Noah Harari[17] has written that political systems evolve to optimally meet the needs of the prevailing economic situation. Correlations between technological development and leadership are among several factors

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[12] Jared M. Diamond. *Guns, Germs and Steel: A Short History of Everybody for the Last 13,000 Years*. London: Vintage, 1998.
[13] Tim Marshall. *Prisoners of Geography: Our World Explained in 12 Simple Maps.* London: Elliot and Thompson, 2015.
[14] David S. Landes. *The Wealth and Poverty of Nations: Why Some are So Rich and Some So Poor.* New York: W.W. Norton & company, 1999.
[15] The term "decimated" is, in fact, a statistical underestimate since one-third of Europe's population perished.
[16] Here "decimation" is even more of an understatement.
[17] Yuval Noah Harari. *Homo Deus: A Brief History of Tomorrow.* London: Vintage, 2017.

that define societal and economic structure. But of these factors, technological development is essential—in certain cases, even critical. As a recurring pattern in the evolution of our societies, technological development has played an important role in (i) the structuring of political entities, from tribes, through kingdoms and fiefdoms, to nations, even empires; (ii) the competition between such structures, and their dominance and fall; (iii) the structuring of social classes; (iv) the structuring of political systems based on competition between these social classes, resulting in different types of democracies, dictatorships, monarchies, and republics; and (v) the very functioning of the entire system itself. Today we are entering a new economic and societal framework, one in which data and technology will dictate and radically change the rules. We can confidently refer to a data-driven society, to a society in the Age of Data. And data, of course, will impact this new framework. This impact and the changes that result will, in comparison to humankind's past, be tremendous, and changes will occur at a vertiginous speed, playing out within a single human life-span.

We have a "constant." We can confidently state that technologies influence society's structure and the resulting political order, meaning the dominance of social classes over others and the evolution of political institutions. Political institutions constitute the political order. This concept of the relation between technologies' evolution, social classes, and political institutions is the first fair wind that our temporal telescope has allowed us a sighting of. And we can use that wind to carry us further on our chosen voyage. "Τα παντα ρει"—everything changes. But we can state that technologies' evolution has a substantial probability of changing societal rules, which itself can change the political order. This happens because new production factors open up new opportunities for human relations and economic relations, and because while humans are busy exploiting these opportunities to create wealth, these same opportunities bring new social classes into being.

Along with opportunities, technologies can also bring with them risks and challenges. This fact is the second constant across the ages, our second fair wind. To understand the nature and role of risks in societal and economic change we will need to identify these risks and to categorize them. Thousands of pages are written year after year on this topic. So where should we begin? Among the extensive literature on the challenges we humans are facing, a good starting point is the World Economic Forum's annual report on global risks.[18] While not exhaustive, it gives a good overview

[18] WEF, *The Global Risks Report 2021*, https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf.

of the major risks. And, as we will see, these risks can be apportioned across three overarching categories: global imbalances, environmental and climate risks, and the risks of poor or insufficient control of technology. If we compare the Forum's report to another important assessment of risk, the United Nations Sustainable Development Goals (UN SDGs), we can confirm that our categorization is sound: all the risks that the UN SDGs seek to address are impacted by the evolution of technologies, and fall within one or more of the above three overarching categories.

Transgressing the boundaries imposed by risks can lead to our reversing the positive trend of history. If we train our temporal telescope on some of the darker periods of our past, we discern a number of examples of this, of which here we can look briefly at two. The first, which we have already briefly touched upon, is the Dark Ages. Peter Frankopan, in his impressive work *The Silk Roads*,[19] identifies the role of late fourth century climate change in the collapse of the western Roman Empire, as consequent massive migratory movements of the barbarian peoples contributed to the Empire's downfall. In other words, an unmanageable environmental risk changed the societal structures of the European continent. The second, equally fascinating example can be found in the Dark Ages of the eastern Mediterranean following the nigh-simultaneous collapse of several civilizations (including the Egyptian, Mycenean, and Minoan). Here, historians[20] credibly claim that the accumulation of several catastrophic events of an environmental nature and the migratory movement of the "Sea Peoples"—the latter probably due to perceived economic imbalances—drove a great network of civilizations to collapse. Poorly managed risks (in this case, environmental risk and imbalances) provoked radical changes to a whole region's economic and societal structures, condemning it to the darkness for several centuries. And these are just two examples.

