Digital Transition and the European Industrial Policy

Edited by Maria Letizia Giorgetti
and Lorenzo Zirulia

Milano University Press

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Foreword

Maria Pia Abbracchio - Vice rettrice dell'Università degli studi di Milano dall'ottobre 2018 al'ottobre 2024
University of Milan
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This book summarizes the key points that emerged from the meeting titled: "Digital transition: what are the challenges for industrial policies (cloud and beyond)" organized on May 15, 2023 at the University of Milan by Maria Letizia Giorgetti and Lorenzo Zirulia.

The meeting focused on the key aspects of digitization in Italian industry, with the primary aim of building up a transversal and interdisciplinary network of competences and collaborations between national universities, research bodies, non-academic institutions, the Italian National Institute of Statistics, ISTAT, Confindustria (the main association representing manufacturing and service companies in *Italy*), the Italian National Federation of managers, senior staff and executive professionals (Manageritalia), MIMIT (the new Ministry of Companies and of the "made in Italy"), and companies themselves.

Specifically, the meeting focused on the digitization and redefinition of production chains within and outside companies, on the key role of cloud data storage and computing in modern manufacturing industry, and on how new industrial policies could favor the digital transition.

The meeting was also part of the ongoing and planned activities of Spoke 4, "Economic impact and sustainable finance" of the innovation ecosystem "MUSA: Multilayered Urban Sustainability Action" (of which University of Milan is part), financed by the Ministry of Education and Research (MUR) within the Piano Nazionale di Ripresa e Resilienza (the National Recovery and Resilience Plan, NRRP).

NRRP is the instrument which, by using Next Generation Europe funds, will make our country more equitable, sustainable and inclusive, and help build a new Italy - leaving behind the negative pandemic's economic and social impacts. As early as during the design phase of the NRRP, economist Mario Pianta highlighted that Italy's economic issues did not originate with the coronavirus pandemic. By 2020, the country was already experiencing the repercussions of a decade-long recession.

The crisis from 2011 to 2014 had already led to the closure of 200,000 firms and the loss of 800,000 jobs. By 2019, compared to 2007, the Italian economy still experienced a 5% reduction in hours worked and nearly a 20% decline in the industrial production index (Pianta, 2021). Moreover, the pandemic has highlighted other weaknesses in the Italian economic system: the extent of precarious work, the gender salary gap and the instability of female work, the distortions of the welfare system, the high level of tax evasion, and the relatively low score on the Digital Economy and Society Index (DESI) compared to other European countries. Despite the fact that, over the past five years, Italy's DESI has increased from 28.2 to 49.3 (representing the most consistent progress among all EU countries), according to the European Commission's DESI 2022 Report. Italy still ranks 18th out of 27 EU member states, and its score remains below the European average of 52.3 and countries such as Spain, France and Germany (European Commission, 2022). Thus, the need for reconstruction would have existed even without the pandemic, and the opportunity provided by Next Generation EU is indeed crucial to fix Italy's digital divide, rebuild production capacities and start a new growth trajectory. To this aim, 25.1% of the entire National Recovery and Resilience Plan (NRRP) funds are allocated to initiatives that promote digital transformation across various sectors, including businesses and industry.

The issues of industrial cloud data storage and computing, as well as of Europe's "digital sovereignty", are equally important. There is growing concern that EU citizens, businesses and Member States are gradually losing control over their data, capacity for innovation and ability to shape and reinforce legislation in the new digital era. The coronavirus pandemic hitting the EU in spring 2020 has shown the essential role played by the high-tech sector in ensuring the continuity of social life, businesses and administrations, but, at the same time, it has highlighted the strong dependence of Europe on Big Tech, the American and Chinese Tech Giants (i.e., Alphabet, Amazon, Apple, Meta, Microsoft, and their Chinese equivalent, Baidu, Alibaba, Tencent and Xiaomi). This has accelerated the reflection on the need for sovereign digital technologies.

In this context, "digital sovereignty" is conceived as Europe's ability to act in the digital world autonomously, and should be realized by both promoting protective mechanisms and offensive tools to foster digital innovation (including in cooperation with non-EU companies), with the final aim of developing a competitive, secure, inclusive and ethical digital economy with world-class connectivity and special emphasis on data security and on artificial intelligence (AI) issues.

It follows that a radical reconsideration of European (and Italian) industrial policies is greatly needed. Public intervention to enable companies facing emerging threats and supporting business choices should no longer be seen as a "distortion" of the market to be utilized only under emergency situations. A strong political commitment and financial investments based on a long term vision going well beyond the time frame of single governments are needed, as are novel policy tools to stimulate research, investments, productions and employment. According to Mario Pianta, the latter should include a public investment agency, a holding company concentrating public shareholdings, and a public investment bank capable of taking over and assisting declining companies and launching new ventures in priority fields (Pianta, 2021).

These new tools should be institutionalized, based on environmentally sustainable economic activities with a high content of technology and quality of work, starting from equal and inclusive access to education and knowledge sharing, according to the prerequisites of a real knowledge-based society.

Industrial policy is now reemerging on Europe's agenda. Germany and France are pushing their plans in key fields - from high technology to electric cars - aimed at strengthening industrial sovereignty and autonomy in strategic areas (Stehr et al., 2020). Italy should pursue a similar direction.

All stakeholders should work together (and not against each other) to find a common, pragmatic, constructive, and non-ideological roadmap, to face the complexity of current challenges, reduce social and territorial disparities, and ensure deeper and equitable industrial collaboration among European nations.

Again, a paramount example of how industrial policies could lead to extraordinary successful results comes from the pandemic: the anti-Covid vaccines, for which a strict collaboration between academies, companies, regulatory agencies and governments has been indispensable and instrumental to reach results in less than 9 months. In this respect, in 2021 former EU Commission President Romano Prodi commented that governments should organize and finance the production of COVID-19 vaccines in "the greatest possible number of firms" across all countries.

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Introduction

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1. The aim of this book

The ultimate aim of this book is to suggest different points of view on the impact of various dimensions of digital transition on industrial policy's challenges.

Relying on contributors with different backgrounds, from academia to the public and private sectors, the book emphasizes two topics that we deem as crucial to inform and motivate industrial policies in current times: namely, the reorganization of the (global) value chains (in which the digital dimension is key), and the role of infrastructures to store data for business.

Industrial policy has become central in the public debate after several years of neglect, during which most authors have criticized any sort of state intervention in markets, with the possible exception of competition policy. The mood now has shifted, with leading economists such as Philippe Aghion, Dani Rodrick and Mariana Mazzucato exploring the possibility of combining industrial policy with efforts to enhance competitiveness. The main current challenges for industrial policy are threefold: i) green and energy transition; ii) digital transition; iii) the dependence on critical raw materials. All of these three challenges are closely interconnected. While our focus lies on digital transition, we are aware that digital and green transition have to proceed together, by taking into account the lack of raw critical material for Europe and the need of dealing with strong competition from China and United States. There is a need for a collective effort, which may vary depending on different perspectives. This book aims to contribute to the debate, regardless of specific ideological viewpoints.

2. The content of this book: summary of individual chapters

The book is organized in two parts.

Digital transition and value chains - The first part, comprised of five chapters, touches several points related to value chains, and how these are undergoing reorganizations due to factors related to digital transition, such as artificial intelligence, cloud computing, Internet of Things, blockchain, the metaverse and the increasing role of B2B and B2C platforms.

Chapter 1 by Cappelli et al. focuses on a new empirical methodology, Atheoretical Regression Trees (ART), to provide a representation of all the Italian manufacturing sector based a rich ISTAT database. Such a representation is a key starting point to understand challenges for industrial policy, as firm size distribution impacts on the design of successful actions to manage transitions or contrast companies' and sectors' crises.

While the previous chapter employs the standard ATECO industrial classification, recent developments try to overcome its limit by adopting a value chain approach. In that respect, Chapter 2 by Alessandro Faramondi presents the state of the art in value chains classification, providing a synthesis of potential advantages (and limits) of such an approach. The analysis builds on the effort of the Italian National Institute of Statistics (ISTAT) to create an alternative framework, where linkages among companies across different sectors are explicitly spelled out.

Another important contribution comes from Mirko Bragagnolo, who, in Chapter 3, emphasizes the importance of digitalization for Small and Medium Enterprises in a global value chain: «In a market that demands high quality and product customization, flexible production and speed of execution, digitalization is the key to competitiveness.» Bragagnolo points out that a supply-chain based digital strategy must be developed for a business to succeed.

In Chapters 4 and 5, Tiziana Vallone and Carlo Alberto Carnevale Maffè respectively put forth two important contributions on the role of digitalization of global value chains.

In Vallone's chapter, the focus is based on the diffusion of IT systems capable of synchronizing supply network data with collaborative planning, processes and procedures to reduce unforeseen events and disruptions. The necessity to make quick decisions can be easily satisfied by digital data. The ability to process information quickly allows for adjustments to decisions and strategies in response to an increasing number of destabilizing factors around the world, both in geopolitical and economic dimensions. Business intelligence, data analytics and artificial intelligence can help to solve the logistics problems that are paramount in the process of huge redefinition of global values chains.

In his chapter, Carnevale Maffè analyzes the added value of the industrial metaverse. The industrial metaverse is a virtual environment in which companies can duplicate and manage their activities throughout the value chain. The industrial metaverse includes several key technologies, including digital twins, augmented and virtual reality, and artificial intelligence. The Metaverse enables the simulation and monitoring of industrial activities, helping to reduce risks, costs, and time while enhancing efficiency, quality, and security.

Digital transition and technological infrastructures - the second part of the book, also comprised of five chapters, is dedicated to the role of technological infrastructures. The first two chapters of this part set the stage for well-informed debate. Chapter 6 by Maria Fazio provides an overview of all the (interconnected) technological challenges for digital transition: cloud and edge computing, artificial intelligence and blockchains. Fazio demonstrates that while the digital transition presents significant opportunities for many companies, its disruptive nature should not be underestimated. Chapter 7 by Adriana Lotti focuses on Italy and its policies for digital transitions, providing an overview of the objective and tools for reaching the National Recovery and Resilience Plan (NRRP) digital-related objectives.

A particular focus in this second part of the book concerns cloud computing, as different owners for companies' data storage could matter for industrial policy.

The European dependence on foreign actors (the so-called GAFAM - Google, Apple, Facebook, Amazon, Microsoft) could be an issue for companies and for a European industrial policy. Possibilities to overcome this problem may differ, being differently located along the traditional state-vs-market axis. In that respect, Marco Berlinguer (Chapter 8) and Massimo Florio (Chapter 9) suggest a bigger role for the public sector, while Francesco Bonfiglio (Chapter 10) proposes a market solution.

Berlinguer points out the importance of increasing innovation in the governance system for Europe in order to achieve a greater "digital sovereignty" in cloud computing. In his chapter he explains the guiding principles developed by Europe for building sovereign cloud computing systems: interoperability, open source, standardization, modularity. These principles have been adopted in two ways: to regulate digital infrastructure and to promote a new kind of industrial policy. To enhance the prospects of European sovereignty, Berlinguer suggests a «bolder use of this matrix of principles», connected with the development of «a new kind of hybrid forms of agency and governance».

Florio aligns with this approach but proposes a new form of governance: a public and supranational alternative to the oligopoly of the major international companies (the *Tech Giants*). He proposes a European supranational entity, along the lines of the European Space Agency, open to partnerships with existing public and private organizations and equipped with an adequate amount of resources, amounting to several billion euros in annual funding. Without such a commitment, the prospect of opposing the Tech Giants remains elusive: «What could an entity of this kind do on a large scale? Firstly, it could provide users with the kind of guarantees that Tech Giants do not offer on how to use data; it could implement and manage a European cloud so that data remains in Europe and stays in a public digital space. And it could effectively deal with a series of technological adjustments, both on data transmission networks and computing, which must be seen in an integrated way».

Francesco Bonfiglio, former CEO of Gaia-X, presents a different solution to achieve European cloud sovereignty, based on a bigger role for the market. Bonfiglio describes the project GAIA-X, whose principal aim is to create a European cloud technological stack, thereby reducing the dependence on non-European platforms. Despite facing several obstacles, this project has sparked significant debate. Participants in the project are required to ensure transparency, controllability and interoperability of their digital services. The Gaia-X project is inclusive but discriminates «against those platforms that rely on the opacity of their features and the difficulty of migration, their strong point, creating a client dependence effect (lock-in).» In this way, technologies that would otherwise be ends in themselves, or often demonized because of misunderstanding (such as for Blockchain, which was for years was called speculative by misleadingly associating it to the use in cryptocurrencies), finally assume a clear and useful role within a specific purpose: creating a network of services that are more transparent, controllable and interoperable with each other.

PART I

Digital transition and global value chains

Chapter 1. A picture of the Italian manufacturing sectors as a first step to design proper industrial policies

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1.1 Introduction

The digital and green transitions are shaping new industrial policies. Simultaneously, the pandemic, energy crisis, war between Russia and Ukraine, shifting geopolitical balance, and high inflation have drastically altered the interactions between big and small companies and institutions, global value chains, and the relationship between Italy and other countries. Understanding these issues and in particular the reorganization of the production chains, the platform economy, the reshoring phenomenon, the new globalization, the right amplitude of reshoring across different economic areas (Europe, United States, and BRICS countries) requires various aspects to be analyzed in order to design proper industrial policies for pushing innovation, firms' growth and internationalization of companies. However, to address this issue, we must identify some priorities.

It is our belief that a preliminary starting point is to analyze the structure of the Italian manufacturing sectors before these crises. For this reason, we focus on the period between 2015 to 2019, a growth period for economic activity time of economic growth for Italy and other countries. Recently, companies have faced a lot of exogenous shocks, making it crucial to examine their strengths and weaknesses before the multiple crises to identify enduring characteristics. We use the Ateco sectors classification, even though one of the recent challenges in industrial economics and policy is identifying production chains without discretion. The state of the art in this area relies on the acquisition of electronic invoicing data, which requires more time. Thus, analyzing sectors remains the only available option.

The adoption of the classical standard ATECO classification serves as the best proxy for our analysis. Instead of focusing on production chains, we analyze ATECO sectors. Although the value chains approach is more compelling as it could help us to understand the linkages among companies within the same production chain, we use sector classifications as our starting point. This approach provides a snapshot of the Italian manufacturing sector, laying the groundwork for future analysis based on production chains. The structure of many sectors shapes the reaction to the conjectural crises (ISTAT, 2021). Therefore, understanding these structures, in particular with a good disaggregation, is crucial for designing effective economic policies for companies and for mitigating the spread of crises across sectors. As shown by the ISTAT Report on the competitiveness of productive sectors (ISTAT, 2021), small and medium-sized companies faced the greatest challenges during the Covid-19 crisis (Di Iorio and Giorgetti, 2020). Despite this, companies that demonstrated dynamic behaviour in the pre-pandemic phase, managed to counteract the effects of the crisis, a trend observed even among smaller units (Costa et al., 2021).

Thanks to a complex micro-sectorial database built by ISTAT, it is possible to carry out a classification analysis at a granular sectoral level (up to 5 digits of the ATECO classification). This analysis focuses on two main indicators: the number of enterprises and the degree of concentration within each sector. Although these indicators are straightforward, their combined analysis effectively characterizes the size distribution of companies within each industrial sector (Di Iorio and Giorgetti, 2022).

The technique used is Atheoretical Regression Trees (ART), first proposed by Cappelli et al., (2008) that exploits the recursive approach of Least Square Regression Trees (LSRT) (Breiman et al., 1984). The aim of this methodology is to partition a continuous variable, such as the number of enterprises and the degree of concentration in each sector, into groups the units by homogeneity with respect to the given considered variable. It is worth noticing that the procedure is data-driven as the number of subgroups is not predetermined. This makes it possible to create a cross-classification of industrial sectors into groups based on the combinations of the levels of the selected indicators.

Identifying the size distribution of firms within sectors can be a useful tool for mitigating the spread of negative effects during crises or to stimulate positive propulsive effects between firms of different sizes in the same sector or across related sectors. Understanding this distribution is essential for designing effective industrial policies or incentives to address potential crises and stimulate growth.

1.2 Theoretical references

As regards the market structure investigation, the Industrial Organization (IO) has evolved through several phases. From the Structure-Conduct-Performance literature to the Chicago School, the post-Chicago School, the New Empirical Industrial Organization (NEIO), the field has gone through several phases. Some phases have been more interested in recovering regularities among sectors, while others have been more focused on the analysis of specific sectors by adopting game theory. Sutton (1991, 1998), identified endogenous sunk costs as a criterion to group different sectors, revealing regularities regarding the level of concentration. In particular, seminal Sutton's (1998) contribution used the concentration ratio (CR1) in combination with the number of firms to explain the coexistence of different submarkets within the same sector. In this analysis, we use the Herfindahl index instead of concentration ratio and examine the number of firms in each sector to identify potential variations in firm size distribution.

As regards the sub-sectors, from a theoretical perspective, the combination of these two indicators, mentioned above (the number of companies and the level of concentration), identifies the following clusters of interest with regard to the size distribution of companies within a sector (see Table 1.1):

CASE A) Sectors characterized by the prevalence of a reduced number of small companies. Low concentration and a small number of companies.

CASE B) Sectors characterized by a large number of small companies. Low concentration and a high number of companies.

CASE C) Sectors characterized by a small number of large firms. High concentration and a low number of companies.

CASE D) sectors characterized by one or a few dominant firms and many small firms. High concentration and high number of firms.

Table 1.1: Size and concentration

	Number of Competing companies	
Herfindahl	LOW	HIGH
LOW	Case A: small number of small firms	Case B: many small firms
HIGH	Case C: small number of large firms	Case D: One or very few dominant firms and many small firms

The joint classification by concentration and the number of firms allows us to make further analysis on the potential firm size distribution in each sub-sector. The primary aim of this analysis is to provide insights that can inform the development of effective industrial policies[1].

In recent years, there has been growing consensus in the literature on the need for explicit industrial policies (Criscuolo and Lalanne, 2023; Giorgetti and Anderloni, 2022), starting from the seminal work of Aghion et al. (2015), which highlights the synergies between competition policies and industrial policies. Recent developments, such as the USA Inflation Reduction Act 2022[2], which provided considerable support for US companies, have sparked a lively debate - both in the world of research and in policy-making - on how to deal effectively with ways to offer incentives and support for businesses.

Building on this contribution, we analyse the entire manufacturing sector with a granular disaggregation, thanks to a rich database provided by the Italian National Statistical Office (ISTAT).

1.3 Data

The database is based on the ISTAT Extended Statistical Business Performance Register (Frame-SBS), which contains individual data on all industrial and service companies in Italy (approximately 4.4 millions of units). This database is linked to official statistical registers providing detailed information on employment characteristics, primarily sourced from INPS (National

1 A next step could be the transition from the ATECO classification of sectors to the identification of production chains, but this will be a further step when data will be available.

2 17th Congress (2021-2022): Inflation Reduction Act of 2022. (2022, 16th august). https://www.congress.gov/bill/117th-congress/house-bill/5376. The Inflation Reduction Act of 2022 will make a down payment on deficit reduction to fight inflation, invest in domestic energy production and manufacturing, and reduce carbon emissions by roughly 40 percent by 2030. The bill will also finally allow Medicare to negotiate for prescription drug prices and extend the expanded Affordable Care Act program for three years, through 2025.

Institute for Social Security)[3]. The sectorial database is further enriched by a wide range of economic aggregates and indicators, coming from National Accounts, able to measure the structure, the performance and the role of each sector within the production system. The main variables are: number of firms by subsector, number of employed, turnover, production, value added, wage, gross operating margin, imports and exports, concentration (Herfindahl index based on turnover).

The structure and economic variables (at national and sub-national level), as well as those concerning internationalization are obtained for each economic sector (up to 5-digit ATECO) from individual company data. Information on the number of enterprises, the employed, the self-employed and the total number of employed were extracted from the ISTAT statistical archive of active enterprises (Archivio Statistico delle Imprese Attive, ASIA) with reference year 2017.

Based on this initial framework, ISTAT has developed similar databases for the period 2015 to 2019. As first step, we don't use all this information.

The aim of this paper is to provide an overview of the manufacturing sector's structure, at two different levels of disaggregation: the 3-digit and 5-digit ATECO breakdown. To achieve this, in light of the motivation section, we focus on classifying sectors by combining data on concentration levels and the number of incumbent companies within each sector.

