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To my grandparents, Rita and Nazzareno

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INTRODUCTION

In the last decades, the advent of technological innovation has progressively changed the world, profoundly affecting societies and economies. Globalization contributed to the development and the spread of digital transformations, leading to the digital era. Digitalization is the determinant of modern societies. It affected how we interact, how companies carry business and how consumers behave.

It is recognized that digitalization largely impacted economies. However, its economic consequences are controversial, and its economic benefits remain unclear. The term *digitalization* is itself subject to misuse and its definition is still to be unanimously agreed. Recently the pandemic has made digital solutions essential, making even more important to question the true impact of digitalization on economies and its role in sustaining growth.

The main purpose of this thesis is to investigate the economic consequences of digitalization and quantify its benefits. In particular, we will analyze the role of digitalization during the COVID-19 pandemic and identify the social and policy issues it arises. As it will emerge in the analysis, the economic impact of digitalization is diverse and complex. If on the one hand digital progress seems to be fostering growth, on the other it generates severe inequalities. Hence there appears a need of government actions and regulations to successfully exploit the full potentials of digitalization, while reducing the significant remaining digital divide.

The thesis is organized as follows:
In the first chapter we address the complex definition of the phenomenon of digitalization and present its different measurements. In the second chapter, we investigate the role of technological progress in economic growth according to models of exogenous growth, as the Solow model, and exogenous growth, as the AK model and

the works of Aghion and Howitt. Then, we discuss the profit shifting practice of digital multinationals, which consist in shifting corporate profits to low tax countries or tax havens and distorts the measurement of digital benefits on nations' welfare. We also examine the free nature of most digital goods and this feature's impact on our analysis. Finally, in the third chapter we investigate the role of digitalization during the COVID-19 pandemic and evaluate its impact on the economy and the digital divide. Conclusions follow.

CHAPTER 1
Digitalization: definitory issues and global trends

1.1 Digitalization: definition and measurement

1.1.1 Definition

The first issue we need to tackle when addressing the digital economy is the definitory one. We must agree on some shared definitions which to ground our future analysis and reasonings on. What is digitalization? What is the digital economy?

Digitalization is widely defined as the process of digitization (transforming analog contents into digital ones) applied to societies and economies as a whole. According to the International Monetary Fund, "*the digitalization of the economic activity can be broadly defined as the incorporation of data and the Internet into production processes and products, new forms of household and government consumption, fixed-capital formation, cross-border flows, and finance*" [1]. The digital transformation of our world has been driven by the rise of the Internet. This new technology revolutionized our life, profoundly affecting businesses, communication and economies. It has shaped the way we consume, we produce, we work, we communicate, we learn, and we trade, therefore "*providing unparalleled opportunities for value creation and capture*"[2]. Indeed, digitalization presents exceptional innovation-driven opportunities for companies and models of business. Its rise led to the emergence of a new economic paradigm that we call the *digital economy*, where digitalization is fully integrated into global economies. Nevertheless, this phenomenon also represents a source of possible risks: "*digitalization is both an enabler and a disruptor of businesses"*[3]. Traditional models

[1] IMF, 2018, "Measuring the Digital Economy", *Policy Papers*, Washington, D.C., USA
[2] World Economic Forum, 2016, "Digital Transformation of Industries: Consumer Industries", *World Economic Forum White Paper*, Switzerland
[3] IMF, 2018, "Measuring the Digital Economy", *Policy Papers*, Washington, D.C., USA
[4] IMF, 2018, "Measuring the Digital Economy", *Policy Papers*, Washington, D.C., USA

of business hence become dated and tend to disappear if failing to comply with the new digital-oriented business practices in force. However, despite its affirmation, the digital economy remains a vaguely defined concept. This fact seems even more problematic when we try to measure this phenomenon. According to the International Monetary Fund, "*the lack of a generally agreed definition of the "digital economy" or "digital sector" and the lack of industry and product classification for Internet platforms and associated services are hurdles to measuring the digital economy*"[4]. How can we measure something we cannot unanimously define? The measurement and the definition of the digital economy seem therefore to be closely related. Measuring the digital economy presupposes that this reality has been precisely defined and so that the choice of the measurement metrics reflects this definition.

The lack of a common definition of the digital economy is mostly due to the relative novelty of the phenomenon and to its poor general understanding. The digital economy is so vast that it becomes difficult to understand all its different forms and implications. Yet, we need to agree on a concise and precise definition of this term. Also, this fast-evolving economy requires to be defined with a great dynamic flexibility. Its definition must therefore be able to evolve with the phenomenon, as fast as it does. In general, we can distinguish two types of definitions, differing according to the aspect of the digital economy they emphasize. The first type of definition focuses on the innovative activities that characterize the digital sector. Thereby, Bukht and Heeks, who have written an entire paper on discussing the definition of the digital economy, define it as "*That part of economic output derived solely or primarily from digital technologies with a business model based on digital goods or services*"[1]. The second type of definition puts the emphasis on the general

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[1] Bukht R. and Heeks R., 2017, "Defining, conceptualising and measuring the digital economy", *GDI Development Informatics Working Papers*, no. 68, University of Manchester, Manchester
[2] Knickrehm M., Berthon B. and Daugherty P., 2016, *Digital Disruption: The Growth Multiplier*, Accenture, Dublin
[3] UNCTAD, 2019, "Value Creation and Capture: Implications for Developing Countries", *Digital Economy Report*, Geneva

digitalization of the whole economy, where the foundations of the digital economy are more broadly defined. According to this view, Knickrehm *et al.* define the digital economy as "*The share of total economic output derived from a number of broad "digital" inputs. These digital inputs include digital skills, digital equipment (hardware, software and communications equipment) and the intermediate digital goods and services used in production. Such broad measures reflect the foundations of the digital economy*"[2]. To us it is clear that both definitory dimensions are important and must be taken into account. Indeed, on one hand the digital economy has led to disruptive innovative economic activities, and on the other hand it seems nowadays to confuse with the economy as a whole.

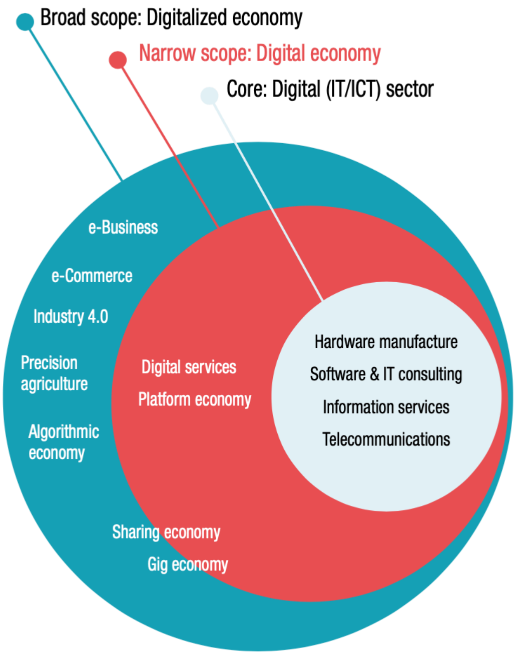
To overcome these discussions, the 2019 "Digital Economy Report" of the United Nations Conference on Trade and Development (UNCTAD), proposes a definition of the digital economy based on three broad components[3]:

i. The core (or foundation) aspects of the digital economy: core technologies (telecommunication devices, computers), fundamental innovations and enabling infrastructures (telecommunication networks and Internet).
ii. The digital and information technology (IT) sectors: producing key products and services that rely on the core digital technologies (including mobile applications, digital platforms and payment services).
iii. A wider set of digitalizing sectors: including the sectors where digital products and services are being increasingly used (e.g. for e-commerce). In those sectors, digitalization is transforming business models and introducing new activities.

In this report, the digital economy is also represented as multiple layers of digital infrastructures.

In figure 1.1, we can distinguish three different layers of the digital economy. They refer to the three broad components of the digital economy on which its definition given by the UNCTAD in its 2019 "Digital Economy Report" is grounded.

Figure 1.1 – A representation of the digital economy



Source: UNCTAD, 2019, *Digital Economy Report*[1]

Having clearly recognized the differences between the three dimensions of the digital economy, we consider that, given the overall spread of digitalization over sectors of the economy, we will define the digital economy as encompassing the core, the narrow and the broad scopes altogether.

1.1.2 Measurement

Having defined digitalization and the digital economy, we will now discuss how we can measure it. The measurement of the digital economy is for sure one of its main

[1] UNCTAD, 2019, "Value Creation and Capture: Implications for Developing Countries", *Digital Economy Report*, Geneva

issues. The relative novelty of this phenomenon, together with its fast-evolving path, have made most of the traditional models of measurement of economic activity inadequate to the digital one. Economists had therefore to propose new metrics and ways to quantify the digital economy. The question that is crucial is to know what we want to measure. Most of the measurements of the digital economy tell about its spread. There exist many different indexes and units of measurement. They express the degree of digitalization of a country, given by the diffusion of digital factors in the economy and in the society. We will present and explain the main ones.

But how to measure the economic benefits of the digital economy, that is, its value added? We will discuss about this issue in the next chapter.

First, let's look at the different measurements of the spread of the digital economy. Those are the most common ones because the type of data they require is relatively easy to collect, often gathered by governments or digital enterprises themselves (e.g., telecommunication companies).

The spread of the digital economy is the extent to which digitalization is integrated into societies and economies. This is usually measured in terms of accessibility to digital technologies (mainly the Internet) and digital services. The OECD in its 2019 publication "Measuring the Digital Transformation: A Roadmap for the Future"[1] measures people's accessibility to digital services using broadband connections[2] as a parameter. *Broadband connections* is an indicator of whether people have access to the Internet, and of the quality (speed) of the Internet connection they benefit. Indeed, this is a clear indicator of whether people have the conditions and are enabled to use digital information and services.

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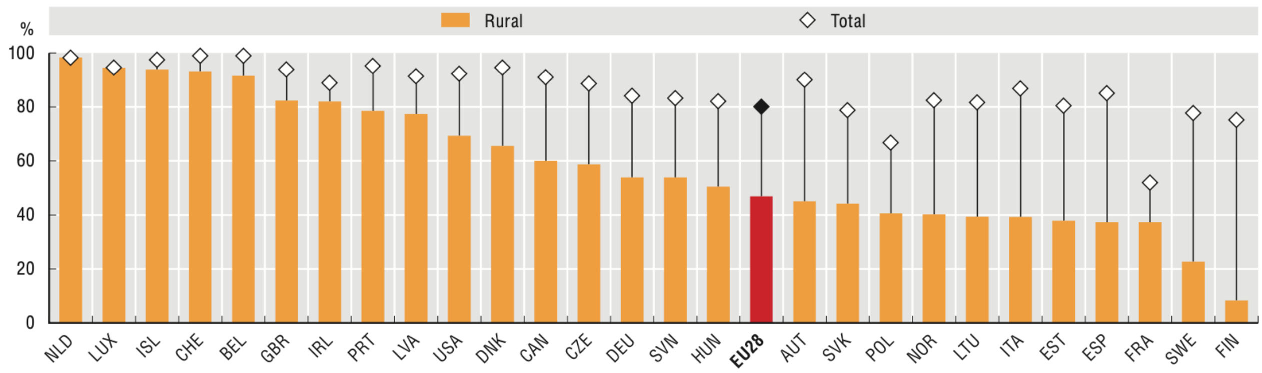
[1] OECD, 2019, Measuring the Digital Transformation: A Roadmap for the Future, OECD Publishing, Paris

[2] The report defines broadband connections as "*fixed line broadband services subscriptions purchased by households or businesses. Fixed broadband comprises DSL, cable, fibre-to-the-home (FTTH), fibre-to-the-building (FTTB), satellite, terrestrial fixed wireless and other fixed-wired technologies*".

[3] A speed of 30 Mbps or more is considered a fast speed.

Figure 1.2 – Households in areas where fixed broadband with a contracted speed of 30 Mbps or more[3] is available, total and rural, 2017

As a percentage of households in each category



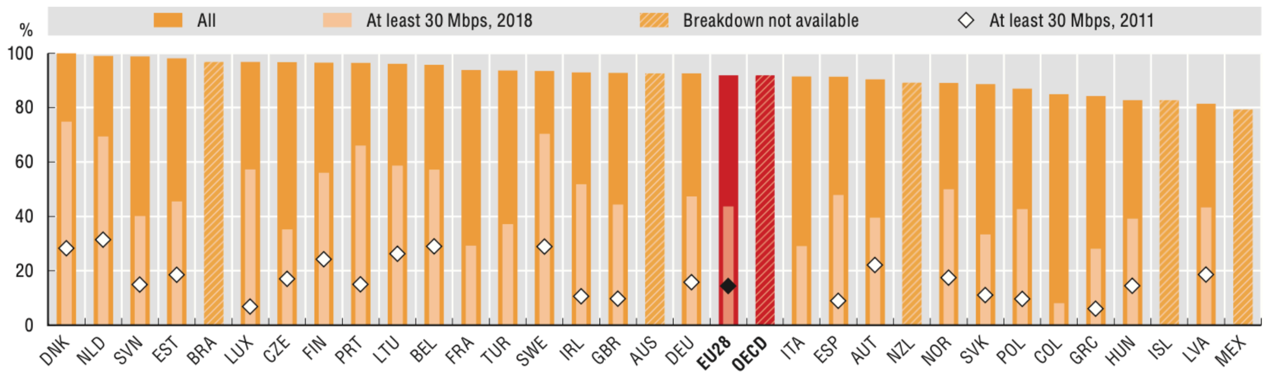
Source: OECD, 2019, Measuring the Digital Transformation: A Roadmap for the Future, OECD Publishing, Paris

Figure 1.2 shows that rural households are less likely to be covered by, and so to have the possibility to purchase, a fast speed Internet connection. Nevertheless, the population disparity in high-speed Internet accessibility seems much lower in highly developed and digitalized countries (like The Netherland, Luxembourg, Iceland and Switzerland) than in less digitalized ones (like Lithuania, Italy, Estonia and Spain). We note that less digitalized countries also have a total populations' percentage access to the Internet that is considerably lower (around 40%) than highly digitalized countries (around 90%). The values for France, Sweden and Finland are mostly due to geographical characteristics of those countries.