From all the above, let us draw and set out two fundamental ideas: First, everything changes. Second, when we examine the specific question of the influence of a new production factor on society and the economy, certain patterns repeat themselves. I summarize these patterns along four axes: (i) changes in technologies are playing an increasingly essential role in the structure of societies and of the political order; (ii) change creates opportu-

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[19] Peter Frankopan. *The Silk Roads: A New History of the World*. London: Bloomsbury Publishing, 2018.
[20] See, for example, Eric Cline. *1177 B.C.: The Year Civilization Collapsed.* Princeton: Princeton University Press, 2014.

nities and risks; (iii) opportunities include ways to build wealth and dominant force (which induces the birth of new social classes, and disturbs the balance of older classes and class relations), which leads to new social and political interactions; and (iv) risks fix the boundaries within which social interaction occurs, and beyond which a system can implode.

Let us paraphrase Werner Heisenberg—one of the great physicists who shaped the way we understand nature today —when he spoke about the elementary laws of physics. And let us postulate, "Not only does history play dice, it sometimes throws them where they cannot be seen." [21]Heisenberg, of course, used the word "God" rather than the word "history." But irrespective of Heisenberg's beliefs on the relationship of God to physics, our reworked statement seems to fit the evolution of history perfectly. We cannot predict the future from a "mere" understanding of history, or at least not with the computing tools available to us today. However, as in physics—where, despite uncertainties at the quantic level, we can, at the macro level, isolate reliable laws, including traditional physical laws such as those of gravity or electromagnetism—in history, we can distinguish patterns, which we may treat as laws. These patterns were my guides as I developed the thoughts expressed in this book.

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[21] This statement was the answer of Heisenberg to the famous proclamation of Einstein "God does not play dice with the universe."

CHAPTER 1

DIGITAL AGE OR AGE OF DATA?

The Epic of Gilgamesh, the Hindu Vedas, Homer's masterpieces. All are stunning works of poetry and imagination inherited from the dawn of human civilization. Stories of gods and titans, monsters and heroes, and the quest for immortality are just some of the tales that our imaginary temporal telescope returns to us from these times, to our awe and admiration. Across the entire planet, children learn about "their" mythology, considered as being at the origin of "their" culture. They learn too about the Enlightenment, about the Renaissance, about the Hellenistic period. They may also learn about ancient Mesopotamia, Egypt, or Greece, and of pyramids and temples. At the same time as pyramids and temples were being erected, science and technology were progressing, giving us irrigation and the wheel, and, indeed, making these very pyramids and temples possible. Thus, despite the paramount role stories and myth have played, and continue to play, in the evolution of our species, when it comes to the naming of eras and ages, technology dominates our nomenclature.

Since technology has a considerable impact on society and the economy, it is logical that historians define periods of human culture as a function of their dominant technology: the Neolithic, the Bronze Age, the Iron Age, and so on. What name should the historians of the future give to the present era? The Digital Age, or Age of Data? Are the first two decades of our present century and millennium indeed a moment of genesis of a new age, a moment of societal and economic revolution?[22] Or are they simply part of the accelerating evolution of what was already happening in the previous century, and thus no naming is required? Why spend time debating two names for an

[22] It is not inappropriate to use the word "moment" to describe even a considerable length of time seen from the standpoint of an observer of radical transitions among societal paradigms. Until recently, such "moments" were of the order of decades or centuries, as typified by the agricultural revolution or the first industrial revolution. Our present revolution, meanwhile, is far more rapid, not least because so many of its key elements have fallen into place simultaneously.

era? What's in a name? Why might the naming of an era change our perception of human culture and its evolution?

These questions might, at first glance, seem meaningless. Not so; they are crucial. They are crucial because they can guide us to an understanding of the critical factors and processes that change our societies. By understanding these critical factors and their processes, we can better understand their impact. The Digital Age began at some point in the 1980s, when computers began to enter our everyday lives in the shape of the first personal computers and Apple's first Macintoshes. These early computers mitigated inefficiencies[23] in manufacturing, services, and agriculture. Automation became far more flexible than before. Administrative performance was also improved upon, and digitization[24] would eventually change business processes. Science changed too: we were no longer solving differential equations analytically only; we now used numerical analysis too. And there was a new production factor—the digital technologies driven by these computers. The large-scale penetration of digital technologies into our lives was undoubtedly a revolution. Let's call it the "digital revolution."