The Herfindahl index is widely recognized as a key tool for analyzing market concentration. Usually the concentration classes are defined using specific thresholds. The usual Herfindahl thresholds, elaborated in an antitrust framework, identifies 4 groups: first group with an index below 0.01, that indicates a highly competitive industry; a level between 0.01 and 0.15 indicates an unconcentrated industry; a level between 0.15 and 0.25 that indicates moderate concentration while a level above 0.25 indicates high concentration[4].

However, using predefined thresholds for classification may lead to the creation of groups that are not necessarily homogeneous, especially when these thresholds are defined in a broad or generalized context. For this reason, we elaborate this data-driven approach using Atheoretical Regression Trees (ART). This method generates homogeneous groups driven by data i.e. not fixing their number in advance.

As regards an analysis of sectors by the number of incumbent companies, there is no universally accepted threshold for grouping. Therefore, we will try

3 The National Institute for Social Security (Italian: Istituto Nazionale della Previdenza Sociale) is the main entity of the Italian public retirement system. All waged labourers and most of self-employed, without a proper autonomous social security fund, must be subscribed to INPS.

4 U.S. Justice Department. "Horizontal Merger Guidelines," Select "5.3 Market Concentration." https://www.justice.gov/atr/horizontal-merger-guidelines-08192010

to cluster sectors using the data-driven procedure aiming to create the most homogeneous groups possible.

We focus our analysis on the years 2015 and 2019. Tables 1.2 and 1.3 present the main characteristics of the 1-digit ATECO sectors for these years.

Table 1.2: Number on firms, number of employees, and degree of turnover concentration (Herfindahl) at 1 digit ATECO, 2015

1 DG ATECO	N. firms	N. employees	% firms.	% empl	HClas.
Mining	2186	30245	0.05	0.19	hconc
Industry	389317	3619121	9.18	23.02	hcomp
Energy	10775	89108	0.25	0.57	unconc.
Water	9231	186988	0.22	1.19	hcomp
Construction	511405	1323554	12.06	8.42	hcomp
Retail trade	1105227	3302193	26.05	21.01	hcomp
Transport	123625	1089419	2.91	6.93	hcomp
Accom.& food	315464	1323345	7.44	8.42	hcomp
Inform.& communication	98381	541978	2.32	3.45	unconc.
Real estate	238273	298553	5.62	1.90	Hcomp
Professional activities	714934	1211338	16.85	7.71	Hcomp
Rent, travel agency	139595	1165287	3.29	7.41	Hcomp
Education	29566	96649	0.70	0.61	Hcomp
Human health	285231	824530	6.72	5.25	Hcomp
Arts, recreation	65022	164032	1.53	1.04	Hcomp
Other services	203680	452496	4.80	2.88	Hcomp
Total	4241912	15718834	100.00	100.00	

Legend: high competitive (hcomp), high concentrated (hconc), unconcentrated (uncon)

Table 1.3: Number of firms, number of employees, and degree of turnover concentration (Herfindahl)
at 1 digit ATECO, 2019

1 DG ATECO	N. firms	N. employees	% firms.	% empl	HClas.
Mining	1971	27744	0.05	0.16	hconc
Industry	372343	3755625	8.70	22.24	hcomp
Energy	12443	84112	0.29	0.50	un-conc
Water sewerage and waste management	9598	209213	0.22	1.24	hcomp
Construction	487266	1319484	11.39	7.82	hcomp
Retail trade	1068883	3442212	24.98	20.39	hcomp
Transport	119550	1142580	2.79	6.77	hcomp
Accom.& food	335140	1592737	7.83	9.43	hcomp
Inform.& communication	108531	586405	2.54	3.47	un-conc
Real estate	236477	309075	5.53	1.83	hcomp
Professional activites	750117	1294996	17.53	7.67	hcomp
Rent, travel agency	157076	1392278	3.67	8.25	hcomp
Education	36510	117679	0.85	0.70	hcomp
Human health	303498	939221	7.09	5.56	hcomp
Arts, recreation	73559	189771	1.72	1.12	un-conc
Other services	205784	480203	4.81	2.84	hcomp
Total	Total	4278746	16883337	100.00	100.00

Legend: high competitive (hcomp), high concentrated (hconc), unconcentrated (uncon)

1.4 Methodology

As mentioned before, the technique applied to classify the industry sub-sectors is Atheoretical Regression Trees (ART). This method, introduced by Cappelli et al. (2008) exploits the recursive partitioning approach of Least Squares Regression Trees (LSRT) (Breiman et al., 1984). LSRT express the relationship between a response variable and a set of covariates in the form of a binary tree. This tree is generated by recursively splitting, i.e. dividing, the data into two subgroups increasingly homogeneous with respect to the response variable.

Specifically, tree growing relies on a data driven top-down algorithm known as recursive partitioning. This method evaluates all potential splits of a current node using a splitting criterion. The best split is selected based on a goodness-of-split measure, which reflects how effectively the split divides the node into two mutually exclusive subsets that are as homogeneous as possible with respect to the given response variable.

ART are an adaptation of LSRT that aim to partition a response variable y while preserving some internal ordering. To achieve this goal, the response variable is tree regressed using a single artificial covariate given by an arbitrary sequence of strictly increasing numbers *K=1,2,...,i,...,n*, hence the name Atheoretical.

A successful application of this method regards the determination of multiple level shifts occurring at unknown dates in various types of time series (see among the others Rea et al. 2010, Cappelli et al 2013) as well as to classify financial institutions by risk (Cappelli et al., 2021).

In this study, the ART framework has been applied to classify sub-sectors either with respect to the degree of turnover concentration or to the number of companies within each sub-sector.

Formally, let y_i, with i=1,…,n, be a target variable, characterized by an internal order, that we want to partition into by *G* a priori unknown groups identified by *G-1* thresholds. The objective is to estimates the set of thresholds or cut points that define the partition of the variable

$$P(G) = \{(y_1, \dots, y_{n_1}), \dots, \left(y_{n_{g-1}+1}, \dots, y_{n_g}\right), \dots, (y_{n_{G-1}+1}, \dots, y_n)\}$$

into subgroups such as the target variable is homogeneous with respect to some statistical feature. In case the feature of interest is the average, the groups will be such that $\mu_g \neq \mu_{g+1}$ and, in order to identify the cut points and consequently the groups, the estimation criterion is based on the least squares principle that selects the split of a current node h that maximizes the sum of square reduction i.e. the difference:

$$SS(h)-[SS(h_l)-SS(h_r)] \qquad (1.1)$$

where $SS(h)=\sum_{y_i \in h}(y_i - \hat{\mu}(h))^2$, is the sum of squares of the father node *h*, $\hat{\mu}(h)$ is the mean of the y values in node *h* and $SS(h_l)$ and $SS(h_r)$ are the corresponding quantity computed for the left and right descendants, respectively. Note that, since h_l and h_r are an exhaustive partition of node *h*, *SS(h)* represents the total sum of squares whereas $[SS(h_l)+SS(h_r)]$ is the within-group sum of squares. Therefore, the splitting criterion stated in equation 1.1 is equivalent to maximize the between-group sum of squares and that for a binary partition resorts to search for the child nodes that are as far as possible, in terms of squared distance between their means. Figure 1.1 graphically displays and explains the splitting of a node h into its child nodes h_l and h_r.

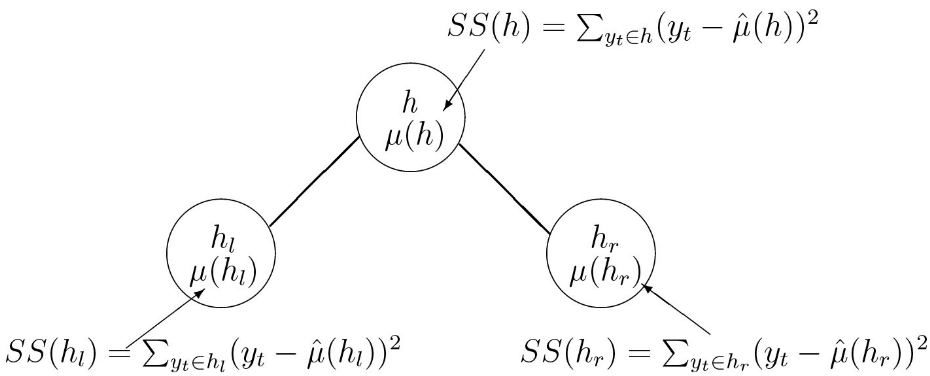

Figure 1.1 Split of a node based on the least squares principle in a Tree diagram

Once a node is partitioned, the process is applied recursively to each child node until a minimum size within a node is reached or the homogeneity cannot be further increased. The resulting tree, known as the maximal tree, is then pruned to generate a sequence of nested subtrees. Among these, the final subtree, which represents the final partition, is selected.

As previously mentioned, within ART, the target variable is partitioned while preserving its internal order. In this case, the two variables considered have been sorted in increasing order. Consequently, the final partition provides groups consisting of sub-sectors characterized by an increasing number of enterprises or degree of concentration.

Specifically, with respect the number of enterprises, ART identifies 4 classes labelled as low, medium, high and very high. For the level of concentration, the procedure defines 4 classes: highly unconcentrated, unconcentrated, medium concentrated, highly concentrated. It's worth noticing that, as the thresholds are estimated on the data at hand, although the number of groups corresponds to the literature, the thresholds of the Herfindahl index are rather different.

1.5 Results

As mentioned in Section 1.2, our aim is to provide an overview of the structure of the Italian manufacturing sectors by leveraging a data-driven approach. The main characteristic of a data-driven classification method is the evaluation of mutual position of different observations instead of their absolute position in relation to a fixed threshold. In other words, groups are formed when the "distance" (measured with respect to a given objective function) between the units in the same group is minimized or when the "distance" among groups is maximized.

Finally, in the light of what was discussed in the motivation section (see Table 1.1), since our aim to capture the firms size distribution for all the manufacturing sub-sectors, in Tables 1.4 and 1.5 we present the classification at 5-digits level obtained by the ART procedure for the number of companies and the level of concentration jointly. We do not present the three-digit classification. By analyzing these two tables we observe that the number of sub-sectors fitting Case D, that is one or very few dominant firms and small firms (see Table 1.1) are close to zero. Some changes happen from 2015 to 2019, but these are not referred to situations with high number of companies and highly concentrated sectors. The changes involve a shift and increase of sub-sectors from a highly competitive classification to unconcentrated sectors classification and the shift from a low number of companies to a medium number of companies. From 2015 to 2019 we observe a slight tendency of 5 digit sectors to be less fragmented, although the manufacturing structure and firms size distribution seem to maintain their main characteristics.

Table 1.4: Sub-sector classification by number of companies and Herfindahl index, 5 digits, 2015

	num. of companies				
Herfindahl	Low	Medium	High	Very High	Total
Highly competitive	177	46	7	4	234
Unconcentrated	43	2	0	0	45
Moderate concentration	25	1	0	0	26
High concentration	10	0	0	0	10
Total	255	49	7	4	315

Table 1.5: Sub-sector classification by number of companies and Herfindahl index, 5 digits, 2019

	num. of companies				
Herfindahl	Low	Medium	High	Very High	Total
Highly competitive	154	33	7	2	196
Unconcentrated	80	2	0	0	82
Moderate concentration	27	1	0	0	28
High concentration	9	0	0	0	9
Total	270	36	7	2	315

1.6 Conclusions

This paper, focusing on the years 2015 and 2019, demonstrates a data-driven methodology for classifying Italian manufacturing sectors based on the firm size distribution. This classification is determined by two simple indicators: the number of companies and the level of concentration within each specific sector.

The main finding is that the majority of sectors, both at 3 and 5-digit levels, continue to be characterized by a remarkable level of small/medium companies. This persists despite the contributions in the literature and public debates about the necessity to strengthen our industrial system by adopting policies able to increase the companies' average size. The analysis conducted provides an important, updated snapshot that can be the starting point for many policy design and evaluation.

Indeed, analyzing the size distribution of firms within sectors can be a useful tool for identifying ways to mitigate the spread of negative effects, as occur in crisis situations, or to stimulate positive propulsive effects between firms of different sizes in the same sector or in related sectors.

We observe some changes regarding the numbers of sectors in 2015 and in 2019 but these are not referred to the case D (see Section 1.2), which is characterized by high number of companies and highly concentrated sectors.

The changes concern the increase of sectors from a highly competitive classification to unconcentrated sectors classification (as regards concentration) and the shift from a low number of companies to a medium number of companies. Between 2015 and 2019 we observe a slight tendency of 5-digit sectors to be less fragmented, even though the manufacturing structure and firms size distribution does not lose its main feature: the presence of too many small companies. Thus, if we want to design policy such that companies help each other in the sense that bigger companies push smaller ones, we have to take into account three important conclusions from our analysis:

1) Sectors with a few dominant companies and many small companies are nearly non-existent (see Table 1.1, Case D). Consequently, within each sector, it is difficult to define actions where big companies can support small and medium size companies in the process of digital and green transitions.

2) We have to investigate linkages among sectors in Italy in order to see if there are asymmetric firms size distributions across sectors, and the successive step is the identification of the value chains.

3) A further step is to identify the same linkages where parts of the production chains are located in other European countries. If the head of the value chain is outside the national borders, the identification of the other players within Europe becomes crucial for developing a cohesive industrial policy.

This is crucial for accurately understanding the situation and for dealing with acquisition and change of company ownership within Europe where the state aids regime has been suspended. This presents a challenge for a common industrial policy. States with better financial resources across Europe can more effectively help their companies, by increasing the inequalities among economies inside Europe.

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Chapter 2. Supply chain analysis: advancements in official statistics

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2.1 Introduction

Many economic experts have addressed and systematized the issue of relations between businesses, considered a key concept underpinning competitive capacity. Economic theory offers several angles for the analysis of production relations and, more generally, supply chains. Concepts related to this include advantages arising from the integration of units, with the reduction of costs due to the presence of positive externalities, economies of scale (greater production capacity and lower unit costs) and economies of scope (reduction of costs due to specialisation in certain activities).

In recent decades, the interest of academics and policymakers has been heightened by globalisation and the consequent extension of supply chains worldwide - the global value chain - in which the stages of production take place in different countries, taking advantage of the expertise and resources available on the global level. In this scenario, the economic theory of the supply chain provides a useful conceptual framework for understanding the complex dynamics of the production of goods and services in a globalised modern economy.

For these reasons, the study of supply chains has gradually gained ground to become an issue of industrial policy, in which the theoretical reference point is no longer the individual company, but rather a cluster of companies engaged in a series of activities and processes that make up the stages of production of a good or service. These stages range from the production of raw materials (acquiring and processing the basic resources necessary for production) to manufacturing (the transformation of raw materials into finished goods or services), then distribution (transporting and delivering products to points of sale or directly to consumers) to retail (direct sale of products to the end consumer) and from there to after-sales (assistance, maintenance and additional services supplied after purchase of the product).

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In order to move from theory to empirical observation, the availability of data is crucial. Analysis of production processes through the lens of the supply chain is essential for characterising the profile of companies and the production system.

Until the final months of 2022, information gleaned from official statistics provided data about supply chains only in aggregated form, mainly sourced from national accounts, and therefore did not allow analysis of individual companies, their positioning within the system and their ability to activate production as part of supply chains. The latter is crucial information in terms of policy and thus of targeting funding in order to activate multiplying processes on state investment.

In this context, ISTAT launched a major project to study such data at the micro level, with the aim of classifying companies and identifying their roles within supply chains.

The sources used for this analysis are the permanent census of enterprises and the electronic invoicing database. These two complementary sources give a comprehensive picture of the country's production system, seen through the lens of supply chains. The first allows us to gain information about the qualitative characteristics of the companies surveyed (target population is enterprises with 3 or more persons employed), how they position themselves within supply chains and the extent of their ability to influence the prices, quantities and quality of the products and services they offer. Businesses involved in the study were asked to indicate, from a set list of 28 supply chains, which they contributed to in terms of the production of raw materials, semi-finished goods, finished products, machinery specific to the chain and service-based activities such as consultancy, R&D, marketing and so on. The resulting data have been available since 14 November 2023 and for the first time it is possible to reconstruct a general picture of supply chains based on information acquired directly from the companies themselves.

Thanks to its comprehensive nature, the second source - electronic invoicing - allows us to identify the entirety of relationships between production units. Electronic invoicing was introduced in Italy as an administrative and fiscal obligation in 2019, and affects all transfers of assets and provision of services carried out between residents or businesses established in Italy[6]. There are three

6 On 6 June 2014, e-invoicing became obligatory for commercial operations with central public administration, and in 2014 this was extended to local administration. On 1 January 2019 electronic invoicing was also applied to transactions between private entities resident or established in Italy. Since 1 July 2022, e-invoicing has been obligatory for flat-rate tax regimes. Since 1 October 2022 moratorium is no longer an option, so e-invoices must comply with the 12-day limit. Electronic invoices must be sent to the customer via the Sistema di Interscambio (SdI), managed by the Revenue Agency, which verifies the existence of obligatory data for tax purposes and the VAT numbers of suppliers and customers.

main types of electronic invoicing, and therefore three different databases held and updated by the Revenue Agency:

- B2G (Business to Government) electronic invoicing - towards central and local public administration (obligatory since 31 March 2015);
- B2B (Business to Business) electronic invoicing - between private entities registered for VAT, i.e. invoices between businesses (obligatory since 1 January 2019);
- B2C (Business to Consumer) electronic invoicing - towards the end consumer, who can decide whether to receive invoices in paper form or by certified email.

Of these three databases, the most useful in terms of analysing supply chain relations between companies is undoubtedly B2B, which includes information at the individual transaction level.

While census data relies on self-declaration to assess belonging to a supply chain in response to the ISTAT questionnaire, with electronic invoicing the reconstruction of relations between companies is based on connections by invoice, which identify the customer and the supplier, allowing the network of exchange for goods and services to be traced. Although a simple process when the number of invoices is limited, this kind of elaboration becomes extremely complicated when the amount of data increases considerably and the network becomes a great deal more complex. To handle such complexity, specific techniques are needed, and graph theory can provide a useful help.

At the current time, census data - available, as mentioned, since 14 November 2023 - allow us to construct an initial general outline of supply chains, while electronic invoicing databases are not yet available to ISTAT, since the process of transferring data from the Revenue Agency to ISTAT is currently being established. Furthermore, once ISTAT has access to the databases, a methodology will be needed to reconstruct the networks of production, and this stage will also require more time, given the complexity of the algorithms required. For this reason, census data remains the only available source for an initial reconstruction of supply chains on the basis of micro data.

2.2 Supply chains – the overall picture emerging from the latest permanent census of enterprises

On 14 November 2023, ISTAT released the preliminary results of the second edition of its multi-scope survey, an integral part of the permanent census of enterprises.

The survey considered a sample of approximately 280,000 enterprises with 3 or more persons employed, representing 1,021,618 units (22.5% of Italian enterprises) producing 85.1% of the value added and employing 96.0% of employees (11.5 million), and therefore an essential segment of our production system. The direct survey was carried out between November 2022 and March 2023, and the reference year for data collected was 2022.

Over three-quarters of the companies studied (805,000, 78.9% of the total) are micro-enterprises (3-9 persons employed); 189,000 (18.5% of the total) are small enterprises (10-49 persons employed), while medium-sized (50-249 persons employed) and large companies (250 or more persons employed) account for 2.2% (22,861 companies) and 0.4% (3,969 companies, including 1,622 with 500 or more persons employed). Over half the enterprises operate in northern Italy (28.7 in the north-west and 22.7 in the north-east); 21.3% in central Italy and 27.3% in the south of the country.

Initial results confirm substantially uniform distribution in terms of production units. As evident in Figure 2.1, the supply chains most commonly contributed to are agro-food (indicated by 20% of respondents), construction (16.2%), tourism (12.9%) and road transport (10%). In this initial analysis it is interesting to see that some supply chains are less important than may be expected. One example is a prominent section of Made in Italy production, "clothing and footwear", which involves fewer than 10% of enterprises (7.5% of the total with 3 or more persons employed).

In terms of value added (Figure 2.1), the picture changes and we see the emergence of other supply chains and a prominent role played by companies with a larger average size. This is the case of energy suppliers, manufacturers of industrial electrical appliances and generic machinery, pharmaceuticals and products for personal, pet and home care.

