LUISS

Department of Economics and Finance

Chair of Entrepreneurship, Innovation and Technology

Technological innovations, intelligent automation - impacts on economic growth

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Academic Year 2020/2021

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"In the entire field of complex systems the important thing is not the single unit, its the interaction between units, that's where the computation, the complexity, or the novelty is emerging..."

Simon Garnier Professor at N. Jersey Institute of Technology - Director of the Swarm Lab.

Introduction

As society evolves creating progressively more complex systems, also its foundations evolve. One of the driving forces that propel this progress are innovations, the embodiment of the human will to create more efficient and better solutions to problems. Innovations may take different forms, but every new creation that is able to stimulate progress can be defined as innovation, be it a method or a technology or a new way to organise. The complexity of the dynamics that regulate the innovation genesis, diffusion, implementation, and effects has called numerous researchers' attention in the past two centuries. Theoretical complexity has increased over time, probably due to the stratification of knowledge and the growing complexity of society and technology, so it is important to consider how it evolved. One of the focuses of the first part of this thesis is the interaction between economic growth and the development of innovative technologies, as well as trying to define the differences between the creation of a broad knowledge base, scientific discovery, innovations and technological application. One of the main problems when trying to identify the correlations is that economics is a social science, and as such, the interpretation of data is prone to be highly influenced by varying perspectives. Factors altering equilibrium may be attributed to different causes depending on the framework the researcher applies. An analysis examining the dynamics of markets will differ from one including labour organisations, institutional jurisdiction and government policy. Clear-cut conclusions will always foster debate, empirical observation is subject to interpretation. The time scale used by researchers is also an important element to consider. In the short run, the effects of a process can be considered external, while in the long run, the effects impact the economy and need to be accounted as internal to the system. Generally, economic studies tend to create simple models, isolating the most significant variables in order to define theoretical rules, but reality is much more complex. Accounting for all the variables necessary to identify economic fluctuations and their interconnection with innovations is probably beyond current human calculating capacity. The use of big data analysis and A.I. assisted methods improves the reliability of empirical research. Recently authors, such as Coccia and De Meyer, have concentrated their research on the systems that dictate innovation behaviour.

Because of the complexity of such systems, attempting to have a clear view of what innovations are and their effect on the economic dimensions is essential to proceed toward the second part of the thesis: Intelligent Automation (I.A.). One of the major innovations affecting modern society, I.A., embraces different technologies such as part of Artificial Intelligence (A.I.) and Robot Process Automation (RPA). They are entirely revolutionising business methods, jobs dynamics and many other aspects of economic and social life. This innovation is triggering what Schumpeter described as a process of *creative disruption*, probably on a bigger scale than ever before. The last section presents some examples of I.A. implementation with empirical data taken from some real cases.

Chapter 1: Innovation and business cycles

1.1 Learning from the past to predict the future

A characteristic distinguishing human beings from other animals on earth is their capacity to perceive time. Through evolution, forming memories and using them to predict the future proved to be a winning strategy. Humans have used this ability in their activities since the dawn of time.

One critical problem in social sciences, such as the economy, is that predictability is much weaker. This is because natural sciences' experimentally verifiable "hard" data leave the place to experiential "soft" data that depend on ever-changing conditions, not reproducible in a laboratory. Still, there have been scholars who have tried to breach the gap. Amongst them, Joseph A. Schumpeter stands out. He claimed that economics needed an evolutionary and empirical approach to bring it closer to the natural sciences. In his work (1908): *Das Wesen und der Hauptinhalt der theoretischen Nationalökonomie* (The nature and essence of economic theory), he argues that the exclusion of innovation and innovative activities in the circulation of money goods and services would lead to a stationary state, and identifies the entrepreneur as the disruptor of equilibrium and primary cause of economic development through innovation.

In their economic analyses, scholars have approached the past from different perspectives in an attempt to identify the underlying structure of complex scenarios. Even observing purely quantitative indexes such as employment, production levels, and price fluctuations, it became evident that economic activity did not have a linear trend, but rather followed a wave pattern of reiterating economic cycles.

When speaking about economic cycles, it is essential to clarify that the term *"economic cycle"* generally refers to the economic activity of complex modern societies and economies, even if fluctuations in the productive capacity have always occurred. For example, in ancient agricultural economies, crises and depressions followed by periods of prosperity were caused by changing environmental conditions, weather and the agricultural practices applied. Even if these ancient fluctuations in productivity resemble the ones of current cycles, scholars differentiate them from modern economic cycles because they are not generated "internally" in the economic system. The degree of interconnection within the economy of modern societies marking the difference.

1.2 Business cycle theories – some general comments

With the rise of industrialism, economic cycles became an ever-growing topic of debate. The interest in these theories grew during the XIX and XX centuries. Many academics attempted to identify the causes and duration of these cycles in the most precise way possible, trying to predict when and how the next phase would manifest. Here follows a definition from 1946 of the term economic cycle or business cycle:

"Business cycles are a type of fluctuation found in the aggregate economic activity of nations…a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions…this sequence of changes is recurrent but not periodic." (Burnes & Wesley,1946)

Essentially a business cycle is an almost coordinated co-movement in different economic variables, such as income, employment, aggregate measures of industrial production and sales, with a sequence of contractions and expansions over a time period that will vary depending on the approach followed and the parameters examined.

Clèment Juglar was a French statistician and physician and was one of the first authorities to study economic cycles. Already in 1862, Juglar focused on short-range movements, identifying business and commercial cycles with fluctuations of seven to eleven years. His approach focused on the variations of investment in fixed capital and on the levels of employment that followed. He observed that during the rising periods, there were oscillations which he attributed to the variations in inventory levels, these were later to be studied in greater detail by Kitchin.

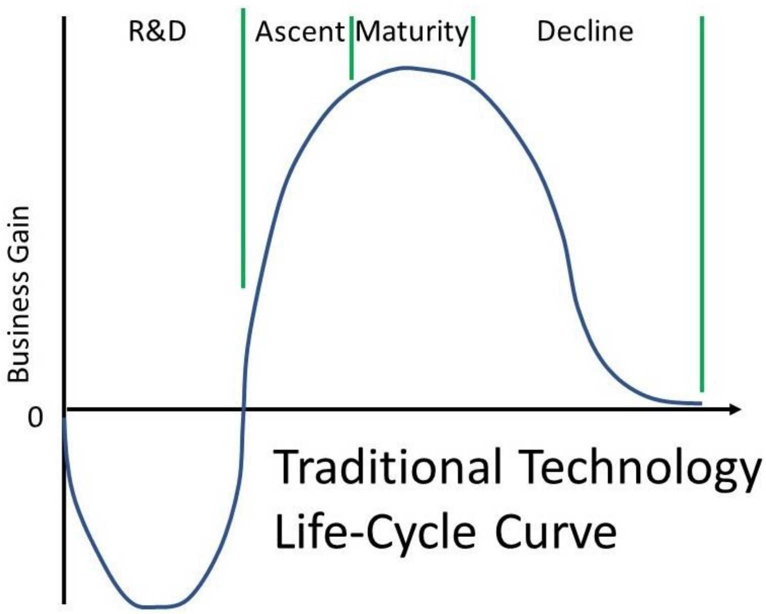
Among the most significant economists pioneering the description of business cycles Kitchin identified cycles with a duration of approximately 40 months, a theory he developed in the 1920s. These cycles focused on the time lag in information circulation in commercial firms and their decision-making process. This produced an increase in the stocks of goods due to the full employment of the available capital, which was seen as fixed in the short term (few months to two years). As price and demand gradually faded away, the increase in production caused an excess in stored goods. The ever-changing conditions took time to be analysed, so the information lag created a decision lag, the time taken by managers to evaluate and adjust production levels. In a similar manner, decreased production created the conditions for a new growth phase. Kitchin's approach observed inventory variation to reveal the dynamics around production and the short term responses to changing market variables faced by firms.

Longer mid-range economic waves were studied and described by Kuznets. They have a range of approximately fifteen to twenty-five years. The Kuznets cycle or swing, was identified in 1930. The author took an entirely different approach from his predecessors, finding a correlation between the economic fluctuations during industrialisation periods and immigration/emigration flows from rural to urban (or agricultural to industrial) sectors of the economy. Kuznets believed inequality would follow an inverse U shape, first growing then decreasing. Critics such as French economist Thomas Piketty argued that inequalities had risen and not decreased, as Kuznets had expected, in most industrialised countries after the 1960s, thus contradicting Kuznets views.

1.3 Kondratiev waves and long term cycles caused by technology

Nikolai Kondratiev was a Russian soviet economist proponent of the NEP[1] and creator of a long-wave economic cycle theory: the Kondratiev waves, also known as Supercycles. He came in conflict with the Stalinist authorities since he did not identify capitalism as necessarily doomed to destruction. Nevertheless, he continued his studies and published but was executed in 1938 during the Great Purge. Kondratiev waves described long economic cycles that lasted forty-five to sixty years, outlining capitalist development patterns. The so-called "K-waves" are usually correlated to the technology life cycles (Table 1). Kondratiev's ideas published in "*The Major Economic Cycles"* (1925) were further analysed in the 1930s by Schumpeter.

[1] New Economy Policy.



(Table 1)[2]

Although K-Wave component causes are still an argument of discussion for scholars,[3] Andrey Korotayev[4] applying spectral analysis[5] to the study of Kondratiev waves, concluded that there was an acceptable level of statistical significance in the data, to sustain that K-waves were mainly caused by renewal cycles of technologies. Furthermore, Korotayev discovered a subordinated class of recurring waves in the Kondratiev cycle, these sub-waves fit three times into the K-wave and are called the harmonics of Kondratiev with a length of 17 years. System theorist Tessaleno Devesaz[6] contributed to the affirmation of the K-wave theory behaviour, a generation-learning model of the non-linear dynamic behaviour of information systems to advance a causal model for long-wave phenomena, such as K-waves.