The advent of mass data has added a new production factor to this mix: data as capital, data capital. Data capital is undoubtedly a production factor as it allows the creation of wealth, just as monetary assets, infrastructure, equipment, and human labor do. This new production factor, data capital, has only very recently penetrated the business environment and our social lives. It is radically impacting the ways in which businesses, society, and the economy function and how they interact. This is why the questions with which we opened this chapter are not meaningless, and why it is essential to precisely define our era as the "Age of Data." By doing so, we emphasize the importance of this new production factor. We are, clearly, in the midst of another revolution, one that we can describe as the "data revolution." Its

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[23] Analysis has shown that in recent years efficiency increases in business processes have flattened out, at least in developed countries. Nevertheless, it is beyond question that business efficiency increased following the introduction of affordable personal computers.

[24] I define the word "digitizing" or "digitization" as the transformation of paper documents into digital ones—a quasi-one-to-one transformation. We must differentiate this process from that of "digitalization," which refers to entirely new business process enabled by digital tools. Besides computers, these new processes extensively use tools such as robots, sensors, wireless communication, and artificial intelligence algorithms. Each of these tools, and all of them collectively, create and process data, going far beyond "digitization," changing the rules of the economic game and driving the digital economy.

nature is fundamentally different than that of the aforementioned digital revolution and it is radically changing the way we lead our lives, and the ways in which our businesses, societies, and economies operate. The digital revolution accelerated processes and rendered them more efficient. The data revolution is changing their nature in a radical way.

Mistakenly, at the turn of the century, less than ten years after web browsers had become widespread and while the concept of e-commerce was still only nascent, we saw this revolution as evolution—a "normal" process of innovation. And my understanding is that very few people indeed predicted or grasped the fundamental nature of the changes that were coming. As an engineer embarking on his career in the mid-1980s, I dedicated my professional life to research and development that was useful to the economy and society. And I could perceive a kind of natural progression, in which each technological innovation brought the next to fruition, and so on. During those years, representatives of civil society and industry regularly inquired as to the social and economic impact of my colleagues' work and my own. And for our part we were always proud to answer, and to speak about helping the elderly, improving healthcare, supporting industry, or caring about the environment by promoting renewable energy sources; we were always proud to talk about how we were creating jobs and wealth.

Meanwhile the flow of data was growing day by day, building up an irresistible head of force for radical change—one that would be neither dammed nor checked. Unbeknown to us, it would soon begin to unleash tremendous social and economic changes. Of course, these could prove to be forces of "creative destruction," as theorized a century ago by Joseph Schumpeter: harmful, certainly, but also heralding the dawn of Golden Ages if properly managed by society. Equally, they could constitute a tsunami, destroying both wealth and well-being.

We engineers and scientists—due to our education and the work we do each day—see the world analytically. The large majority of us are "formatted" to think this way. Historians and social and political thinkers are also formatted to think and act analytically. They, perhaps, see the world from another angle, but it is still an analytical angle. Artists and creative people, meanwhile, see the world differently. Their artistic, Dionysian spirit is complementary to our analytical, Apollonian thinking. Some creative people can foresee the future much more instinctively and rapidly and with much greater clarity than scientists of any discipline can. This is because they can perceive the first telltale ripples of upcoming radical change. Jules Verne, Isaac Asimov, H. G. Wells, Stanley Kubrick, and others foresaw the future and anticipated the transformations it was bringing. They prophesized evolutions and revolutions, including the conquest of space and conscious robots, and ubiquitous connectivity—the hell described in Orwell's seminal *1984*.

But none of us, not one social or natural scientist, nor those impregnated by the artistic, Dionysian spirit, not even the most prophetic and visionary among them, foresaw the fundamental nature of the paradigm change that was to take place during the last two decades. In *1984*, Orwell predicted ubiquitous connectedness, but not the role of data. In Kubrick's (and Arthur C. Clarke's) *2001: A Space Odyssey*, a powerful computer can lip-read and understand human speech, and has the prerogative to act against the well-being of an individual. Today, and for that very task—lip-reading and comprehension—computers use algorithms and employ advanced machine learning techniques trained on and applied to large sets of data. Kubrick (and Clarke) and Asimov foresaw artificial intelligence, but not the role of data as an enabler of artificial intelligence. Prior to the turn of the millennium, no one, or at least to my knowledge no one, foresaw that role.