Figure 1.3 shows that, on the other hand, enterprises' internet accessibility is much higher: OECD's average is 90% and Mexico is the only country slightly below 80%. We can also observe that the percentage of enterprises with a broadband of at least 30 Mbps has significantly risen on general from 2011 to 2018. This shows that Internet accessibility is generally more diffused among enterprises than households, highlighting the importance of digital technologies for businesses and the economy.

Figure 1.3 – Enterprises with broadband connections, by speed, 2018

As a percentage of all enterprises



Source: OECD, 2019, Measuring the Digital Transformation: A Roadmap for the Future, OECD Publishing, Paris

However, the integration of digitalization doesn't concern only households and enterprises, but societies as a whole. Therefore, three major indexes of digitalization have been developed: the DESI (and I-DESI) index, the Digital Density Index (DDI) and the Industry Digitalization Index (IDI).

a. DESI and I-DESI indexes

DESI stands for Digital Economy and Society Index, and I-DESI stands for the International DESI. Those two very similar indexes have been developed by the European Commission to measure the digitalization of economies and societies. The DESI is a "*composite index that benchmarks relevant indicators on digital performance*"[1] and shows the evolution of the EU27 Member States in terms of digital competitiveness thus analysing Europe's digital performance. This index is developed according to five dimensions[2]:

[1] European Commission, 2018, *International Digital Economy and Society Index*, Final Report, Luxembourg

[2] European Commission, 2018, *International Digital Economy and Society Index*, Final Report, Luxembourg

1. Connectivity: the deployment of broadband infrastructure and its quality.
2. Digital skills: the skills needed to take advantage of possibilities offered by a digital society.
3. Citizen use of the Internet: the variety of activities performed by citizens online.
4. Business technology integration: the digitalization of businesses and development of the online sales channel.
5. Digital public services: the digitalisation of public services focusing on eGovernment.

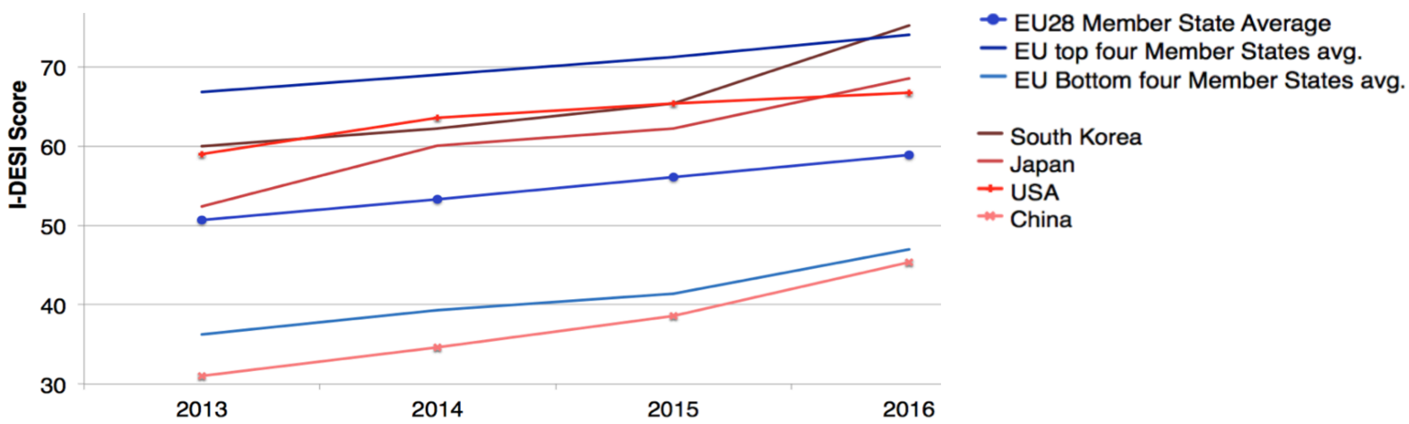
Those five dimensions are then united with the following weighting system: connectivity accounts for 25%, digital skills for 25%, citizen use of Internet for 15%, business integration for 20% and digital public services for 15%. The DESI index has the particularity to measure not only the digitalization of the economy, but also the digitalization of the society.

The I-DESI index simply compares the EU27 Member States accounted for in the DESI with 17 other countries (Australia, Brazil, Canada, Chile, China, Iceland, Israel, Japan, Mexico, New Zealand, Norway, Russia, Serbia, South Korea, Switzerland, Turkey and the United States). The intent of the I-DESI index is to mirror and extend the results and the measurement practices of the DESI index to other non-European countries. The I-DESI index "*combines 24 indicators and uses a weighting system to rank each country based on its digital performance with the aim to benchmarking the development of the digital economy and society*"[1]. I-DESI maintains the same five components and weighting system of the DESI index. It can be viewed just as an extension of the DESI to other 17 countries. The values of the DESI and I-DESI index are mainly meaningless alone, but they allow comparisons between countries. Indeed, the analysis is based on comparisons between the

[1] European Commission, 2018, *International Digital Economy and Society Index*, Final Report, Luxembourg

average performance of all EU27 Members State, the four best-performing and four worst-performing countries of EU27, and selected countries (USA, China, Japan and South Korea) representing the group of non-EU countries.

Figure 1.4 – Average scores across all dimensions for the I-DESI, 2013 to 2016



Source: European Commission, 2018, *International Digital Economy and Society Index*

Figure 1.4 shows the performance of the countries and group of countries previously mentioned, from 2013 to 2016. The first observation is that the trend is increasing over time for all the groups of countries. The best-performing group is without any surprise the EU top four Member States average that outperform USA and Korea by approximately 10 points over time, except for 2016 where Korea slightly surpasses the group. Japan's trend increases faster than USA's and surpasses it in 2016. USA, Korea and Japan are always above the EU27 Member States average. China is below the EU bottom four Member states average but its trends strongly increases, especially from 2015 to 2016.

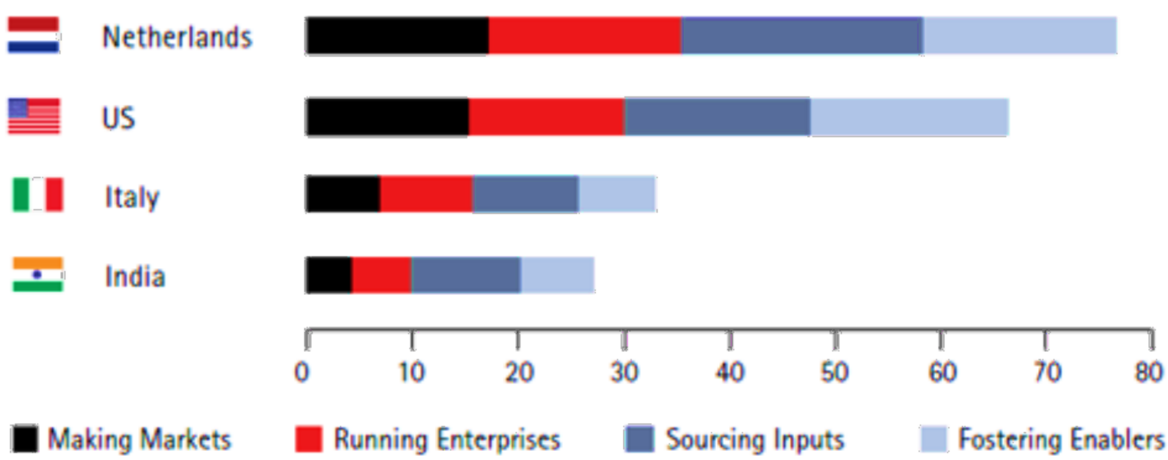
The I-DESI index shows that the EU27 Member States group contains countries with strong performance disparities. Indeed, the gap between the four best-performing and four worst-performing countries is around 30 points and remains roughly constant over time.

b. Digital Density Index (DDI)

The Digital Density Index has been jointly developed by Oxford Economics and Accenture. This index measures the impact of digital technologies on economic growth, underlying the importance of investments in both business and public digital development to foster economic growth. This index is built from 50 indicators that are grouped into four activities areas: making markets, sourcing inputs, running enterprises and fostering enablers. Further details on the activities areas and their metrics are available in the Appendix A1.
The DDI gives an overall score, ranging from 0 to 100, to each country, reflecting the digital profile and the state of digitalization of each one. The score also enables benchmarking between countries.

The first observation in Figure 1.5 is that, for each country, the four domains of economic activities are approximately equally balanced. Then we observe that Italy has a DDI score of around 35, which is significantly lower than the Netherlands and the United-Stated which are both highly digitalized country.

Figure 1.5 – Digital Density Index scores for selected countries



Source: Kotarba M., 2017, *Measuring Digitalization – Key Metrics*, Foundations of Management, Vol. 9

c. Industry Digitalization Index

This index was developed by the Mckinsey Global Institute in 2015 with the objective to develop a better understanding of the evolving global economy that is always more digitalized. This index combines 27 indicators and measures digital usage, digital assets and digital workers in each sector. The Industry Digitalization Index was built as part of an analysis, conducted by the Mckinsey Global Institute, of the digitalization of US's economy.
In appendix A2 are the results of this analysis and the scores of the index. The analysis of digitalization of each sector is conducted according to the measurement of digitalization of three criteria: assets, usage and labor.

Results show that the US economy comprises sectors whose level of digitalization is very heterogeneous. Indeed, there are some highly digitalized sectors (ICT, media, professional services and finance and insurance). Those are knowledge-intensive sectors. Then there is a majority of medium digitalized sectors (e.g. Wholesale trade, real estate, education) and finally there are low digitalized ones (e.g. agriculture, health care, government).

The three indexes we presented are among the most advanced indicators of the state of digitalization of countries and they are used by intergovernmental organizations (as the European Commission) to measure the spread of the digital economy. Yet, their diffusion remains relative. Indeed, we can affirm that nowadays there still isn't one generally used indicator to measure digitalization. Digital economy is rather measured using a grouping of different statistics and parameters that, when gathered, can help to assess the state of digitalization of nations. It is the case of the G20 2018 Toolkit for Measuring the Digital Economy Report, that lists many statistics with the aim of reporting the digitalization level of G20 nations. Examples are statistics on broadband subscriptions (as shown in figures 1.2 and 1.3), on computers, on internet users, on digital natives, etc…

None of these measurements are meaningful if taken alone, but when gathered and looked at as a whole, they picture the general state of digitalization of the countries. Later on, in chapter 2.1 we will discuss the economic benefits of digitalization and their measurement issues.

1.2 Digitalization trends in the past two decades

The development and the diffusion of digitalization is best known as the *digital revolution.* The extreme innovative power of the digital revolution and the profound changes that it led in society and economy make it comparable to the Industrial Revolution. The key technology of the digital revolution is of course the Internet, which became a general-purpose technology, that is, a technology that affects the entire economy (as the steam engine in the Industrial Revolution).

The milestones of the digital revolution start before the 21st century, in the second half of the 20th century. Here are some of them:

1971: the first e-mail
1974: ARPANET, the first Internet Service Provider (ISP)
1975: the first Personal Computer (PC)
1985: Windows 1.0
1990: invention of the World Wide Web (the Internet as we know it)

However, it is clear that the real evolution of the digital era occurred in the 21st century. We are also aware that the digital revolution is more an evolution than a revolution. Indeed, it is continuously changing with non-stopping innovations that generate new paradigms in the economy and the society. Nowadays, we talk about the digital era, characterized by a high diffusion of digitalization in developed countries and a fast-growing diffusion in developing ones.

The digital evolution boosted in the beginning of the 21st century, as it is depicted in the figure in appendix A3.

The digital revolution has profoundly affected economy, leading to a new paradigm: the digital economy. We can distinguish three different phases of the development of the digital economy:[1]

1. *Business economy:* marked by the digitization of information and digital marketplaces, where the Internet changed the distribution of images, videos and texts.
2. *Economy of people*: characterized by digital thinking.
3. *Economy of things*: market by digital technologies, Internet of the Things (IoT) and its evolutions.

The digital economy is intrinsically characterized by the spread of the Internet. This technology is so diffused that the expression *internet economy* has become a synonym of digital economy. Indeed, digital economy can also be viewed as the set of economic activities that arise from online connections and growing interactions between people, organizations and devices.

We estimate that in April 2020, 4.57 billion people are active internet users[2] and this number has strongly increased from the 1.1 billion in 2005 (see appendix A4). Nowadays more than half of world population has access to the Internet. It is thus a truly global technology.

We can also measure the development of the Internet in terms of the number of online websites. Indeed, this number significantly increased: there were only 17 million websites in the year 2000, but in 2019 they reached more than 1,7 billion.

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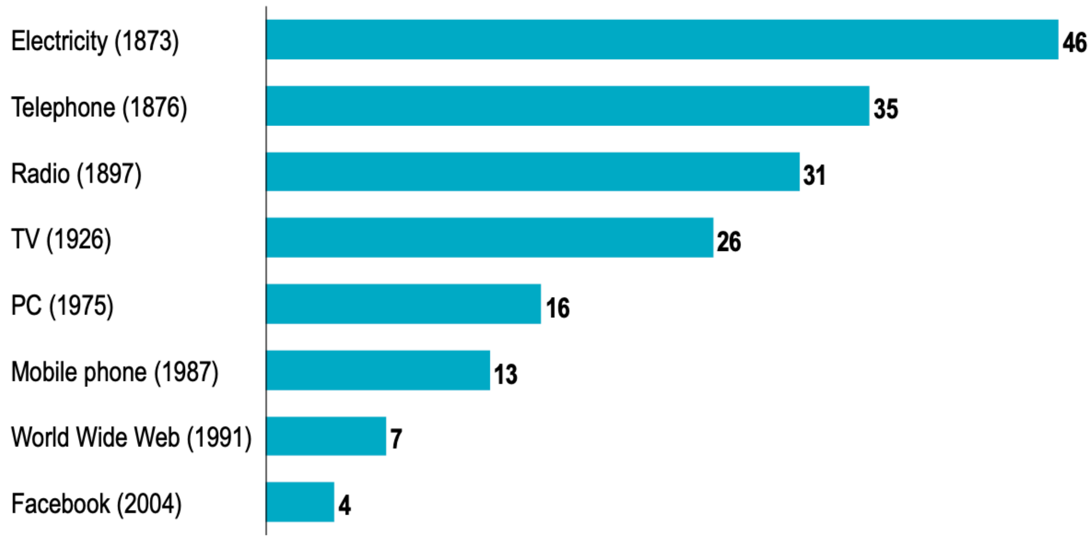
[1] Cellini P., 2019, Seminar on the Digital Economy, LUISS
[2] Statista, 2020, *Global digital population as of April 2020*, https://www.statista.com/statistics/617136/digital-population-worldwide/

Also, many of the most known websites where lunched in this period of strong development: Facebook (2004), YouTube (2005), Instagram (2010) (see appendix A5).