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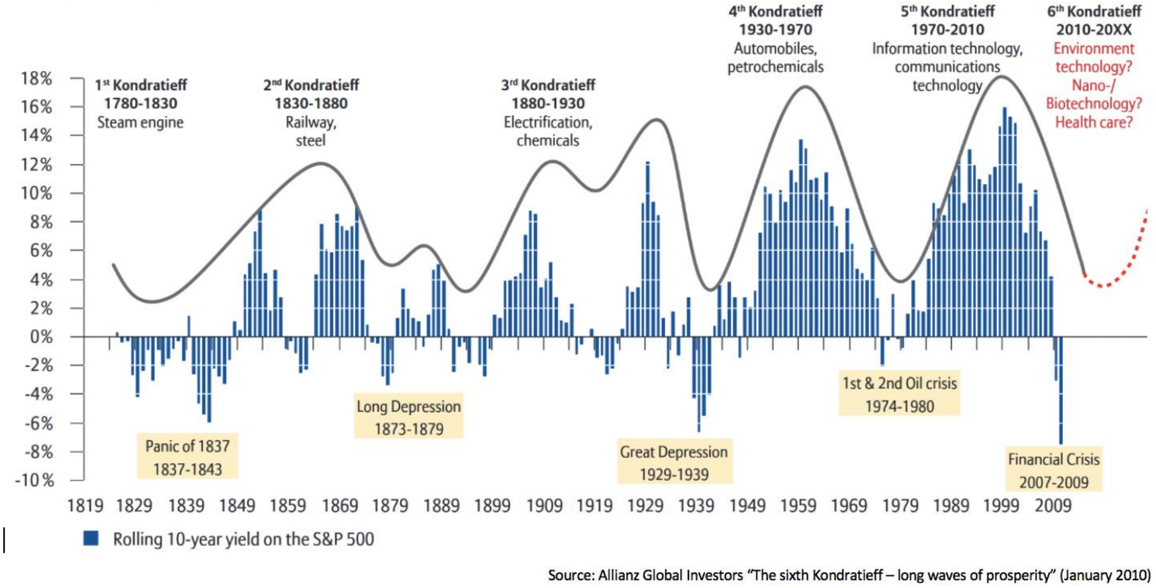
[2] Source: Southard, Steven R. *The Life-Cycle of Technology*. Blog article.

[3] The debate sees factions sustaining K-waves are caused by land value speculations; debt deflation; and demographic booms.

[4] A Russian, economic historian, with major contributions to world-systems theory and mathematical modelling of social and economic macro-dynamics.

[5] Spectral analysis is a mathematical technique that is used in such fields as electrical engineering for analyzing electrical circuits and radio waves to deconstruct a complex signal to determine the main frequencies and their relative contribution. Signal analysis is usually done with equipment. Data analysis is done with special computer software.

[6] A Brazilian-born Portuguese physicist, systems theorist, and materials scientist.



(Table 2)[7]

This table outlines the coherence of the 10-year yield on the S&P 500 index and the entrance of new technologies into the market described by K-waves. Taking into consideration that the 10-years yield is used to monitor the mortgage rates, it probes investors' expectations and sentiment about the market. Changes in expectations and movement of capital from bonds to riskier investments can be seen as a natural response to the introduction of new technology that brings new opportunities and opens the doors to innovative means of production and delivery. These seemingly never-ending cycles that feed on new technologies and other innovations also create the conditions for the constant renewal of debate. As can be perceived already by the few examples cited above, the variety of approaches encompass great differences in scope, methods and timescales. Authors and scholars of different disciplines offer a vast array of possible perspectives when analysing causes and sources of business cycles and broader long-term economic trends.

[7] Source: *The sixth Kondratieff – Long waves of prosperity* by Allianz Global Investors (2010)

1.4 Schumpeter: cycle theories and innovation clusters

Schumpeter took inspiration from the theories of his predecessors, combining their different approaches and exploring the interrelationships between the different types of waves. Following Schumpeter's line of thought, the nature of economic fluctuations is found similar to the behaviour of waves in nature. They coexist in an ever-moving "sea", where instead of energy flows, he finds the transmission of growth impulses to be a key factor. When waves are out of phase, they dampen each other, both in periods of expansion and depression. When they synchronise significant impact on the trend or equilibrium occurs. Schumpeter started developing his theories in *The Theory of Economic Development* (1934). Schumpeter identifies the entrepreneur as the crucial promoter of this continuous-wave movement. Without the push provided by investors, a static equilibrium would soon be reached. The changes introduced by the entrepreneurs, he argues, modify the economic environment, the creation of new products, managerial approaches to production, and the discovery of blue oceans. These generate the conditions for the future phases of the business cycle. Schumpeter implements a dynamic approach to business cycle theory, where conditions are continuously changed by innovations that do not appear in a constant flow. Their introduction is usually concentrated in certain periods of time, this is why he speaks of *innovation clusters,* which give rise to moments of significant renewal and expansion. After the rise, eventually, a new depression comes, bringing the cycle to a new phase of "creative destruction" and a new beginning, completely mutated by the influence of the innovations that characterise it. Schumpeter describes this selective mutation process as *disruptive creation* since many activities will cease to exist through a process similar to natural selection, and many others will be born in the process.

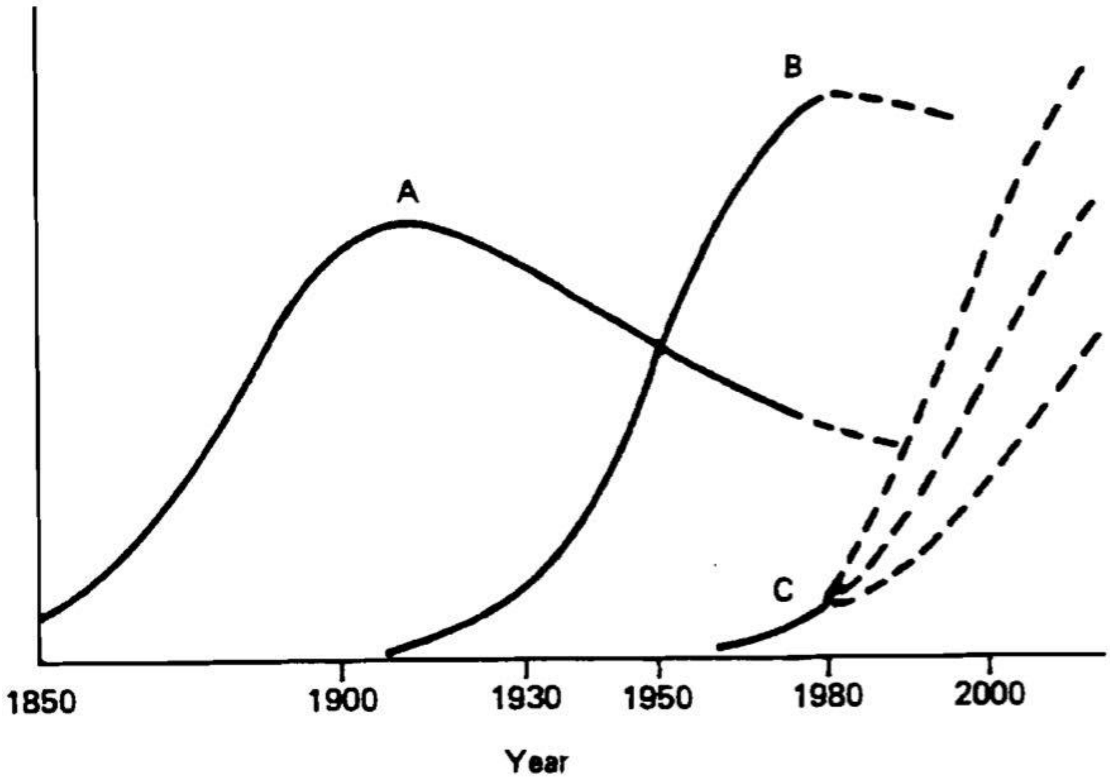
1.5 Industrial advancement, innovation and cycle phases.

The past centuries have seen industrial advancements take off at an accelerating pace. Fueled by the Schumpeterian "innovation clusters", knowledge is accumulated and tested in the first phase of a new cycle. The new ideas generate a proliferation of attempts. Ideas and all the new hypothetical applications of innovations must before be available, then accessible and then financeable to be put into practice. This is called the *embryonic phase*, characterised by a large number of small and medium-sized companies. Big companies participate too, often in collaboration with states and international institutions, they develop the major innovations through their financial means. The proliferation of different attempts generates many methods and proposals that will be naturally selected later on[8]. After the slow start of the embryonic phase, there follows a *phase of accelerated growth*, defined by the progressive concentration of the industry. Those who were able to conquer the market in the first phase are now competing with each other. The products and services show now a tendency to homologation. Unoccupied zones of the market get occupied by more specialised products. In this phase different applications of the original innovations are discovered and implemented, giving birth to secondary innovations. The third phase is the *mature phase,* the market reaches saturation and secondary innovations become more relevant. Growth may still be present, but the pace is considerably slower compared to the previous phase. In Andrè Piatier[9]'s *Long Waves and Industrial Revolution*, an important observation is made, the difference between innovations and renovations. Innovations are the trigger of the industrial revolution, but renovations are the moment when the revolution is spent. Some innovations developed in the long-movement effect of the radical innovation may incarnate the renovation. Alternatively, the secondary innovations may be exploited in their completeness in the successive industrial revolution. The last phase is the *phase of stationarity, decline or death*, the industrial innovation cluster's end. The technologies developed after the innovation cluster may stabilise after some shocks in the equilibrium or may decline at a slow or fast pace.

[8] E.g. all the different projects regarding innovations in the automobile industry, or the different methods initially tested to generate nuclear power.

[9] André Piatier (1914-1991), economist, statistician and social scientist. Appointed by the Finance Ministry to direct France's Institute National de la Statistique et des études économiques (INSEE) after WW2. He also held top level academic research positions.

Logistic curves best represent the four movements of the industrial revolutions[10].