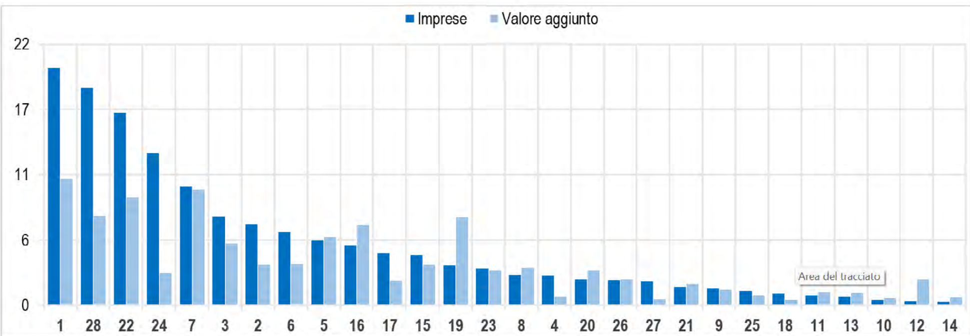

Figure 2.1 Distribution of companies and added value by supply chain. Year: 2022 Percentage values (a) (b) (c).

Source: ISTAT.

(a) Supply chains: 1 = Agro-food; 2 = Furniture; 3 = Clothing, footwear and accessories; 4 = Publishing; 5 = Pharmaceutics and products for personal, pet and home care; 6 = Health and social care; 7 = Road vehicles; 8 = Road transport infrastructure and services; 9 = Sea transport vessels; 10 = Sea transport infrastructure and services; 11 = Railway and cableway vehicles; 12 = Railway and cableway infrastructure and services; 13 = Aerospace and defence equipment; 14 = Air, aerospace and defence infrastructure and services; 15 = Electrical and electronic household appliances; 16 = Industrial electrical appliances, machinery and gear for unspecified supply chains; 17 = Non-electrical tools and equipment; 18 = Precious stones; 19 = Energy infrastructure and services; 20 = Waste management and circular economy; 21 = Water infrastructure and services; 22 = Construction; 23 = Finance; 24 = Tourism and leisure; 25 = Audio and audiovisual content; 26 = Telecommunications infrastructure and services; 27 = Education and professional training; 28 = Other (e.g. toys, sports equipment not for gyms or wellness centres, personal services and public services other than the above).

(b) The sum of percentages may be higher than 100 because each company was permitted to indicate more than one chain.

(c) Due to the design of the statistical records used in the survey, the distribution in terms of added value does not include companies in the banking and financial sectors (Codes 64, 65 and 66 of the Ateco classification – Section K). The added value of supply chain 23 shown in the figure therefore refers to companies that participate in the Finance chain but do not belong to the banking, finance and insurance sectors; similarly, the graphs relating to other chains do not include the added value of companies in the same sectors.

An important development at ISTAT is undoubtedly the centrality of statistical registers, which provide information on the subjects of analysis at micro level. This has made it possible to cross-reference data from surveys with statistical registers, which contain information about the economic variables of enterprises.

By drawing on a classification of forms of internationalisation[7], it was possible to gain an idea of the level of Italian companies' participation in global value chains. In particular, the taxonomy in question classifies production units in five mutually exclusive groups. The first group is companies that only import goods ("importers only"); the second, companies that export solely ("exporters only"); the third is companies that both export and import ("two-way traders"); the remaining two categories group companies engaged in internationalisation of production, consisting of active units in Italy that are owned

7 For example see ISTAT's Report on competitiveness in manufacturing sectors, 2022 edition (https://www.ISTAT.it/it/archivio/268378).

by foreign-controlled multinationals ("foreign multinationals") or by Italian groups ("Italian multinationals")[8].

In such scenario (12.4% of companies have commercial and production relations with other countries), it is possible to map Italian companies' participation in global value chains. The chains that see the greatest participation by Italian companies are aerospace and defence equipment (where 41.3% of companies are internationalised), air and aerospace infrastructure and services (in which 37.9% of companies are internationalised), railway transport infrastructure and services (33.2%) and precious stones (32.8%). At the other end of the scale, the chains whose focus is primarily on the domestic market are tourism (with just 5.5% of companies internationalised), education and training (6.9%) and finance and insurance (7.9%, despite a relatively high number of companies belonging to multinationals).

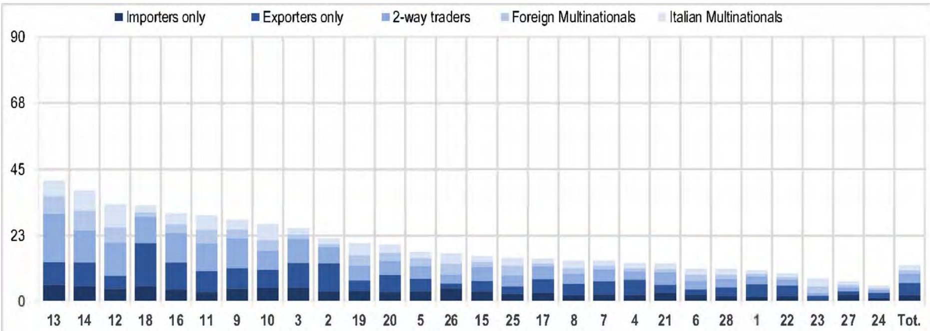

Figure 2.2 Forms of internationalisation by supply chain. Year: 2022. Percentages of the total number of companies participating in the chain (a).

(a) See note (a) Figure 2.1

One interesting analysis is that which combines the economic sector with the value chains. This gives us possible to analyse the production system by sector (horizontal) and by supply chain (vertical).

By considering the weight of the economic sectors (see the table, we can make an initial horizontal analysis, highlighting the sectors that affect the greatest number of chains. This provides confirmation that the production system is concentrated in certain areas: commerce, chemicals, rubber and plastics, metal products,

8 Each company is placed in just one category; where a company has more characteristics than those selected on the scale of internationalisation, it is placed in the higher category. This means that, for example, the Italian Multinationals or Foreign Multinationals categories contain companies belonging to multinational groups (Italian and foreign respectively) which export and/or import.

machinery, specialist construction, storage and support for transport, software production, staff selection and recruitment, architecture and engineering studies. Now if we if we proceed with a vertical reading, it is possible to consider the length of the supply chains. More economic sectors are involved in a supply chain, the longer it is. The data reveal that the longest supply chains in terms of value added, are agro-food, road transport, clothing, industrial plant and appliances, energy and construction. While the shorter supply chains are: air and sea transport infrastructure and services, precious stones, audio and audiovisual content, education and professional training.

2.3 Conclusions

In recent years, the increasing importance of interpreting the production system through the lens of supply chains, and its implications in terms of both analysis and policy, have demanded greater commitment to the production of statistics, and official data in particular.

Prototype studies and analyses carried out on sub-samples of the electronic invoicing database on the one hand, and the addition of a section on supply chains to the ISTAT census questionnaire on the other, are a demonstration of that commitment.

In the short term it is expected that the main source of information will continue to be the census, making full use of the extensive information collected by the survey which, as we know, consists of 9 sections.

Although data from surveys are valuable, they have limits; in particular, they are based on pre-determined supply chains and the self-classification of enterprises. In this sense, on the one hand we have a pre-determined view of the production system (the 28 supply chains are defined upstream) and on the other, a possible statistical distortion due to well-known issues of errors in measure, typical of surveys.

These issues can be overcome with the use of electronic invoicing, since the definition of networks is not based on a definitive theoretical framework, but rather on direct relationships between customers and suppliers.

While the prospect of data from electronic invoicing opens extremely interesting avenues for study, it is also true that issues around the availability of data and the methodology to be adopted currently constitute an obstacle, with the consequence that at this stage it is not possible to give an exact idea about when the first results from this key source will be forthcoming.

Chapter 3. The role of supply chains

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3.1 Introduction

In recent years, due initially to the pandemic and subsequently to the war in Ukraine, we have witnessed a global economic crisis with a considerable impact on businesses and, in particular, on the SMEs that form the backbone of our economic system.

In these circumstances, supply chains have constituted the Italian route to competitiveness and to the digital and environmental transition of our production system; and it is through supply chains that many small businesses have found the way to grow and create medium-sized manufacturing groups.

Several recent studies have shown that companies that operate as part of a chain enjoy higher-quality governance. In some SMEs this quality may even make up for a lack of spillover from large companies. More structured governance allows SMEs to grow faster, has a considerable influence on capacity for international expansion and also has a positive impact on the adoption of sustainable practices.

Supply chains are accelerators of innovation, and this is our way of working: small or large companies are connected by ties that are very often informal (but no less solid for that), grouped around a product or a service. The system is complex but has the ability to act extremely rapidly, displaying the famous resilience that has allowed our manufacturing sector to recover faster than those of other countries.

Supply chains can also explain the excellent performance of Italian exports, which increased by 19.9% in 2022 (and very probably more in 2023), despite numerous shocks to the system; indeed, the dynamics of Italian exports have proved to be resistant to the global crises of the past few years, both in absolute terms and relative to other leading European exporters.

Italian industry is firmly integrated within international supply chains, with a huge diversity of product type and position within global value chains. In particular, it is well-placed upstream in production chains as a supplier of high-quality semi-finished goods. Diversification and flexibility have allowed Italian companies to suffer relatively fewer of the bottlenecks and asymmetric shocks that have affected international supply chains.

The events of recent years have accelerated the shift in supply chain relations in Italy - already underway for several years - in two directions: reshoring and re-verticalisation.

Indeed, to adapt to market changes and improve their sustainability and resilience, many companies have decided to to re-locate their facilities and logistics to their home country in order to gain greater flexibility and control over the quality of their products, and be better prepared for interruptions in their own supply chains.

For example, a recent survey by the Osservatorio Export showed that over a third of manufacturing companies in eastern Veneto have changed at least one strategic supplier in the past two years, with 58.1% of these choosing new suppliers close to home in Italy. The main reason for this change is the availability of suitable suppliers locally, followed by convenience in price terms and reduced risks to supply.

The need to embrace the dual transition - digital and environmental - could also push companies towards a greater degree of formal coordination of their strategic decisions within the chain, in other words towards further re-verticalisation. This is because, in general terms, both require greater information sharing among the various actors upstream and downstream in the chain than in the past, in order to maximise return on investment by strategic use of data relating to production and consumption and - in the case of environmental sustainability - also for reasons of market accountability. Furthermore, growing vulnerability to cyberattacks, which are becoming increasingly common, may lead some parties in the chain to a desire to share data transmission standards and methods in order to enhance digital security and resilience to shock. From this perspective, cybersecurity is no longer an option. Small businesses cannot even think of going international, becoming part of a chain and handling employee and customer data without appropriate protection from cyber threats.

The goal that has guided Confindustria's actions in recent years is to embark on a course within the Italian economy that will see supply chains as increasingly integrated and dynamic ecosystems made up of connected, interdependent companies: we firmly believe that considering growth and transformation processes (but also corrections and incentives) as interventions that involve small and large companies connected and integrated by the sharing and dividing of stages in the production process, services and know-how, is undoubtedly ambitious, but essential today for the future of our economy.

More generally there is a need to increase coordination throughout supply chains by giving the most strategic (and structured) suppliers the implicit task of becoming managers of sub-systems, and also encouraging aggregations of smaller companies in order to protect artisan capacity while at the same time supporting it with organisational and financial development. Such a process is already happening, for example, in the luxury clothing sector, where many

SMEs are seeking to establish a few larger groups. Another step towards the future and the survival of supply chains is the need to strengthen those companies that are fragile but strategic. The stronger the weakest link, the stronger the chain. The route to greater strength includes measures implemented for years by Piccola Industria Confindustria geared to cultural development in entrepreneurs; indeed, it is essential to abandon the idea that 'small is beautiful': the goal of small business owners should be growth.

From the supply chain angle, we have seen that as a company increases in size, it also increases its ability to influence the price, quantity and/or quality of the product or service it buys or sells and, consequently, its position in the chain.

Supply chains are drivers of technology and digitalisation, and for this reason it is necessary to act on all the factors that boost their role: ESG transition, density and size of company, capitalisation, research infrastructure and training.

3.2 The importance of digitalisation

According to the latest DESI report, Italy is only in 18th place among EU member states; in 2020 it was in 25th place. 60% of SMEs have achieved at least a basic level of digital intensity and, in particular, the use of cloud-based services has seen considerable growth. These data indicate that, although the situation has improved in recent years, partly due to the pandemic, which accelerated the process, there is still much to be done, especially in the area of digital skills, in which Italy - where 46% of the population have basic knowledge - lies in fourth to last place in the EU. The EU itself is committed to digitalisation and has allocated 127 billion euros to reform and investment in the digital sector.

To be competitive, an SME needs to set itself pragmatic targets for efficiency and profitability geared to improving production and the balance sheet; and to do this it needs to draw on a series of digital technologies, not only to coordinate its various production processes, but also to interconnect with the main functions of the supply chain. With digital technologies, companies become more flexible and more able to adjust their facilities to produce smaller batches in response to their customers' specific needs. Thanks to digitalisation, words that until recently appeared oxymorons have become inseparable: quality and speed, economies of scale and bespoke production.

The numerous digital technologies poised to enter the scene are based on the Internet of Things (IoT), which collects data from appliances and processes which can then be analysed in real time using predictive Machine Learning tools, ultimately leading to the use of Artificial Intelligence (AI) to automate various processes that can be carried out autonomously.

In these new operational circumstances, the supply system does not happen independently from all the other operations, but in line with them, drawing on end-to-end visibility and with the ability to make use of all data, analyses and forecasts; and on a continuous self-learning process over the whole system.

However, it is essential that all companies in the chain are involved in this process, and therefore a supply-chain based digital strategy must be developed. For this reason, Confindustria is carrying out a major awareness-raising and training programme to engage the many SMEs that make up the Italian industrial fabric and that need further support to embark on their digitalisation journey and make plans to use digital technologies in their production processes.

A key source of support is the Confindustria Digital Innovation Hub network (DIH), set up to assist companies with digital transformation, helping them to assess their digital maturity and directing them to bodies offering innovation, technology centres and competency centres where they can see the concrete application of technology.

To raise SMEs' awareness of AI as a tool to increase productivity and reduce the dimensional gap, Piccola Industria Confindustria organised a series of talks, "Artificial Intelligence and SMEs: experiences of a present future", in partnership with Anitec-Assinform and in collaboration with Confindustria local associations and DIHs. The talks focused on the experiences of companies and the operational applications of AI, as well as analysis of risks and critical issues, in order to encourage its informed and progressive use. The seven events were attended by over 1000 entrepreneurs, demonstrating that the issue of AI is now a priority for our businesses.

For SMEs, this is a challenging transformation, but company size is certainly not a limit in terms of digitalisation. There are many examples of pioneering SMEs whose ability to innovate has made them essential links in supply chains that are strategic to the manufacturing industry.

Chapter 4. The digitalization of the supply chain

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Supply chain disruptions have emerged as a major challenge for the global economy in recent years.

The pandemic in 2019 disrupted global economic operations, causing unprecedented disruptions in supply chains and affecting both local and international trade. The difficulties were especially pronounced during the post-pandemic recovery phase when demand for commodities and goods exceeded their limited supply.

Factory closures (particularly in Asia), widespread lockdowns and mobility restrictions have caused bottlenecks in logistics networks. These disruptions have resulted in increased shipping costs and sea freight, longer delivery times and shortages of raw materials due to the subsequent race for available resources.

A number of bottlenecks have emerged in complex supply chains, impacting the global manufacturing process. Monitoring this process has become important not only from the perspective of businesses directly affected by the disruptions, but also for policymakers. It helps them assess potential imbalances between supply and demand and consequent inflationary pressures.

In view of these complex dynamics, the digitalization of the entire supply chain was considered more important than ever.

Supply chains have expanded significantlyin recent years, and this growth has been compounded by increased complexity. Customer needs, the competitive environment, and the standards of various industries have changed. Companies and entire supply chains have formed strategic alliances, engaged in mergers and acquisitions, outsourced functions to third parties, adopted new technologies, launched new products, and expanded their operations into new geographies with different time zones and markets.

In other words, the growth of supply chain complexity has accelerated dramatically with trends such as globalization, sustainability, personalization, outsourcing, and manufacturing innovation.

The events of recent years and in particular the Covid-19 pandemic and the outbreak of the Russian-Ukrainian war, as well as the Israeli-Palestinian conflict, have in fact led to a perfect storm with strong repercussions on all markets.

For instance, the microchip sector, energy and the main foodstuffs have all been significantly impacted.

Today, every business has to deal with the complexity of the supply chain, which encompassesstatic, dynamic and decision-making complexity. While static (structural) complexity describes the structure of the supply chain, the variety of its components, and the strengths of interactions; in contrast, dynamic (operational) complexity represents uncertainty in procurement and involves aspects of time and randomness.

Static structural complexity has existed for several years and, as we have pointed out, depends on factors such as globalization, sustainability and technological innovation of production.

Dynamic complexity, on the other hand, is linked more to unpredictable events, the so-called black swans, which now seem to be very widespread.

Decision-making complexity is an immediate consequence of the previous static and dynamic decisions as well as from the choices to be implemented.

The static-dynamic distinction has been used primarily to study complexity within production systems.

Today, we talk about supply chain resilience in reference to the complexities to be faced, the solutions that often lie in greater standardization of products and shipping methods, in the automation of decision-making processes through the management of business rules and, above all, in collaboration with supply chain partners.

In fact, supply networks are referred to as the optimization or redesign of supply networks, especially when they are characterized by a large number of suppliers and varieties of parts (complex products).

There has been a tendency to diversify suppliers and sub-suppliers by relocating them closer to the main production site through reshoring, nearshoring and regionalization of strategic supply chains. This approach aims to optimize time and costs by alternating the just-in-time model with that of increasing safety stocks and developing the logistics real estate market.

In making these decisions, the supply chain is increasingly a variable to be evaluated from a financial point of view, with impacts in terms of investments and ROI. Supply chain finance (SCF), in fact, has grown significantly in recent years thanks to the digitalization of supply chains, expressing the need leverage financial tools to enhance not only the efficiency of one's own company but also the broader supply chain, optimizing available financial resources. Yesterday's linear, global, and predictable supply chains - where suppliers were more or less the same, certified, qualified, and controllable - are increasingly rare. Today, supply chains are asymmetrical and variable due to geopolitical, economic and social factors.

Sudden variables such as embargoes, wars, internal revolutions, climate crises (like floods or earthquakes) and possible future pandemics can cause blockages in the face of which valid alternatives will have to be identified in a very short time. Strategic suppliers or customers will have to be replaced to avoid production stoppages and consequent huge economic losses.

Additionally, trade routes - such as those from the Suez Canal to the Black Sea to the Baltic to the China Sea can be suddenly blocked, requiring rapid changes of strategy.

Climate change, particularly the melting of the ice, is expected to shift the focus toward the Arctic, opening new routes for international trade. The increasing congestion and vulnerability of the Suez Canal and the Panama Canal - as demonstrated by the Ever Given accident in the Suez Canal - require possible alternative routes. Additionally, the Arctic's vast natural resources, spanning approximately 8 million square kilometers, are becoming increasingly significant on a global scale.

The supply chain will therefore increasingly become a strategic variable to be analyzed on an ongoing basis and possible disruptions will have to be monitored as much as possible.

In fact, for some years there have been measures to assess them, such as the Fed's new indicator: the Global Supply Chain Pressure Index (GSCPI). This index integrates a series of data and indicators[9] to provide the most complete summary possible of the potential disruptions affecting global supply chains. More specifically, the index is based on data from seven interconnected countries[10] and a range of indicators from SMEs and transport costs.

The GSCPI could therefore be used as a monitoring tool to assess the conditions of the global supply chain, but also as a statistical model to understand trade flows between countries or price movements.

Even without disruptive events such as pandemics or wars, disruptions can arise within countries - such as build-up at ports or truck driver shortages - or they can spread to different countries, as in the case of a widespread container shortage.

The ongoing redesign of global value chains is crucial, especially considering the severe economic crises faced in recent years. The sector has a very high value, it is estimated to be worth up to 12% of the world's GDP for an absolute value of between 8 and 12 trillion dollars and growth forecasts for the coming years continue to be significant (Maiden, 2020).

9 The Fed's index complements two well-known maritime indices, the Baltic Dry Index and the Harper Petersen Index of Container Rentals, to the Purchase Manager Index (PMI), the U.S. Bureau of Labor Statistics' Air Freight Cost Indexes, and many other economic datasets from the transportation and manufacturing sectors. The GSCPI is updated monthly on the fourth business day of each month.