Each step forward—be it in terms of connectivity or of robotics—foreseen by Orwell, Kubrick, or others is in some way the result of a revolution in digital technologies and the democratization of computing power. But none was the result of digital technologies alone. It was the accumulation of data and how we learned to process it that made these steps reality. The emergence of data as a new factor in our lives has taken us beyond the digital revolution. We are no longer in the "Digital Age," the age of the democratization of computational power and of microelectronics and robotics "alone." We are now in a new age—the Age of Data. A new age. And a paradigm shift.

Figure 1 illustrates, in simplified manner, the relation between technology trends, on the one hand, and society and the economy, on the other. The three leftmost boxes comprise the focus of my 2021 work, *Data, New Technologies, and Global Imbalances: Beyond the Obvious*. In it, I focused on understanding the mechanisms via which new technologies and data are accelerating societal and economic change and reinforcing global imbalances between individuals. I identified three major technology trends: digital technologies, new manufacturing technologies, and technologies used to access resources. In defining the technology trend "manufacturing technologies," I included all technologies related to manufacturing, including technologies

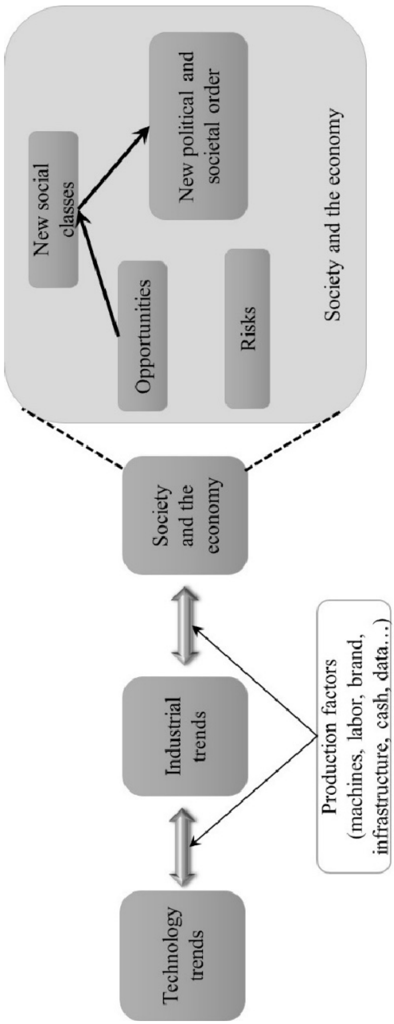

Figure 1. Production factors labor, infrastructure, machines, and money, and the new arrival—data—influence society and the economy by creating opportunities and risks. The presence of the new production factor modifies the entire landscape of economic and social interaction.

that principally concern the life sciences. I then identified three major industrial[25] trends: (i) the **digitalization** of industry and services, (ii) **new manufacturing paradigms**, and (iii) the **complexification** of value chains, products, and processes. Since the dawn of sedentary societies, technologies have brought forth new production factors: equipment, machines, materials, infrastructure. This was the case for agricultural technologies and for materials-based technologies (ranging from stone to copper to bronze to iron). And it is still the case for our newest technologies: computers, robotics, and artificial intelligence. These technologies generate our newest production factor, data.

Data capital is not a traditional production factor. It has specific features that impact the way in which it shapes societal and economic change. I will discuss these features later in this book, including how data capital acts as an accelerator with regard to the interactions between technology trends, industrial trends, and society and the economy. And how data capital acts as a lever of traditional capital, the latter—particularly in its monetary incarnation—growing in a quasi-irrational way when leveraged by data.

Returning to Figure 1, note that data capital as a production factor creates opportunities and risks. These new opportunities are often radically different from those of the past. They enable elaborate, new, entirely unforeseen ways of creating wealth, including new business models and new value chains. Thus, these new opportunities contribute to the genesis of new economic classes, which are simultaneously new social classes. The new social classes have new interfaces and debates, which in turn modify societal relations and political institutions. Risks frame this entire evolutionary process: they are the process's boundaries. Some of these risks are directly induced by the imbalances caused by data capital. Here, on the right side of Figure 1, we focus specifically on the influence of today's data and today's technologies on the societal evolution and the interactions of the new social classes each has contributed to bringing into being.