(Table 3)[11]

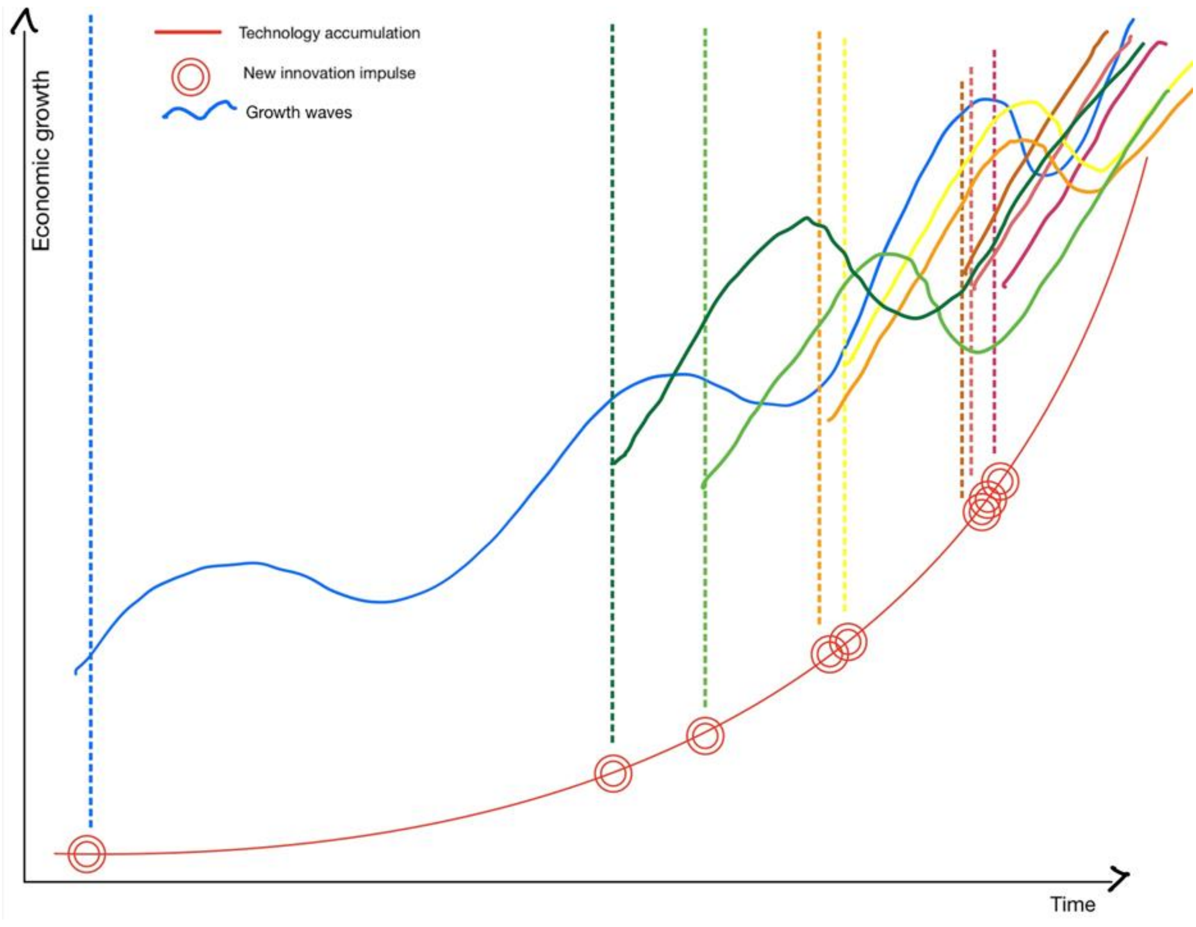
1.6 Long term movements linked to innovation

As stated before, the Industrial Revolution concept cannot be adequately applied to all the great upheavals experienced in human economic history. However, it can generally be stated that innovations are strictly correlated to increases in production and quality of life. Following Schumpeter's ocean wave analogy, It is possible to visualise innovation clusters as the triggers of expansion waves. As an earthquake deep in the ocean generates a long wave, whose frequency and height increase as it approaches the shoreline, the "rise in the seafloor" can be seen as caused by the increasingly rapid accumulation of knowledge and newly implemented technologies during time.

The following table describes how innovations produce expansion waves. During periods of growth, new technologies are implemented, raising the technology accumulation curve. Since

[10] S-shaped curves that represent an exponential function used in mathematical models of growth processes.
[11] Source: *Long Waves and Industrial Revolutions* Conference proceedings, extended paper: Andrè Piatier (1984)

the interaction between innovations and technologies is a virtuous cycle, the shape of the curve is exponential. New technologies bring new means to improve life, do research and understand reality, so that more innovations can be introduced. Each important innovation generates its own wave because of the consequences it brings to the economy. Since capitals will be invested in the more promising innovations with the highest potential returns, the embryonic ideas will travel under the surface, waiting for the cycle phase where entrepreneurs actively search for new opportunities. This may be one of the causes for the clustering phenomenon described by Schumpeter.

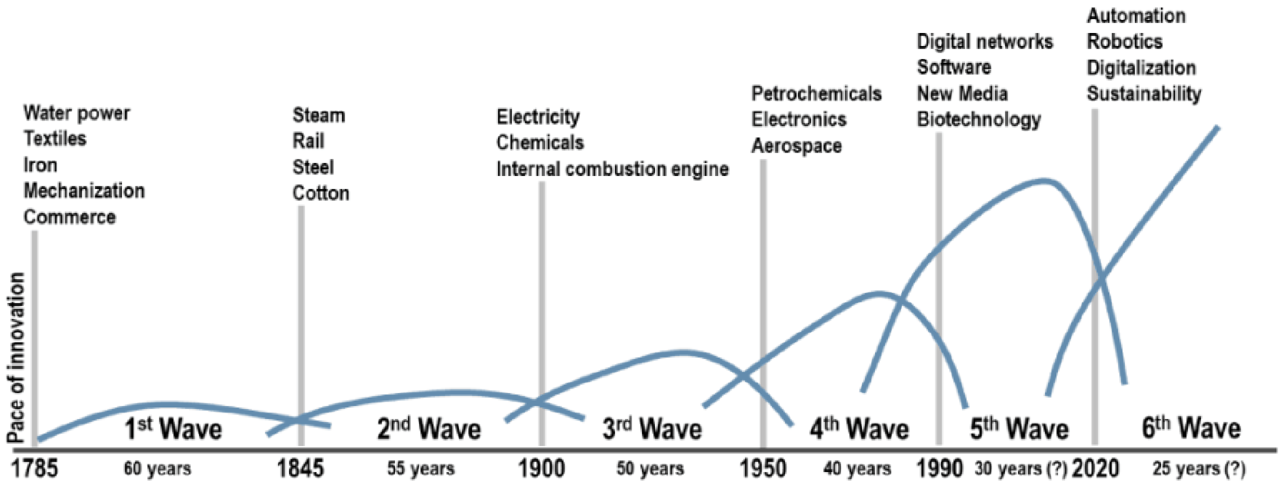


(Table 4)[12]

The late XX century and the XXI century are showing faster cycles compared to the past. Technology renews faster and faster, probably breaking the time scales predicted by the

[12] Source: original

Kondratiev cycles, the growth waves are shortening. Technology never saw a growth comparable to the one of modern days, the exponential trend is showing its acceleration, and the waves are displaying increasingly accelerated movements,



(Table 5)[13]

I.T.[14] technologies are accelerating every aspect of human life, including the economy, the information gap is almost non-existent. Therefore, the reaction time at disposal to stem the waves is also reduced.

Many innovations have occurred during history, and as time goes on, it is possible to analyse and study the changes that have occurred. Innovations impact almost all fields, and it would be impossible to cover all of them.

According to Carlo M. Cipolla,[15] the first "cluster" of game-changing innovation that upgraded the human quality of life in a most significant way was animal husbandry and the cultivation of plants, or in other words: the harnessing of solar energy to produce animals and plants in a controlled manner. The transition from hunting and gathering allowed to sustain and stabilise a constant food production, generating the conditions for the population's growth and stable social structures. Continuing to consider agriculture, one of the most relevant methods introduced during the middle ages implied the use of iron to make improved

[13] Source: *The Geography of Transport Systems* fifth edition by Jean-Paul Rodrigue

[14] Information technology

[15] Italian historian specializing in economic history, author of the book *The Economic History of World Population* an analysis of modern society development and the connection with number of men and disposable energy.

ploughshares. The clearing of more land for cultivation resulted in an extended period of economic expansion that created the basis for society and economy as it is known today. Even in periods of human history that have been described as stagnant and “dark”, innovations have influenced growth, laying the foundations for long waves of expansion.

Still, the acceleration of rhythms also increases entropy, generating chaos, the disruption of ecosystems with the depletion of natural capital poses new limits, climate change is forcibly irrupting in the economic scenario, economic theory faces new questions: is exponential growth in a closed system possible in the long run?

Chapter 2: Innovation and technology

2.1 Invention and innovation

These two terms often overlap semantically in ordinary language use, but an important distinction between the terms *invention* and *innovation* has become generally accepted, the Cambridge dictionary defines as follows:

- *Invention: is either something that has never been made before, or the process of creating something that has never been made before.*
- *Innovation: is the use (implementation) of a new idea or method (invention).*

Seen in this way, invention and innovation are two terms that are interconnected but quite distinct in nature.

Inventions are the main underlying base enabling technological development and social evolution. In an article in the Encyclopaedia Britannica, James Burke defined invention as: *"the act of bringing ideas or objects together in a novel way to create something that did not exist before".*

Still, the mere creation of something that previously did not exist does not by itself determine whether it will have an impact on society. An invention needs to be spread and implemented in the industrial processes or, more generally in people's lives, to accomplish its purpose and become an innovation. Innovation is intended here as an invention implemented and used on a broad scale.

Innovation is a fluid concept, entrepreneurs, inventors, technicians, consumers and anyone coming in contact with it may all have different perceptions concerning it. Although the concept is abstract, the impact innovations have on reality is more than tangible.

Sometimes the two figures of the inventor and the entrepreneur may coincide, the same actor will then find viable ways to implement the invention. If the inventor does not personally have the ability to convince people of the advantages of his invention, or the resources to forward its introduction, it is likely that a third party with technical, marketing and financial capacities, such as an entrepreneur or an institution, will take over the process of transforming the invention into an innovation.

Creativity is the mental process that humans carry on to produce novel ideas, the process by which inventions are generated, it is also the indispensable starting point of innovation. Authors such as Rosenfeld and Servo (1991) identify creativity as the fundamental element of the entire process leading all the way up to innovation. In this view, creativity is a process that could just as well be termed inventiveness. A possible variable defining when and where the invention will transition into an innovation could perhaps be termed "implementation".

Martin (1994), Von Stamm (2003), and Roberts (1988) found that the missing piece bringing about the transition between invention and innovation, the minimum common denominator, is the exploitation of the new idea to create a product or method that becomes something tangible and marketable, concluding that:

Innovation = invention + exploitation

" The innovation therefore can be broadly viewed as the systematic approach to create an environment based on creative discovery, invention and commercial exploitation of ideas that satisfy unmet needs" (Bacon & Butler, 1998)[16]. It could be said that these studies examine the positive, constructive, aspects of the "creative destruction" theorised by Schumpeter.

At large, innovation encompasses a pool of good and bad ideas, all of which eventually cumulate despite positive or negative single outcomes, bringing about collective growth. This view avoids a strict interrelation between profit and growth. It is then possible to argue that even the know-how produced by unsuccessful innovations contributes to growth, the *"knowledge pool"* accumulated while failing deepens the understanding of what works and what does not. In other words: only trial and error can reduce the waste of resources on faulty ideas or products, improving competitiveness in the long run.

In his work *Long waves and industrial revolution,* André Piatier[17] examines the whole phenomenon of invention and innovation, pointing to the usefulness of a dual approach when analysing innovation: on the one side examining it as a *process* and on the other as a *result*.