10 The economies interconnected through global supply chains referred to are: China, Eurozone, Japan, Korea, Taiwan, United Kingdom and United States.

Digitalization and artificial intelligence are set to play an increasingly crucial role thanks to advanced e-procurement, an effective analysis and evaluation of new partners, and a total digitization of transport documentation that allows continuous tracking of the distribution network.

Today, during an expedition, information is shared and collaboration between the various components of the supply chain is the best solution to face the complexity of new challenges. The adoption of IT systems capable of synchronizing supply network data with collaborative planning, with defined processes and procedures helps minimize unforeseen events and disruptions.

Owning and rapidly processing digital data allows you to change decisions and strategies. After the appropriate collection of information and data, we proceed with their evaluation which, given the speed of the decisions required, can hardly be carried out in a coherent and fast way by a single human mind, even if it reasoned in a pool.

Increasing immediate support is being used by the most advanced technology, linked to business intelligence, analytics and artificial intelligence.

Highly efficient calculation algorithms, expertly configured, enable rapid adaptation to changes in critical indicators related to procurement, inventory, production, and distribution. These algorithms proactively suggest alternative solutions to address emerging issues and disruptions. The introduction of blockchain in logistics has also begun to allow for the authentication of certain steps in the supply chain. In a world where trust is constantly undermined by the destabilizing factors, there is a need for technological support that links the correct evaluation of the supply chain to guaranteed and unchangeable qualitative factors.

It is essential to have daily certainty of what you buy, where you buy it, who the partner really is and how they behave, how and where you transport the goods, the relative delivery and distribution times and the complete and reliable tracking of the commercial transaction in physical, economic and legal terms.

IoT systems and an effective TMS are the basis of all this, but a blockchain notarization system is crucial in convincing companies and their customers of the validity of a system that is constantly evolving and changing.

“Logistics 4.0” has profoundly transformed organizations and roles, pushing towards the demand for new skills especially for data analysis, automation and artificial intelligence.

However, supply chains are increasingly vulnerable to frequent cyberattacks, which can compromise the security of client companies.

The methods used to attack the supply chain are different and often unfortunately unknown. The Enisa (2021) report clearly illustrates a series of methodologies and cases of attacks that occurred between January 2020 and early July 2021. It proposes interesting conclusions that can make us reflect on the need to develop adequate security models integrated into the supplier-customer supply chain.

Purchases on e-commerce platforms have grown exponentially with the acceleration of the Covid-19 pandemic, suggesting a consistent growth in the demand for logistics operators to prepare, transport and deliver purchase orders. This boom has highlighted the immense need for workers in the logistics sector. When analyzing future trends in logistics, it is impossible not to refer to the ongoing decarbonization process and therefore to the ecological transition of freight transport. The mission is one of the most arduous. First of all, the sector is characterized by an almost total dependence on fossil fuels and the adoption of low-emission technological solutions is progressing slowly, particularly in long-distance heavy transport. Secondly, the movement of products is set to more than double in the next three decades (ton kilometers will grow 2.6-fold between 2015 and 2050)[11] partly due to the increase in the world's population. This means that the reduction in emissions and average carbon intensity that current decarbonization policies will bring will be cancelled out by increased demand for transport. In addition, the assets used have a very long average life: ranging from 5-7 years for vehicles to 30 years for a ship and an aircraft (McKinnon, 2021). Finally, the stakeholders along the supply chains are numerous and the climate policy framework is not yet well defined and is fragmented into watertight compartments by type of carrier without an overall vision, not to mention the increase that this transition will entail on overall transport costs.

Reducing demand for freight transport is certainly one of the most politically sensitive issues. There was a close correlation between ton-kilometer growth, logistics performance and GDP growth. Governments are therefore concerned that limiting the growth of freight traffic could also inhibit future economic development. Despite the fact that the pursuit of the Net-zero goal may ultimately force policymakers to accept the fact that an infinite economic expansion is unsustainable for the climate, few governments are yet willing to pursue such measures.

The solutions being pursued are mainly at national and intra-continental level, where the goal is to move as many goods as possible from trucks to trains and ships. In fact, road freight accounts for 44% of all freight transport emissions, while maritime traffic only accounts for 20%, due to its high capacity and low carbon intensity.

Another measure is optimizingthe load capacity of freight transport, as available load capacity is seriously underutilized for all modes of transport.

Efforts are also being made to train hauliers in the conscious use of vehicles to limit fuel consumption. This includes strategies such as scheduling night departures to reduce traffic and improve fuel efficiency.

11 International Transport Forum (2021).

In Norway, the Norwegian Forum for Autonomous Ships has been established to promote the concept of unmanned navigation. Since 2021, the Norwegian fertilizer company Yara has been carrying out the first "pilot" project with an autonomous and electric container ship called Yara Birkeland, which has a capacity of 120 TEUs and has already been dubbed the "Tesla of the Seas". In 2024, at the end of the pilot project, the zero-emission ship could set the standard for the short sea shipping of the future. With no need for fuel and crew, the vessel will save up to 90% of annual operating costs compared to conventional vessels of similar size.

The future of logistics is already upon us, but the transition will not be painless in terms of upfront costs for all operators and the consequent impact on consumer goods.

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Chapter 5. Digital supply chains and the industrial metaverse

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5.1 Introduction

Digital supply chains are the expression of a far-reaching transformation of methods of production, distribution and consumption of goods and services, based on the intensive use of digital technologies such as artificial intelligence, the internet of things, cloud computing, blockchain, and augmented and virtual reality. Digital supply chains allow companies to create new business models, optimise processes, improve quality and security, reduce costs and environmental impacts, and increase competitiveness and resilience.

The metaverse is a vision of a shared and immersive virtual world in which people, things and information interact in real time through a range of platforms and devices. The metaverse is not only a place for entertainment or social contact, it is also a space for innovation and opportunity for businesses, particularly those operating in the manufacturing sector.

The industrial metaverse can be described as the convergence between the metaverse and digital supply chains; in other words a virtual environment in which companies can simulate, monitor, control and improve their activities throughout the value chain by integrating real-world data with the data and functionalities offered by the digital world. The industrial metaverse constitutes a new frontier for innovation and sustainability that can generate added value and competitive advantage.

However, the industrial metaverse also brings challenges and risks in terms of both technology and legislation. In order to build the industrial metaverse, companies need to address problems relating to connectivity, scalability, security, privacy, intellectual property, governance, standardisation, interoperability, data quality and skills development. In addition, companies must comply with the rules and obligations imposed by national and supranational authorities, the European Union in particular, in matters of social and environmental responsibility.

This article will analyse the concept and characteristics of the industrial metaverse, examine the opportunities and challenges it presents to companies, touch upon the EU's legislative framework, with particular reference to the

Supply Chain Due Diligence Directive, and illustrate some examples and case studies of the industrial metaverse's application in different sectors and fields.

5.2 The concept and characteristics of the industrial metaverse

The term metaverse is a blend of the words meta (beyond) and universe, and describes a parallel alternative universe in which people can interact with each other and with things through virtual characters known as avatars. The metaverse was originally conceived as a form of science-fiction narrative, but in recent years it has taken on a more technological and practical connotation, thanks to the development of platforms and tools that allow the creation of and access to increasingly realistic and immersive virtual worlds.

The industrial metaverse is a specific variant of the metaverse, which focuses on industry and its needs and peculiarities. The industrial metaverse is a virtual environment in which companies can duplicate and manage their activities throughout the value chain, combining real-world data with the data and functionalities offered by the digital world. The industrial metaverse is underpinned by a number of key technologies, including:

- Digital twins: virtual representations of real-world objects, processes, systems or services which reflect their status, behaviour or performance thanks to the collection and analysis of data from sensors, devices and various sources. Digital twins allow industrial activities to be simulated, monitored, controlled and improved, thus reducing risk, costs and times, while increasing efficiency, quality and security.
- Augmented and virtual reality: the methods used to access and interact with the virtual world, based on devices such as goggles, visors, helmets and gloves that overlay or replace perceived reality with digital elements like images, video, sound, text and graphics, and thus enrich or modify the user experience. Augmented and virtual reality allow the creation of and access to the industrial metaverse by offering greater immersion, engagement and collaboration among operators and between these and machines.
- Artificial intelligence: a discipline that designs and builds systems capable of carrying out tasks that would normally require human intelligence, such as learning, reasoning, decision-making, communication and creativity. AI allows real-world and virtual-world data to be elaborated and interpreted in order to provide information, suggestions and solutions, automate and optimise processes, and generate innovative and personalised content and features.

The industrial metaverse has several distinctive characteristics that differentiate it from the generic metaverse or other forms of virtual reality. One of these is the degree of realism and accuracy with which the industrial metaverse duplicates the real world, both visually and functionally. The industrial metaverse needs to be able to capture and transmit the details, properties, relationships, dynamics, variables and events that characterise industrial activity in order to provide a realistic and reliable representation that allows companies to operate effectively and efficiently.

A second important factor is scalability, in other words the ability to adapt to and manage a high and variable number of users, objects, data and operations interacting in the industrial metaverse. The industrial metaverse has to be able to support and coordinate enormous and growing complexity due to the plurality and diversity of industrial activity, which involves an array of actors, levels, sectors and geographical areas requiring different resources, times and structures and producing different results, impacts and feedback.

Lastly, it is essential - in order to support industrial supply chains - to ensure interoperability, in other words the ability to communicate and exchange information and functions with other systems, platforms and devices operating in the real world or the virtual world. The industrial metaverse must be able to integrate and interact with a range of sources and destinations for data and services that are key to industrial activity, such as sensors, machinery, software, applications, networks, clouds, protocols, standards, laws, authorities, partners, customers, suppliers, competitors, regulators and consumers.

5.3 The opportunities and challenges of the industrial metaverse

The industrial metaverse offers companies a series of opportunities and benefits, which can be summarised in four main categories:

- Innovation: the industrial metaverse allows companies to trial, test, validate and launch new digital products and integrated services with lower testing and prototyping costs and drastically reduced times for planning, industrialisation and market launch, thanks to the huge potential to simulate and create scenarios using "generative design" technologies, alongside collaborative open innovation platforms throughout the chain.
- Competitiveness: the industrial metaverse allows companies to optimise, automate and customise their processes of production, distribution and consumption, thus reducing costs, time, waste and errors, and increasing quality, safety, flexibility and differentiation. The industrial metaverse also allows companies to access new markets, customers, suppliers and sources

of funding, and to create and benefit from economies of scale, network and scope, increasing added value and profit margins.

– Sustainability: the industrial metaverse allows companies to reduce the environmental impact of their activities, save and efficiently use natural resources, energy and materials, forecast and manage environmental risk, adjust to climate change, and contribute to the transition to a green circular economy on the basis of carbon emissions. The industrial metaverse also allows companies to improve their social impact by promoting health, wellbeing, education, culture, social cohesion, inclusion, participation, citizenship, and respect for human rights, moral principles and the law, and to create shared value for stakeholders.
– Resilience: the industrial metaverse allows companies to address the challenges and opportunities caused by the complexity and dynamics of the economic, social and technological environment within which they operate; to anticipate and manage change, crisis, emergencies and threats, to safeguard and upgrade their capacities, functions and performance, to adapt and evolve in an agile, flexible and robust manner, and to continuously learn and innovate.

Nevertheless, the industrial metaverse also entails challenges and risks, first and foremost in terms of technology: the industrial metaverse requires companies to have infrastructure, devices, software, algorithms and high-quality data that is reliable, secure, compatible and up-to-date; they need to be able to support and manage the complexity and variety of industrial activity, protect and guarantee privacy, intellectual property and cybersecurity, and to preempt and resolve the problems, malfunctions, vulnerabilities and attacks that may arise from the use of digital technologies.

Added to these are the regulatory risks: the industrial metaverse requires companies to comply with the rules and obligations imposed by national and supranational authorities, the European Union in particular, in matters of social and environmental responsibility, the protection of consumers, workers and personal data, competition, fiscal obligations, safety, quality, traceability, certification, accounting and industrial activity, which may vary depending on the sectors, countries and markets in which they operate; these may require procedures, documentation, checks and sanctions that may limit or constrain a company's access to and operation in the industrial metaverse.

Furthermore, there are organisational risks and obstacles to consider: the industrial metaverse requires companies to adopt new organisational models and to be in a position to manage and coordinate the various activities, functions, processes and projects occurring in the industrial metaverse, integrate and harmonise the different cultures, skills, roles and responsibilities of the actors involved - employees, managers, consultants, partners customers, suppliers, regulators and consumers -, to foster and sustain the collaboration, communication, participation, motivation, training and wellbeing of the various actors involved. Ethical repercussions also merit consideration: the industrial metaverse requires companies to respect ethical principles and values, to guarantee and foster respect, dignity, equity, transparency, responsibility and sustainability in their industrial activities, to preempt and combat any potential distortion, manipulation, discrimination, abuse and fraud that may arise from the use of digital technologies.

5.4 Applications of the industrial metaverse in ESG regulations

ESG (Environmental, Social and Governance) regulations are a series of criteria and standards that assess the performance and impact of companies in terms of environmental, social and governance sustainability. ESG regulations are increasingly pertinent and required by stakeholders such as customers, suppliers, employees, investors, regulators and society in general, who want to learn about and monitor companies' conduct and contribution to the achievement of the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement on climate change.

The ESG regulations offer challenges and opportunities for companies, which are required to adopt strategies, practices and systems that can measure, track, communicate and improve their ESG performance and impact. To this end, the industrial metaverse can offer innovative and competitive solutions, which allow companies to:

- Measure: the industrial metaverse allows companies to collect, analyse and interpret data relating to their ESG performance and impact, thanks to the use of digital twins, artificial intelligence and blockchain, which enable the creation of faithful virtual representations of their activities; view and elaborate information in real time, and verify and certify the origin and quality of data. The industrial metaverse also allows companies to compare and integrate their own data with those of other sources such as public administration, international organisations, sector associations and benchmarking platforms which provide parameters, indicators, standards and goals relating to the ESG regulations.
- Track: the industrial metaverse allows companies to monitor, control and manage their ESG performance and impact, thanks to the use of augmented and virtual reality, blockchain and the internet of things, which enable them to interact and intervene on their industrial activity, track and record the operations, transactions and modifications occurring throughout the value chain, and guarantee and demonstrate transparency, security and responsibility in their activities. The industrial metaverse

also allows companies to engage and collaborate with other actors in the ESG regulations, such as customers, suppliers, partners, regulators and consumers, who can access and participate in the industrial metaverse in order to check, validate and influence the ESG performance and impact of companies.

- Communicate: the industrial metaverse allows companies to communicate, report and disclose their ESG performance and impact, thanks to the use of augmented and virtual reality, blockchain and artificial intelligence, which enable them to create and share digital content and services that illustrate and showcase their industrial activities, supply and certify information and data relating to the ESG regulations, and generate and stimulate the interest, trust, reputation and preferences of company stakeholders. The industrial metaverse also allows companies to receive and integrate feedback and evaluations by other actors involved in the ESG regulations, who can express and share their opinions, expectations, suggestions, criticisms and acknowledgement of companies' ESG performance and impact.
- Improve: the industrial metaverse allows companies to improve, optimise and innovate their ESG performance and impact, thanks to the use of digital twins, artificial intelligence and augmented and virtual reality, which enable them to simulate, test, validate and launch new industrial solutions and practices that respond to and anticipate ESG regulations and which increase the efficiency, quality, competitiveness and sustainability of their industrial activities, creating added value and competitive advantage for the companies and their stakeholders. The industrial metaverse also allows companies to learn and innovate continuously, thanks to the possibility of accessing and benefiting from the knowledge, experience, expertise and opportunities of other actors involved in the ESG regulations, which can offer and exchange information, services, resources and collaboration in the industrial metaverse.

5.5. The industrial metaverse market: size, trends and opportunities

The industrial metaverse market is growing rapidly and showing extremely promising prospects for development, both globally and regionally. This article will analyse the size, trends and opportunities of the industrial metaverse market, with a particular focus on Europe, in comparison to other areas of the world.

5.5.1 Size of the market

The industrial metaverse market is made up of two main segments: supporting technologies, which include hardware, software and services that allow companies to create and access the industrial metaverse; and vertical applications, which include specific solutions for the various sectors and industrial fields that use the industrial metaverse.

According to Grand View Research estimates, the global industrial metaverse market was worth 82 billion dollars in 2022, and is expected to reach a total value of between 250 and 400 billion dollars by 2025, with a compound annual growth rate (CAGR) of 40%. The supporting technologies segment accounts for 60% of the market, while the vertical applications segment accounts for 40%. The former is dominated by augmented and virtual reality, which makes up 70% of the segment, followed by artificial intelligence with 20% and other technologies with 10%. The vertical applications segment is dominated by the automotive sector, which accounts for 30% of the total, followed by manufacturing with 20% and other sectors, which make up 50%.

According to estimates by Nokia-EY, the European industrial metaverse market was worth 15 million euros in 2022, and is expected to reach a value of 50 million euros by 2025, with a CAGR of 35%. The supporting technologies segment accounts for 55% of the market, with vertical applications representing 45%. The former is dominated by augmented and virtual reality, which makes up 65% of the segment, followed by artificial intelligence with 25% and other technologies with 10%. The vertical applications segment is dominated by the energy sector, which accounts for 25% of the total, followed by transport with 20% and other sectors, which make up 55%.

5.5.2 Market trends

The industrial metaverse market is influenced by a range of factors that determine its growth and evolution, both globally and regionally. The most important market trends are the following:

– Digitalisation and the digital transformation of companies, which drives them to invest in innovative technologies and solutions in order to improve their efficiency, quality, competitiveness, sustainability and resilience, and to create new business models, products, services and experiences in response to the needs and expectations of customers and stakeholders.
– The Covid-19 pandemic and its consequences, which have accelerated the process of digitalisation and digital transformation, due to the restrictions imposed by containment and prevention measures, which limited mobility, presence and communication between people and things, and stimulated the demand and supply of digital solutions that enable companies to operate and interact remotely in a secure, immersive and effective manner.

– Sustainability and social and environmental responsibility, which pushes companies to invest in technologies and solutions that enable them to reduce the social and environmental impact of their activities, save and optimise natural resources, energy and materials, preempt and manage social and environmental risk, adapt to the changing climate, contribute to the transition to a green, circular low-carbon economy and create shared value for stakeholders.
– National and supranational laws and regulations, which oblige companies to comply with rules and obligations in matters of safety, quality, traceability, certification and reporting of their industrial activities, and also their social and environmental responsibilities in terms of the protection of consumers, employees, personal data, competition and fiscal obligations, which can vary depending on the sectors, countries and markets in which companies operate, and may require procedures, documentation, verification and sanctions that may limit or condition companies' access to and operation within the industrial metaverse.

5.5.3 Market opportunities

The industrial metaverse market offers opportunities for growth and development at both global and regional level, which can be exploited by companies operating in the segments of supporting technologies or vertical applications. The main market opportunities include the following:

– The demand and supply of innovative and competitive solutions that allow companies to create and access the industrial metaverse, to trial, test, validate and launch new products, services and experiences in response to the needs and expectations of customers and stakeholders; increase the efficiency, quality, competitiveness, sustainability and resilience of their industrial activities and create added value and competitive advantage for companies and stakeholders.
– Collaboration and cooperation among actors involved in the industrial metaverse, which allows companies to interact and harmonise their activities, functions, processes and projects with those of other actors such as customers and suppliers.
– Standardisation and harmonisation of regulations and standards relating to the industrial metaverse, which allow companies to operate securely, transparently and responsibly within the industrial metaverse, comply with and implement the rules and obligations imposed by national and supranational authorities, guarantee and demonstrate quality, traceability, certification and reporting of their industrial activities, and facilitate and encourage integration and interoperability among the various systems, platforms and devices operating in the industrial metaverse.

– Education and training of users and operators of the industrial metaverse, which allows companies to develop and acquire the skills, knowledge and expertise necessary to create and access the industrial metaverse, to operate within it in an effective, efficient and immersive manner, to learn and innovate continuously, thanks to the possibilities offered by the industrial metaverse, and to access and use information, experiences and opportunities of other actors involved in the industrial metaverse.