Figure 1.6 – Time from introducing a product of an adoption rate of 25% across US citizens (years)



Source: Roland Berger, 2017, "Milestones in the digital evolution", *Trend compendium 2030*

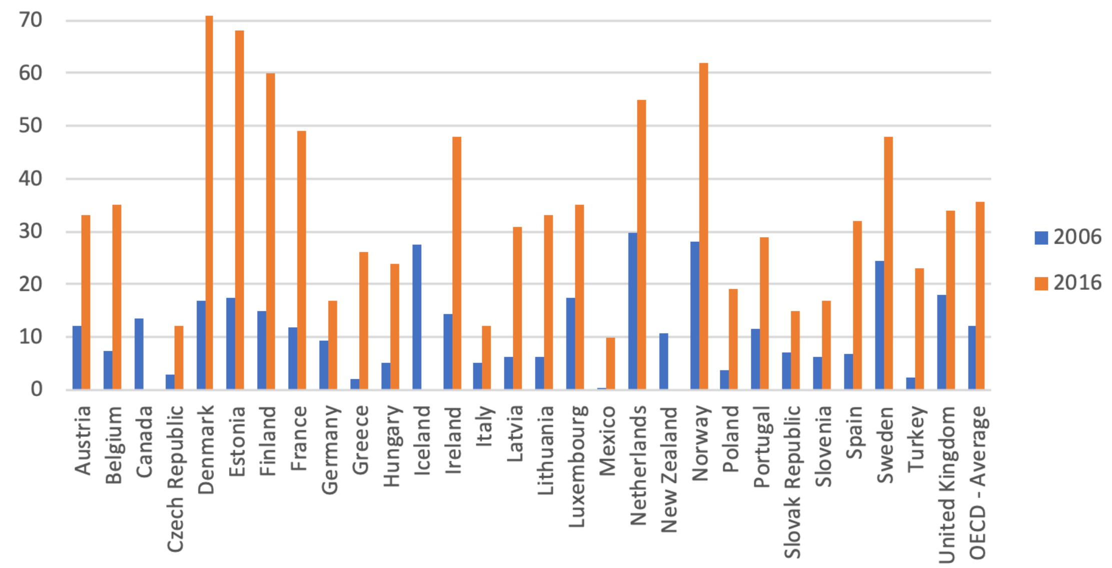
Another remarkable feature of the digital revolution is the speed of diffusion of digitalization. Indeed, the length of time between the introduction of a product and its wide diffusion is particularly low for digital products, as shown in figure 1.6. It is the case for Facebook, the World Wide Web, Mobile phone and PC (all digital goods) compared to other non-digital goods as TV or telephone.

Digitalization has also changed the way people interact with institutions. Indeed, we can recall that the European Commission chose Digital public services (the digitalisation of public services focusing on eGovernment) as one of the five dimensions on which to build the DESI index of digitalization. Figure 1.7 shows that the percentage of individuals using the Internet to send filled forms to public authorities in OECD countries has considerably increased from 2006 to 2016. Indeed, in 2006 the OECD average percentage was about 10%, with only a few exceptions with percentages around 30% (e.g., Iceland, Netherlands, Norway). Ten years later the OECD average percentage is of 35%, with many countries having a percentage above 50 (e.g., Denmark, Estonia, Norway). However, the rise of digitalization of the public sector was very heterogeneous. Some countries experienced a very fast evolution between 2006 and 2016, as Finland or France, while others remained at considerably low levels of digitalization, as Italy or Czech Republic (whole percentage stagnated around 10%). These data demonstrate once again that the development of digitalization is unequally distributed across sectors, even among developed countries.

Furthermore, the spread of digitalization in the last two decades has profoundly affected the economy and disrupted traditional models of business. Digitalization led to the rise of new types of economies and new forms of business that exploit the digital technologies. The most significant ones are the e-commerce economy, platforms and the sharing economy. These new economic phenomena progressively enhanced the importance of data in the economy, not only as a form of information, but as a means of value.

Figure 1.7 – Digitalization of public authorities in OECD countries, 2006 to 2016

Individuals using the Internet for sending filled forms via public authorities (in % of population)



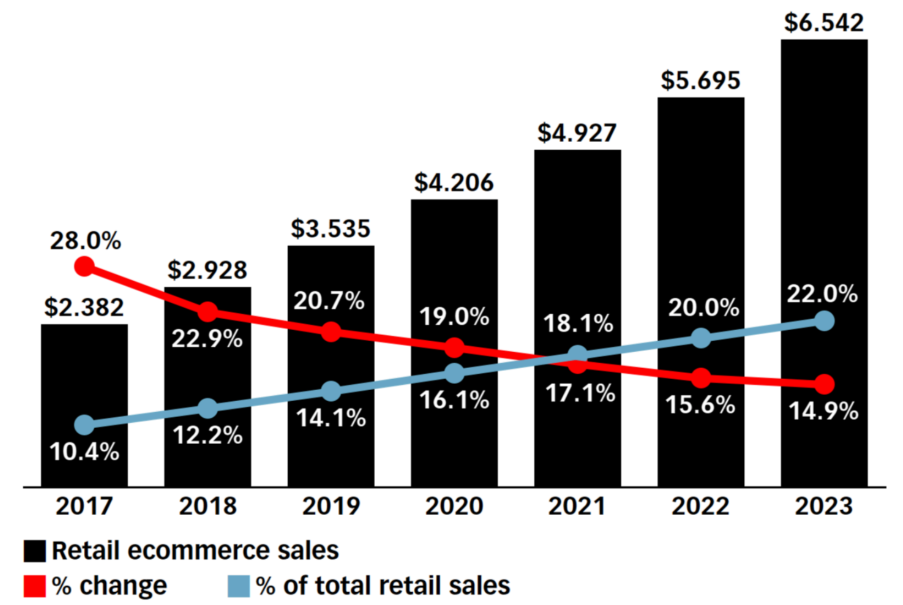
Source: OECD Statistics

The term *e-commerce* (also known as internet commerce or electronical commerce) refers to the selling and buying of goods and services online. In this way, companies can increase their sales by having access to a major number of customers: the e-commerce widens markets. The majority of enterprises selling online uses the e-commerce as an extension to their original business model that consists in physical business practices but there are always more online companies who only sell online. Indeed e-commerce has several benefits for companies as the decrease of production costs, the reduction of market access barriers, a better understanding of clients and customers profiles (by the acquisition of their data) and the improvement of the quality of services (allowing to extend the range of services before and after the sale). The best example of a successful e-commerce company is Amazon. Its revenues increased year on year at an average of 30% from 2005 to 2019. The company, that had 8,5 million of US dollars in 2005, achieved an annual revenue amount of 280 million of US dollars in 2019 (see appendix A6).

Figure 1.8 – Retail E-commerce Sales Worldwide, 2017-2023

In trillions of US $, % change and % of total retail sales

Data for 2020, 2021, 2022 and 2023 are estimates



Source: eMarketer, 2019

E-commerce worldwide market size is experiencing a rapid rise, as shown in figure 1.8. The significant information that this figure points out is the fast-increasing percentage of worldwide total retail sales that are e-commerce sales. Also, it shows that in 2019 the e-commerce market size was expected to have almost doubled by 2023.

E-commerce's country leaders are China and the United-States with revenues of $636.09 billions and $504.58 billions respectively in 2018[1].

Another key feature of digitalization is the rise of *two-sided*, or *multi-sided platforms*. Rochet and Tirole[2] define two-sided (or multi-sided) markets as "*markets in which one or several platforms enable interactions between end-users and try to get the two (or multiple) sides "on board" by appropriately charging each side*". This definition can be completed with be one given by Evans[3] who states that "*multi-sided platforms coordinate the demand of distinct groups of customers who need each other in some way*". He also makes a distinction within different types of multi-sided platforms[4]:

- *matchmakers*: they help members of one or more sides of the platform to search for coupling on the other side
- *transaction-based businesses*: charging for transactions that occur between different sides of the platform
- *audience-makers*: they make match advertisers with audience
- *platform shared-inputs*: where participants enter the platform to provide value to participants on the other side of the platform

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[1] World Retail Congress, 2018, *Global Ecommerce Market Ranking 2019*
[2] Tirole J. and Rochet J.M., 2004, "Two-Sided Markets: An Overview"
[3] Evans D.S., 2003, "Some empirical aspects of multi-sided platform industries", *Review of Network Economics*
[4] Evans D.S. and Schmalensee R., 2005, "The industrial organization of markets with two-sided platforms", *National Bureau of Economic Research*, Cambridge, MA.

Platforms have developed in a wide range of sectors and now include some of the best-performing companies in the world. Examples of platforms for different types of sectors can be found in appendix A7.

Some of these companies are true global companies and market leaders. For example, Facebook and YouTube had 2,5 billion and 2 billion monthly users respectively in 2019. Platform have disrupted entire sectors and their traditional models of business. Airbnb is world's biggest accommodation provider and it doesn't own any housing. Uber is the biggest taxi company in the world, and it doesn't own any taxi.

Many platforms rely on a new form of business, called the *sharing economy*. This economic model is a peer-to-peer based model of providing, lending, acquiring or sharing access to goods and services though a platform. This type of economy is new and fast growing, indeed PWC estimated that it will reach $335 billion by 2025[1]. Some examples of leading companies in the sharing economy are Airbnb (whose worth has been estimated by Forbes at $38 billion), Turo, a peer-to-peer car rental platform founded in 2009 that raised $250 million in 2019 at a valuation of over one billion US dollars, and BlaBlaCar, a car pooling platform founded in 2004 that now operates in 22 countries and has more than 80 million users.

Finally, the latest major trend in the digital era is the development of two technology-led innovations: the artificial intelligence (AI) and the Internet of things (IoT).

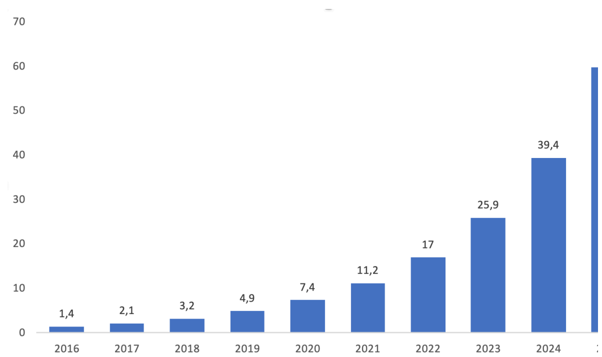
AI is defined as "*the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings*"[2], that is computers that have features ad capacities associated to human beings. The spread of AI is drove by machine learning, that is, the idea that a computer program can learn and

[1] PWC, 2015, The Sharing Economy, Consumer Intelligence Series, https://www.pwc.fr/fr/assets/files/pdf/2015/05/pwc_etude_sharing_economy.pdf
[2] Encyclopedia Britannica, https://www.britannica.com/technology/artificial-intelligence

improve by itself through its algorithms, without the interference of a human being. AI is one of the fastest-growing technologies today, whose development is particularly strong in the retail sector. Worldwide spending on AI in 2019 are estimated at $35 billion[1], which means they have doubled from 2018. Also, we expect that by 2021, 80% of new technologies will have AI foundations[2] and global revenues from AI are expected to increase considerably by 2025, as shown in figure 1.9.

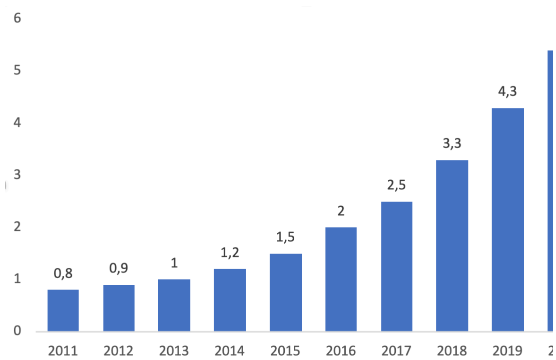
Lastly, IoT refers to the extension of internet to physical objects and places. In this new network revolution, goods and products are connected to the Internet and acquire intelligence by their capability to communicate data. Figure 1.10 shows the increasing path of the number of global IoT connections. This fact is also due to the diffusion of home connected devices as the virtual assistants Amazon Alexa and Google home and other connected home appliances as connected fridges, smart televisions, etc…

Figure 1.9 - AI Global Revenues, 2016 2025, *In $ US billion*



Source: Cellini P., 2019, Seminar on the Digital Economy, LUISS

Figure 1.10 – Number of IoT Globa Connections, 2011-2020
In billion



Source: Cellini P., 2019, Seminar on the Digit Economy, LUISS

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[1] International Data Corporation, 2019, https://www.idc.com/getdoc.jsp?containerId=prUS44911419

[2] Adobe, https://cmo.adobe.com/articles/2018/9/15-mindblowing-stats-about-artificial-intelligence-dmexco.html#gs.70rq0x

In conclusion, we can say that digitalization is a relatively modern phenomenon that has profoundly disrupted economies, traditional models of business and societies. The modern digital era is characterized by new forms of business (e-commerce, platforms and sharing economy) and technology led innovations (AI, IoT).

CHAPTER 2
Digitalization and economic growth

2.1 Economic benefits of digitalization

To discuss the economic benefits of digitalization we must examine the impact of digitalization on economic growth. Is digitalization boosting economic growth? If so, by which means?