[16] Rosenfeld & Servo; Martin; Von Stamm; Roberts; Bacon & Butler. All mentioned in: *Understanding Innovation: A review,* Arpita Metha, 2013, Metha Enterprises, India. Course material.

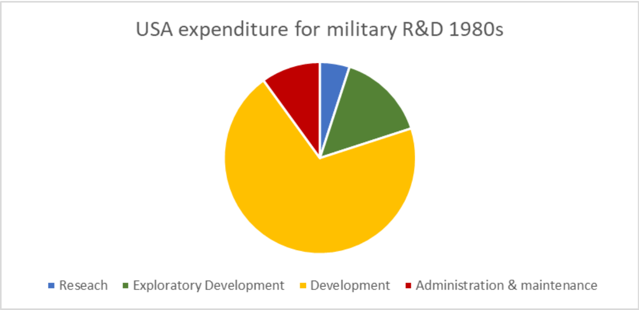
[17] *Long Waves and Industrial Revolution* Conference proceedings, extended paper: Andrè Piatier (1984).

In his analysis, innovations are often viewed as a succession of intangible risks: concerning the idea, feasibility, reproducibility, diffusibility, adaptability, price, reliability and final quality.

2.1.1 The *process* side of innovation

In Piatier's view of innovation as a process, the first step needed is to accumulate knowledge through scientific research. The scientific process in its entirety aims at knowing and understanding (primary research) but also at putting the discoveries into practice. Without the practical possibility of applying the knowledge, the scientific output will not be considered part of the innovation process. R&D follows a series of steps through which the innovation is developed. The process is complex and may require many attempts and setbacks. There are trial and error loops with returns from technology back to science and from industry back to technology. This is the phase where most tests (and inputs) are required. Piatier observes that the cost structure of technological advancement is often perceived in a skewed manner. In almost all cases, only a very small portion of total capital goes to research proper, most of the investment going to the subsequent phases of development leading to the final "*mature*" implementation. Here is an example of the expenditure structure from an efficient government-supported innovation program active since 1945: USA – overview of military R&D program:

- 5% for Research.
- 10% for exploratory development.
- 70% for development.
- 10% for administration and maintenance.



(Table 6)[18]

[18] Data source: *Long Waves and Industrial Revolutions* Conference proceedings, extended paper: Andrè Piatier (1984)

2.1.2 The *result* side of innovation

Piatier observes that innovations are becoming more complex and interrelated. Innovations supported by increasingly versatile technologies can expand their utility to different fields with greater ease, no longer constrained to the sector where they were initially conceived. This explains why Piatier considers earlier ideas of innovation propagation (e.g. Schumpeterian models of "creative destruction") as surpassed. Piatier tries to identify more sophisticated evaluation criteria necessary to describe structured innovation. Separating the *result* side of innovation as an independent analytic entity allows for more precise differentiation of different types of innovation, such as: a new product, machine, technique or new managerial method. Some innovation evaluation criteria he introduces are:

- *Technological impact level*: e.g. trivial, normal, radical.
- *Degree of novelty*: regards the newness of the new process or product, if it is already diffused elsewhere or entirely new.
- *Extent*: product or process is entirely new or if the innovation upgrades older products.
- *Tangibility*: if the innovation is visible or invisible, visible when there is a concrete new product, invisible when the innovation increase the efficiency of something, e.g. lower petrol consumption.
- *Application*: the innovation regards the product or one of the inputs in the production line, e.g. a new metal alloy to produce existing objects.
- *Transferability*: the capacity of an innovation to disseminate into different sectors from the initial one.

Piatier had acquired significant experience in government level economic policy formulation and the use of "*hands-on"* empirical methods of statistical analysis. (methods he had contributed to develop). He knew that statistical analysis had been constructed based on relatively stable clear-cut industrial sectors. Directing France's *Institut National de la Statistique et des études économiques* (INSEE) in the post-war period, he understood that these methods were rapidly becoming obsolete. For this reason, he suggested more refined evaluation concepts and methods in his academic works. New technologies were becoming so versatile and with such a high degree of transferability that the industrial environment became increasingly interconnected and integrated. Digitalisation would bring an unprecedented acceleration to this transformative process.

As mentioned above, creativity, inventions, innovations, and all the pertaining processes involved, have been studied and analysed from a vast array of different perspectives highlighting the need for more sophisticated instruments of analysis.

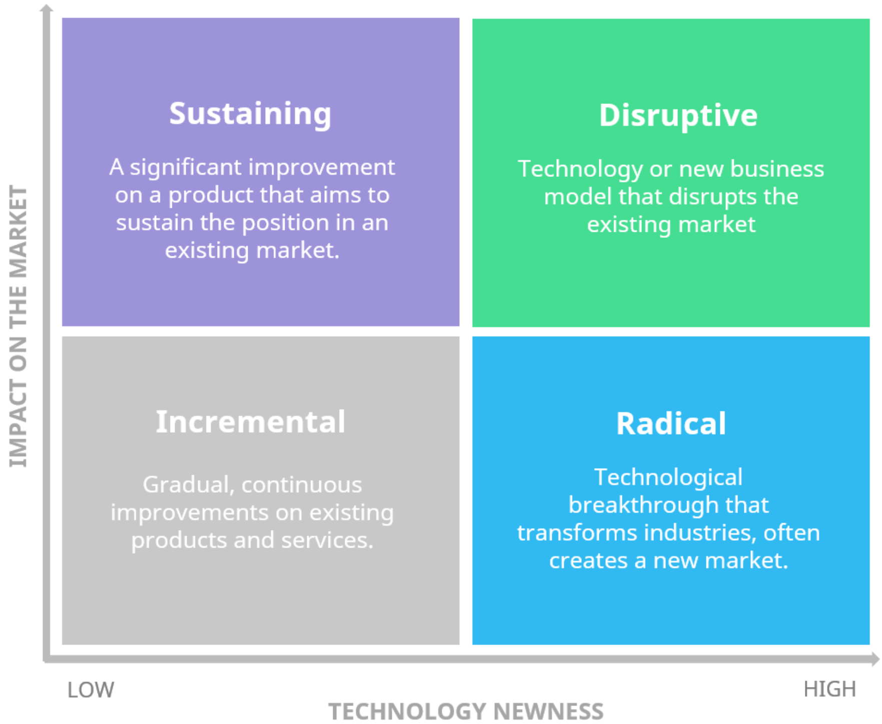
"*Innovation is the process through which productive resources are developed and utilised to generate higher quality and/or lower-cost products than had been previously available. (…) Innovation requires the visualisation of a range of potentialities that were previously hidden and that are now believed to be accessible. Thus, innovation strategy is in its essence, interpretative and therefore subjective, rather than rational and objective*" (O'Sullivan, 2008)

It is safe to conclude that inventions and innovations have become an increasingly crucial aspect of economic activity. This was well understood in the USA. In 1945 Vannevar Bush, scientific advisor to USA President F.D. Roosevelt coined the term "*the endless frontier*"[19] in a ground-breaking and comprehensive report which identified science's crucial role in economic growth and strategic security. In the report, Bush clearly indicated the fundamental importance of Government supported, stable, long-term R&D investment programs.

[19] Vannnevar Bush, engineer, inventor and administrator became responsible for Army R&D during WW2, he was the first Science Advisor under F.D. Roosevelt's presidency. He initiated the Manhattan Project, obtaining top priority from the highest levels of government. As director of the Office of Scientific Research and Development he wrote a groundbreaking report: *Science, The Endless Frontier – a report to the President*, 1945. In it Bush called for an expansion of government support for science, pressing for the creation of the National Science Foundation.

2.2 Types of innovations

One way to distinguish innovations types is a matrix with two dimensions, the market and the technology.



(Table 7)[20]

2.2.1 Incremental innovations

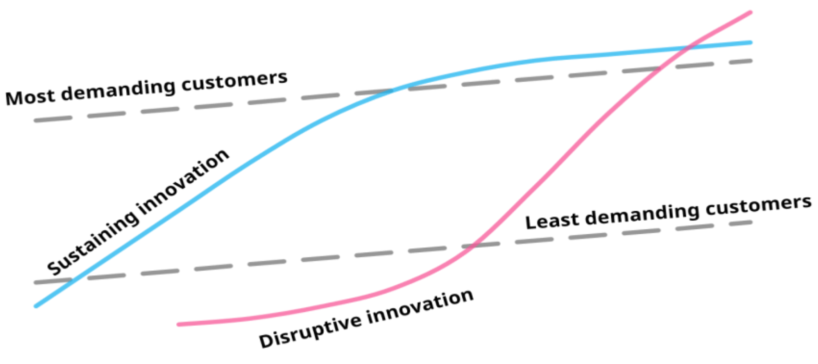
Incremental innovations improve to some degree previous products and services, they do not necessarily have a significant impact because of the minor improvements they bring. They do not create new markets and are often easy to sell because customers are familiar with the features they bring. On the other hand, this kind of innovation may allow firms to create market segmentation in which high demanding customers purchase the higher-priced/featured/new products or services, and mainstream customers may find their needs satisfied with basic or older products. Incremental innovations are also very often influenced

[20] Source: *Types of Innovation – The Ultimate Guide with Definitions and Examples*, Viima article, by Julia Kylliäinen

by customers' opinions and feedbacks. Therefore, firms should not only focus on incremental innovations due to the menace of disruptive innovations that may conquer the market.

2.2.2 Disruptive innovations

The disruptive innovation concept has been defined by Clayton and Christensen and their collaborators starting from 1995[21]. Christensen suggests that managers should not ignore new technologies that do not yet meet the needs of mainstream customers. In order for corporations to survive, they must be willing to let some of their divisions die. Disruptive innovations create new value networks by creating new markets, blue oceans, or by invading existing markets. This kind of innovation appeals to early adopters and not to mainstream customers. Initially, new technologies do not show their potentialities, existing ones perform better, but later they prove themselves to be way more efficient and better performing. In the *Innovator's Dilemma*, Christensen describes the dilemma of incumbents who have to choose what to focus on: improving existing technologies' performances or focusing on the R&D of new technologies. The latter exposes capitals to a higher risk of failure since the older technologies have proven to work. Incumbents are often not able to surf the wave of innovation, new entrants become the ones that take advantage of the conditions that are mutating and are able to conquer significant portions of the market.



(Table 8)[22]

[21] Joseph L. Bower and Clayton M. Christensen, *Disruptive Technologies: Catching the Wave*, Harvard business review article, 1995, the idea was later developed in the book: *The innovator's dilemma*.
[22] Source: *Types of Innovation – The Ultimate Guide with Definitions and Examples*, Viima article, by Julia Kylliäinen

2.2.3 Sustaining innovations

Sustaining innovations improve the existing value network and are the opposite of disruptive innovations. The advanced technology is applied to existing products and continues to add value to them, satisfying the most demanding customers. Established firms often rely on sustaining innovations because of the low-risk, high-profit ratio. This kind of innovation allows established firms to strengthen their market position, with a growing trend that gradually slows down. Generally, capitals are attracted to this low-risk model until a disruptive innovation does not become more profitable.