5.6. Public policy for the industrial metaverse: how to benefit SMEs

Small and medium-sized enterprises (SMEs) are an essential part of the European economy, because they account for 99% of companies, 67% of employment and 57% of added value. SMEs are also drivers of innovation, growth and social cohesion, as they contribute to diversification, specialisation, competitiveness, sustainability and inclusion in a range of sectors and geographical areas. However, SMEs face a number of challenges and barriers which limit their ability to adapt and prosper in the economic, social and technological environment in which they operate; these include lack of financial, human and material resources, difficulties accessing markets, customers, suppliers and partners, regulatory, fiscal and bureaucratic complexity, and vulnerability to risk, crises and threats.

This article will analyse a series of public policy recommendations which could be proposed to the European Commission and, more generally, to national and European institutions to facilitate the use of the industrial metaverse by SMEs, particularly those that belong to industrial supply chains and global value chains. The recommendations focus both on encouraging the adoption of the necessary technologies, and on supporting the training and innovation needed to support digital transformation in preparation for the industrial metaverse.

5.6.1 Recommendations to facilitate the adoption of enabling technologies

Enabling technologies are those that allow the creation of and access to the industrial metaverse, such as digital twins, augmented and virtual reality, artificial intelligence, blockchain, the internet of things and cloud computing. These technologies require infrastructure, devices, software and services that are high quality, reliable, secure, compatible and updated, which can support and manage the complexity and variety of industrial activities, protect and guarantee privacy, intellectual property and cybersecurity, and preempt and solve the problems, malfunctions, vulnerability and attacks that may arise from the use of digital technologies.

SMEs often lack the financial, human and material resources they need to acquire, implement, maintain and update these enabling technologies, and also face difficulties with access, integration, interoperability, standardisation, regulation, training, assistance and support in these technologies. To facilitate the adoption of enabling technologies by SMEs, the following policy recommendations can be proposed:

- Provide financial support for SMEs for the purchase, implementation, maintenance and updating of enabling technologies by means of grants, subsidies, incentives, loans, guarantees and tax concessions; these should be appropriate for the needs of SMEs, easily accessible, transparent and simplified, coordinated and harmonised at national and European level, and monitored and assessed in terms of impact and effectiveness.
- Encourage collaboration and cooperation between SMEs and other actors in the industrial metaverse ecosystem such as large enterprises, universities, research centers, sector associations, digital platforms, technology providers and public services, so that they can offer and exchange information, knowledge, experience, skills, resources, services and collaboration relating to enabling technologies, create and enjoy economies of scale, network and scope, foster open innovation, dissemination, transferability and scalability in the enabling technologies.
- Stimulate the supply and demand of innovative, competitive solutions based on the industrial metaverse, which can respond to and anticipate the needs and expectations of the customers and stakeholders of SMEs, increase the efficiency, quality, competitiveness, sustainability and resilience of industrial activities carried out by SMEs; create added value and competitive advantage for SMEs and stakeholders through the promotion, circulation, dissemination, demonstration, validation, certification and prioritisation of solutions based on the industrial metaverse.
- Facilitate standardisation and harmonisation of the laws and standards relating to the enabling technologies, so that they ensure and guarantee the quality, security, compatibility and updating of the technologies in order to facilitate and encourage integration and interoperability among the different systems, platforms and devices operating in the industrial metaverse; comply and adapt to the rules and obligations imposed by national and European authorities relating to the privacy, intellectual property, cybersecurity, social and environmental responsibility, protection of consumers, employees and personal data, competition and fiscal obligations of industrial activities.

5.6.2 Recommendations to support organisational training and innovation

Organisational training and innovation are practices and processes that allow companies to acquire and develop the necessary expertise, skills and abilities to create and access the industrial metaverse, to operate and interact in an effective, efficient and immersive manner within the industrial metaverse, and to learn and innovate continuously, thanks to the possibilities of the industrial metaverse.

Organisational training and innovation require strategies and systems that can manage and coordinate the various activities, functions, processes and projects operating in the industrial metaverse in order to integrate and harmonise the different cultures, skills, roles and responsibilities of the actors involved, such as employees, managers, consultants, partners, customers, suppliers, regulators and consumers; foster and support the collaboration, communication, participation, motivation, training and wellbeing of the various groups.

SMEs often lack the financial, human, material and organisational resources they need to develop the skills, knowledge and competence necessary in order to create and access the industrial metaverse, and they also need to address various difficulties related to adaptation, learning, innovation, change, culture, leadership, management, engagement, training, assistance and support for organisational training and innovation. To facilitate organisational training and innovation by SMEs, the following policy recommendations can be proposed:

- Train and qualify the human resources of SMEs for the industrial metaverse through programs, courses, pathways and certifications that are appropriate for the needs and capacities of SMEs and easily accessible, transparent and simplified, coordinated and harmonised at national and European level, monitored and assessed in terms of impact and effectiveness, and centered on the acquisition and development of the expertise, knowledge and skills necessary to create and access the industrial metaverse, operate and interact in an efficient, effective and immersive manner in order to learn and innovate continuously, thanks to the possibilities offered by the industrial metaverse.
- Innovate and transform the organisational models of SMEs for the industrial metaverse by means of advice, assistance and support geared to the needs and capacities of SMEs, which should be easily accessible, transparent and simplified, coordinated and harmonised at national and European level, monitored and assessed in terms of impact and effectiveness, and centred on the development and implementation of strategies, practices and systems that are able to manage and coordinate the various activities, functions, processes and projects operating in the industrial metaverse; able to integrate and harmonise the different cultures, skills, roles and responsibilities of the various actors involved and to foster and sustain

the collaboration, communication, participation, motivation, training and wellbeing of the various actors involved.

– Create and exploit the opportunities for learning and innovation offered to SMEs by the industrial metaverse through the promotion, communication, circulation, demonstration, validation, certification and rewarding of good practices, success stories, experiences, expertise and opportunities relating to organisational training and innovation in the industrial metaverse, so that these will stimulate and encourage SMEs to invest in and commit to organisational training and innovation in the industrial metaverse, and create and strengthen networks, communities and ecosystems of learning and innovation between SMEs and other actors involved in the industrial metaverse.

5.7 Conclusions

The industrial metaverse is an emerging and fast-evolving reality, which offers industrial companies a series of opportunities and benefits, but which also brings challenges and risks that require the adoption of appropriate and innovative strategies, practices and systems. SMEs are an essential part of the European economy which can benefit greatly from the industrial metaverse, but which must face challenges and barriers that limit their capacity to adapt and prosper in the economic, social and technological environment in which they operate. To facilitate use of the industrial metaverse by SMEs, a number of policy recommendations can be proposed, focusing on both encouraging the adoption of enabling technologies, and support for the organisational training and innovation necessary to support companies' digital transformation in preparation for the industrial metaverse.

PART II

Digital transition and technological infrastructure

Chapter 6. Technological challenges for the digital transition

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6.1. Introduction

Digital technologies offer enormous growth potential to companies that invest in innovative ICT (Information and Communication Technologies). Indeed, the adoption of digital services can impact business processes in different ways, such as reducing management costs, increasing production, and increasing customer satisfaction. This pushes enterprises to invest in the digital transition, digitalizing data, systems and procedures, optimizing processes and the overall management of resources. Digital Transition integrates digital technology into all the areas of a business, also changing how companies operate and deliver value to customers. It represents a technological but even business, economic and cultural transformation, where new production and delivery models need to be redesigned to address digital advances.

However, to implement a fruitful digital transition, each enterprise must identify the key opportunities, which depends on the real needs of the company itself, the long term objectives and the eligible economic investment. It is essential to identify clearly how technologies can really give added value to business processes.

This chapter aims to show which are the emerging technologies that are enabling the ongoing digital transition of public and private companies. It discusses how such technologies are evolving and why they are becoming so necessary in every application domain. Additionally, it analyses how the combination of such technologies can generate a disruptive potential in creating new solutions and business opportunities, even addressing the setup of innovative value chain models. Finally, it describes the long-term perspective of technological advances and the future direction of digital transition.

6.2 How Information and Communication systems are evolving

Digital transformation is driven by contemporary advances of technologies in different sectors, which unlock their potential whenever combined. First of all, research on microelectronics have brought a high variety of computing devices, with different hardware equipment and computation capabilities. These components range from small, inexpensive devices with limited computer resources (IoT) to modest priced servers with mid-range resources to expensive high-performance computers with extensive computing, storage and network capabilities. Different electronic solutions implement different computation tasks aimed to address specific needs. For example, IoT/Edge devices are primarily used to interact with the environment and users, and to provide time-sensitive responses, such as event alerting, home automation, health status monitoring. In contrast, HCP/Cloud architectures are used to run highly resource-intensive services, such as AI model training, big data analysis, and scientific application execution [2][3].

IoT/Edge — Fog — HPC/Cloud/Instrument

Size	Nano	Micro	Milli	Server	Fog	Campus	Facility
Example	Adafruit Trinket	Particle.io Boron	Array of Things	Linux Box	Co-located Blades	1000-node cluster	Datacenter
Memory	0.5K	256K	8GB	32GB	256G	32TB	16PB
Network	BLE	WiFi/LTE	WiFi/LTE	1 GigE	10GigE	40GigE	N*100GigE
Cost	$5	$30	$600	$3K	$50K	$2M	$1000M

Figure 6.1 Cyberinfrastructure scale [1]

In telecommunications, wide-bandwidth data transmission enables high-speed internet access worldwide. 5G and 6G networks have great potential to support large volumes of web-based services and real-time and streaming applications, envisioning hyper-connected systems over the internet. The availability of heterogeneous, hyper-connected computing devices has spurred the massive deployment of distributed systems. In these systems, nodes work on a variety of tasks across a network, splitting up the work, balancing workloads and coordinating efforts to complete tasks, even more efficiently than traditional standalone computers [4][5]. However, distributed systems can become highly pervasive and ubiquitous because they can use smart objects to bring computation close to the user, even in a transparent way for the users themselves opportunities to provide new digital services to support users in all their daily activities.

Finally, advances in computer science brought to the development of new key technologies for massive interaction with the environment, storage and processing of huge amounts of complex data through heterogeneous and performing hardware and software infrastructures, e.g. Big data, Internet of Things, Artificial Intelligence and more [6, 7, 8].

On one hand, technology is advancing rapidly. On the other hand, users are evolving in how they interact with these technologies and what they expect from them. Mobile devices, smart apps and automation systems allow users to access data and services quickly and easily. Users expect to have seamless access to customized digital services 24/7 and the provisioning of real-time multimedia communications to address both professional and personal activities. This shift requires a new approach to designing digital solutions, which has to address the fundamental principle that the user is the central focus of the design process itself [9, 10].

6.3 Key technologies for Digital Transformation

Figure 6.2 reports the Gartner Hype Cycle for Emerging Technologies for 2023. It identifies the 25 key technologies that are expected to have a significant impact on business and society over the next two to ten years, in particular enabling digital business transformation.

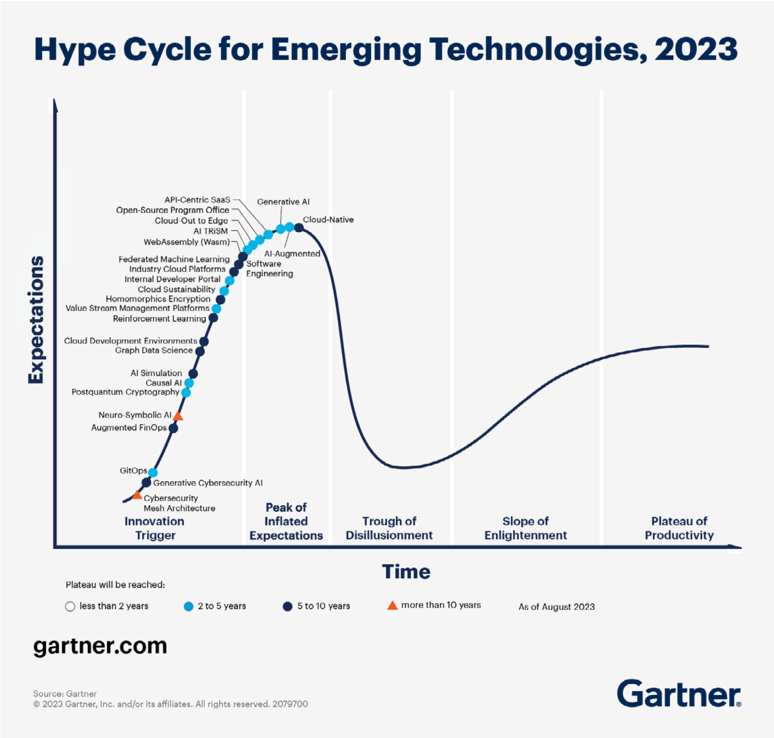

Figure 6.2 2023 Gartner Hype Cycle for Emerging Technologies

In the *Innovation Trigger* and *Peak of inflated expectations* stages there are several Cloud-oriented technologies (e.g., Cloud Development Platform, Industry Cloud Platforms, Cloud-Out to Edge, Cloud-Native...). *Cloud Computing* refers to the delivery of computing services, including storage, processing power, and software, over the Internet [11]. Instead of owning and maintaining physical servers or hardware, users can access these services on-demand from Cloud service providers. This model offers several advantages, including scalability, flexibility, cost-efficiency, and the ability to access resources remotely. Key characteristics of Cloud computing include:

- On-Demand Self-Service: Users can get provision and manage computing resources as needed, without requiring human intervention from the service provider.
- Broad Network Access: Cloud services are accessible over the internet from a variety of devices such as laptops, smartphones, and tablets.
- Resource Pooling: Resources are pooled and shared among multiple users, allowing for more efficient use of computing resources. Users typically don't have direct control over the exact physical location of the resources.
- Rapid Elasticity: Cloud services can be quickly scaled up or down based on demand. This allows users to adapt to changing workloads and only pay for the resources they use.
- Measured Service: Cloud computing resources are metered, and users are billed based on their usage. This pay-as-you-go model is cost-effective and allows for better financial management.

The cloud computing technology can be deployed using to two basic deployment models, each with its characteristics and use cases: public and private models. In a *Public Cloud*, computing resources are owned, operated, and provided by third-party service providers. These providers make resources - such as virtual machines, storage, and applications - available to the general public or multiple organizations over the internet and are typically offered on a pay-as-you-go or subscription basis. Popular Public Cloud service providers include Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform (GCP), and others. In a *Private Cloud*, computing resources are deployed and used exclusively by a single organization. The infrastructure can be owned and managed by the organization itself or by a third-party provider, but the key characteristic is that the resources are dedicated to the specific organization. Private clouds offer a higher level of control, customization, and security compared to public clouds. Organizations can tailor the environment to meet their specific needs and compliance requirements. Additionally, since resources are not shared with other organizations, private clouds are often selected for their enhanced security and privacy. VMware Cloud, OpenStack, and Microsoft Azure Stack are examples of technologies that enable the creation of private clouds.

Cloud computing is a key technology for enabling the deployment and massive usage of advanced computing solutions. Indeed, scalable Cloud infrastructure and resources allow to store, manage and process massive volumes of data (Big data). Artificial Intelligence (AI) algorithms can then extract valuable insights and patterns from this data, empowering organizations to harness the potential of these technologies without the challenges of managing complex on-premises infrastructures. The integration of cloud computing with AI and Big Data is a powerful combination that can enhance and optimize various business processes, decision-making, and innovation. Big data technologies, like Apache Hadoop or Apache Spark, are used to store, process, and manage these vast datasets across the Cloud data centers. Cloud-based analytics services and platforms, including Amazon Redshift, Google BigQuery, or Azure Analytics, can be leveraged for scalable and efficient data processing, allowing organizations to handle complex analytics tasks.

Significant opportunities for the future of computing are emerging from IoT and edge devices, as discussed in Section 6.2. These devices extend storage and computational resources towards end users. They include physical objects or "things" embedded with sensors, software, connectivity, and other technologies, allowing them to collect and exchange data with other devices and systems over the internet. The goal is to facilitate interactions and communication between devices without human intervention, creating a smart and interconnected environment around the user. IoT, Edge computing and cloud computing are interconnected ecosystems that collaborate to enable efficient data processing, analytics, and decision-making. These technologies work together to handle the vast amounts of data generated by IoT devices across distributed edge and cloud infrastructures [12, 13].

When these technologies work together, they implement an agile and data-driven approach for decision-making and problem-solving, which is central to the current digital transition. Organizations that invest in such technologies will unlock the full potential of their data, gain actionable insights, and build intelligent applications that drive innovation and enhance business processes.

6.4 Enterprise investments for digital transition

The 2020 IDG Cloud Computing Survey [14] asserts that cloud computing represents a third of the ICT cost for enterprises. Most companies surveyed plan to use Cloud services for over half of their infrastructure and applications. In particular, the primary reason for companies to move to the cloud is support in using the essential software, platform and infrastructure quickly and cost-effectively. Another key reason for enterprises to adopt cloud based solutions is the lower cost of IT infrastructure. In a traditional ICT ecosystem, the Total Cost of Ownership (TCO) includes factors like server hardware storage and maintenance, security system maintenance costs, administrative IT costs for systems and databases and more. Cloud services, however, offer a pay-as-you-go subscription model, where costs are proportionate to the effective usage of ICT resources. This approach makes digital transition more accessible, allowing even small enterprises to innovate and enhance their operations without substantial upfront investments. The worldwide enterprise spending on Cloud and data centers shows a significant growth of spending allocation in Cloud services, reaching almost $130 billion. Cloud spending by enterprises has surpassed enterprise spending on on-premises data centers, which has remained relatively stable in recent years. This shift indicates that many enterprises are adopting hybrid and multi-Cloud strategies, leveraging a combination of public and private Clouds to meet specific business requirements. This approach allows organizations to balance factors like performance, security, and compliance effectively.

Eurostat published an analysis on how EU enterprises bought Cloud services. In 2023, 45.2% of EU enterprises purchased Cloud computing services. This marks a 4.2 percentage point (pp) increase compared with 2021. The highest adoption rates were registered in Finland (78.3%), Sweden (71.6%), Denmark (69.5%) and Malta (66.7%). Conversely, less than a quarter of enterprises in Greece (23.6%), Romania (18.4%) and Bulgaria (17.5%) made such purchases.

The Cloud Transformation Observatory reported that Italian companies invested €4.5 billion in cloud services in 2022, marking an 18% increase compared to the previous year.

Additionally, according to the estimate of Statista's Technology Market Outlook, revenues for Italian companies serving as public cloud providers are projected to exceed €8 billion by 2025, up from €3.16 billion in 2020. Notably, about half of this growth is expected to come from the Software as a Service (SaaS) sector (see Figure 6.3).

These statistics prove the ongoing need of enterprises to invest in the cloud, albeit with varying budgets in different countries. These investments have become increasingly crucial for staying competitive, agile, and efficient in today's rapidly evolving business landscape.

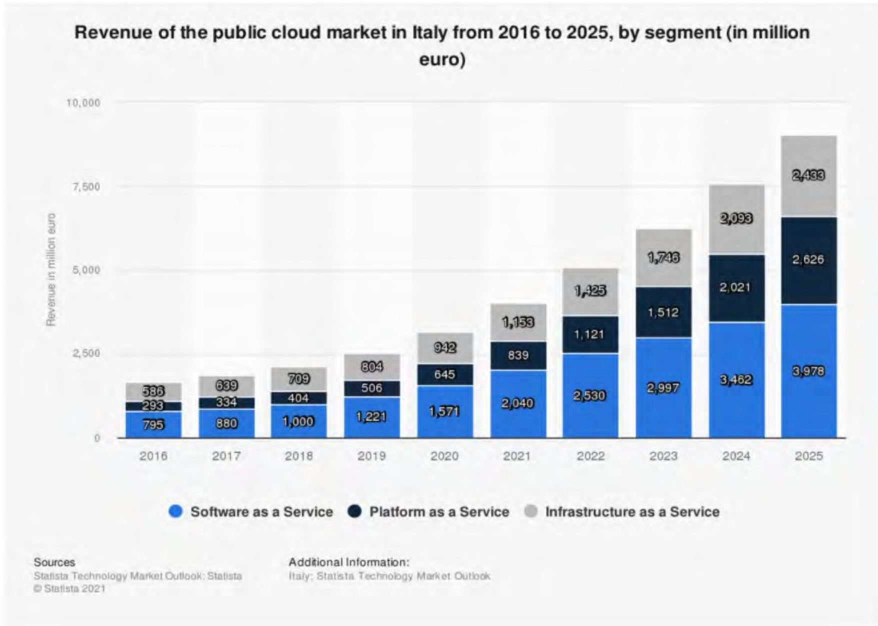

Figure 6.3 Cloud Revenue in Italy

6.5 New digital services

In recent years, cloud technologies provided great support for the deployment of IoT solutions thanks to their high availability of computing and storage resources. However, usually resources in the Cloud are distant from the IoT placement, causing performance degradation, mainly due to network connections. To overcome these problems, a multi-level computing architecture (working at the IoT, edge and cloud levels) can be adopted. In this approach, critical data can be kept and processed close to the environment (e.g., on IoT devices or at the edge of the IoT environment), while the activities that require less responsiveness or more resources run in the cloud (see Figure 6.4). To fully leverage the capabilities of various technologies, complex software applications can no longer be developed as monolithic solutions. Instead, they must be redesigned as a more flexible configuration of components, which implement different and well-defined functionalities. This modular approach allows each component to use the most appropriate resources available within the existing infrastructures. This brings to a new approach in application development, which is based on m*icroservices*. Microservices structure an application as a collection of small, independently deployable services [15]. These services are designed to be highly modular, loosely coupled, and focused on specific business capabilities. Each microservice operates as an independent unit, communicating with other services through well-defined interfaces, commonly referred to as APIs (Application Programming Interfaces).