First, we need to acknowledge that digitalization is a form of technological progress.
Assuming that digitalization is beneficial for the economy if it fosters economic growth, we therefore question what drives growth.
We model output as the result of the combination of productivity and factors of production. That is,

$$Output = Productivity \times Factors\ of\ Production$$

This idea is well represented in the Cobb-Douglas production function, which shows,

$$Y = AK^{\alpha}L^{1-\alpha}$$

Where output Y is a function of the factors of productions, physical capital K and human capital, or labor, L, and a parameter A which represents productivity, or the level of technology development. Also, α is capital's share of the production function and, by consequence, $1\text{-}\alpha$ is labor's share.
We now want to investigate the role of digitalization in growth. To do so, we must first state that digitalization is a form of technology. Hence, digitalization represents a technological progress.

We start by modelling the role of technology in growth. We start from the Solow model of growth. This model assumes positive and diminishing returns of capital and labor and constant returns to scale. Another major assumption is that technology is free, that is, it is publicly available as a non-rival and non-excludable good and we are in a closed economy.

The Solow model in its simple version states that the change in the capital stock (ΔK) at any time can be represented as the difference between the amount of investments (I) and depreciation (D):

$$\Delta K = I - D$$

We can express this equation in per worker terms, and we get:

$$\Delta k = i - d$$

where k is capital per worker, i investment per worker and d depreciation per worker. We also define investment and depreciation as:

$$i = \gamma y$$

$$d = \delta k$$

where γ is the constant fraction of output that is invested and δ is the depreciation rate of capital. By combining the preceding equations, we can therefore obtain that:

$$\Delta k = \gamma y - \delta k$$

Or, as $y = f(k)$,

$$\Delta k = \gamma f(k) - \delta k \qquad 1.1$$

The equation 1.1 is the Solow model equation that shows how capital changes over time: if investments ($\gamma f(k)$) exceed depreciation (δk) capital will increase, otherwise it will decrease. It admits that when $\gamma f(k) = \delta k$, the steady-state level of capital (k^{ss}) is reached. It is a level of capital that will be reached where capital per worker will not change over time.

To analyze how technological progress affects growth, we must introduce the following elements.
According to Uzawa's theorem[1], we assume that after a period of time τ, with $\tau < \infty$, we have $g_Y = g_K = g_C$, where,

$$\frac{\dot{Y}(t)}{Y(t)} = g_Y > 0$$

$$\frac{\dot{K}(t)}{K(t)} = g_K > 0$$

$$\frac{\dot{C}(t)}{C(t)} = g_C > 0$$

Where C is consumption. That is, when $t \geq \tau$, capital, investment, consumption and output are increasing at constant and equal rates.
Also, always according to Uzawa's theorem, we have

$$Y(t) = F[K(t), A(t)L(t)]$$

That is, when $t \geq \tau$, technological progress is purely labor augmenting (or *Harrod-neutral*[2]).

Now assume that population grows at rate n,

$$\frac{\dot{L}(t)}{L(t)} = n$$

We have that,

$$\frac{\dot{A}(t)}{A(t)} = g = g_y - n$$

where g is the growth rate of technology.

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[1] Uzawa's theorem is also known as the steady state growth theorem and it shows the forms that technological progress can take in the Solow model. The theorem is reported in Appendix A8.
[2] *Harrod-neutral* technological progress is defined as: $\tilde{F}[K(t), L(t), A(t)] = F[K(t), A(t)L(t)]$

Again, using equation 1.1, with a constant saving rate s, we have,

$$\dot{K}(t) = sF[K(t), \dot{A}(t)L(t)] - \delta K(t)$$

Now we define $k(t)$ as the capital per effective worker, i.e.,

$$k(t) = \frac{K(t)}{A(t)L(t)}$$

Then there exists a unique steady state equilibrium level where capital per effective worker is equal to k^*

$$\frac{f(k^*)}{k^*} = \frac{g + n + \delta}{s}$$

where output per capita grows at the same rate g of technology growth.

We now denote *work effectiveness* by e and define it as

$$e = A^{1/_{1-\alpha}} \text{, or alternatively, } e^{1-\alpha} = A$$

The production function hence becomes

$$Y = e^{1-\alpha} K^{\alpha} L^{1-\alpha} = K^{\alpha}(eL)^{1-\alpha}$$

It shows that increasing e increases L and thus leads to an increase in output Y. eL is the total number of effective workers in the economy. We define output per effective worker as $y = Y/eL$, and capital per effective worker as $k = K/eL$.
The production function in per worker terms becomes

$$y = k^{\alpha}$$

We then define

$$\dot{k} = \frac{d(\frac{K}{eL})}{dt} = \frac{\dot{K}}{eL} - (\hat{L} + \hat{e})k$$

where $\dot{k}$ is the change in capital stock over time.
We then substitute into this equation the differential equation describing the evolution of the aggregate capital stock

$$\dot{K} = \gamma Y - \partial K,$$

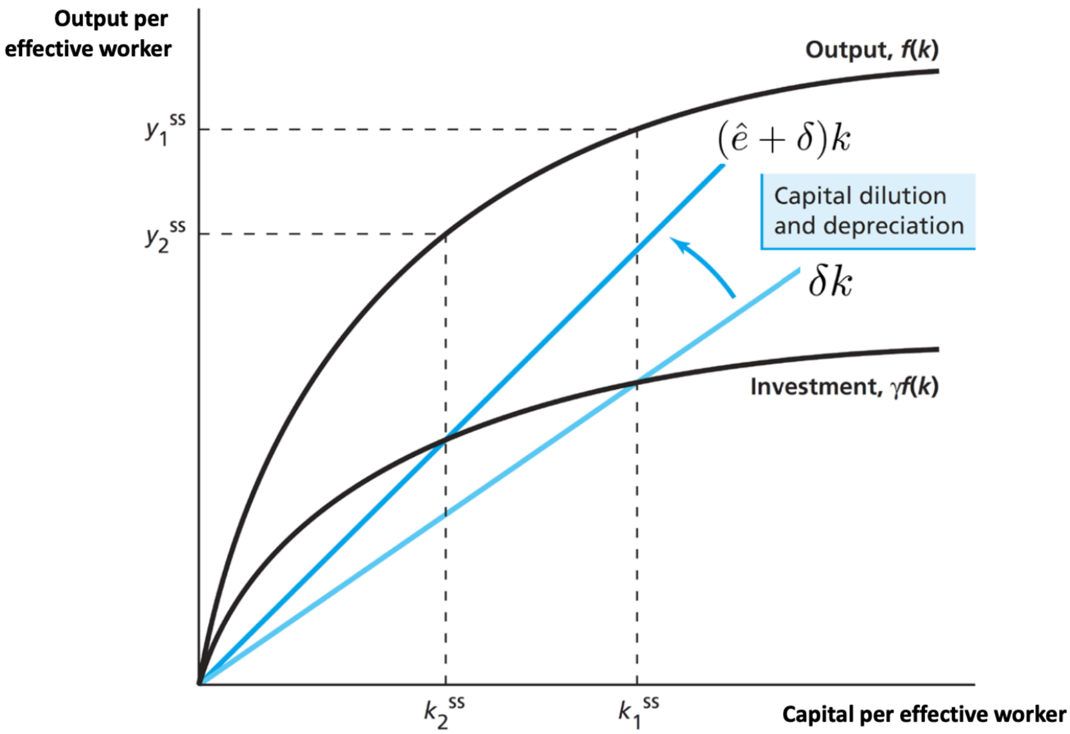
where γ is the fraction of output that is invested and ∂ is the depreciation rate. This substitution, along with the assumption that the growth rate of the labor force, $\dot{\hat{L}}$, is 0, yields

$$\dot{k} = \gamma y - (\hat{e} + \partial)k = \gamma k^{\alpha} - (\hat{e} + \partial)k$$

where $\hat{e}$k provides capital for the new effective workers created by technological progress.

Figure 2.1 shows the very important role that technological progress plays in the Solow model. We can observe that an increase in the technological level, represented by an increase in e, leads to an upward shift of the blue line $(\hat{e} + \delta)k$. This causes a reduction in the steady state level of capital per effective worker, from k_1^{ss} to k_2^{ss}, together with a reduction in the steady state level of output per effective worker, from y_1^{ss} to y_2^{ss}. This result might seem counterintuitive, as we would expect an increase in the level of technology available to increase the steady state level of output. However, technological progress does increase the level of output per worker, even if it lowers the level of output per effective worker that is represented in figure 2.1. Indeed, it raises the number of effective workers per worker.

Figure 2.1 - The role of technological progress in the Solow model



Source: Weil D.N., 2013, *Economic Growth*, 3rd ed., Pearson Education

Therefore, we can state that, according to the Solow model of growth, technological progress does raise the level of output per worker, which means that it leads to economic growth.

We can also view this analysis in a one country model.

We define human capital, labor, as,

$$L = L_Y + L_A$$

Where L_Y is the number of workers producing output and L_A is the number of workers engaged in R&D activities.

We also have that here γ is defined not as the constant fraction of output that is invested as we did previously, but as the fraction of labor force that is engaged in R&D activities. Therefore, it follows that, $\gamma = \frac{L_A}{L}$.

We can thus express the number of workers producing output, L_Y, as,

$$L_Y = (1 - \gamma)L$$

Then we make a strong assumption, we assume that workers are the only input that produces output. The production function that follows is simple,

$$Y = AL_Y$$

Which can be rewritten as,

$$Y = A(1 - \gamma)L$$

and in per worker terms,

$$y = A(1 - \gamma) \tag{1.2}$$

Then, we model technological progress (the growth rate of A) as:

$$\hat{A} = \frac{L_A}{\mu}$$

This equation means that technological progress is represented as a function of the number of workers engaged in R&D activities L_A, and a parameter μ which represents the “price” of a new invention. This price is measured in units of labor and tells how many units of labor are needed to achieve a given level of technology growth. We can rewrite technological progress as:

$$\hat{A} = \frac{\gamma}{\mu}L \tag{1.3}$$

Now we use this model to investigate the role of technological progress in growth. We observe that, as long as γ is constant, equation 1.2 shows that output per worker is proportional to the technology level A. Hence we get that:

$$\hat{y} = \hat{A}$$

Output per worker and technology grow at the same rate.

Combining the previous equation with equation 1.3, we get that:

$$\hat{y} = \hat{A} = \frac{\gamma}{\mu}L$$

This equation tells that if the fraction of workers employed in R&D activities, γ, increases, then output per worker (together with technology) will grow at a higher rate. It also says that if the price of a new invention, μ, decreases, output will growth at a higher rate.

This model has shown that output per worker growth at the same rate of technology. This implies that technological progress (an increase in the growth rate of technology), leads to economic growth (an increase in the growth rate of output per worker). This model also shows that technological progress is the only element that allows growth in output in the long run. Without technological progress, the level of output in the long run remains constant.

However, this model relies on strong assumptions as the fact that technological progress is only labor augmenting. Specifically, it lacks in explaining what determines technology growth. Indeed, the Solow model is an exogenous growth model because it takes technological growth as an exogenous variable.
To propose a solution to these problems, economists have built other models of growth, those of endogenous growth. They investigate the determinants of technological progress by endogenizing it. Technological progress is no longer taken as given and treated as an exogenous variable, it is now an endogenous variable.
An entire branch or the growth theory is hence called the endogenous growth theory. This theory states that innovation, knowledge and human capital play an important role in growth over the long run, and that these forces are endogenous. It holds that long run growth depends on policy measures as incentives on R&D.

The main model of endogenous growth is the AK model. This model is built with a Cobb-Douglas production function that exhibits constant returns to scale:

$$Y = AK^{\alpha}L^{1-\alpha}$$

An alternative form is the one where K embodies both physical and human capital:

$$Y = AK$$

Expressed in per capita terms, it becomes:

$$y = Ak$$

where y is output per capita and k is total capital per capita (both human and physical). A represents the level of technology and it is a positive constant.

Now assume that there is no depreciation, i.e. $\delta = 0$, and that n represents the constant growth rate of population. It follows that the differential equation of the growth model is:

$$k(t) = s \cdot f(k) - nk$$

By dividing each side by k, we get: $\frac{k(t)}{k} = s \cdot \frac{f(k)}{k} - n$, but as in the model $A = \frac{f(k)}{k}$, we can substitute this in the previous equation and we get that:

$$\frac{k(t)}{k} = s \cdot A - n$$

From this equation we can clearly see that the change in the per worker capital stock over time is positively related to technology. That is, when the level of technology is increased, say, by a technology improvement like the digitalization, then the capital stock is increased.

Another branch of the endogenous growth theory is developed according to the Schumpeterian idea of creative destruction. It says that the process of innovation embodied by technological growth renders old technologies obsolete and thus destroys them. This is recognized by Schumpeter as one of the key elements of capitalism. Through this mechanism, innovation fosters economic growth.

The main model investigating the role of technology in growth according to the idea of creative destruction has been developed by economists Aghion and Howitt. In their book *The Economics of Growth*[1], they have widely discussed the role that

[1] Aghion P. and Howitt P., 2009, *The Economics of Growth*, The MIT Press, Cambridge, Massachusetts

technological progress and innovations play in economic growth. They analyzed innovations through the measurement of Total Factor Productivity (TFP) and have also questioned the role of technological progress in cross-country growth convergence and the forms of market power and their implications. They dedicated an entire chapter of their book to the analysis of general purpose technologies[1], as is digitalization, and their effect on growth. They highlighted the crucial importance of R&D activities, as well as policies incentivizing R&D, as key determinants of economic growth. They consider innovation as an activity held by economic agents (i.e. the "entrepreneur") through R&D, that has a cost and is uncertain. However, the higher the spending on R&D, the higher the likelihood that it will generate innovation. Finally, Aghion and Howitt also questioned the use of accounting relationships in determining the relationship of causality between growth and technological progress. In general, their studies underlined the fundamental role that technological progress plays in economic growth and their analysis revealed the complex mechanisms of this relation.