To illustrate how production factors modify social classes, let us return briefly to the Industrial Revolution. Once machines had made mass production possible, wealthy individuals could grow their fortunes by accumulating capital in the form of combinations of manufacturing machinery, the first industrial factories. This opportunity is directly attributable to the very

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[25] I use the term "industry" with the broadest possible definition; so, for all productive activities of the primary, secondary, or tertiary sectors, including agriculture, manufacturing industry, and services.

existence of these machines. This opportunity led to the birth of the industrial capitalist. At the same time, the geographical concentration of the means of production attracted people to these factories. This concentration enlarged the working class and modified its nature; it was no longer composed only of farmers and artisans. Manufacturing machinery "created" factory workers, and the very nature of the working class changed. It was now what Karl Marx, borrowing from Sismondi, referred to as the proletariat.

When a new social class is created or an existing class is changed radically, new forms of competition and cooperation between new classes and pre-existing ones emerge. Competition and cooperation between classes can lead to changes in political systems and institutions. Examples are numerous. One I consider most illustrative is the role of the Janissaries, the class of soldier–slaves in the Islamic world at the time of the Abbasids. Among several impacts of the presence of this social class is the complete dominance of the Egyptian caliphate by the Mamelukes for several centuries and the imposing role of this class in the Ottoman Empire until their power was extinguished in the early nineteenth century.

Returning to the present and to the work at hand, how should we now procced? The first step of my methodology involves describing the possible evolutionary pathways that present themselves to the new social classes currently being generated by new business opportunities and associated global risks. Here, I will attempt to understand how the newcomer among production factors—data capital—is driving the genesis of these classes. This will entail a comparison of production factors, traditional and new. I will then examine the forces of mutual interaction, cooperation, and competition between social classes, forces that depend heavily on the distinguishing features of production factors, particularly those of the newcomer, data capital. As we shall see, data capital distinguishes itself by its mobility. But also by its "intangibility"—tangibility being the quality of our being able to quantify it, valuate it, and render it material. Another important feature of production factors is their ability to be generated or regenerated: Work is performed once and cannot be regenerated ex nihilo. The same is true of products. The single act of monitoring objects or processes, meanwhile, generates data—and therefore economic value—ex nihilo or quasi ex nihilo. This last feature is influenced by the potential to share a production factor. Traditional production factors such as money, infrastructure, or real estate normally have a single owner; data can have several owners simultaneously. More interesting still, data can have a different value for each of these owners.

I will also attempt to understand the forces of attraction that drive social classes to converge, and the centrifugal forces that drive them to diverge, particularly in terms of their relative economic prosperity,[26] including the question of whether the data capital—driven emergence of new social classes creates an additional centrifugal force acting on some of the classes. Further, the emergence of new social classes means new interfaces between those classes—indeed, between all classes—and the mechanisms that govern these interfaces require careful analysis. I will argue that the complexification of products and processes, and innovation, are simultaneously (a) virtuous mechanisms that create value and (b) mechanisms that increase the divide between classes. Complexification and innovation result in better products and services. Innovation drives economic growth. Tuning complexification and innovation to suit framework conditions could lead to the optimal distribution of the economic benefits they generate. But when it comes to cohesion across social classes, the picture is, perhaps, less rosy.

This divergence of social classes isn't the only "less rosy" thing. There are other flipsides too. The "heads" of the social evolution induced by opportunities generated thanks to the new production factor data capital conceals the "tails" of risks. Thus, I will look at how this new production factor combines with traditional production factors to bring novel risks to bear on our societies. Risks compose the boundary that delimits the scope of societal evolution. And I will try to understand the risks faced by human society, classify them, and understand the role of technologies and data in their evolution, both real and perceived. This will allow us to imagine how we might mitigate these risks and optimize the opportunities presented to us by the Age of Data. The mutual interaction of opportunities and risks can influence the governance of our societies. New social class structuration drives changes to the political order and political institutions.[27] The role of data

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[26] Alongside imbalances between individuals and social classes, economic imbalance can lead to imbalances between humans and nature. Overexploitation of the oceans or of tropical forests by the more economically fortunate portions of the human population leads to a loss of biodiversity.

[27] By "political order," I refer to two elements. The first is that of the governance system. The dominant governance system under different social stratifications can take the form of the tribe, the kingdom, the city–state, the empire, fiefdoms, or—more recently, since the early seventeenth century—the nation, and most recently the democracy. A democratic system may apply to only a portion of the population, as was the case in the Athens of antiquity; or it may be (as is common currently) "fully" democratic. The second element of the political order resides within democratic states, in the form of those forces—both parties and individuals—that debate and seek power. For a significant part of the twentieth century these forces have