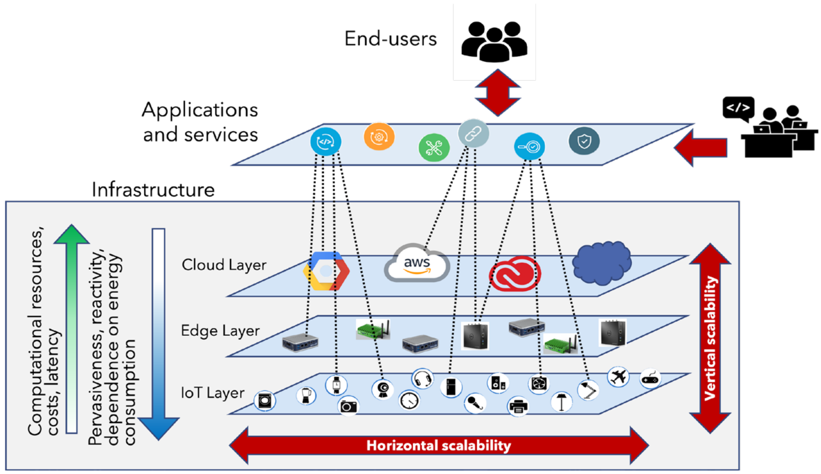

Figure 6.4 Distributed computing opportunities

Innovative principles at the basis of the multi-layer design are as follows:

– Compute Continuum (for vertical scalability): dynamical management of resources (or micro- resources at the IoT and Edge layers) across the different computing layers in a transparent way for the end use and according to several criteria, such as: application/service requirements, infrastructure resource availability, QoS, user QoE, energy consumption [16].
– Collaborative computing at the Edge (for horizontal scalability): IoT and Edge devices do not work in stand-alone mode, but they need to cooperate with each other and with Cloud datacenters for the efficient provisioning of services to the end-user. It implies auto-configurating and self-adaptative strategies for service management, even in presence of mobile nodes (e.g., drones, vehicular equipment...) [17].
– Intelligent orchestration of microservices: orchestration strategies to implement both vertical and horizontal scalability will be developed using AI based solutions, that will allow to predict necessary resources or possible migration of computation, thus to increase the reactivity of the orchestrator to events and to adapt the behavior of the whole system to the specific application-oriented and context- based needs [18].
– Security by design and trust: limits possible system vulnerabilities from the very first phase of creation to be compliant with the principles of lawfulness, fairness and transparency, integrity and confidentiality. In this view, it will integrate secure mechanisms for data integrity, authentication, privacy and trackability. It will safely manage processing workflows and establish

trust among different actors, in particular end-users and/or stakeholders of infrastructure or services [19, 20].
- Environmental sustainability: in line with EU policies to protect the environment, the project will explore strategies to optimize energy consumption in the allocation of computing and storage tasks, thus reducing CO2 emissions. Also, it will define allocation policies that take in consideration green energy sources (e.g. Solar Cells) [21, 22].

6.6 Cloud-based value chains

Value chains represent the full chain of a business's activities in the creation of a product or service based on cooperation, sovereign data sharing and controlled data usage among different organizations.

The value chain in cloud computing involves a series of activities and processes that add value to the delivery of cloud services [23]. It encompasses various stages, from infrastructure and platform provision to the delivery of software and applications, as illustrated in Figure 6.4. However, future value chains can be envisioned as federated ecosystems built on the Compute Continuum. In fact, microservices deployment in the Compute continuum facilitate agile development practices. This approach enables teams to iterate quickly and respond to changing business requirements. The ability to release and update individual services independently supports faster time-to-market for new features and improvements.

The new era of application and services will efficiently articulate opportunities around data spaces, where different Administrations/Country Domains are involved and, hence, need to extend data governance strategies across multi domain data (Figure 6.5). Different tasks in the value chain are modelled as a composition of *Smart Precision Data Services* (i.e. microservices for data-oriented processing) deployed across heterogeneous edge/cloud infrastructures. Each Smart Precision Data Service identifies a computing black box, where input data and metadata are processed to generate new data and metadata. For each Smart Precision Data Service computation, data governance strategies need to be clearly implemented to securely manage the data life cycle (from data generation/collection to the final use and disposal/deletion of data) related to the referred EDS. Value chain management involves both vertical and horizontal collaboration between companies to extract additional value out of data. The horizontal collaboration facilitates interactions among different actors through a well-specified sequence of tasks and rules for controlling the data flows across multidomains. Such interactions can be automatized by using digital components (e.g. triggers, message-based protocols...) or handled by human-based controls (e.g. vocal command, face recognition, sign of a document...). The latter approach puts humans at the center of the data processing flow, further characterizing Data Spaces, which are enriched by human-generated data and metadata. Smart Precision Data Services, which rely on the behavior of the "human in the loop," introduce new challenges for effective data governance strategies. Vertical collaboration, on the other hand, includes the management of Smart Precision Data Services and their execution over the available infrastructure, with a management of the whole data life cycle for involved Data Space(s).

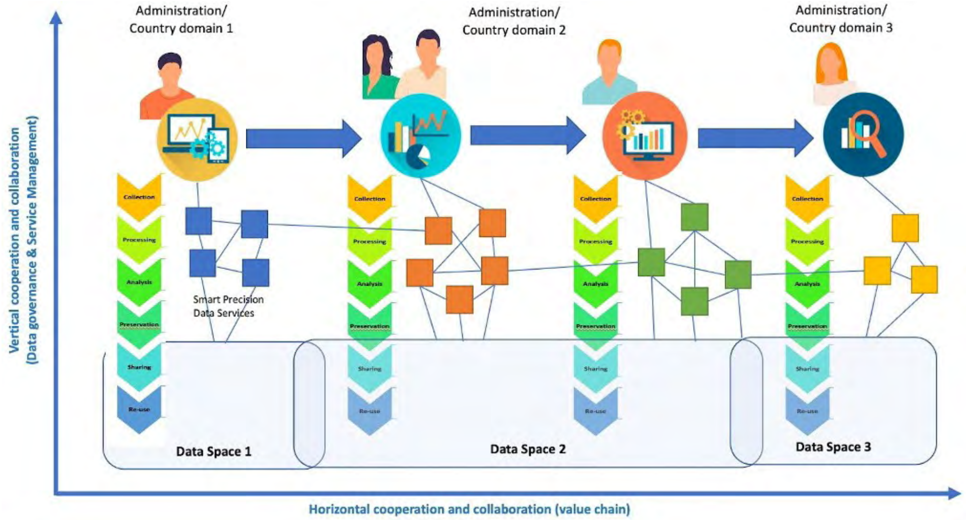

Figure 6.5 Complex Federated systems

6.7 Conclusions

This chapter explores emerging technologies for digital transition, revealing a rich landscape of opportunities and transformative potential. The integration of cloud computing, AI, Big Data, Edge computing and IoT is reshaping the way organizations operate, innovate, and connect with their stakeholders. As we navigate the digital transformation era, it becomes evident that these technologies are not merely tools but catalysts for profound change. However, adopting these emerging technologies is not a one-size-fits-all endeavor. Organizations must meticulously assess their readiness, strategically plan their adoption, and seamlessly integrate these technologies into their existing ecosystems. Change management becomes a critical aspect, recognizing that the successful digital transition is as much about empowering the workforce as it is about deploying cutting-edge tools.

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Chapter 7. NRRP and digital adoption: what are the effects on the country's system?

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DOI: 10.54103/milanoup.180.c272

The National Recovery and Resilience Plans (NRPP) are programs for the period 2021-2026 that European countries define to access funds from the Recovery and Resilience Facility (RRF) under the NextGenerationEU framework. This framework is the European Union's initiative for the recovery of Europe after the pandemic, integrating the Multiannual Financial Framework for the period 2021-2027.

Italy's NRRP was officially approved at the European level on July 13, 2021, through the Decision of the EU Council (CID). Aligned with the community framework (more green, more digital, and more resilient), it has three key objectives:

– Repair economic and social damages from the pandemic crisis and revitalize the country.
– Achieve greater environmental sustainability and stimulate digital transition.
– Promote consistent change by addressing structural weaknesses, such as weak product and productivity growth and extensive and lasting regional disparities.

The NRPP is characterized by three strategic axes:

– Digitalization and Innovation
– Ecological Transition
– Social Inclusivity

Additionally, three transversal priorities include:

– gender equality,
– improvement of skills, capacity, and employment expectations for young people
– territorial rebalancing and development of the southern regions.

In accordance with EU Regulation 2020/852 ("Taxonomy for Sustainable Finance") and in line with the goals of the European Green Deal, the measures of the Plan must comply with the principle of Do No Significant Harm (DNSH) to contribute substantially to ecosystem protection without causing significant harm to the environment.

Unlike other European spending programs, the NRPP is structured as a performance-based plan, committing Italy to achieve milestones and targets associated with reforms and investments within set deadlines. Each measure includes an implementation schedule and a list of outcomes to be achieved, serving as a prerequisite for receiving financial contributions or loans. These funds are allocated in ten installments, with the final disbursement scheduled by June 30, 2026. Each reform and investment is accompanied by a description of its objectives and the indicators that measure its success. These indicators serve as benchmarks for evaluation.

Milestones represent the completion of essential phases in the implementation (both physical and procedural) of measures, such as the adoption of specific regulations, the full operation of information systems, or the completion of works.

Targets represent measurable indicators in terms of the results of public intervention (such as kilometers of railways built) or the impact of public policies (such as a two percentage point reduction in the incidence of undeclared work).

Additionally, in order to establish mechanisms for periodic verification related to the achievement of goals and objectives, Operational Arrangements have been signed.

The NRRP commits Italy to a comprehensive program of reforms, linked to investments, aimed at improving regulatory and legislative conditions and steadily increasing the equity, efficiency, and competitiveness of the country.

Specifically regarding digitalization, the first phase of the NRRP involves some reforms and enabling investments for the digital transformation of Italy. These measures allow for a paradigm shift to ensure greater integration and cohesion in society, as peripheral areas, both territorially and socially, can have the same opportunities as more developed regions. Connectivity, coupled with the migration to the cloud of public administrations, both central and local, ensured by security requirements and the strengthening of cyber defense capabilities, will enable universal access to services for citizens and businesses alike. Simplification and interoperability can prospectively ensure compliance with the "Once-only" principle and greater transparency. As digital authentication eliminates unnecessary verification and control steps or mere ratification of identity, it will ultimately lead to a relationship of greater "trust" between institutions and citizens.

The reforms of the Plan can be distinguished into three main categories:

Horizontal or contextual reforms applicable to all Plan missions, aimed at improving the regulatory and legislative framework to enhance equity, efficiency, and competitiveness (e.g. Public Administration and Justice reforms).

Enabling reforms directly functional to implementing the Plan, removing administrative, regulatory, and procedural obstacles affecting economic activities and service quality (e.g. reforms related to public contracts and simplification).

Sectoral reforms within individual missions, addressing specific areas or economic activities to introduce more efficient regulatory and procedural regimes (e.g. labor market and education reforms).

The original NRRP (2021) is divided into six missions, corresponding to thematic priority areas consistent with the six pillars identified in EU Regulation 2021/2411, and 16 components addressing specific challenges.

Mission 1, "Digitalization, innovation, competitiveness, culture, and tourism," has the overall objective of the country's digital transformation, innovation in the productive system, as well as the development of two key sectors for Italy, namely tourism and culture.

Mission 2, "Green revolution and ecological transition," aims to improve environmental and energy sustainability and resilience, ensuring a fair and inclusive transition.

Mission 3, "Infrastructures for sustainable mobility," aims to promote the rational development of a modern, sustainable, and extensive transportation infrastructure covering all areas of the country.

Mission 4, "Education and research," aims to strengthen the educational system, digital and STEM skills, research, and technology transfer.

Mission 5, "Inclusion and cohesion," aims to facilitate participation in the labor market, including through training, strengthen active labor policies, and promote social inclusion.

Mission 6, "Health and resilience," aims to strengthen prevention and healthcare services on the territory, modernize and digitalize the healthcare system, and ensure equitable access to healthcare.

The Italian Plan, the largest in Europe, encompasses 132 investments and 63 reforms as defined in 2021, amounting to 527 goals. Many of these goals are highly ambitious and aimed to modernize the country and revamp its social and economic environment, both nationally and internationally.

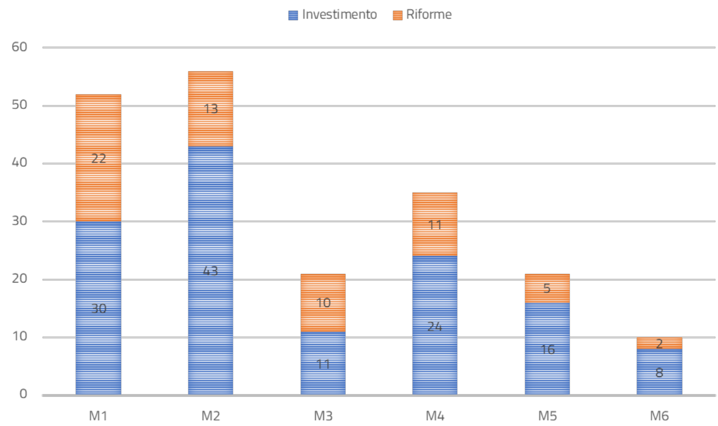

Figure 7.1 Number of Investments and Reforms per Mission

Source: Processing of the NRRP Mission Structure based on data from the ReGiS System

The related resources to the 2021 Plan amount to €191.5 billion financed by the EU through the RRF, with €68.9 billion in non-repayable grants and €122.6 billion in loans. Approximately 27% of the resources are allocated to digital transition, and at least 37% contribute to the green transition.

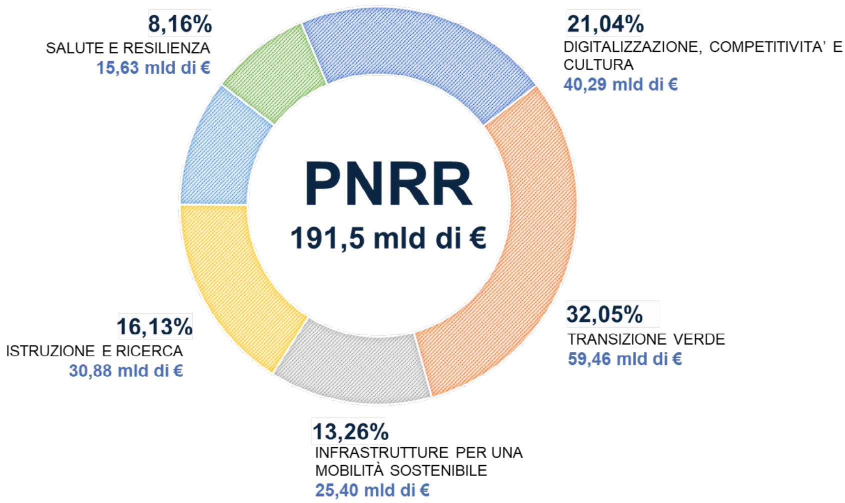

Figure 7.2 NRRP per Mission

Source: Processing of the NRRP Mission Structure based on data from the ReGiS System

Each measure, whether a reform or investment, is broken down into multiple connected milestones and/or targets. For example, Investment 3 in Mission 1, Component 2 (M1C2 - Investment 3) related to Ultra-Fast Broadband and 5G Networks and amounts to approximately 6 billion euros, is structured into five targets and one milestone, comprising five sub-investments.

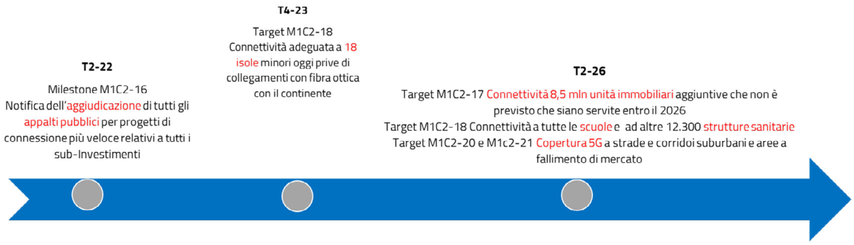

Figure 7.3 Mission 1

The Results-Based Plan introduces a new approach focused on outcome-oriented planning and logic at the heart of public policies, to be implemented within a specific timeframe. Additionally, it involves close monitoring and new tools to prevent potential delays in completion and to ensure the timely verification of the expected outcome. A team effort is necessary to gain efficiency and effectiveness, presenting a cultural challenge for public administration. To overcome resistance to the inevitable change, it is crucial to prepare public administrations by providing appropriate backgrounds in public administration, implementing new monitoring systems, and utilizing extensive databases.

The Plan's opportunities for Italy are numerous:

- High growth potential, ensuring a more digitalised, transparent, and efficient country.
  - Public Administration efficiency (digitalization, justice, procurement offices).
  - Businesses digitisation.
  - Education and training (upskilling-reskilling-education).
- A more cohesive country, social inclusion and equal opportunity, connected and innovative.
  - Labor market: women - youth.
  - Healthcare improvement: territorial healthcare - elderly.
  - Connectivity, transportation and environmental sustainability.
- An environmentally respectful country ready to face the challenge of climate change.
  - Adaptation of the production system to environmental criteria.

– A new perspective in public policies with administrations focused on results.

On December 8, 2023, the Plan was modified and the revision was approved by the Council of the European Union. The revision of the NRRP provided the opportunity to refine the way in which the original objectives of the measures are being pursued, by means of more effective alternatives (RRF Regulation, Art. 21) in response to the economic and political evolution.

The revised Plan increases resources to €194.3 billion, reflecting the European REPowerEU adjustment in response to the Ukrainian crisis. The updated Plan has especially increased ambition in the green transition, reinforcing this area in various aspects. Mission 7 - REPowerEU specifically addresses this, with significant measures for businesses.

The revised NRRP has now 7 Missions, 66 reforms, 150 Investments and a total of 617 milestones and targets.

New measures related to energy security goals, as outlined in the European REPowerEU regulation, focuses on reducing dependence on fossil fuels, enhancing energy efficiency, and increasing the use of renewable energy sources.

The most ambitious reforms have been reinforced introducing additional milestones (e.g. to support the reduction of the civil justice backlog or to speed up payments of public administrations). Specific investments have been introduced to enhance administrative capability with specific reference to green skills and public procurement.

The new plan upholds the commitment to a results-oriented approach, emphasizing vigilant monitoring to ensure the timely achievement of expected outcomes. This presents a cultural challenge for public administration. The opportunities for Italy encompass a more digitized, transparent, and efficient society, and a revitalized perspective in public policies.

Chapter 8. EU cloud policy requires an innovative governance

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8.1 Introduction

The European Union aims to achieve "digital sovereignty", that is, to regain an active role in the digital revolution and avoid an irreparable worsening of its dependence in technology and the digital economy. This is occurring in a moment in which the digital revolution is entering into a new phase. In fact, a new generation of general purpose technologies and enabling infrastructures are in the process of being designed, developed and deployed. Cloud computing, Internet of things, 5G, Artificial Intelligence form the core of this group of new technologies, which are set to develop in a highly integrated manner and will have a profound and far-reaching impact on all social and economic sectors, as well as on the functioning of all types of organizations and institutions.