Having presented how different models of growth present technological progress as one of its key determinants, we can now quantify the impact of digitalization.
In the previous chapter, we already discussed how the rise of the Internet have impacted the economy. The Boston Consulting Group, in its report on "The Internet Economy in the G-20"[2] quantified that the Internet already accounted for 4,1% of GDP in the G-20 countries in 2010, and they expected this percentage to increase considerably. They considered that this rise would have been led by online retail and ROPO (research online, purchase offline). In this report, the authors also analyzed the case of Italy. They showed that the Italian sectors where the Internet accounted for a larger percentage of the sector's GDP were real estate and business services, followed by manufacturing (see Appendix A9).

[1] General purpose technologies are a set of technologies that affect the entire economy.
[2] Dean D., Digrande S. et al, 2012, "The Internet Economy in the G-20", *The Connected World*, The Boston Consulting Group, Boston

2.2 Profit shifting practice and the free digital goods

Having discussed the positive impact of digitalization on economic growth, we will now see to which extent it remains difficult to measure it. We will analyze two elements that contribute to this problem: the profit shifting practice and the free nature of digital goods.

2.2.1 The profit shifting practice

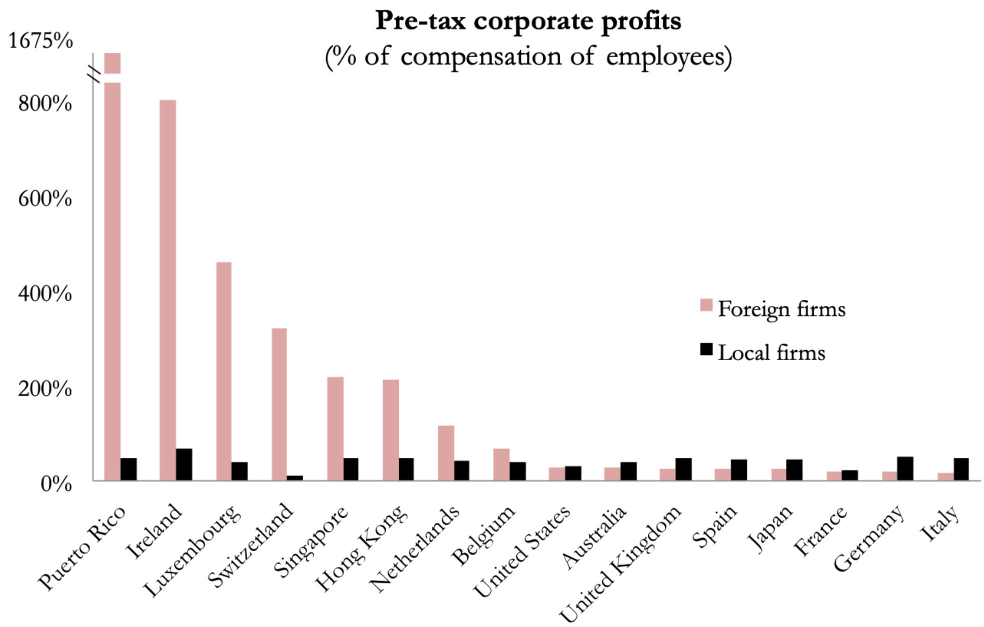
Economist Gabriel Zucman, in his many studies on global wealth and inequalities, analyzed one particular set of activities undertaken by multinationals that have a strong impact on nations' welfare. This practice, known as *profit shifting*, is investigated by Zucman, Tørsløv and Wier in "The Missing Profits of Nations"[1] and is typical of multinationals (i.e. companies that have affiliates in foreign countries). Profit shifting consists in moving a part, or the totality, of a company's profits to its affiliated based in a tax-haven or low tax country. Moving profits from high tax countries to low tax ones within the same multinational allows the company to save a considerable amount of its profits that would have been payed as taxes otherwise. This is possible because of cross-country differences in tax policies. Corporate income tax rates have specifically decreased globally: from 1985 to 2018, the global average corporate tax rate decreased from 49% to 24%[2]. The reduction in corporate tax rate is used by governments as a measure to attract foreign capital and profits. This phenomenon is particularly present in multinationals. They are, by definition, international companies that have affiliates in many countries which are located aiming at reaping local benefits. Also, multinationals are global corporations and are therefore either highly digitalized or digital companies. Among the largest global firms by market capitalization we

[1] Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER
[2] Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER

can find many digital multinationals on top of the ranking as Microsoft, Apple, Amazon, Google (Alphabet) and Facebook[1]. These are often referred to as the tech titans. Shifting their profits is therefore a common practice for digital multinationals and is eased by the free nature of most of their goods (we will discuss this issue in section 2.2.2). Profit shifting is therefore an important matter in the digital economy.

Zucman and his co-authors quantified the global volume of shifted profits. They find that, globally, "*close to 40% of multinational profits—defined as profits made by multinational companies outside of the country where their parent is located—are shifted to tax havens in 2015*"[2] and showed that US multinationals shift their profits more than other countries' ones. This impressive amount of profits being shifted also means that foreign firms are systematically more profitable than local ones in low tax countries. However, machines and physical capital have not been moved to those countries, only paper profits have been shifted.

Figure 2.2 – Profitability in Foreign and Local Firms (data from 2015)



Source: Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER

[1] Edelman B., 2019, *Multinationals in the Digital Economy*, Brookings, Washington
[2] Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER

In figure 2.2 we can see that foreign firms have higher pre-tax profits only in low tax countries as Puerto Rico, Ireland, Luxembourg and Switzerland, Singapore, Hong Kong, Netherlands and Belgium.

We can already find evidences that digital multinationals are more inclined to shifting their profits in Zucman and his co-authors' analysis. Using the Orbis database, they compared worldwide consolidated profits with the sum of all profits recorded by a company's subsidiaries for some multinationals. Figure 2.3 shows that, among the four multinationals being analyzed, the differences in the sum of observable profits and the true global profits are bigger for the three multinationals that are digital: Google, Apple and Facebook. They reported that the worldwide consolidated profits of Apple, according to Orbis, were 55.3 billion euros in 2016. However, by adding the profits of all Apple's subsidiaries we only find 2.0 billion euros. This means that more than 53 billion euros of profits made by Apple in 2016 were hidden. As the authors state, "*none of the profits made by Apple in the United States or in Ireland, Jersey, or similar tax havens are visible*". These large incongruencies are observed for other multinationals and, in particular, for digital ones as Google and Facebook. Globally, the authors estimate that 40% of multinationals' profits are shifted to their unknown tax-haven subsidiaries and, therefore, hidden[1]. This practice is particularly present in digital multinationals because of firms' intrinsic characteristics that are linked to their digital aspect, as their business models. The authors state that "*There is evidence that the typical business structure of digital services multinationals involves shifting intellectual property to tax haven subsidiaries and then directly selling services to final customers without involving any non-haven subsidiary*"[2]. Digital multinationals don't even need any non-haven subsidiary to run their business. They directly shift their source of profits, i.e. their intellectual property, to their tax haven subsidiaries.

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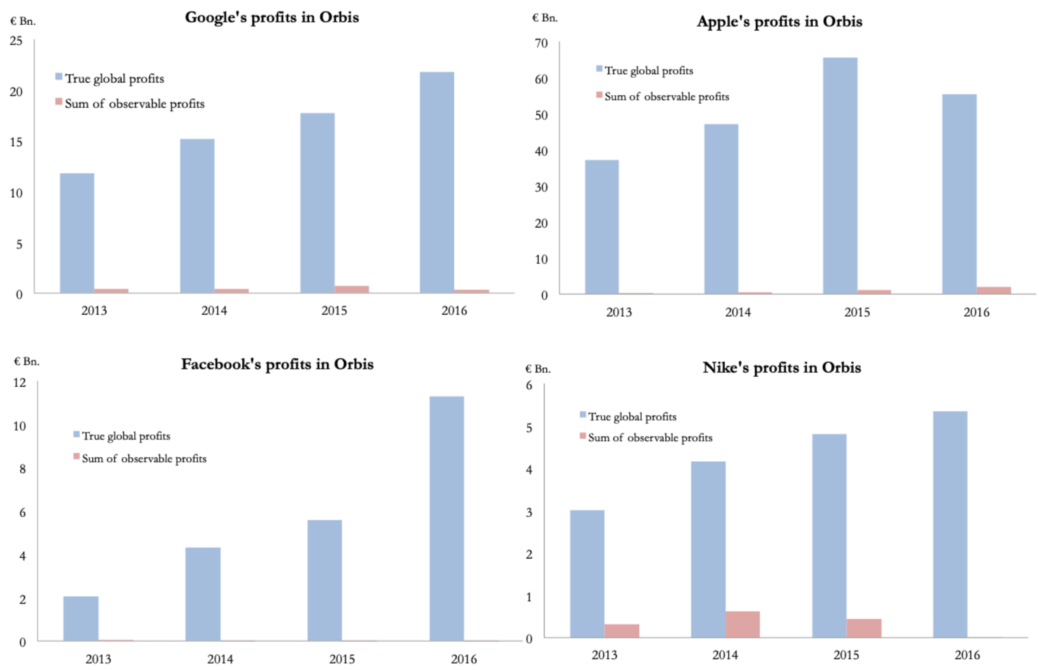
[1] Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER
[2] Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER

Figure 2.3 – Consolidated Global Profits vs. Observable Profits Across Subsidiaries



Source: Zucman G., Tørsløv T. and Wier L., 2020, *The Missing Profits of Nations*, NBER

There is thereby evidence that profit shifting is a widespread phenomenon of digital multinationals. This practice has consequences on economic indicators as it affects trade balances, corporate capital and labor shares and, especially, GDP. These variables are underestimated in high tax countries and overestimated in high tax ones. It follows that net exports, output and profits recorded in high tax countries are misleading and fail to account for the true contribution of globalization and digitalization to economic growth.

Finally, profit shifting is not the only cause of miscounted benefits of digitalization. There is another fact that complicates the assessment of its true impact and is linked to the free nature of most of goods and services provided by digital companies.

2.2.2 The problem of the free digital goods

Digital companies are of many kinds and with different business models. Nonetheless, some of the biggest ones provide goods or services that are free. It is the case of some tech titans as Google and Facebook.

Google is an Internet multinational that provides several online services. Even if some of them come with a fee, as for advertising, the majority is supplied for free. This holds for Google's search engine, the Android operating system, the web browser Google Chrome, YouTube and Gmail. Similarly, Facebook is a social media platform providing free online services, as any social media.

Usually, the price of items sold by a company is an essential element in computing its profits. Likewise, a nation's GDP can be computed as the sum of prices of final goods and services sold by firms within a country in a given period of time. The alternative way of computing GDP as the sum of the value added also relies on prices of goods and services. When items are consumed for free, this extremely complicates the measurement of both profits and GDP as these free goods and services are simply not accounted for. However, consumers have a high valuation for these free items and, sometimes, pay an indirect price to consume them, often being unaware of this hidden price.

Even if digital Internet products are often free, customers tend to value them significantly. Consumer's valuations can therefore be used as a method to price them indirectly. To measure the true value of digital goods and services the Federal Reserve relied on a MIT study[1] conducted by three economists. They conducted large sample questionnaires in which they asked how much monetary compensation people would ask to give up the use of certain digital goods for a period of time. This method allows to evade the problem of the free digital goods in assessing their value. The authors also say that digital goods represent a large part of consumer welfare that is currently not captured in GDP measurements. Results of this study are reported in figure 2.3, where WTA (willingness to accept)

[1] Brynjolfsson E., Collis A.,Eggers F., 2018, *Using massive online choice experiments to measure changes in well-being*, PNAS

stands for the monetary compensation needed to compensate losing access to the good for one year.

Figure 2.3 – Median WTA estimates for most popular digital goods categories

Category	WTA per year 2016, $	WTA per year 2017, $	95% CI WTA per year 2016, $		95% CI WTA per year 2017, $		n
			Lower	Upper	Lower	Upper	
All search engines	14,760	17,530	11,211	19,332	13,947	22,080	8,074
All email	6,139	8,414	4,844	7,898	6,886	10,218	9,102
All maps	2,693	3,648	1,897	3,930	2,687	5,051	7,515
All video	991	1,173	813	1,203	940	1,490	11,092
All e-commerce	634	842	540	751	700	1,020	11,051
All social media	205	322	156	272	240	432	6,023
All messaging	135	155	98	186	114	210	6,076
All music	140	168	112	173	129	217	6,007

Source: Brynjolfsson E., Collis A. and Eggers F., 2018, *Using massive online choice experiments to measure changes in well-being*, PNAS

Results show that the median monetary compensation required to give up access to all search engines for a year in 2017 is 17.530$. This allows to price the use of search engine services and understand how much consumer value is missed in GDP. It is interesting to observe that from 2016 to 2017, required monetary compensations have increased for all categories of digital goods. We also notice that Google is a top-service provider in all highest ranked categories of digital goods. Google owns the most used search engine, it provides Gmail, one of the principal email services, Google Maps, the main geographic Internet service, and YouTube, the most used video streaming platform. Following, Facebook is the biggest social media company, owning the social medias Facebook and Instagram and the messaging platforms WhatsApp and Facebook Messenger. This shows that, by shifting their profits, Google and Facebook suffice to make most of the digital economy's economic benefits disappear. Also, as digital goods tend to be free, their

use is not taxed. This entails that tax revenues are lost twice by high tax countries: digital multinationals don't pay taxes on providing free digital goods and services; and profits coming from advertising selling's revenues are mostly shifted.
The difficulty in assessing the value of digital goods is, therefore, one of the principal causes of the misestimating of the contributions of digitalization to economic growth.

Another element that must be discussed is the fact that free digital goods often have a price that consumers are not aware of being paying. The hidden price that consumers pay is their personal data. This issue particularly arose during recent privacy scandals (such as Cambridge Analytica) that recently affected many digital companies, as Facebook.

In conclusion, we have discussed the reasons why the economic contributions of digitalization are difficult to measure and largely underestimated. This is due to the profit shifting practice that is widely undertaken by digital multinationals and to the fact that most digital goods and services are free.

