Technological trends, **industrial** trends, impact on **society**, and the evolution of the **economy**

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1. Introduction

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 their 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, this standpoint 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 being on **three levels** that are parallel to one another: the technology trend level, the industry trend level, and the level of societal and economic changes. 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 and the economy, societal and economic changes require that industry follows such changes, which—in turn—means new, adequate technologies.

At the high level we can state that all of todays' major technological developments fall into one or more of three major technological trends; namely, **new manufacturing techniques**,[1] digital technologies, and technologies related to **resource generation**, **management**, and **access**.

Technology trends are at the origin of the creation of industrial trends,[2] 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, though in the background, 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 1.

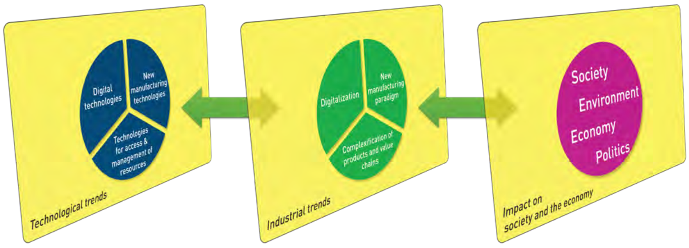

Figure 1. The accelerating evolution of technology in the form of its three key trends is having an increasingly strong effect on the way industry (including service provision) operates, which in turn creates rapidly evolving changes in how the key elements of our lives—society, the economy, politics,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

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

Our analysis below is structured so as to follow the aforementioned logic: It starts with an analysis of technology trends (Section 2) followed by a description of convergence mechanisms (Section 3). Then, industrial trends are illustrated (Section 4) as are the impacts on society and the economy (Section 5). The mechanisms that link these three levels are discussed in depth. Following this, the focus moves to the role of data in interactions (Section 6), 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 close this analysis.

1 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

2 Here, the words *industry* and *industrial* are understood to include all value creating economic activities, including those taking place beyond the secondary sector (i.e., manufacturing), and thus include, for example, service provision.

2. Technological trends

The first step of our analysis is to try to understand the trends behind the big technology evolutions that are today commonly accepted as mainstream and expected to mature. These are diverse, and include the dominance of artificial intelligence, 3D manufacturing, 5G and 6G, 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 paths—can be gathered together in 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.

Let's take them one after the other.

2.1 Digital technologies

Digital technologies include all Internet and networking technologies but also go well beyond them, including all technologies that allow the extraction of data and their transmission in digital form through communication networks. All 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 to 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 examples. These single devices 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. IoT is only the natural extension of the Internet, which humans, of course, will 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. These are the very advanced algorithms that can replace basic human operations. Tomorrow, it is expected that such algorithms will be able to command more and more complex functions.

Robots are "simply" complex mechanisms that can today carry out actions commanded by simple algorithms, soon by more and more complex algorithms. But, "more and more complex algorithms" become artificial intelligence, which—in turn—becomes more and more evolved. Artificial intelligence, as it becomes more evolved, is increasingly able to take decisions currently taken by persons or organizations, or at least gives very precise information to persons and organizations, allowing them to take 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.

2.2 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 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 manufacturing technology: additive manufacturing. The concept is simple; the consequences can be enormous. 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 repercussions 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 production, "classically" manufactured goods. What does this mean? It means that single individuals can buy one of these additive manufacturing systems. This means that each individual—although, of course, this is the extreme case—will be able produce his or her own goods, such as footwear and clothes, at home and at will. This possibility may have a deep impact. 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 inconceivable that mass-produced goods will stop inundating 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 most probably will play a key role in the building of biological structures, such as human organs, that will change medicine disruptively. The implications go beyond 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 bring more 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 therefore this choice of paradigm is pertinent. Medication is the evolution of whatever 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) cannot even be considered today. For example, today animal species such as whales or bats have the biological function of localization. Would it be feasible to invent (and manufacture) and implant new human organs that can perform such functions? 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?

2.3 Technologies for accessing and managing resources

To begin with let's look at energy: the generation and management of energy, in particular renewable energy, is typically heavily dependent on cutting-edge technologies,. It is a key element for sustainability. 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 part of global greenhouse effect emissions caused by digital technologies is approximately 4 percent of global emissions.[3] In 2030 it may range between 6 percent and 14 percent.[4]

Beyond sustainability per se, 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?

Meanwhile, wise use of digital and manufacturing technologies can be a defining factor for the sustainability of our societies. Such careful use of digital technologies can preclude, in the medium term, greenhouse effect emissions by a projected overall 9 percent by 2030.[5] Proper use of manufacturing technologies, meanwhile, can reduce the quantity of material resources used in manufacturing processes (e.g., additive manufacturing does not "sacrifice" matter, while traditional manufacturing does, taking away and wasting material during the manufacturing process).