2.2.4 Radical innovations

Radical innovations, the rarest kind of innovations, introduce significant changes and bring new technologies flanked by new business models. In general, these kinds of innovations address needs that are still not evident to people and completely revolutionise the market.

"radical innovations represent technical advance so significant that no increase in scale, efficiency, or design can make the older technologies competitive with the new technology" (Tushman & Anderson, 1986)

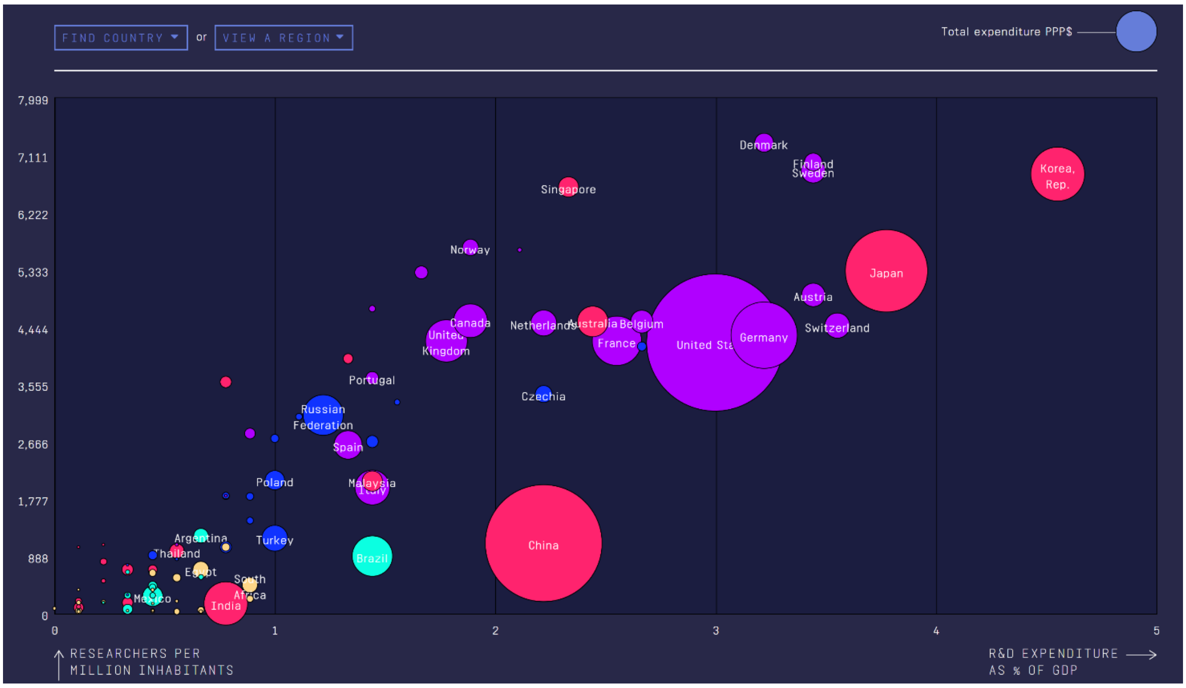
2.2.5 User-driven innovation

User-driven innovations have been described by Eric Von Hippel (1979). This kind of innovation is manifesting more often thanks to the internet and the possibility of forming communities or groups that are sometimes able to produce exceedingly complex products or services, even without any manufacturer involvement.

2.3 Global view of R&D expenditure

Who is providing the resources for new cycles of innovation?

The amount spent in R&D in the world has reached approximately 1.7 trillion, however, 80% of the global spending is attributed to the activities of ten countries. The following table shows the data collected by the *UNESCO Institute for Statistics* (UIS) that monitors the progress towards achieving the *Sustainable Development Goals* (SDG).



(Table 9)[23]

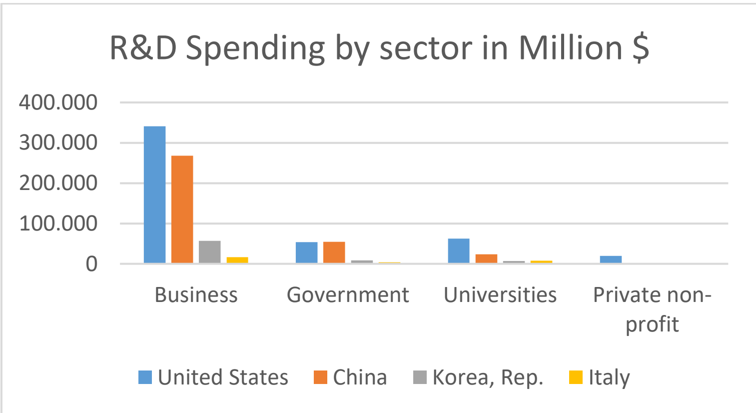
This table presents the R&D spending by country relative to the percentage of GDP invested, researchers per million inhabitants and total expenditure converted in dollars at the PPP$[24] rate. It is clear that the higher the density of researchers in the population, the higher is the percentage of a country's GDP spent on research and development.

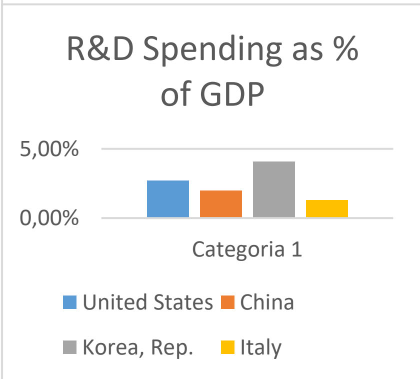
The following graph describes the top 15 R&D spenders of the world in terms of percentage of GDP and in terms of Billions of dollars spent, with the brighter inner circle accounting for the amount spent by the businesses over the total expenditure.

[23] Source: *How much does your country invest in R&D?*, UNESCO Institute for Statistics (UIS)
[24] Purchasing power parity in USD

(Tables 10 and 11)[25]

Here follows a comparison of four states: the United States, China, Republic of Korea and Italy. As can be seen in these graphs, ROK[26] is the country with the highest R&D/GDP ratio while the United States have the highest dollar expenditure. *Table 9* represent numerically *Table 7* to make visible data for all the sectors.





	United States	China	Korea, Rep.	Italy
Business	340.728	267.652	57.180	16.688
Government	54.106	54.720	8.186	4.001
Universities	62.349	23.894	6.614	7.863
Private non-profit	19.275	0	1.108	0,894

(Tables 12, 13 and 14)[27]

It is important to underline that the UNESCO tables do not consider the time dimension and thus do not show countries' spending and result trends. The image shows the relative

[25] Source: *How much does your country invest in R&D?*, UNESCO Institute for Statistics (UIS)
[26] Republic of Korea
[27] Data source: *How much does your country invest in R&D?*, UNESCO Institute for Statistics (UIS)

positioning of countries, and in some respects, Cina does not appear to be doing too well. However, the figure does not say much about the results of the human and financial capital invested in R&D. We see the input side, but what matters are the end results produced by the expenditure. Cina places second after the U.S. in total spending, but as far as the results of R&D, if the number of patents produced is compared, China registered 530,000, while the U.S. registered 399,055 patents in 2020. One of the causes could be that the Chinese almost double the average 35-45 work hours per week of other industrialised countries. Especially in the tech industry, the so-called 996 rule means that Chinese employees work an average of 72 hours a week (from nine to nine six days a week). This is forbidden according to Chinese law, but most companies continue to practice it in various forms. It can be argued that burning out employees is not a good strategy, but firms have more than 30 applicants for every position in the company, so no complaints are tolerated. The government goal is clear: world dominance in the A.I. sector before 2030.

2.4 Innovation in management to support innovations

Innovation embraces all the dimensions of business, including obviously, also the managerial side of activities. Anoud De Meyer[28] , with his colleague Peter Williamson,[29] discovered that some companies were innovating in an entirely new manner, different from the traditional one. For example, they noticed that ARM Holdings[30], located in Cambridge, has 98% of the market share in a particular type of cell phone microprocessor, but it still remains a small company (4892 employees) for its leadership in the sector. Furthermore, they noticed that in the area, there is a network of companies that synergically work together to innovate, these companies are independent and not controlled by other firms. They concluded that companies that form this kind of network are well-organised even though no entity controls the processes. By allowing a high degree of freedom in the structure of industries, it is often the case that the creativity and contribution of the partners are not constrained so that co-innovation may happen more efficiently. According to De Meyer and Williamson, the two key factors are that companies were able to provide flexibility to the industrial environment, an essential component of innovation, and co-learn as a group. Flexibility and co-learning may bring significant potential advantages compared to structures that are vertically integrated. ARM's network, for example, has a mixture of official and unofficial relationships between its components, with the purpose of creating knowledge. Remarkably enough, the incumbent in this situation welcomes new entrants into the network. According to the authors, it is a trade-off, vertically integrated organisations may excel in efficiency and productivity, but these ecosystems are much more suitable to support innovations and new businesses in circumstances characterised by uncertainty and complexity.