2.3 The uncaptured benefits and their consequences

Even if the economic contributions of digitalization, in terms of profits and GDP, are difficult to measure, these are not the only type of economic benefits of this technological transformation. Also, economic growth cannot be limited to GDP accounting. Digitalization widely affects other economic indicators such as employment, trade and taxation and it generates new forms of inequalities.

The first consideration is that digitalization, by profoundly affecting the entire economy, has changed the way people work. It has modified entire industries, destroying some forms of employment and creating new ones. This relates to the Schumpeterian idea of creative destruction which is perfectly applicable to digitalization. According to this principle, the industries that digitalization renders obsolete will dissolve causing many jobs to disappear. This is also true for industries or companies that will not succeed in digitalizing themselves. They will be outperformed by the ones that have accomplish their digital transformation. Digitalized companies increase their productivity, they can produce the same amount of output with less labor. On the other hand, digitalization has led to the emergence of new flourishing industries creating new jobs. It is particularly the case of recent technological trends such as the rise of AI and machine learning. In general, the phenomenon of digitalization entails an efficient reallocation of production factors, from less digitalized industries to highly digitalized ones. In the process of reallocation, some jobs are destroyed and other are created. In Italy, professions characterized by a high degree of digitalization are growing faster than the others[1]. Finally, there also is the risk of automation of some occupations, potentially causing unemployment. However, workers seem to be already responding to this threat by either changing their occupation or by becoming entrepreneurs[2]. This last option seems yet less available to women or workers whose occupations are at a higher risk of automation and having limited digital skills. This shows that the effects of digitalization on employment are complex and diverse. They seem to vary according to the digital skills and the gender of workers, together with the level of digitalization of their industry.

Digitalization strongly affects trade too. It has increased the speed, the scale and the scope of trade and changed the way we trade goods. We speak about digital trade when referring to any digitally enabled trade of goods and services that is either physically or digitally supplied. This means that "*while all forms of digital trade are enabled by digital technologies, not all digital trade is digitally delivered*"[3].

[1] Cirillo V., Evangelista R., Guarascio D. and Sostero M., 2019, *Digitalization, routineness and employment: An exploration on Italian task-based data*, GROWINPRO
[2] Fossen F.M. and Sorgner A., 2018, *The Effects of Digitalization on Employment and Entrepreneurship*
[3] OECD, *The impact of digitalization on trade*, https://www.oecd.org/trade/topics/digital-trade/

Digital trade has been strongly enhanced by information technology companies. They are at the origin of a new good, data, which is not only empowering digital trade, but is also traded itself. Data is a highly valued good, especially in technology industries, such as the Internet of things (IoT) which entirely relies on it. The movement of data is fostering digital trade. This new form of trade allows firms to enlarge their market and reach digitally connected customers across the world. This new form of technology also facilitates payments and transactions and has contributed to the development of international value chains. The digitalization of trade is also raising important policy issues, such as regulating the flows of data within and across countries.

Another element that must be discussed is the impact of digitalization on taxation. In the previous section, we saw how international tax competition is causing inequal repartitions of digitalization's benefits. The taxation of digital goods is another issue of digitalization. This problem is due to the fact that digital economy is essentially immaterial, leading to the vanishing of tax bases. A possible path for taxing the digital bases is to complement the corporate profit tax with a tax on digital transactions. This could let emerge the real hidden value added created by digital firms. Along these lines, the European Commission [1] and OECD [2] have recently suggested specific action plans to introduce some forms of web taxes allowing a fair taxation of digital bases.

Finally, the consequences of digitalization and its uncaptured benefits spill over on inequalities. First, there is a new form of inequality arising from the profit shifting practice of digital multinationals. By shifting their profits where taxes are low, these companies generate indirect benefits in these countries. This generates

[1] European Commission, 2018, *Proposal for a CONCIL DIRECTIVE laying down rules relating to the corporate taxation of a significant digital presence*; *Proposal for a COUNCIL DIRECTIVE on the common system of a digital services tax on revenues resulting from the provision of certain digital services*

[2] OECD, 2018, BEPS Report; OECD/G20, 2019, Inclusive framework on BEPS: Progress report July 2018–May 2019, 8 June 2019

productivity spillovers from digital multinationals to local firms. In the case of Ireland, this occurs when non-European multinationals shift their profits and their local affiliate invests in R&D, spreading productivity gains across the local supply chain.[1] Finally, differences in the degree of access to digital technologies impinge countries' potential of growth. This phenomenon, also called the digital divide, causes the rise of inequalities between and within countries. In the next chapter, we will analyze of the Covid-19 pandemic has impacted inequalities caused by digitalization.

[1] Di Ubaldo M., Lawless M. and Siedschlag I., 2018, *Productivity Spillovers from Multinational Activity to Local Firms in Ireland,* OECD Productivity Working Papers, No. 16

CHAPTER 3
The role of digitalization during the COVID-19 pandemic

Originating from China, the COVID-19 virus spread all over the world and this global health crisis became a pandemic. This, of course, has strongly impacted the global economy. In this chapter, we will discuss the role of digitalization during this pandemic, focusing, in particular, on its contributions to the economy.

3.1 Digitalization in the economy during COVID-19

The world COVID-19 pandemic has intensely impacted the economy. The consequences, especially due to the lockdown, are the rise of a new economic crisis and profound economic and social restructurings. The first economic repercussion of the pandemic is the increase of unemployment. Since mid-March in the United States, more than 40 million people have requested unemployment benefits[1]. This level of unemployment and its growing path are comparable to those of the Great Depression. The American unemployment rate is actually close to 15% and the United States' GDP suffered a 4,8% decline[2]. Also, COVID-19 is forcing a rapid restructuring of the economy and the way companies work. Erik Brynjolfsson, MIT professor and director of the MIT Initiative on the Digital Economy, says the pandemic is "*compressing 10 years of structural change into 10 weeks*"[3], and companies are not expected to go back to their old habits once the pandemic will be over.

However, some tech companies seem to be taking advantage of COVID-19. Indeed, Amazon announced it is hiring 10.000 warehouse workers, Facebook's CEO, Mark Zuckerberg, said that traffic for messaging and video-calling has exploded and

[1] "'Still Catching Up': Jobless Numbers May Not Tell Full Story", The New York Times, May 29, 2020

[2] "What happens to industry and jobs after COVID-19?", MIT Sloan, June 1, 2020

[3] "What happens to industry and jobs after COVID-19?", MIT Sloan, June 1, 2020

Microsoft announced that online collaborations using its software increased by nearly 40% in a week[1].

The role of tech companies during the coronavirus pandemic seems therefore to be positive. Digitalization has particularly impacted the way people work, how they purchase goods and the role of social media. Digital companies have also contributed to the fight against the spread of the virus.

First, the lockdown has forced employees, when possible, to continue working from their home. Thanks to digitalization, a new form of work has spread, teleworking. This is the biggest changed brought by the pandemic. Teleworking and online conferencing have affected worker's daily life and how companies' structures. By allowing people to continue working from their homes, digitalization has saved countless employments and companies. This is, without any doubt, the most positive impact of digitalization on the economy during COVID-19. Shifting work practices online has ensured the stability of the majority of the economy. Technology has suddenly become essential for companies to allow them to keep running their businesses. As stated by digital economy expert McAfee [2] , if the COVID-19 pandemic happened ten years ago, without the availability of today's technologies, the economic consequences and the general socio-economic situation, would have been much worse. The demand for remote work applications of messaging and video conferencing, as Zoom, Cisco Webex, Microsoft Teams and Skype has exploded. Figure 3.1 shows the example of China, the first country affected by COVID-19. We can see that the number of users of remote work applications widely used in China, as WeChat Work, Tencent Conference and DingTalk, has increased tremendously since the beginning of the coronavirus crisis in late January 2019.

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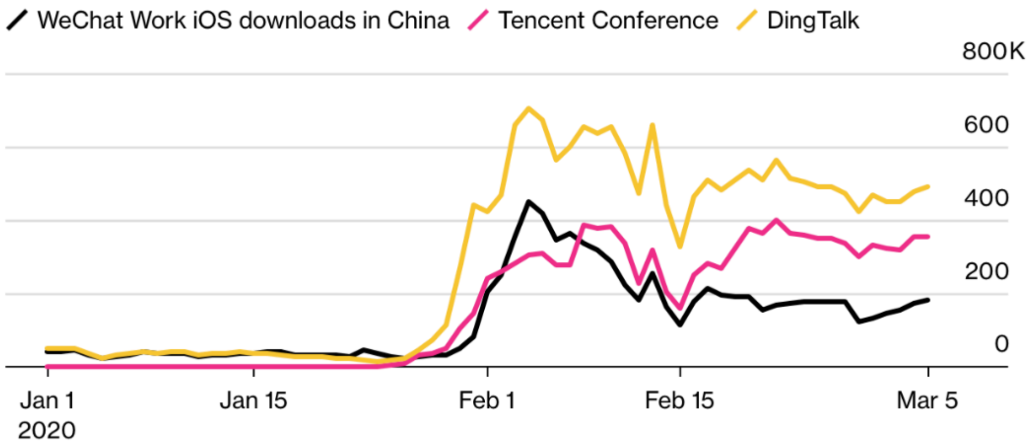
[1] "Big Tech Could Emerge From Coronavirus Crisis Stronger Than Ever", The New York Times, March 24, 2020

[2] ''Il y a dix ans, la situation aurait été bien pire'', Les Echos, March 28, 2020

Figure 3.1 - Use of selected remote work application in China, 1 January 2020 – 5 March 2020



Source: UNCTAD, 2020, *The COVID-19 Crisis: Accentuating the Need to Bridge Digital Divide*

This digital shift of daily activities is also the case of education. Universities and all types of schools used digital platform to continue their educational activities and classes took place online. However, as we will further discuss in the next section, this phenomenon increased the digital divide. Finally, this pandemic is also forcing managers to profoundly rethink their companies' organization and evaluate if machine learning can help in maintaining companies' daily operations.

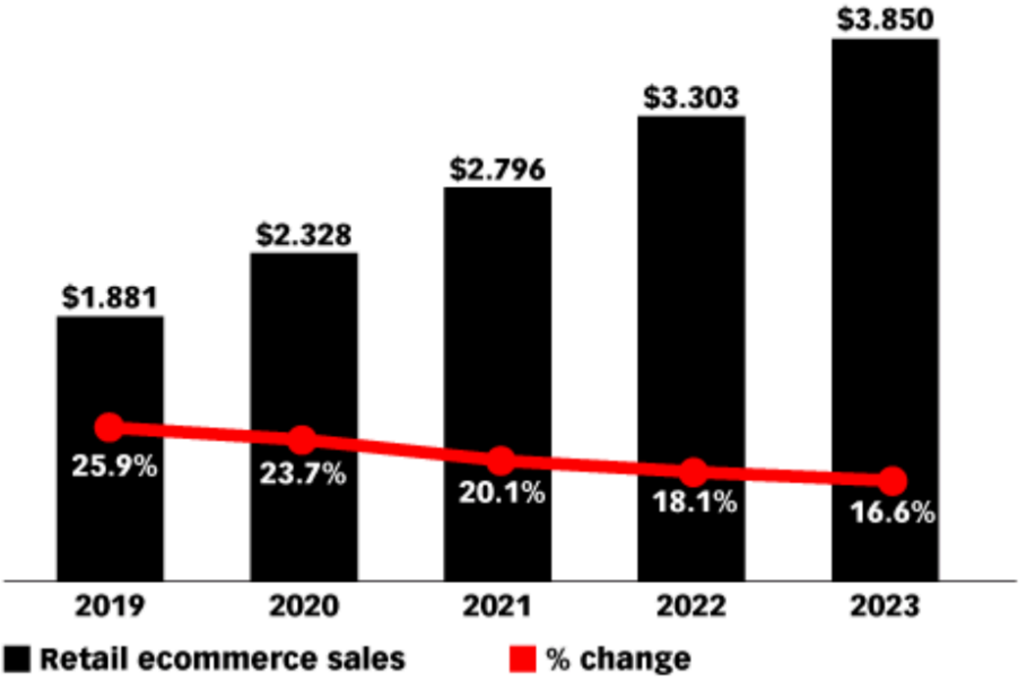
Another consequence of the coronavirus lockdown is that it changed the way people purchase goods and services. The closing of stores pushed consumers to turn to the e-commerce. Food and goods delivery companies, such as Uber Eats or Amazon, became indispensable for the maintaining of commercial transactions. As previously mentioned, Amazon is prospering during this pandemic and is hiring more workers to be able to face its increasing number of orders. Accordingly, Uber Eats' sales in Italy increased by 55% in March 2020[1]. During the COVID-19 pandemic, e-commerce is particularly increasing for retail sales. The important element is that these changes in consumers' habits are expected to last after the end of the pandemic, causing long term economic transformations. Figure 3.2

[1] Ansa, April 9, 2020

shows that the volume of e-commerce sales in China is expected to continue growing, year by year, until 2023.

Figure 3.2 – Retail e-commerce sales in China, 2019-2023

Trillions and % change



Source: eMarketer

The strong increase in Chinese e-commerce has characterized the coronavirus pandemic. Indeed, the Chinese online retailer JD.com said that in a 10 days period from January 2020 to February 2020 its grocery sales grew by 215%[1].

Another remarkable change in consumers' habits during the pandemic is the increase in demand of movie streaming. This results from the closing of cinemas and theaters. Consequently, the downloads of Netflix's app increased by 66% in Italy, by 35% in Spain and by 9% in the United States, where the platform was already popular before COVID-19[2]. Another example is the very successful launch of the Disney+ platform that occurred during the pandemic.

[1] UNCTAD, 2020, *The COVID-19 Crisis: Accentuating the Need to Bridge Digital Divide*
[2] "Big Tech Could Emerge From Coronavirus Crisis Stronger Than Ever", The New York Times, March 24, 2020

The coronavirus crisis has also contributed to reshaping the role and the importance of social media. In a period where physical gatherings where prohibited, people relied on social media to maintain their social contacts. Zuckerberg, Facebook's CEO, announced that voice callings over WhatsApp, which is owned by Facebook, have doubled in volume. A similar grow was also experienced by Facebook app Messenger[1]. Social media hence helped social interactions in this period of crisis. They were also widely used as sources of information. In more than 20 countries, the World Health Organization used *COVID Connect*, the automated information service of WhatsApp, as the official service of information on the coronavirus[2]. The downside of this phenomenon is the danger represented by the spread of fake news through social media.