Energy is hardly the only resource that might be lacking in the decades to come. Other elements or resources that, for the time being, are assumed to be sufficient—including bandwidth, storage space, and computing resources—might also be lacking. Today, the number of IoT (Internet of Things) devices are counted in tens of billions[6] 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[7]: in 2020, every person on earth is going to produce—on average—1.7 MB of data per second; over the years to follow, this pace of data creation may well increase at a double figure growth rate. Even if these volumes of data can be accommodated by 2020, in terms of storage, processing, and communication, this situation will not be able to continue forever, unless completely disruptive technologies such as quantum computing mature on time. Today, real-world[8] quantum computers are not yet a reality, and the realization of real-world commercial devices is not even a certainty.[9]

Other considerations include "footprint" and the space occupied by IoT devices, and the footprint occupied by 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.

So far, we have not addressed other essential resources such as water, food, clean air, 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. These resources, however, fall much more comfortably in the field of the economy and society—which we will discuss below—as they are only indirectly related to specific technologies.

3. 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

3 https://theshiftproject.org/wp-content/uploads/2019/03/Executive-Summary_Lean-ICT-Report_EN_lowdef.pdf

4 http://www.electronicsilentspring.com/wp-content/uploads/2015/02/ICT-Global-Emissions-Footprint-Online-version.pdf

5 https://gesi.org/storage/files/__DIGITAL%20WITH%20PURPOSE_Summary_A4-WEB.pdf

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

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

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

9 https://spectrum.ieee.org/computing/hardware/the-case-against-quantum-computing

coexistence is the first step toward convergence, as we will analyze below. 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 analyze. Convergence happens in different dimensions.

3.1 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.[10]

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

3.2. 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 the convergence between operations as design, manufacturing, assembly, and testing might be the need for a faster and faster 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**.

3.3. 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" (IoT)—digital and virtual on the one side, real and manufactured on the other—the Internet of Things cannot exist. Meanwhile, the IoT is more and more 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 can allow the optimization of the energy consumption of novel microelectronic devices, thus making possible a steep increase in their deployment.
- Communication technology is making advanced networking techniques—including 5G, but also numerous alternatives such as Lora, Wifi, Bluetooth, and many others—a reality.

Because of 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.

4. Industrial trends

The three technological trends create 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 sake of simplicity in this text integrates both industrial production and service provision activities.

10 One example that illustrates this convergence is security that is materialized by the use of micro and nanodevices. Nanodevices are expected to play a role in protecting persons 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.

(i) The continuous **change and adaptation of the manufacturing paradigm**.

(ii) The **digitalization** of a continuously enlarged 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 and 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 toward those areas attractive for manufacturing: engineering and R&D jobs rapidly moving from Europe and the US toward 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.[11]

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.[12] It is feasible now because several of the required technologies are maturing: 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 allowed frequent and efficient interaction between industrial actors, together with the fast and efficient exchange of data, designs, and images.

Complexification is the result of naturally increasing convergences, as outlined in Section 3, 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, longer and naturally more complex. One example is our complex and multifunctional smartphones, and the digital services associated with them.

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

To illustrate the impact on everyday life of these industrial trends, 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 acceleration of the role of technological and industrial trends in our social and economic lives.

5.1 Impact on the business world

Today, several diseases, in particular cardiovascular diseases (CVDs) and cancers, are becoming chronic, particularly in middle- and high-income countries. Cancer

11 The notion of the digitalization of industry is often perceived differently by different parties. This perception reaches 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.

12 The notion of "Society 5.0" was recently introduced (initially in Japan), and implies the digitalization of all aspects of human life.

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 frequent, 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 amounts 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 the existing economic actors while new economic actors enter the competitive arena. The latter include new companies that produce new types of medical devices and 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.[13]

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 during the 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, which 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 rapidly upgrade 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 (research and development).

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 them. Furthermore, and perhaps more important, 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 locations 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 geographically approach manufacturing units in order to be efficient and attractive to the industry in question, exploiting fast, in situ interactions between manufacturing, engineering, and research. The movement of skilled persons to and economic growth in specific areas and decline in others are the direct economic impacts. Modification of the required skills patterns, and therefore training and education, are also important.

The example of health provided here demonstrates the interrelationship between industry trends and technology

13 https://www.ibm.com/watson-health/learn/artificial-intelligence-medicine

trends (in particular the digital technologies) and societal or economic impact. More interestingly, the improvement of medical technologies is 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 that 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[14] 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 is a clear indicator of the impact of technologies (i.e., the failure of the digital technologies involved to control the aircraft), creating huge risks for an aeronautics giant with a long supplier 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 toward socioeconomic impact could run to pages of text. It is virtually impossible to demonstrate quantitatively this strengthening; its presence, however, is beyond doubt. And data play a key role in that strengthening.

5.2 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 being expanded, 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 areas of the world that have lower labor costs. The same digital technologies that 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[15] set the objective that 20 percent of microelectronics components would be produced in Europe, up on the 7–10 percent figure at the time of her announcement. By 2018, Europe's stake was at only 9 percent.[16] Disequilibrium 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.

14 Hyperspectral cameras, i.e., 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.

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

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

Conclusions

The role played by technology in our society and economy 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 understanding 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 in 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[17]: 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 upon 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[18]) 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 in Section 2, 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 the macroeconomic (i.e., the political) and economic (business) levels.

17 https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs.

18 One credible definition of the term Deep Tech, which 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.