"This potential has already been proven in high-technology industries. In the future, more and more industries will be subject to the forces that favour ecosystem strategies over those that either concentrate activities into vertically integrated organisations or rely on traditional outsourcing." (De Meyer & Williamson, 2012)

[28] President of Singapore Management University

[29] Honorary professor of International management and Director of studies in management at Jesus College University of Cambridge Judge and Business School

[30] Industry: microprocessor and Graphic Processing Unit Design; Revenue of 1.69B. Data of 2018

2.5 Technology

Another critical aspect of social advancement is technology. It represents the practical application of all the discoveries brought by inventions and innovations. The definition given by the Cambridge dictionary for technology is:

- *Technology: the study and knowledge of the practical, especially industrial, use of scientific discoveries.*

Economist Mario Coccia provides a more detailed explanation concerning technology and innovation:

"... New technology is driven by inventions of new things and new ways of doing things (originating in advances in basic and applied science) that are transformed into usable innovations in markets to satisfy needs, achieve goals, solve problems of adopters that take advantage of important opportunities, or to cope with consequential problems/environmental threats… An Innovation is the initial market introduction of a new product or process whose design departs radically from past practice" (Coccia, 2019)

Thus, technologies can be seen as the means by which scientific discoveries become innovations and are implemented in society. Coccia outlines the steps describing this process in this way:

1. *Problems/opportunities.*
2. *Inventions.*
3. *New technologies.*
4. *Usable innovations.*
5. *Effects.*
6. *New problems/opportunities.*

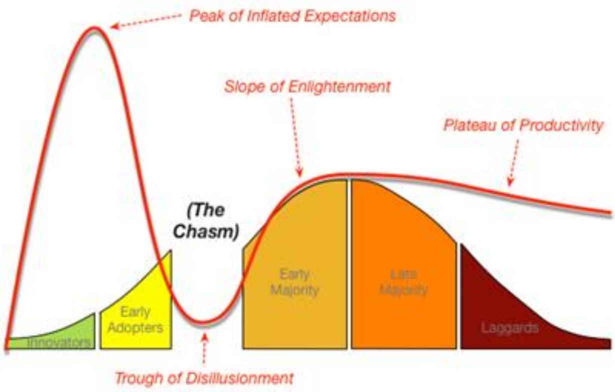
Economist Mario Coccia, a member of CNR, Italy's National Research Council, devoted his research to the analysis of technological development and its structure, more precisely, he explored how technology evolves and interacts with innovations and other technologies, creating the conditions for significant socio-economic changes in modern society. In his works, exploring how technology and innovations are tied to one another, he often refers to his subject of study as "*technological innovations*". Technological innovations are described as a macro group containing different typologies ordered by their degree of impact on the socio-economic environment. In a certain way, Coccia's categorisations broaden the horizon of the previously mentioned innovation types by adding to the *incremental* and *radical innovations* two other categories: *technological systems* and *technological revolutions*:

- *Radical innovations*: a drastic change in existing products/processes, the creation of something new that addresses a significant need.
- *Technological systems*: a cluster of technically and economically inter-related innovations, e.g., nanotechnology or biotechnology.
- *Technological revolutions*: pervasive changes in technology affect many economic branches that have a technological dynamism and are used in a wide range of sectors.

Following Usher (1954), Coccia argues that the need to solve problems triggers technological innovations. The genesis of technological innovation follows these steps:

1. *Perception of the problem.*
2. *Setting the stage.*
3. *Act of insight.*
4. *Critical revision.*

Having described the genesis of technological innovations, Coccia then proceeds to outline how the diffusion of technological innovation takes place. According to him, it mainly depends on how the members of a particular socio-economic group adopt the innovation. Rogers (2003) suggests that adoption is influenced by four elements: the type of innovation itself, communication channels, time, and social system. The categories of adopters are: innovators, early adopters, early majority, late majority and laggards. Between early adopters and the early majority, there is often a gap called *chasm*. It corresponds to the moment in which the peak of inflated expectation collapses, leading to disillusionment, which is then rebalanced by more realistic expectations. Rogers is also the creator of the innovation diffusion theory and its terminology, as presented in *(Table 15).*



(Table 15)[31]

In 2005 Coccia suggested that the diffusion of technologies had a pattern similar to that of seismic waves. He applies a method similar to Mercalli's scale that defines the earthquake's intensity based on the impacts on the geographical environment. Coccia's seismic approach instead focuses on the effects reported by subjects, objects, and society as a whole, after introducing technological innovations.

The scale of the intensity of the diffusion of technological innovation in society. (Coccia, 2005).

Innovation degree	*Intensity of the impact of diffusion*	*Type of technological innovation*	*Examples*
1	*Lightest*	Elementary, micro-incremental	From black to red rollerball
2	*Mild*	Incremental	Progressive lenses
3	*Moderate*	Minor radical innovation	Contact lenses
4	*Intermediate*	Major radical innovation that affects different industries	Laser
5	*Strong*	New technological paradigm	Television
6	*Very strong*	New technological system	Satellites
7	*Revolutionary*	Change of techno-economic paradigm	Electricity; information and communication technology; artificial intelligence

(Table 16)

[31] Source: *Technology-adoption, technology-evolution and lifecycle-management.*

2.5.1 Technology evolution

(Is an) *"Advancement of a complex system of artifact, driven by interactions with subsystems and other technological systems, considering scientific advances, technical choices, and technical requirements to achieve specific goals in society. (…)to satisfy increasing needs of people and/or to solve complex problems of communities, businesses, and countries, supporting human progress."* (Coccia, 2021; Sahal, 1981.)

Among all the theories that describe technological evolution, there is the traditional idea that technologies evolve through substitution. Coccia, on the other hand, introduces a more complex theory he calls "*technological parasitism"*. He states:

"technologies and technological innovations evolve by interacting with other technologies / innovations…" (Coccia, 2019).

This theory sees the interaction between technologies and innovations acting on multiple layers or nodes, offering a richer analytical framework. According to Coccia, new technologies are unable to exist, develop and function independently from other systems and therefore assume a behaviour that can be defined as parasitic, where the old technology is often the *hosting or master organism*[32]. A parasitic technology within a host or master technology creates a complex system leading to co-evolutionary processes forming complex systems. Coccia sustain his theory by providing some observations on the evolution of technologies, he breaks down the main properties of the evolution of technologies and technological innovations as follows:

1. *Theorem of not being independent of any technology:* especially in the long run, technological innovations' behaviour and evolution are not independent of the behaviour of other technological innovations.
2. *Property of mutual benefice between technologies:* technologies interacting with each other create virtuous cycles, producing reciprocal adaptation and catalysing the overall advancement.

[32] E.g. audio headphones, speakers, software apps, etc. that function if and only if they are associated with host or master electronic devices, e.g., smartphone, radio receiver, television, etc.)

3. *Rapid evolution driven by manifold technological parasites*: observation driven data suggest that technologies hosting numerous parasites, or more complex systems characterised by interaction, sustain a more rapid evolution of Parasitic technologies, while, on the other hand, more simple systems, with low levels of interaction, improve slowly over time.
4. *Asymmetrical shape of the technological cycle:* Technological evolution of innovation has an up-wave phase (in years, months, or days) longer than the down-wave phase (Coccia, 2020).

The professional profiles of the writers and researchers cited and their approach show clearly how vital it is to have a broader view when trying to identify the rules that regulate complex systems. Many of them have specialisations spanning several fields and, as a consequence, tend to study concepts and events with interdisciplinary approaches, taking into considerations how the micro is part of the macro, and as such, it is influenced by many other factors that are invisible to the microscope but apparent to the naked eye. Just as in the case of ARM Holdings, studied by De Meyer and Williamson, Coccia's description of the parasitic behaviour of technologies can be understood by considering the networking environment as a whole. This type of approach is conquering an increasing number of fields and changing roles and rules. For example, from the business management perspective, it is producing an ever-growing demand for eclectic professionals figures such as the growth hackers, who are not specialised in only one field but are able to consider situations in many dimensions at the same time as an interactive system.

The dynamics concerning the interaction between complex systems, like those that regulate inventions, innovations and technologies, are constantly evolving at an accelerating pace. Now more than ever, thanks to modern technologies, it is possible to consider and observe a systems' nature from a holistic and complementary point of view. Artificial intelligence, generational algorithms, chaos theory mathematics and big-data methodologies are able to find patterns in data that are too hard to identify for humans, opening the doors for new frontiers. Bush was right when he declared that science was the land that would never be entirely conquered since it was the only land with an *infinite frontier*.

Chapter 3: Artificial Intelligence and RPA

3.1 The impact of A.I. and RPA

3.1.1 A.I. definition

The term Artificial Intelligence was coined in 1956 by John McCarthy, He defines A.I. as:

The science and engineering of making intelligent machines

The modern definition of is:

The study and design of intelligent agents

Systems that perceive their environment and perform actions in order to maximise their probability of success are called agents. A.I. generally indicates machines performing human-like cognitive activities[33]. Among all the innovations that are being developed, A.I. is one of the most relevant. Almost every field is involved, from agriculture to e-government, banking and medicine. The possibilities that intelligence enhanced computer systems can provide are almost limitless. The countries investing the most are United States, China and Japan, holding together 78% of all A.I. related research. The economic impact of such technologies is predicted to be massive. Due to the creation of a virtual workforce that can work non-stop flanking humans, the increase in labour productivity will revolutionise the current way to carry out business and work. A.I. will probably be the main engine of the 6th Kondratiev wave, starting the 4th industrial revolution.

3.1.2 Data

By now, entrepreneurs, organisations and governments clearly understand that data is the new gold. Entrepreneurs initially used digital technology to enhance marginal efficiencies in the existing production systems, but the increased capacity to process data began to affect all sectors, often in unexpected ways. For example, product personalisation became suddenly

[33] E.g. Understanding, reasoning, interacting, creating.

feasible, offering customers greater choice and businesses the ability to extract more value from every purchase.

The symbiosis between the data generated by pervasive digitalisation, the internet (of people) and now the Internet of Things (IoT), summed to the ability of A.I. to organise and process vast amounts of data, has disruptive effects, transforming the very nature of business. The explosion in the quantity and quality of available data rapidly turn existing business models obsolete. The digitalisation of processes and products has generated a scenario of unprecedented rapid transformation. Access to tools, capable of processing the immense quantities of information produced (Big Data Analytics BDA), has become a strategic asset, essential to implement informed strategies in the ever-changing conditions. Expert systems are gradually becoming more capable of evaluating enormous data sets, and A.I. systems are being applied, attempting to provide answers, or at least to pose some relevant questions.

Sometimes even enterprises that have been leaders in the transformation struggle to keep up to the pace. For example, Altan Yazar, a Senior Engineer at Apple, stated in a conversation: *"We have become very good at delivering cutting edge tech-consumer products, collecting enormous amounts of data in return, yet, often we are at a loss as to what we could or should do with all of this…."*

A fundamental problem is that the direction of change is often unfathomable. This is a challenge even for education. For example, a report from the U.S. Department of Labour predicts that 65% of the children now in school will be working in jobs that have yet to be invented.

3.1.3 Jobs

Machine learning is improving its capacity to react to external dynamic stimuli, while robotics provides the machine tools needed to interact with the material world, radically transforming production.

On the other hand, there is growing fear of significant negative impacts on the labour market, producing a wage shock and reducing labour-force demand. The less specialised fraction of the workforce probably will suffer a spike in unemployment, as it is already happening. Ian

Barking[34] foresees that five hundred thousand jobs in the United States will be replaced by RPA alone in the next five to ten years.

The optimistic narrative sees innovations as freeing the human workforce from tedious, highly repetitive tasks allowing them to carry out more value-added jobs. However, this implies that there are enough high-quality creative tasks to engage all the labour force freed from tedious tasks and that all the labour force has the capacity to adapt to the new creative mansions required rapidly. Otherwise, "freed" could easily become synonymous with "fired". This poses severe ethical and socio-political issues.