Finally, digitalization played a very important role in the fight against COVID-19. Digital technologies are the enablers of successful management of the coronavirus crisis in some countries, especially in Asia. In South Korea, digital platforms were used by the government to map all movements of people tested positive to the virus. Also, through the app "Corona 100m", all the movements and transactions of people who tested positive were tracked by GPS technology and surveillance cameras and then made public. By downloading the app, people could verify if they have had any contact with a person that was affected by COVID-19. Digital platforms are also widely used by all types of researchers to share data and their findings. Digitalization is therefore considerably contributing to the progress of the scientific research on coronavirus.

The COVID-19 pandemic has therefore been characterized by a positive role of digitalization. Technologies stood up and substituted many daily actions and interactions by digitalizing them.

[1] "Big Tech Could Emerge From Coronavirus Crisis Stronger Than Ever", The New York Times, March 24, 2020
[2] "What happens to industry and jobs after COVID-19?", MIT Sloan, June 1, 2020

However, as we will discuss in the next section, the increasing importance of digitalization contributed to widening the digital divide.

3.2 The digital divide

The digital divide can be defined as the asymmetry in the degree of digitalization. This phenomenon has always existed. However, in a world that is always more relying on digital technologies, this divide is frighteningly widening.
Nowadays, as work and classes are performed online, not having access to digital technologies means being excluded from employment and education. The coronavirus pandemic has exposed the true dimensions of information divide. As access to digital devices is expensive, income inequalities translate in stronger inequalities in employment and educational opportunities. As long as purchasing an internet connection or a connected device remains expensive, the divide will widen.
The digital divide is particularly impacting the education. In the United States, for example, 40% of children in poor neighborhoods don't have connected devices[1]. Similarly, figure 3.3 shows the development of digital competences of teachers in Italy. We can observe that less than half of Italian teachers teach their daily classes using digital technologies. This means they lack technological capabilities to be able to successfully shift their teaching practices to an online platform. In fact, the digital divide is of many forms. It doesn't only concern the accessibility of technologies, but also technological skills.

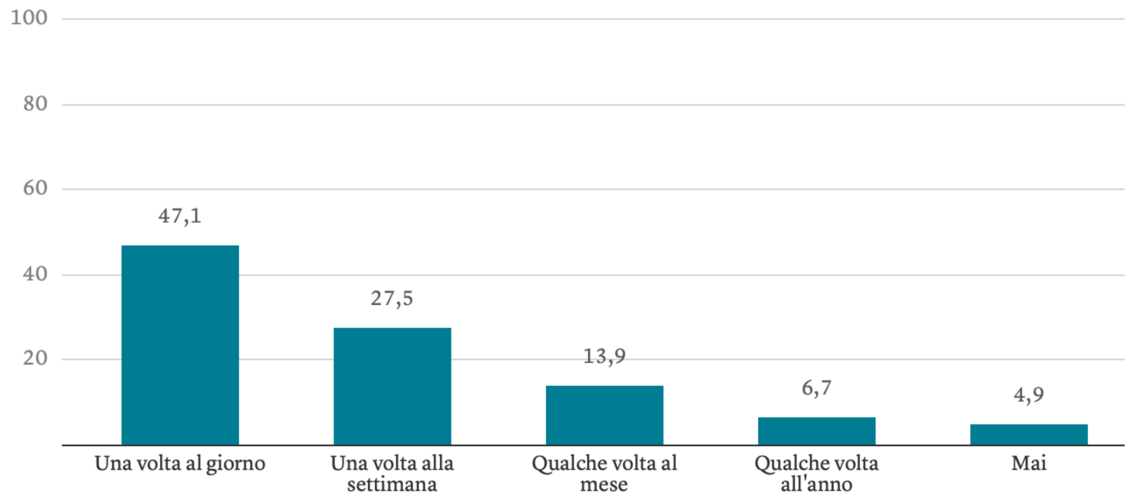
Another form of digital divide that is being widened by COVID-19 is digital market concentration. Most of the world's principal digital platforms are owned by a small number of digital firms, especially by American and Chinese companies. Before the

[1] ''Pandemic widens digital divide – Congress may spend billions to narrow it'', San Francisco Chronicle, May 19, 2020

pandemic, in 2017, world's top seven digital platforms already had a market capitalization of $100 million and accounted for two-thirds of total platforms value [1]. The increasing dependence of our societies on digital platforms, accentuated by COVID-19, will further strengthen the market positions of big tech companies.

Figure 3.3 – Digital competences of Italian teachers

How often teachers use digital technologies in class, in %



Source: "Il divario digitale è una zavorra per l'Italia", Internazionale, March 23, 2020

As previously discussed, the coronavirus pandemic will contribute to generate a long-term digital shift of work, education and social practices. This will widen the digital divide generating more inequalities. This is reason why policies are needed to narrow the divide.

Finally, the digital divide is also reflected in the differences in the level of digitalization across countries. There are substantial gaps in many policy areas that need to be tackled. These range from legal frameworks to the development of infrastructures of information and communication technologies. One example is the range, affordability and quality of broadband connections.

[1] UNCTAD, 2019, *Digital Economy Report*

The European Digital Initiative, an initiative of the Europe 2020 strategy plan, already had among its objectives the reduction of the digital divide. Similarly, as a consequence of COVID-19, the United States government is planning important spending aimed at reducing this divide.

As a conclusion, we can acknowledge that digitalization has certainly played a major role in the coronavirus pandemic, by providing countless solutions to the changes imposed by lockdowns. If this global health crisis had occurred just ten years ago, its economic damages would have been much more important. However, as digital technologies become always more essential to the functioning of modern societies, governments must implement concrete policies aimed at reducing the digital divide. If they will fail, societies' increasing dependence on digitalization will generate more profound socio-economic inequalities within and across countries.

CONCLUSIONS

In the past two decades, the digitalization has increased productivity, allowing companies to produce more efficiently. As we saw in the second chapter, digital transformations can be considered as a creative destruction which renders obsolete traditional models of production and gives rise to new economic paradigms as the e-commerce. Even if the impact of digitalization on productivity is positive, it appeared in our analysis that the measurement of its economic benefits remains complex. It is worth to underline that the definition of digitalization itself remains controversial and this is, in part, due to the vastity of the phenomenon. However, there exist some indicators, such as DESI, I-DESI, the Digital Density Index (DDI) and the Industry Digitalization Index, that measure the level of digitalization of countries. They evaluate the diffusion of the use of digital technologies in societies and economies. It would be interesting to further investigate the relationship between digitalization and economic growth with an econometric analysis of the correlation between digital indicators and countries' GDP.

Moreover, it is still difficult to estimate the true impact of digitalization on the economy due to the fact that the tech industry is very concentrated and digital multinationals largely shift their profits to low-tax countries or tax havens. This practice hides the true contribution of digital companies in terms of nations' welfare accounting, such as GDP. High-tax countries, whose corporate profits are shifted abroad, also loose other forms of benefits that arise from digitalization. This is due to the productivity spillover effect that big tech companies generate. Furthermore, the fact that most digital goods are free, considerably complicates the evaluation of digitalization's economic benefits. As digital economy is essentially immaterial, taxation problems arise, as well as difficulties in the assessment of the true value of digital goods for consumers.

Eventually, we underlined that digital technologies have been essential during the COVID-19 pandemic reducing significantly the economic damages. Companies were able to successfully react and adapt to lockdowns by shifting their operations into digital platforms. On the other hand, the increased reliance of economies on digital technologies strongly accentuated the social inequalities by widening the digital divide. Actions and policies from governments and international organizations are needed to fight those inequalities and bridge digital divides.

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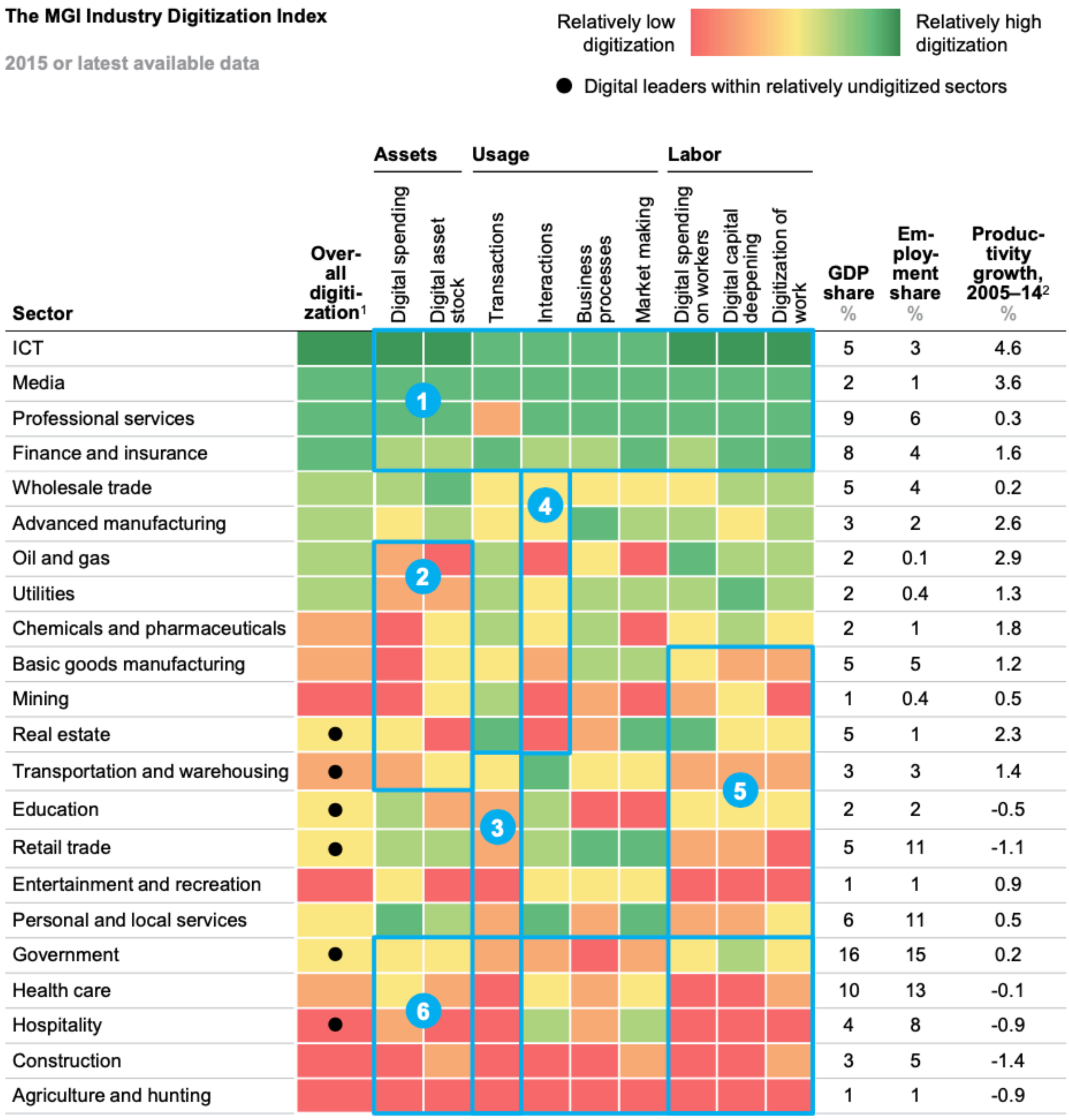
APPENDIX

A1 - The Digital Density Index (DDI)
Measurement framework of the Digital Density Index

Activity area	Description and metrics	
1. Making markets	Increasing digitalization of existing markets and creation of new digital markets. Recognition that existing markets are becoming increasingly digital and new markets are being created through digital means.	
Metrics:	• Customer activity cycle • Digitally contestable markets[2]	• Interfirm collaboration
2. Sourcing inputs	Use of digital technologies to source and/or use factors of production. Degree to which digital technologies change the lifecycle of sourcing these factors for the business.	
Metrics:	• Plant, property, equipment • Labor	• Finance (capital, liquidity)
3. Running Enterprises	Business use of digital technologies and activities to execute key business functions.	
Metrics:	• Technology process • Strategy process • Human capital/talent	• Business model • Innovation • Research and development (R&D) spending
4. Fostering enablers	Changes in institutional and socioeconomic environments to facilitate digitalization.	
Metrics:	• Organizational flexibility • Connectivity • Attitudes in society	• Government spending • Ease of business • Long-term regulatory outlook

Source: Kotarba M., 2017, *Measuring Digitalization – Key Metrics*, Foundations of Management, Vol. 9

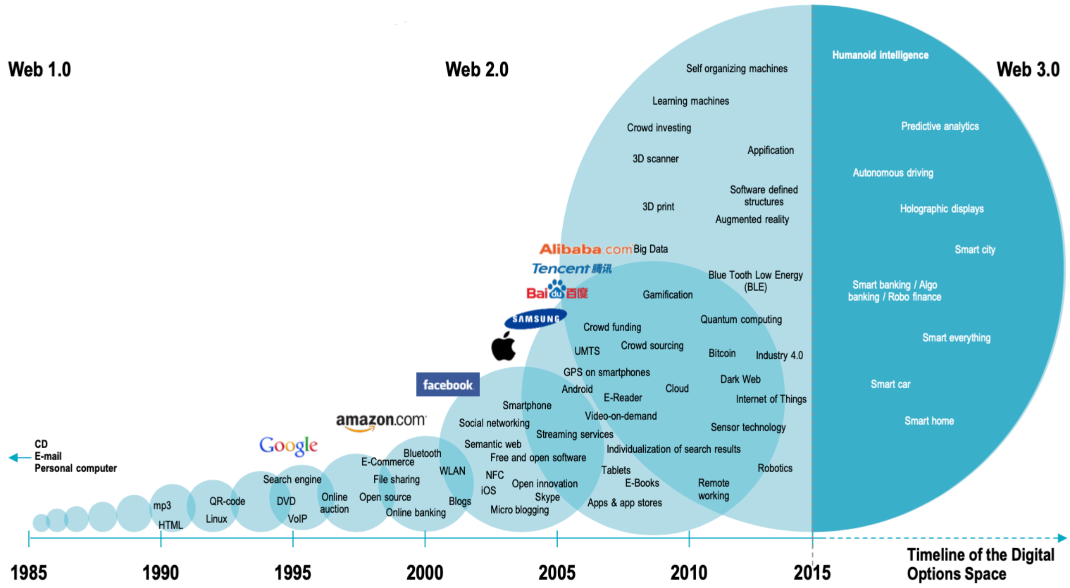
A2 – Industry Digitalization Index scores for US economy, 2015