Against this backdrop, the EU is seizing this moment of change as an opportunity to re-enter the "race" for digital transformation, in which it has so far failed to participate as a major player.

This article focuses on the EU's cloud computing policy. Cloud computing, the most mature of these new technological infrastructures, are being deployed and has been the subject of numerous EU initiatives and legislative interventions. It is also a paradigmatic infrastructure, in the sense that it incorporates a number of characteristics exemplary of this phase of transition. Cloud computing is an enabling infrastructure for the transition to a society based on the intensive exploitation of data and computational capabilities. It is an infrastructure whose introduction destabilizes and reconfigures modes of operation and boundaries of economic sectors, organizations, and institutions. Finally, it is an infrastructure that is extremely complex, in its components and architecture, and subject to constant dynamism. All these characteristics make it emblematic and, likewise impart a push toward innovations in the existing systems of governance.

This latter point is one of the reasons why it is particularly interesting to study, the ongoing attempt by European governments and the EU to regain an active role in the digital revolution. In fact, added to the advent of a new stage of the digital revolution, there is a clear return of industrial policy and public intervention in the governance of technological and economic development. This shift is driven by the very importance of these new infrastructure technologies, the explosion of geopolitical competition between the U.S. and China for the control of these new technological frontiers, and the crisis of neoliberal globalization.

Europe is entering this new stage of development facing hard challenges. It must reorganize its functioning and policies, which have been for long shaped by the neoliberal consensus. At the same time, Europe needs to find innovative ways to foster a robust and autonomous digital industry. It also faces the task of overcoming a highly fragmented system of governance in digital policy, which is disjointed even within individual nation-states. This fragmentation appears inadequate for the large-scale design, coordination, and governance required for the next generation of digital infrastructure.

Despite its intentions, Europe is thus being forced to become a laboratory for innovative forms of governance, which will have at the same time to reflect the maturing of the digital revolution and the new techno-economic paradigm that has been forming around it.

Our thesis is that, in this process of renewed public intervention, there will be a need for institutional and organizational creativity. An innovative strategy can be seen in the diverse initiatives that EU governments have launched in the field of cloud computing. The implementation, however, has been uncertain and inconsistent. Therefore, a clarification effort can help EU to act more boldly, address some blind spots that remain in its policy, and identify areas of innovation that have not yet been adequately focused.

Specifically, the argument will focus on a number of design and technology development principles that have been identified by the EU as levers for achieving internal coordination and sovereignty in cloud computing systems. By delving into these principles, their rationale, and their development, we will argue that the challenges the EU is facing require experimentation with a new type of hybrid forms of agency and governance.

8.2 EU cloud strategy in a nutshell

The EU identified the importance of the shift to cloud computing as early as 2012 (EU Commission). Since then, regulatory activity and promotion of initiatives have scaled up and intensified. There have been in fact 4 strategic statements, 15 legislations (approved or in the process of being approved) and at least 8 initiatives that - directly or indirectly - relate to cloud computing (Berlinguer, 2024). However, EU has so far failed to reverse the trend toward a deepening of the structural dependence of the European economy and public administrations on a few oligopolies, mainly from the United States, that dominate the cloud computing market[12].

The overall goal of all EU activism can be summarized by the notion of digital sovereignty, which has taken on at least two distinct meanings. The first, which is more classical, focuses on regulating the digital sphere. In this regard, the EU, alongside China, is leading the way in pioneering new legislation across various areas of digital development. The second, more innovative meaning, aims to ensure that individuals, organizations, and governments maintain autonomy, self-determination, and freedom of action and choice within new digital environments.

Concretely, the initiatives undertaken by the EU and European governments operate along three complementary axes.

The first is the regulation of the new digital platforms and critical infrastructures. In doing so, the EU is *de facto* acknowledging the nature of essential services of many digital technologies and the numerous monopolies ("gatekeepers" in EU legislative language) that have formed in digital services. Regulations span across multiple subjects, given the critical and pervasive nature of these infrastructures. They range from the protection of users' fundamental rights and freeing users and businesses from private and unsupervised rules, to the introduction of transparency on algorithmic content moderation and prioritization, to the introduction of rules to ensure "sovereignty" aka control over one's own data or immunity from surveillance by non-European authorities. Economically, the main concern is to protect users and businesses from power asymmetries vis-à-vis platforms and "gatekeepers" and the possibility of abuse by the latter due to their dominant position. The most ambitious goal is to increase competition by beginning to disarticulate monopolistic positions, for example by making interoperability of services on these platforms mandatory.

The second line of action is the preservation of security and sovereignty over the most sensitive data of citizens, businesses and governments. In the wake of the pioneering GDPR, an important part of EU initiatives and legislation has been dedicated to this goal. These initiatives include Gaia-X, the EUCS - Cybersecurity Certification Scheme for Cloud Services - under discussion within ENISA (the European cybersecurity agency), the new rules on the regulation of critical infrastructure, and the new legislation on data governance. The EU aspires to make these superior legal data security guarantees its own competitive advantage and a tool to overcome the main barrier to cloud adoption and data exploitation, which is the lack of trust of companies, citizens and institutions. Second, these security requirements can form the basis for creating

12 According to recent estimates, the collective market share of the European players in the European cloud infrastructure services sector, for example, has shrunk in the last 5 years from 27% to a mere 13% (Synergy Group, 2022).

in critical infrastructure and public services a protected market in which to grow a European autonomous industry and set of systems and technology standards.

Finally, the third line of action is the reactivation of industrial policy, a fundamental shift in EU policy, which is not limited to cloud computing or the digital sphere. Edge computing and industrial data have been identified as the two main opportunities for European industry in cloud computing. Edge computing is considered the next evolutionary stage of cloud computing and is expected to support the exponential increase in data flow and data exploitation made possible by the Internet of Things and 5G. In addition to being a new technological frontier, edge computing requires a more decentralized architecture for data and computational resources and open communication protocols. Thus, it can help advance the goal of disrupting the centralized, closed and proprietary systems that currently monopolize cloud computing service offerings. The intensive use of data in industrial processes, instead, is a new frontier, on which the EU aspires to build a leading ecosystem of innovation based on its strength in traditional manufacturing, which potentially provide a rich source of strategic data for the development of innovative services.

In both areas the EU aims at leveraging on the size of its market and its leadership in regulation, to become a "trustworthy" global standard setter.

8.3 … and some of its limitations

Will the EU achieve its digital sovereignty in cloud computing? It is still too early to assess the effectiveness of the new EU cloud computing policy fully. In the area of regulation, the European Union has become a pioneering laboratory for digital regulation and certainly will influence global regulatory standards on emerging digital technologies. As it happened with the GDPR, laws such as the Digital Market Act (DMA) and the Digital Services Act (DSA), which regulate the platforms and gatekeepers of the digital economy, or the long-awaited AI act, are regulations that are poised to have a global impact. The EU's legislation on data is similarly ground-breaking. The "data strategy", introduced in 2020, has been central to Europe's new digital policy from the outset with the declared ambition of making the EU a leader in the future "data-driven society". To support this, there are six specific regulations addressing data governance - three approved in the previous legislature and three proposed or approved in the current one[13].

13 The "data strategy", presented in 2020, has been at the heart of the new European digital policy from the outset, with the declared ambition is to make the EU a leader in the future "data-driven society". EU data legislation is undoubtedly the most prolific and extensive in the world. The issue of data cuts across all sectors of the digital economy and is therefore present in any digital regulation. However, there are 6 specific regulations focused on data. The first foundations were laid in the previous legislature with the General Data Protection

Overall, it is possible to discern the outlines of a technological, regulatory and industrial strategy that advances toward the goal of achieving greater European digital autonomy in cloud computing. This strategy is succinctly articulated in the Berlin Declaration of the 2020 European Council (European Council, 2020). The principles relied upon in that document to build sovereign cloud infrastructures in the critical area of European public administrations are: interoperability, open source, standardization, modularity. Accordingly, this strategy would fundamentally rely on a bold and strategic use of Free and open source software (FOSS) and open standards, ideally supported by regulations and coordination at the European level. Though undeniably challenging, this strategy would be based on existing - and most predictable future - trends in the evolution of contemporary digital systems. Moreover, the EU has allocated significant resources with the Next Generation EU fund, 20 percent of which - about 160 billion euros - dedicated to investments in the digital sphere.

However, the first steps of implementing these policies have been uncertain and inconsistent. The most critical step to look at is the migration to cloud computing of European administrations. This transition involves substantial investments and the need to preserve the security of the most critical data. As a result, many major European countries have chosen to exclude non-European or non-domestic providers from handling their most critical data and services. Examining the plan approved by the Italian government - which benefited from the largest share of the EU's Next Generation fund - reveals that it primarily involves using local encryption for managing the most sensitive data and transferring licenses from U.S. hyperscalers to a consortium of Italian companies. This approach suggests that Europe's technological dependence will not only be unaffected, but will actually be strengthened. On the other hand, the plans presented by France and Germany for the migration of their public administrations, while more ambitious in terms of pursuing strategic autonomy, appear uncoordinated (Berlinguer, 2024). In sum, obvious weaknesses emerge: the main ones being the lack of clarity and determination on common goals, the lack of coordination among European governments, and the absence of an effective digital policy governance system. While a further difficulty arises from the highly innovative nature of the industrial policy that the European strategy demands. This challenge is due in part to the absence of an autonomous

Regulation (2016) which regulates the use of personal data and with the Free Flow of Non-Personal Data (2018) for non-personal data, aimed at liberalizing the flow of data within the EU; and the Open Data Directive (2019), replaced the Public Sector Information (PSI) Directive, with the aim of promoting access and re-use of data held by public institutions. In this legislature, three new legislative initiatives have been added (of which only the first has been definitively approved): the Data Governance Act, the Data Act and the European Health Data Space. All these last regulations have as their main objective to incentivize and facilitate the economic, scientific and technological exploitation of data.

European digital industry and partly to the difficulty of reconciling the competing interests of different governments and economic sectors.

8.4 An innovative matrix for governing technological systems

Overall the European digital policy in cloud computing must be seen as a tentative and unfulfilled attempt.

But what can we learn from this attempt, particularly in terms of innovations in the governance systems that have not yet been sufficiently thematized by the EU policy?

One approach to answering this question is to look at what is perhaps the most original insight followed by the European strategy: the specification of a set of design and technology development principles as a guide for building sovereign cloud computing systems.

The principles of interoperability, open source, standardization, modularity are, on closer inspection, principles widely used in the construction of software systems. These principles have increasingly gained prominence, especially with the advancement of information and communication technologies, and software development in particular. The main and most innovative of these principles is undoubtedly the Free and Open Source Software (FOSS). FOSS is in fact a digital commons, as its open licensing allows anyone to use, study, modify and redistribute the software. Despite this challenging feature, it has come to largely dominate the production of software, which is the cornerstone technology of the digital revolution. Today, in fact, it is estimated that between 70 to 90% of existing software systems is made of open source components (Synopsis, 2023), and thousands of companies participate in the FOSS ecosystem. FOSS is a center piece on all the main frontiers of digital innovation, from Cloud computing, to Internet of Things, Artificial Intelligence, 5G, Blockchain Technology, or even Quantum computing. In certain cases, open source solutions have become an arena for convergence, standardization and industry-wide forms of collaboration. In other cases, FOSS alternatives have become a central instrument for capitalist competition (Berlinguer, 2018; 2021).

Moreover, FOSS non-proprietary logic has expanded and exerts a growing influence on the other principles of the matrix, and their governance models, as for example, with open standards or open APIs. And it is, to a large extent, in this vein that the EU has adopted these principles.

In fact, FOSS, standardization, modularity, interoperability have so come to be increasingly intertwined in their evolution. Overall, this already allows to draw a first teaching. Already today - and predictably even more so in the future - the core of digital infrastructure is developed and regulated by nonmarket forms of governance, which are based on novel forms of collaboration and competition. More specifically, delving deeper into the relationship of the principles of this matrix to markets, a common feature of these principles is that they shape but also eliminate markets and release productivity according to a different logic. The majority of the value they generate is shared and not directly measurable through market transactions. This is an aspect that Big Tech companies have come to know and strategically leverage (Berlinguer, 2018; 2023). However, it still remains a key blind spot for public policy and it is among the most underestimated aspects of the EU approach.

But what is behind the success of this matrix? There is no single determining factor. However, the main common denominator is that these principles constitute a set of strategies that respond to the need to manage the growing complexity, scale and integration of software systems and their constant dynamism (Steinmueller, 2003; Baldwin, 2008; Gottschalk, 2009; Benkler, 2013; Blind, 2016)[14]. While, in turn, the adoption and use of these principles have further facilitated the growth of the complexity, integration and dynamism of these systems, in a self-reinforcing cycle (Berlinguer, 2024).

This resulting complexity is evident in the sometimes hardly understandable system of dependencies and unexpected fragility of present software systems. This complexity has become a major force pushing for an evolution in the governance of software systems and for the governmental intervention in it, and thus in the governance of this same matrix.

Another key factor in understanding the success of this matrix is its alignment with a family of organizational forms that have gained prominence with the digital revolution, differing markedly from those typical of the Fordist era. These include phenomena like networks[15], platforms[16], and ecosystems[17]. All of which are more aptly defined as "meta-organizations" (Gawer, 2014). These "meta-organizations" are characterized by "policentricity" (Ostrom, 2010) and porous and elusive boundaries (Parker & Van Alstyne, 2016; Berlinguer, 2023). Furthermore, the main economic device through which they generate value is collaboration, not competition. And indeed, at a closer look, FOSS, modularity, standards, interoperability, are all arrangements that facilitate decentralized collaboration among people, and organizations with weak or nonexistent ties and different or even competing interests and agendas. Or, as Powell would have

14 This is just a selection of a vast literature that has been developed around each of these principles. Looking at this literature, there are two general rationales that are most widely used to justify and explain the adoption of each of these design rules separately: to simplify complexity management and to reduce communication and transaction costs.

15 For networks, see for example, Powell (1990), Castells (2004) or Benkler (2006).

16 For two different approaches to platforms, see Srnicek (2017) and Constantinides et al. (2018).

17 For ecosystems, see Baldwin (2018), Jacobides et al. (2018) or Cennamo et al. (2018).

put it, under conditions in which "neither markets nor hierarchies" provide effective means of promoting collaboration (Powell, 1990).

This suggests that the development of the digital revolution is driving a shift in organizational and institutional forms. Nevertheless, this doesn't mean that these principles of technological development have affirmed themselves or evolved naturally. Rather it has unfolded through a tense and evolutionary path, characterized by conflicts and innovations. Moreover, the use of this matrix can take various forms, especially as these principles have been variably combined with markets. The clearest example is provided by the parallel growth of the widespread use of FOSS with the formation of giant monopolies in the digital sector (Berlinguer, 2018)[18]. This apparent paradox also means that the importance of this matrix does not allow any simplistic technological determinism to be deduced and applied from it.

8.5 … and its next stage of evolution

What does it mean to find these principles of technology design and development articulated as tools in a policy document? Primarily, two things.

First, is that this matrix offers new levers for governing digital ecosystems. This is something that Big Tech companies are already familiar with[19]. What is new is that public policy is beginning to experiment with its use. As EU policy shows, this matrix can be leveraged in two distinct but complementary directions: to regulate new digital infrastructures and to implement a new kind of industrial policy. However, we are still in the early stages of this process, and there is still significant hesitancy in its implementation. But we can expect a gradual increase in clarity, capacity and more decisive actions based on these new tools in the future.

Secondly, this indicates that we are entering a new phase of evolution in the forms of governance of this matrix. The trajectory of FOSS is again illustrative of how important this evolution has been. FOSS has experienced two distinct

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18 Began with the same adoption of Linux. Linux, in fact, did not succeed so much as operating system for personal computers (where Microsoft maintained its dominance). Instead it found its way as a dominant platform in other areas such as mobile devices (Android is a derivative of Linux) and in servers and Web servers. This latter is the use that started to be made of Linux, since the mid-90s, by large organizations, with supercomputing necessities, such as NASA or later Google, that exploited it to build relatively inexpensive huge data centers and processing capacities. Which, in turn, highlights a paradox. Linux, often celebrated for the democratization it brought in software production and in a crucial layer of technological innovation, provided a potent foundation to what is the processes of "industrialization" and "platformization" of the Internet, and the present hugely concentrated architecture in cloud computing itself.

19 One of the first and most successful examples of wide use of this matrix to gain a monopolistic position has been Android.

phases: the first hegemonized by communities of developers and the second by enterprise adoption and new forms of market competition. Each of these phases has been characterized by important innovations. The first created and consolidated the institutional, organizational and cultural innovations that are still the basis of FOSS today (Benkler, 2006). In contrast, the second phase saw these initial dynamics complemented and increasingly overcome by new driving forces, represented by FOSS adoption by business, and the new competitive dynamics and business models that have characterized the growth of the digital economy (Berlinguer, 2023).

As a result of this trajectory, a number of hybrid organizations and arrangements have emerged. The most obvious example are the large foundations that have arisen within the FOSS ecosystem. Some of these foundations have grown spectacularly and which so far managed to dynamically maintain contradictory principles, such as private profit and sharing, the logic of voluntary communities and that of business organizations[20].

The active and structured involvement of governments in this ecosystem signals the onset of a new phase in its evolution. This more direct involvement of governments is not a phenomenon limited to the European case and is driven essentially by three factors: the systemic and infrastructural role that FOSS has assumed, the widespread impact of the latest digital technologies, and the intensification of international competition. As a result, the FOSS ecosystem is probably on the brink of changes, which are likely to be as profound and unpredictable as those seen during its previous transformations. However, some anticipations can be made. In the near future, we will see the emergence of new forms of governance, which we might call second-generation hybrids, that will have to integrate public powers and sovereign instances in their mode of operation. In truth, traces pointing in this direction are present in all initiatives promoted by the EU and major European governments. Nevertheless, a clear awareness and explicit thematization of this challenge is still lacking in European strategy.

This new phase of development is unlikely to be straightforward. In fact, it is likely that these new governance systems will play a much larger role in the future, and a more systematic use of this matrix could have repercussions in many areas, from antitrust and competition policy to industrial policy, financing and management of public goods, and tax and redistributive policy.

Nevertheless, the EU's chances of advancing its digital strategic autonomy will depend largely on its ability to play a role in this new frontier of governance innovation.

20 The most important by large is the Linux Foundation, which has become an highly influential hub in the relationships between global tech companies and open source projects. Other important foundations are Eclipse, Apache and the newly founded Chinese OpenAtom Foundation.

Acknowledgement

The argument presented in this contribution is explored in greater detail in an upcoming essay by Berlinguer, M. (2024), titled "*The Matrix. Is there a European way to Cloud computing? Lessons from an unfulfilled endeavor on the governance of digital transformation.* " This essay will be published in Transform! E-papers.

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Chapter 9. A European alternative to Tech Giants in the public interest

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9.1 Introduction

In this brief contribution, I propose establishing a public and supranational alternative to the oligopoly of major information technology companies, commonly referred to as Tech Giants. Following this introduction, the text is divided into two parts: the first of which is a summary analysis of the scale of the problems we face, while the second relates to the proposal I initially formulated in the book "*The Privatization of Knowledge*" (Routledge, 2023).

It might seem naive or overly ambitious to make proposals for public policy beyond regulation in a field completely dominated by oligopolistic giants. However, I believe there is room for new feasible public policies. For example, the European Parliament recently voted on some legislative texts on environmental issues, that, while faced strong opposition from sectoral lobbies, are on their way. In a different field, that of the Big Pharma oligopoly, a majority of European members of Parliament, after a lengthy study on lessons learned from the pandemic, approved various recommendations to the European Commission and member states last July. These included the creation of a supranational public infrastructure dedicated to the research, development, and production of vaccines and drugs in the face of market failures. The proposal I am advancing for the digital economy is similar to that for biomedical research. It stems from the development of the concept of a European public enterprise with a high knowledge intensity, an idea matured since 2019 within the Forum on Inequalities and Diversity[21], a think tank.