Makridakis[35], the founder of the homonymous competition[36], argues that almost 60% of available jobs can, potentially, already be substituted by automation. Furthermore, he thinks RPA and Artificial intelligence will outperform human labour by 2033 and that 47% of jobs will be automated by that year.

A.I. generates innovations but raises questions and perplexities. Prominent figures such as scientist Stephen Hawking and entrepreneur – inventor Elon Musk have publicly expressed their concerns regarding advanced Artificial intelligence impacting humans negatively.

"A.I. could spell the end of the human race."

Stephen Hawking (2014)

[34] RPA specialist and innovator

[35] Professor of the University of Nicosia UNIC where he is the Director of the Institute for the Future (IFF) and an Emeritus Professor of Decision Sciences at INSEAD as well as the University of Piraeus and one of the world's leading experts on forecasting

[36] Competitions to evaluate the accuracy of forecasting methods

3.2 A.I.

3.2.1 A.I. stages

Considering the potentialities of A.I., current progress can be defined as an embryonic phase, marking what has been termed as the fourth industrial revolution. The possible stages of A.I. development can be summarised as follows:

- *ANI Artificial Narrow Intelligence / weak A.I.:* The machine does not possess any thinking ability and can only perform narrowly defined tasks.
- *AGI Artificial General Intelligence / strong A.I.:* Machines are able to think, make decisions and perform tasks at a human level.
- *ASI Artificial Super Intelligence:* Cognitive capabilities superior to those of human beings.

3.2.2 A.I. types

While the types of A.I. are:

- *Reactive machine A.I.:* This kind of A.I. can only react to data, considering only the current situation, they cannot form inferences to evaluate their future actions, are characterised by the ability to perform predefined tasks.
- *Limited Memory A.I.:* Make decisions on data previously collected, it has a temporary memory used to store past experiences and evaluate future actions.
- *Theory of Mind A.I.:* Focuses on programming the ability in machines to comprehend and interpret human emotions. This kind of A.I. is expected to play a significant role in psychology. Still not fully developed.
- *Self-aware A.I.:* Machines that possess a consciousness and that are self-aware. They do not exist yet.

3.2.3 A.I. domains

A.I. Domains or branches:

- *Machine learning:* a machine designed to learn from data sets, it finds the logic behind data without having been provided with ex-ante algorithms to find the solution. Most common types of learning:
  - Supervised: the machine is provided with data sets and information concerning the desired solution. The machine has to identify the rules connecting input and output data.
  - Not supervised: the machine is provided data without indications regarding the desired result to identify the logical structure of the data and find hidden patterns.
  - Reinforcement: the machine interacts with a dynamic environment, its data source, aiming at an objective. The learning process is guided by process of reward and punishment.
- *Deep learning/ neural networks:* learn using algorithms inspired by the neural structure of biological brains. Deep learning simulates a multi-layered neural network.
- *Robotics:* A field of A.I. that aims at creating autonomous machines capable of substituting humans in manual activities
- *Expert systems:* innovative systems that do not require specifically designed algorithms, these kinds of systems produce applicative problem solutions inferentially.
- *Fuzzy logic:* Fuzzy models mathematically mimic imprecise or undetermined decision-making systems. Fuzzy logic imitates the human decision-making processes involving more choices than the clear-cut ones between true or false. Useful for non-numeric values.
- *Natural language processing:* one of the most problematic fields, since verbal communication is complex, involving interpretation of psychological inference, facial expressions and phonetics.

3.2.4 A.I. applications

The applications of artificial intelligence are numerous. A.I. has a high degree of flexibility; therefore, many fields show curiosity and interest in this technology's new approaches. Nowadays, A.I. is appreciated due to its rational characteristics. Efficiency in providing results is the key element, particularly in industrial applications. A.I. is currently developed to perform highly specialised tasks in limited environments, it is not yet capable of facing situations with a high variance of possible outcomes.

- *Autonomous industrial planning:* these kinds of applications use computational thinking approaches to solve highly complex tasks. They break down processes into smaller and simpler problems.
- *Games:* one of the traditional areas of A.I. often used to develop new methods and techniques.
- *Autonomous control:* a field where A.I. performs with efficiency, it consists of controlling complex systems, such as a space probe or a car
- *Autonomous demonstration of mathematical theorems:* machines given a set of data or facts can deduce consequences, new facts, or relations among different variables.
- *Autonomous programming:* starting from highly defined specifics relative to the program's purpose, it can autonomously generate new programs efficiently and correctly.
- *Artificial vision:* elaborates and interprets visual information, identifying 2D and 3D shapes.

3.2.5 Advantages and disadvantages of A.I.

If adequately programmed, A.I. reduces process errors. Unlike humans, A.I. can therefore be used to flank humans, especially when taking risks. A.I. analysing data can help humans maintain an objective (data-based) point of view, reducing decision-making time. Another strength of A.I. technologies is that they can run non-stop, allowing businesses to provide uninterrupted services, an example is A.I. empowered digital assistance. On the other hand, A.I. is still not able to understand or emulate emotions, reducing the effectiveness of team management and customer relations. A.I. is constricted into its boundaries and is not capable to "think out of the box". A.I. mass implementation may bring significant job losses.

3.3 RPA

3.3.1 RPA categories

Robotic Process Automation (RPA) is a technology that builds and manages software robots that can perform complex repetitive tasks faster and more precisely than humans. Simple RPA lacks the cognitive capabilities of artificial intelligence and is therefore bound to strict rules that dictate how the process must be done.

RPA divide into four categories:

1. *Data entry robots:* the task consists of copying and pasting data or moving information from one system to another. When done by humans, it is slow, error-prone and costly. This kind of robots do not require complex integration, since the task is simple, they can transform information following previously determined business rules.
2. *Verification and Validation robots:* this kind of robots verify data from inside and outside the business connecting to a third party or internal system. The primary benefit is the reliability of the process. The robot reports errors to experienced humans, who then solve the problem at hand.
3. *System integration robots:* used to fuse internal systems when different companies merge, significantly reducing the problems experienced by staff and customers. These robots interface systems perfectly without the need for specifically developed code.
4. *Schedule or trigger robots:* perform specific tasks subordinated to specific events, reminding human workers to start procedures on time. This kind of robots can organise information, set the following steps to be taken, ask for authorisation, and then proceed to complete the task.

3.3.2 Advantages and disadvantages of RPA

Compared to humans, robots are cost-effective. Tasks are completed faster, resulting in high returns on investment, higher outputs in less time. The quality of work is error-free compared to humans, bringing higher customer satisfaction and boosting an organisation's returns. Robot cycle times are faster, bringing the same results as humans but in a fraction of the time, think about data entry robots. Automating tasks and not requiring supervision helps employees focus on topics that need expertise. RPA does not need specific code to perform tasks, thus transferability of tasks to the machine is easy. Robots eliminate risks related to outsourcing, such as information leakage, allowing companies to have better control. RPA can collect and organise information providing managers with coherent data enabling analytics and decision-making processes.

On the other hand, RPA has some disadvantages, such as the lack of technical skills required for robots to flourish, according to researchers. Although the returns on investment are high compared to human costs, developing, implementing, and maintaining these robots is costly. This often limits access to this kind of technology to established organisations, excluding start-ups. In addition, there are risks related to cybersecurity and data breaches. RPA does not gain experience if not flanked by A.I.

Chapter 4: A.I. applications and Vincix case studies

4.1 A.I. advantages and applications

Innovations have often revolutionised the organisation side of businesses. In modern days, intelligent automation is giving companies the possibility to advance significantly. Excluding the ethical problems relative to unemployment and job loss, I.A.[37] can bring significant economic advantages. Because of that, organisations are starting to feel competitive pressure, to keep pace with technological advancement is mandatory in order to maintain the current market share or to conquer bigger portions of the market. One of the major advantages brought by robots, as stated in chapter 3, is the possibility of streamlining bureaucracy. For example, it is possible to examine how much time doctors spend compiling documents and doing paperwork, on average more than 30%. By automating this kind of task, the health system would be more productive and efficient. Doctors would have more time to examine patients. This kind of technological advancement would undoubtedly have helped during the Covid19 pandemic outbreak, reducing the amount of time used to register all the paper data into informatics systems, and hypothetically find direct correlations between severity of the illness, treatment procedure and percentage of healing, establishing an objective path to follow. For example, this case could have been automated using image recognition intelligence to interpret handwritten paperwork and insert the data into a database, an expert system to organise and analyse data and a learning algorithm to find correlations. Other impressive applications of artificial intelligence in medicine are deep learning algorithms that are able to learn how to identify risk and first stages of cancer by analysing x-rays. These robots are being trained and tested in these years and seem highly promising. This kind of technology, if properly handled, could lead to a democratisation of healthcare. Countries with low levels of instruction and small numbers of doctors could receive precise diagnoses easier and at a lower price, allowing the doctors to dedicate their time to emergency cases.

A.I. technologies need higher computational capabilities to run compared to regular programs. This aspect boosts the research in other fields such as quantum computers that have proved to be highly adequate to run some types of artificial intelligence. Domains of A.I. like

[37] Intelligent Automation

natural language processing and generative models have now proper simulation environments. This means that the first kind of programs can attain sentence awareness and not only word awareness, and for the latter to be capable of simulating molecules to the quantum level (not only atomic level), opening the doors to the almost realistic simulation of new drugs and catalysts helpful also in studies about cancer for example. The interaction between these two types of innovative technologies is providing the conditions for further developments. This interaction is close to Coccia's *technological parasitism* concept: quantum computers are *hosting* A.I., and A.I. is boosting the research on quantum computers, proving their utility. An immense amount of fields are experiencing significant productivity enhancement thanks to intelligent automation.

4.2 Vincix case studies, advantages of implementing RPA and A.I.

For this thesis, Vincix Group, an international firm that produces RPA and A.I., kindly provided some data collected from their clients after they implemented intelligent automation. The productivity increase is measured in FTE, Full-Time Equivalent. One unit of FTE is a person-employed full time, so if RPA or A.I. substitutes three FTE, it corresponds to three salaries saved for the client. A.I. and especially RPA automations need stable rules and procedures for being effective. For this reason, implementation plans are made over a three-year-long period, which is considered a proper amount of time, taking into account technological advancements and changes in firms' rules and procedures. Client names in these case studies will be substituted with Firm A, Firm B and Firm C for privacy.