1. Knowledge-intensive sectors that are highly digitized across most dimensions
2. Capital-intensive sectors with the potential to further digitize their physical assets
3. Service sectors with long tail of small firms having room to digitize customer transactions
4. B2B sectors with the potential to digitally engage and interact with their customers
5. Labor-intensive sectors with the potential to provide digital tools to their workforce
6. Quasi-public and/or highly localized sectors that lag across most dimensions

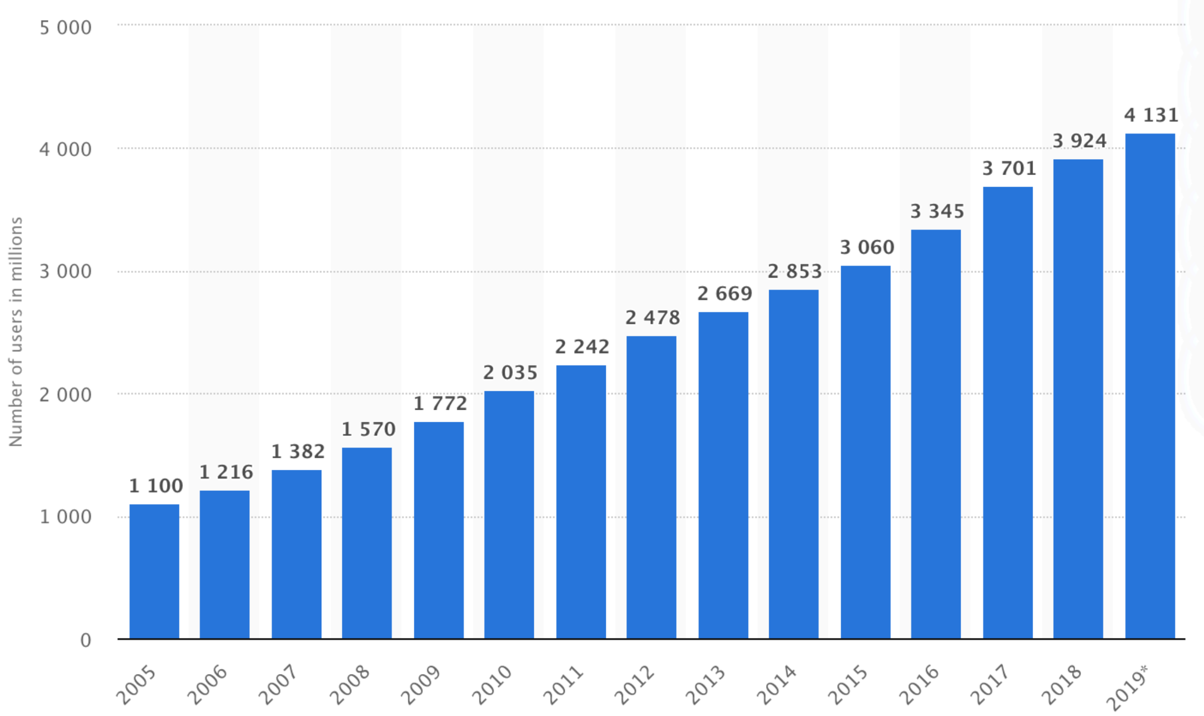
Source: Mckinsey Global Institute, 2015, *Digital America: A Tale of the Haves and Have-Mores*

A3 – Milestones in the digital evolution



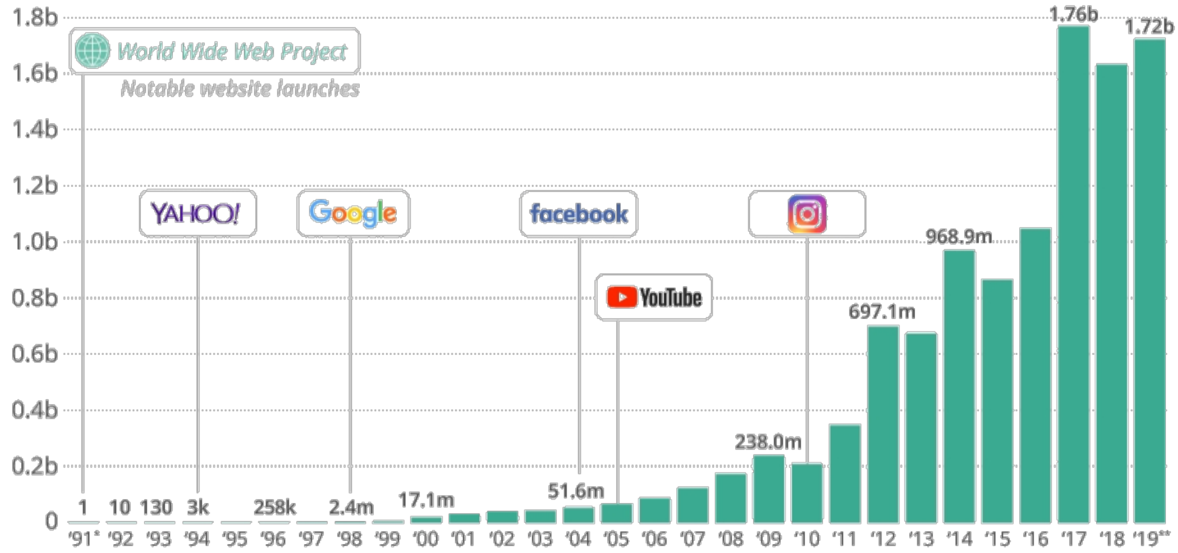
Source: Roland Berger, 2017, "Milestones in the digital evolution", *Trend compendium 2030*

A4 – Number of internet users worldwide from 2005 to 2019



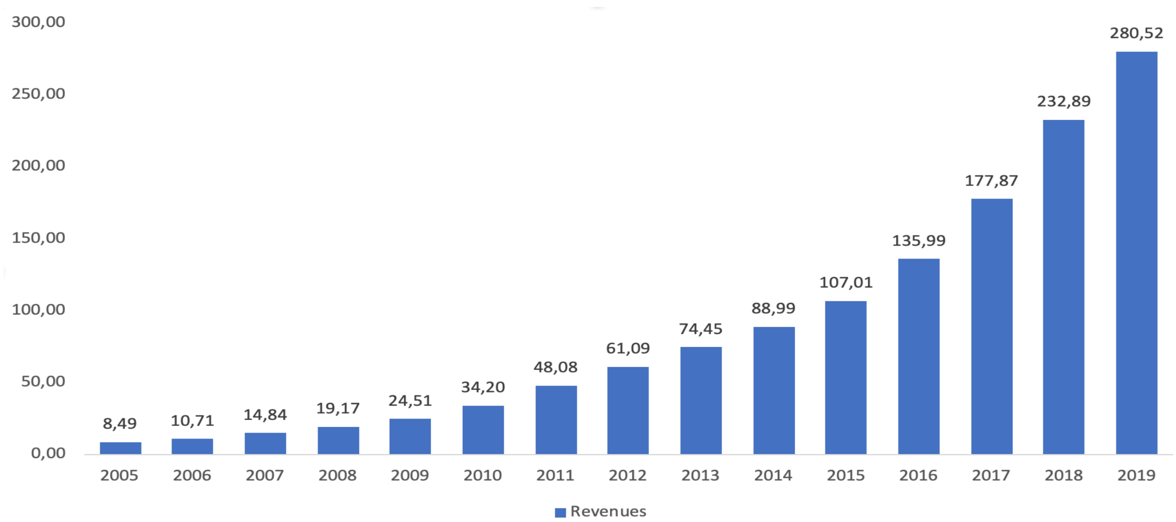
Source: Clement J., 2020, *Statista, Global number of internet users 2005-2020*, https://www.statista.com/statistics/273018/number-of-internet-users-worldwide/

A5 – Number of websites online from 1991 to 2019



Source: Armstrong M., 2019, Statista, *How many websites are there?*, https://www.statista.com/chart/19058/how-many-websites-are-there/

A6 – Amazon Annual Revenues (in Millions of US $)



Source: personal elaboration of data from Macrotrends, 2019

A7 – Examples of platform in different sectors

Sectors	Examples
Media	YouTube, Netfkix, Wikipedia, Huffington, Kindle
operating systems	iOS, Android; MacOS, Microsoft windows
food	Foodora, OpenTable, Justeat, Deliveroo
communication & networking	Facebook, Twitter, Linkedin, Snapchat Instagram, Skype
transport	Uber, Lyft, BlaBlacar, GrabTaxi
Travel	Airbnb, Tripadvisor, Booking.com, Hotel.com Roomster
retail & delivery	Amazon, Alibaba, Walgreen, Wholefoods Ubereat, Glovo, Ebay

Source: personal elaboration

A8 – Uzawa's Theorem

We have an aggregate production function

$$Y(t) = \tilde{F}[\tilde{A}(t), K(t), L(t)]$$

where $\tilde{F}: \mathbb{R}^2_+ \times \mathcal{A} \rightarrow \mathbb{R}_+$ and $\tilde{A}(t) \in \mathcal{A}$ represents technology at time t. $\mathcal{A}$ is a subset of $\mathbb{R}^N$ for some natural number N. We assume that $\tilde{F}$ exhibits constant returns to scale in L and K. We represent growth in capital at time t by:

$$\dot{K}(t) = Y(t) - C(t) - \delta K(t)$$

where δ represents the depreciation rate and $C(t)$ is consumption at time t. Suppose that population grows at a constant rate, $L(t) = \exp(nt)\, L(0)$, and after a time $\tau < \infty$ such that $t \geq \tau$ we have:

$$\dot{Y}(t)/Y(t) = g_Y > 0$$
$$\dot{K}(t)/K(t) = g_K > 0$$
$$\dot{C}(t)/C(t) = g_C > 0$$

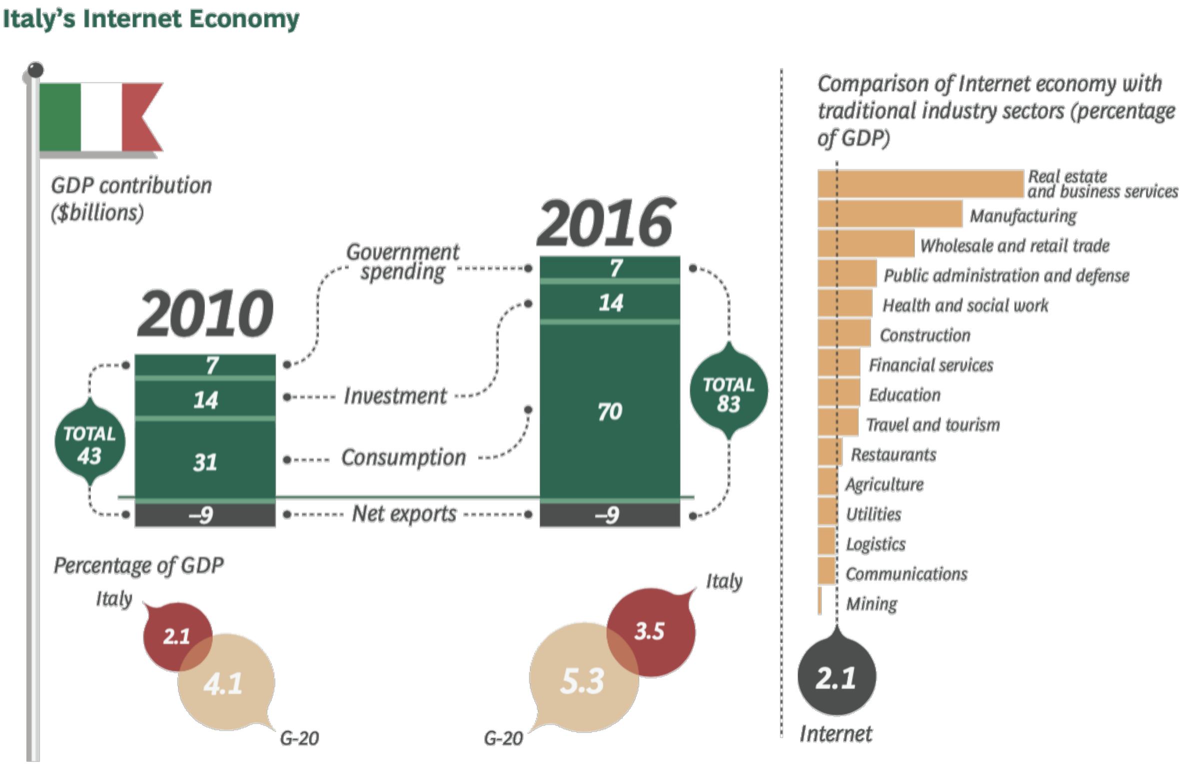
Then,

1. $g_Y = g_K = g_C$; and
2. For any $t \geq \tau$, there exists a function $F: \mathbb{R}^2_+ \rightarrow \mathbb{R}_+$ and this function is homogeneous of degree 1 in its two arguments, such that the aggregate production function can be represented as

   $$Y(t) = F[K(t), A(t)L(t)]$$

   where $A(t) \in \mathbb{R}_+$ and $g = \dot{A}(t)/A(t) = g_Y - n$.

A9 – The Italian Internet Economy



Source: Dean D., Digrande S. et al, 2012, "The Internet Economy in the G-20", *The Connected World*, The Boston Consulting Group, Boston