4.2.1 Firm A Case

Firm A produces consumer electronics, especially cameras and printers, generating 18 billion dollars per year in revenue. The automation process implemented deals with the order acquisition process. Humans had to examine e-mails in order to copy requests into the database that collects clients' requests. This highly repetitive process does not require any expertise, and when done by humans it is often slow and tedious. The RPA, in this case, has been programmed to analyse the requests and copy-paste them into the order database. The robot will be flanked by artificial intelligence in the future. When implemented, it will be able to find incongruences with past orders, correct typing errors in product numbers and understand the meaning of e-mails. The A.I. side reports eventual anomalies to a supervisor (e.g. client complaining about wrong delivery address), allowing humans to concentrate on value-added tasks and solve complex situations, such as contacting the client and modifying the registered address. After a period of training the A.I.,[38] is able to understand if the mail contains complaints or different requests. It can intercept 90% of the anomalies. Through inference and data evaluation, the A.I. produces new rules, finds exceptions (e.g. on average, the products break after N. months), and asks if the new rule is relevant. Regardless of the affirmative or negative nature of the answer, the machine learns. The machine, trained with 3 G.B. of e-mails, is autonomously finding new phenomena that would have required human intervention to be discovered.

By integrating RPA and A.I., Firm A saved 20 FTE units with a medium-cost per year of €18,000, saving €360,000 per year. The upfront investment for the firm was €80,000 with a maintenance cost of €8,000 per year. As a result, firm A saved €272,000 in the first year and €352,000 in the following years.

Quality index[39] improvements: since data entry tasks are prone to errors, the percentage of errors or exceptions moved approximately from 20% ex-ante to less than 2% ex-post the integration.

[38] Generally three to five months

[39] The quality index is used, in this case studies, as a measure to report the quality of the service provided considering errors and exceptions as factors that worsen the firm's client experience.

4.2.2 Firm B Case

Firm B is a car rental business that operates in 140 countries, generating yearly revenues of 2.9 billion euros. In this case, the intelligent automation implementation consists only of RPA. The firm relies on local autonomous mechanics to fix cars. Ensuring fast repairs is mandatory because a broken car is missed profit. The RPA is programmed to organise the repair requests, assigning the maintenance to mechanics in the area. The mechanics communicate their availability (e.g. for ten cars weekly), so the RPA automatically distributes the cars to be fixed among the available mechanics, following minimum distance criteria, to put the car back to work as soon as possible. Firm B had approximately twelve employees assigning vehicles to mechanics. Since the rules were clear, defined and stable over time, RPA technology was applicable.

The firm has a medium salary of €23,500, for operators, automatisation halved the staff required, 6 units of FTE were saved, resulting in €141,000 saved per year. The upfront investment for Firm B was €40,000 with a maintenance cost per year of €7,200. The net savings were €93,800 for the first year and €133,800 for the following years.

The quality index improved due to the decrease in errors and exceptions that went down from approximatively 10% to less than 1%.

4.2.3 Firm C Case

Firm C is a society that delivers products and services in the water and energy sector. The firm generates almost 3.3 billion euros per year in revenues. The automation made by Vincix, in this case, is pure artificial intelligence, more precisely an expert system. The society needed to evaluate data from all the sensors in the hydric net to act on pipelines that had contaminations or water leaking. The analyses were conducted by one staff member, a chemist, who needed to read several pages of tables filled with numbers for every sensor (hundreds per week). Due to lack of time, the operator could only take random samples, evaluate them, and report the issue to the maintenance staff in case of problems. Intelligent automation reads the results of all the analyses, processing data significantly faster than a human. Thus, finding all the parameters that break the pre-established boundaries and, if present, report them to the operator to further evaluations. This system will be upgraded with a machine learning A.I. in order to propose new rules and spot anomalies, e.g. related to seasonality, problems due to maintenance such as an excess of chlorine. Even if parameters are within legal limits, they can be dangerous if maintained over time. The A.I. can suggest solutions, such as more frequent and less intensive chlorine inputs.

In Firm C case, there have not been FTE savings, the chemist still supervises the machine's reports, but the percentage of data examined went up from less than 10% to 100%. The capital investment for the client was €70,000, with a maintenance cost of €12,000 per year. To reach such levels of supervision, the firm would have needed to hire a dozen chemists, with an average salary of €35,000 - €40,000 each, resulting in a yearly expense of €420,000 in the best-case scenario.

The estimate of errors and exceptions due to the human variable before the A.I. integration was around 10%, thanks to the machine activity, it went down to less than 1%. As a consequence, the improvement of water quality benefits the consumers directly, it is also an unaccounted asset for the firm.

4.2.4 Final thoughts on the case studies

As seen in the real-life examples above, intelligent automation can significantly improve productivity with very low operational costs. In case A, there is a decrease in costs of 75,5% in the first year and 97,7% in the following two years, while in case B the first year decrease in costs is 66,6% and for the following years 95%. Although Firm C did not have an explicit cost reduction like the other two firms, it significantly increased productivity and quality of the service. Clearly, in these cases, the ROI[40] is impressive. Even though not all sections of an organisation is automatable, integrating I.A. can bring important competitive advantages.

[40] Return on investment.

The savings presented here are still small relative to the revenues of these companies. Only the future will disclose the true potentialities of intelligent automation. Using Rogers's terminology, these companies may be considered early adopters of this technology. A phrase often heard in Automation circles is: "Almost all companies need automation, but they do not know yet".

Concluding remarks

Innovation in all its forms is one of the main driving forces of change and evolution in society. In the scientific literature, innovation is indicated as an important driver of economic growth but also contributes to recurring fluctuations, or cyclic waves, in modern market economies. In the past two centuries, the authors and researchers mentioned in this thesis have explored the connections between the cyclic nature of the economy and the rhythm of innovation introduction into the market. Innovations are increasingly responsible for the creation of new value in the globally interconnected and science-driven economies. In empirical studies, the study of innovations has confirmed that it provides competitive advantages, industrial transformation and quality improvement in public services. Under intense competition in changing markets, innovations provide the means for adaptation, survival and sustainable goal achievement. On the other hand, the rapid transformations are also causing the demise of parts of existing production chains.

During the past century, the description of innovation types has focused on technological approaches carried out in firms inducing transformation through R&D programs of product, process and organisational innovation, mainly in manufacturing activities. Schumpeter's work defined innovation as the first introduction of a new product, process, method or system. Although broad, the definition noted the dual aspect of innovation to be understood as a process or sequence of activities, as well as a result or outcome of the activities. Schumpeter remarked that a well-informed observer could gain knowledge of "the creative response" (innovative process) after it had occurred, but stated it was almost impossible to understand its outcomes while it still was in progress. Subsequent research (e.g. Piatier), refined the analysis focusing on the different stages of the innovation process, from the emergence of a new idea or invention to its actual economic implementation. Rogers (2003) developed the terminology and described the ways innovations were diffused in society. O'Sullivan (2008) reasoned on innovation strategies. He stated that decision making was in its essence "interpretative and subjective". Actors were forced to take imperfect decisions facing unknown outcomes. The literature dealing with decision-making in uncertain conditions shows difficulties are found at all levels. A.I. will undoubtedly play a growing role in assisting decision-making. It provides data-based (objective) instruments capable of calculating the probabilities of success in uncertain situations, evaluating amounts of data out of the reach of human calculating capacity.

Despite all the risks and costs, strategies of change and innovation offer opportunities. Being an early implementer of innovation can bring rewards, that are expected to be greater than those of a conservative strategy. In the past few decades, the theoretical approaches have become more varied. This is probably a response to the type of change affecting economic systems. An example is the system-theory approaches that focus on how economic actors cooperate in networks (e.g. see the example of ARM Holdings, dominating a high-tech market, described by Williamson & Meyer, 2012). However, also the competitive interaction between independent actors can be studied in this way. Despite the greater complexity of these methods, they prove useful in exploring the new types of innovation strategies that the advancement of digitalisation and A.I. permit. Small firms successfully networking seem to confirm Schumpeter's observation that innovative products and services tend to emerge in clusters. Coccia (2009) states they also tend to co-evolve.

Moving from the analysis of companies in a single sector- to multi-sector analysis, to more complex systems, the scope of innovation research seems to be changing. User-driven innovation networks, connecting virtual groups of like-minded decentralised inventors – producers, would probably not have emerged without the internet (Von Hippel 1979). We can already see that as new information technology comes into use, such as narrow A.I. and Robot Process Automation (RPA), ripple effects extend far beyond the immediate field of application. Consider a normal RPA, the technology is defined as incremental innovation, in the sense that it is applied within a pre-existing process. Another example is a narrow A.I., which is now used with driver-assistance functions in our cars. These incremental innovations will find extensive use. They will, therefore, probably also have impacting outcomes. Even simple innovations can have a significant impact as they go through their life cycle. For example, the RPA software robots described in chapter 3.3 are introduced to execute repetitive routines in existing companies. Initially, only the direct cost and time-saving effects are observable. However, they will change the number and type of personnel the company requires in the long run. The structure of the company will be affected. The "narrow A.I." of driver-assist technology sustains already existing machines (standard cars). The low costs and straightforward application make it a success, but the technology has imperfections and sometimes results in mistakes (accidents), as the technology spreads, it shows its limitations.

The quest to reduce errors will cause the evolution of safer car models with more advanced applications, but this will probably also result in an evolution of the whole transportation infrastructure in the long term. A co-evolutionary process, as Coccia (2019) terms it. It has already happened in the past century: faster cars caused accidents on the roads. They generated better cars, but also a demand for highways, where it was possible to drive fast in relative safety. The innovations that created fast vehicles eventually changed infrastructure.

Some scientists, like Hawkins, are worried by A.I. technology reaching and surpassing human-like capacity. Others define it optimistically as the most important social advancement in history. Considering how I.T. has affected the world in a few decades, it is impossible to deny that an artificial intelligence enhanced by computer capacities will greatly accelerate problem-solving activities, bringing important changes to the world. Now more than ever, innovations substitute each other at an unprecedented rate. The diffusion of the internet and the connection of minds that it generates has created the perfect environment for idea circulation. The velocity of innovation introduction and circulation influences the economic cycles. In the past 250 years, each cycle has been shorter than the preceding one (see table 5). Idea circulation generates and influences more innovation, the knowledge-based creative process accelerates (Rodrigue 2020). The rate at which innovations now are adopted is unparalleled in history (Rogers 2003).

Some topics have been presented in a highly synthetic manner to maintain focus on the technological side of the subject. Non-technological dimensions affecting innovation, such as power structures, government policy and socio-cultural issues, have not been treated. Education comes to mind. A US department of labour report predicted that more than 65% of current U.S. students will be working in jobs that have still to be invented. This is another crucial indicator of the unprecedented degree of transformation that the near future holds. Students will require specialisation in fields that still need to be created. Other developed economies will probably undergo similar changes.

In 1945 Vannevar Bush, scientific advisor to USA President F.D. Roosevelt had identified science's crucial role in economic growth and strategic security. He had grasped its fundamental quality, calling it *"the endless frontier".*

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