9.2 Some Facts

Tech Giants are not only the world's largest companies in terms of revenue and profits but also lead in research and development investment. The top five US Tech Giants spent nearly USD 400 billion in capital expenditures in 2022, of which over USD 220 billion was allocated to research and development

21 https://www.forumdisuguaglianzediversita.org/imprese-pubbliche-europee/

(R&D) (see Tables 9.1-9.2). By contrast, in 2019, the last pre-pandemic year, they had spent less than half of this amount on tangible and intangible investments, including R&D; they then doubled their investment in three years. Over the past decade, the nominal increase in capital expenditure has been eightfold, while R&D expenses have increased elevenfold. Relative to total net revenues, Meta, for example, spent more than one dollar for every five earned on research in 2020. This formidable spending capacity, facilitated by very high oligopolistic profit margins, lays the groundwork for market dominance that will likely persist for at least a generation. The scale of today's research investments will determine what businesses and consumers will purchase tomorrow, with the additional legal monopoly protection derived from thousands of patents.

In addition to artificial intelligence (AI), the technologies being developed extend beyond the Internet, smartphones, and cloud computing. These innovations are poised to transform the entire technological landscape. This has implications for software we use every day, even seemingly mundane ones like Excel or Word, where AI routines developed by startups, often later acquired by Tech Giants, could be embedded.

The role of acquisitions is a significant aspect of the broader picture. In recent years, 20% of Tech Giants' acquisitions have been in the field of AI. Job openings in these companies now list AI skills as a key requirement, reflecting its central importance to their strategies. Perhaps more impressive is the data on corporate acquisitions: in the last four years, the top five Tech Giants have taken control of 200 companies that had developed expertise in this field (see Table 9.3). A well-known example is OpenAI, a startup partly owned by Microsoft, ChatGPT, and Gpt4; Microsoft has invested $11 billion, acquiring a 38% stake. This suggests the prospective value of these acquisitions in terms of expected profits.

Another example of this strategy is Gradient Ventures, controlled by Alphabet. In the period between 2019 and 2022 alone, it invested in 200 companies. In this case, it is usually not complete acquisitions but often portfolio investments, including minority stakes, in companies involved in AI. This strategy allows for access to information about the development of new products from within the most innovative startups, and potentially gaining control later. It is a strategy that has turned Big Pharma into an apparently impregnable oligopoly fortress.

Even from the perspective of scientific publications, Tech Giants dominate, surpassing universities in productivity. Researchers affiliated with Alphabet published 9,000 papers between 2020 and 2022, while those affiliated with Microsoft published 8,000. Thus, each of these companies publishes more in these fields than some prestigious universities.

In this sense, we are facing an unprecedented oligopolistic concentration of knowledge production, exclusively aimed at capital accumulation. Our societies, the relationships between classes and nations, and the orientation of governments and public policies will be defined by these formidable concentrations of power, in addition to those of Oil & Gas, Big Pharma, Automotive, and other sectors with rigid hierarchical structures.

Table 9.1 Who spends the most in the world on R&D

Company	**R&D in 2020 (USD billion)**	**Percentage on revenues**
Amazon	42.7	11%
Alphabet	27.6	15%
Huawei	22	16%
Microsoft	19.3	13%
Apple	18.8	7%
Samsung	18.8	9%
Meta	18.5	21%

Source: https://www.statista.com/statistics/265645/ranking-of-the-20-companies-with-the-highest-spending-on-research-and-development/

Table 9.2 - Expenditure on capital and R&D

The Five Tech-Giants combined: Alphabet, Amazon, Apple, Meta e Microsoft		
Year	**Capital expenditure (USD billion)**	**R&D (USD billion)**
2013	50	20
2014	70	30
2015	90	40
2016	100	50
2017	120	70
2018	160	90
2019	180	110
2020	220	120
2021	298	150
2022	398	220

Source: «The Economist», 26 March 2023, Big tech and the pursuit of Ai dominance.

Table 9.3 - Acquisitions of companies related to Artificial Intelligence (2019-2023)

Company	Share of the total
Apple	45%
Meta	23%
Microsoft	23%
Alphabet	10%
Amazon	7%

Source: «The Economist», 26 March 2023, Big tech and the pursuit of Ai dominance.

9.3 Proposals

How does politics react to this dangerous concentration of oligopolistic power? The ability to influence public policies - and thus the very foundation of sovereignty - hinges on the critical confrontation between governments and entities like Tech Giants. This confrontation is essential for addressing and managing the vast power wielded by these corporations and for safeguarding democratic governance and market fairness. The government of the People's Republic of China, which is home to some of the major players such as Tencent (fintech and online services), Alibaba (software and retail), China Mobile (Telecom), Huawei (Telecom and devices), Jd.com (retail) - with cumulative revenues of USD 550 billion in 2021 - has shown the ability and willingness to exert authoritarian control over the sector, including both public and private enterprises. In response to this global dynamic, essentially between US and Chinese companies, the European Commission appears to be pursuing a dual approach: adopting forms of supranational regulation, such as EU legislation on data protection, the Digital Services Act, and through competition supervision actions, including bans and fines.

Details of this EU strategy cannot be discussed here in depth, but it is worth quoting verbatim the recently approved position of the European Parliament in June 2023 on AI, which served as the basis for negotiations with the EU and member states[22]:

> As part of its digital strategy, the EU aims to regulate Artificial Intelligence (AI) to ensure better conditions for the development and use of this innovative technology. AI can bring many benefits, such as improved healthcare, safer and

22 https://www.europarl.europa.eu/news/en/headlines/society/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence

> cleaner transportation, more efficient production, and cheaper and more sustainable energy. In April 2021, the Commission proposed the first EU regulatory framework for AI. It suggests that AI systems used in various applications be analyzed and classified based on the risk they pose to users. Different risk levels will entail greater or lesser regulation. Once approved, these will be the world's first AI rules. The Parliament's priority is to ensure that AI systems used in the EU are safe, transparent, traceable, non-discriminatory, and environmentally respectful. AI systems should be supervised by humans, rather than automation, to avoid harmful consequences.
> The risk classification, from "unacceptable" to "limited risk," is shown in the Appendix (note that the Commission initiated the legislative process in 2021, and it is not expected to be completed by this Parliament. An agreement between Parliament and Council for an Artificial Intelligence Act was reached December 9, 2023, but further steps will be needed for a bill to be approved). Meanwhile, the AI landscape is evolving rapidly.

The EU approach is defensive: AI is acknowledged as potentially useful but it is admitted to be in the hands of entities over which the EU and its institutions have no direct control. Consequently, risks are classified and efforts are made to contain them, somewhat like dealing with the dangers of chemical compounds and toys, for example.

The current strategy is inadequate. Even though in some cases there are encouraging political signals, it is difficult to counter Tech Giants with such an approach, let alone with antitrust actions that require years of litigation and are themselves defensive by definition.

An alternative policy option should establish strong public entities producing digital knowledge and related services. Rather than merely overseeing the actions of others, these public entities would actively drive research and development in directions that align with societal needs and priorities.

Perhaps there is an initial sign of this ambition not to be just a guardian by the European Commission with the Gaia-X project, which should be a federation of clouds, open to participation by hundreds of public and private enterprises that have joined a European association under Belgian law. However, a closer examination of Gaia-X reveals that, despite its aspirations, the current scale of its activities, budget, and staffing is significantly smaller compared to the vast resources and operations of the Tech Giants. Gaia-X is an idea put forward by Germany at the Digital Summit in Dortmund (2019), subsequently joined by France and others. The aim was to create an "Airbus Cloud", analogous to the Airbus consortium, which successfully challenged US dominance in the aerospace industry. Without Airbus, Boeing would likely be the sole major player in the field, with regulatory and antitrust policies having limited impact. The goal of Gaia-X is similar: to establish a European cloud infrastructure that can compete with the dominance of US tech giants. Gaia-X envisions a cloud federation adopting common protocols, with specialized clusters such as Gaia-Health, Gaia-x4futureMobility, with variable geometry for memberships. Essentially, it would be a "cloud of clouds" characterized by a single standard for data sharing. This ecosystem will harmonize the protocols of various network providers and interconnections, integrating both Cloud solution providers and High-Performance Computing centers. According to the latest public information[23], 350 entities have joined the project, organized into various thematic groups. But looking at the concrete landscape[24], certain facts become clear. Focusing on the "platforms" segment of the digital economy, the market value of companies active in the field was distributed as follows (Gartner data 2020): 74% in the hands of twenty US companies, 21% with sixteen Asian companies, 4% with nine European companies, 1% with one African company. Considering that, for example, nearly three-quarters of public services of all kinds in Europe are expected to rely on platforms within a few years, it seems unlikely that Gaia-X can compete with Tech Giants without a scale of investments in the order of several billion euros per year. Such investments would be needed to build the necessary infrastructure (servers, proprietary software, marketing) that convinces businesses and ministries of EU member states to migrate from US platforms. Currently, the largest provider in the EU has only a 2% market share.

The alternative proposal is fundamentally to have supranational technology hubs - new-types of public enterprises characterized by high knowledge intensity and a supranational nature. This concept draws from the merger of two existing models: on one side, large research infrastructures such as CERN and the European Space Agency, and on the other side, public enterprises in fields such as energy and telecommunications, which have ultimately proven to be just as efficient, if not more so, than private enterprises, despite being weakened by governments' reluctance to establish clear public missions.

The idea is to counter Tech Giants not only with speeches, rhetoric, and defensive regulation but instead with an entity armed with budgetary capacity, managerial expertise, and possessing tangible and intangible assets needed to compete. This entity would have dedicated personnel and the capacity to seriously counter the digital oligopoly. The combination of the concepts of research infrastructure and public enterprise, as I have already mentioned, is an idea that the Forum on Inequalities and Diversity is trying to develop in other fields as well. This includes biomedical research, to counter the oligopolistic dominance of Big Pharma, as well as in the field of energy transition and, precisely, in the digital economy.

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23 https://gaia-x.eu.

24 As reported by the previous CEO of Gaia-X in a recent presentation at the University of Milan, https://gaia-x.eu/wp-content/uploads/2022/07/Gaia-X-standard-Presentation_06072022.pdf

The proposal is to establish a European supranational entity, essentially a company similar to the European Space Agency in terms of legal form and operational capacity. This entity would be equipped with resources open to partnerships with existing public and private organizations - excluding potential rivals that have joined Gaia-X. To be effective in countering the tech giants, the entity must operate on a sufficient scale, which means securing several billion euros in annual funding. Without such resources, the possibility of challenging the tech giants remains out of reach. To achieve this, highly competent individuals would need to be recruited. In Europe, there are tens of thousands of young talents at risk of being hired by the United States or elsewhere by Tech Giants, rather than being attracted by a project of public interest. It may be beneficial to imagine having a campus that serves as a central hub, but with several branches in different countries.

A concrete example can be found in the field of computer science. The European Bioinformatics Institute, part of the European Molecular Biology Laboratory (the "CERN" of molecular biology), has its own physical server infrastructure, a central office located at the Wellcome Genome Campus near Cambridge, UK, dedicated personnel, and ample resources. It serves the global biology community by providing free and open access to thousands of databases. It is not a weak federation of institutes; it is an entity capable of intervening and implementing a policy of digital knowledge. Hundreds of thousands of biologists rely on it through highly efficient online data acquisition procedures.

What could an entity of this kind achieve on a large scale? Firstly, it could provide users with the kind of guarantees that Tech Giants do not offer on how to use data; it could implement and manage a European cloud so that data remains in Europe and stays in a public digital space. Additionally, it could effectively deal with a series of technological adjustments, both on data transmission networks and computing, which need to be addressed in an integrated way.

To those who argue that the public sector cannot do these things, consider two notable examples. First, Fraunhofer in Germany, with an annual budget of 2.8 billion, has 28,000 employees and is among the main holders of technological patents. It is an entirely public structure, answering to the German federal government. A second example, less known to the general public, is the inter-university consortium for microelectronics in Leuven, which, with more than 5,500 scientists and 600 industrial partners, designs some of the chips that Tech Giants either purchase or further develop. Paradoxically, Europe has a de facto public, non-profit entity that designs semiconductors. These designs are purchased or further developed by Intel, and then all profits are privatized downstream by Tech Giants.

In conclusion, it is feasible to establish a European public enterprise in the digital field that embraces and develops the positive, public interest side of Artificial Intelligence and other technologies. This initiative could be considered not just as a niche topic, but as a proposal of general interest for the future of the upcoming generations, which might otherwise be determined elsewhere.

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Appendix: Risk Classification of AI in the Proposal by the European Parliament

Unacceptable Risk:

Artificial Intelligence systems are considered to pose an unacceptable risk and are therefore prohibited when they constitute a threat to people. These include:

1. Cognitive behavioral manipulation of specific vulnerable individuals or groups, such as voice-activated toys encouraging dangerous behaviors in children;
2. Social classification, categorizing people based on behavior, socio-economic status, personal characteristics;
3. Real-time and remote biometric identification systems, such as facial recognition. However, some exceptions might be allowed. For instance, post-identification remote biometric systems, where identification occurs after a significant delay, will be permitted to address serious crimes and only with prior court authorization.

High Risk:

Artificial Intelligence systems that negatively impact safety or fundamental rights will be considered high risk and will be divided into two categories:

1. AI systems used in products subject to the EU General Product Safety Directive. These include toys, aviation, automobiles, medical devices, and elevators.
2. AI systems falling within eight specific areas must be registered in a EU database: biometric identification and categorization of natural persons, management and operation of critical infrastructures, education and vocational training, employment, worker management and self-employment access, access and use of essential private and public services and benefits, law enforcement, migration management, asylum and border control, assistance in interpreting and legal application of the law.

All high-risk AI systems will be assessed before being introduced to the market and throughout their lifecycle. Generative AI, such as ChatGPT, must adhere to transparency requirements: disclose that the content was generated by AI, design the model to prevent the generation of illegal content, and publish summaries of copyrighted data used for training.

Limited Risk:

AI systems with limited risk should comply with minimum transparency requirements allowing users to make informed decisions. Users should be made aware when they are interacting with AI, including applications that generate or manipulate images, audio, or video content (e.g., deepfakes). After engaging with such applications, users should have the option to decide whether to continue using them.

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Chapter 10. A new age of digital trust

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10.1 Digital, this great unknown

Many now recognize the significant overlap between technology, economics, and politics, but few fully understand it. The reason lies in the lack of a common knowledge base, and in the complexity of the ways in which this becomes entrenched creating dependencies in the real world, in the economy, in the political action, and in our everyday lives.

Today, digital sovereignty is seen as a crucial legal initiative aimed at reclaiming market share from a handful of dominant American companies, often referred to as GAFAM - a term that originally stood for Google, Amazon, Facebook, Apple, and Microsoft, but has since evolved to include new entrants and rebranded entities. We search spasmodically for a single solution, identifying from time to time a single problem affecting the digital world: digital divide across regions, personal data protection, cybersecurity, and most recently, digital sovereignty. We strive to find a way to translate into our canons of understanding, a world by now predominantly made of totally digitized ecosystems.

The result of the inextricable integration of an endless array of technology platforms and applications, responding to rules largely invisible to the end users, almost impossible to be verified objectively. In the hands of software developers who wield the creative power of inventing new systems, machines, and products from the ground up, this dynamic has led to an unprecedented level of stochastic uncontrollability - something that humans are increasingly unable to manage. What is needed is a new awareness of the digital world, not as a simple set of technologies, but as a true parallel ecosystem to the physical one, increasingly independent and autonomous.

It is therefore necessary to create new paradigms of governance, which will accelerate the exit from the era of fear and 'control' of technology, and the transition to a new era of trust and 'economic evolution' through technology.

10.2 Digital sovereignty or digital autonomy?

They sound synonymous but are not.

Sovereignty is a political concept, applicable to boundaries within which a specific jurisdiction - that is the application of specific laws - must be exercised.

Autonomy, on the other hand, is an independence, i.e., the opposite of the dependence we experience from today's substantial monopoly of a handful of non-European data platforms and solutions.

But it is necessary to understand that sovereignty and autonomy are closely related when talking about dependencies on raw materials, energy sources, or resources that can irreversibly affect our ability to govern a territory and its people according to their own defined rules.

The fear that a web giant, such as Microsoft, or Alphabet, or Amazon - companies with a market capitalization each greater than the GDP of any European member state, and a customer base larger than the population of any nation in the world - may in fact define their own rules, and decide not to abide to those of the countries hosting or using their services, is not unwarranted.

But if the hypothesis of the subjugation of Europe, through industrial espionage, targeted attacks, or even belligerent actions, appears to the most (not all) mere science fiction, it is not difficult to understand how the economic weight of these platforms becomes relevant at the negotiating tables on major decisions affecting the European economy. This influence is particularly evident as the European Commission is introducing with the new digital regulations (GDPR - General Data Protection Regulation, DSA - Digital Service Act, DMA - Digital Market Act, DGA - Data Governance Act, DA - Data Act, AIA - Artificial Intelligence Act, etc.).

10.2.1 A model of 'Trust' is needed.

Digital maturity has advanced significantly, and the most powerful outcome has been a new awareness, developed in recent post-Covid years, of the need for a new generation of data platforms, and more generally 'digital services', that can be 'trusted', i.e., that respond to a common 'trust' model.

The word 'trust' has thus begun to proliferate since the advent of European projects, such as Gaia-X, where the concept of 'Trust Framework' became central (trust framework = trust ruleset + ruleset verification) is central.

Gaia-X, a debated project with many critical issues, on which the hopes and frustrations of many European companies, both suppliers and consumers of cloud technologies, are seeking a real alternative to the substantial dependence on non-European platforms. Gaia-X deserves credit for having focused the effort, not in another attempt to create a European cloud technology stack (which in the best case would not even compare to its American siblings). Instead it has identified a lack of trust as the key roadblock for cloud adoption. Gaia-X has redefined digital sovereignty as the achievement of trust, and in the definition of concrete and technological mechanisms to verify the trustworthiness of existing digital services in terms of their transparency, controllability, and interoperability.

This new perspective is inclusive, yet it discriminates against those platforms that made of the opacity of their features, and the difficulty of migration, their strong point, creating constraint of client dependence effect (lock-in).

10.2.2 The digital democratization

Therefore, if trust is important, here is where magically the promise of Web3 (a more democratic, user-controlled Internet, not subject to individual checkpoints, where every action and decision is recorded indelibly and uncorruptible) seems to have a clearer meaning and value to the market.

In the new era of digital democratization, it is necessary to have software and hardware architectures with an increasing level of autonomy, which means controlled by a community of equals, and not subjugated to any individual interests. It is necessary to identify the actors collaborating in a relationship to uniquely isolate responsibilities. It is also necessary to make the characteristics of a digital service - whether it is a social media or a storage application of my personal data or photographs - intelligible. This transparency enables users to make informed choices, knowing how their data will be handled. It is necessary to implement these verifications in an automated manner. And finally, we need to build trust in this new digital ecosystem, which we initially thought we could control like traditional analogic ecosystems. However, it quickly became unmanageable due to the complexities of system integrations, and through the twists and turns of hundreds of European rules, often unverifiable, billions of lines of code unknown and never tested, trillions of access breaches and data exfiltration.

The adoption of a decentralized, autonomous architecture (DAO) can then enable secure and sovereign identification of participants in a digital collaboration, or transaction (through SSI - Self Sovereign Identity, DID - Decentralized Identity). It allows for the exposure and verification of the structure and credentials of a service with machine-readable descriptors (such as JASON-LD, SHACL, ODRL) and verify credentials digitally (through TA - Trusted Anchors). Additionally, it enables the tracking of results incorruptibly and immutably (through DLT - Digital Ledger technology and Blockchain) which shows us how it is possible to equip ourselves with a more transparent, secure, controllable, non-human manipulable technology.

In this way, technologies that would otherwise be ends in themselves, or often demonized because they are not understood (such as Blockchain, that for years was called speculative by misleadingly associating it to the use in cryptocurrencies), finally take on a clear and useful role within a specific purpose: realizing a network of services that are more transparent, controllable and interoperable with each other.

10.3 Regulation and innovation – can they live together? The reaction of the institutions: hyper-regulation

Europe and member state governments, aware of the risk and impact, have in fact already developed strategies and industrial policies to address the phenomenon and regain the so-called 'digital sovereignty,' or should we say: the technological autonomy needed to compete in any market. However, regulation alone is a double-edged sword. On the one hand, the restrictions imposed reduce the ability of operators to make the most of the potential of technology (leaving competitive advantage to countries with looser regulation). On the other hand, the cost of complying with the ever new and complex rules of the digital market (such as GDPR, DGA, DMA, DA, AIA, CSA, GIA...) allow only the few with great economic means to invest human and economic resources dedicated to compliance. This not only reinforces the competitive advantage to the big few, but making it almost impossible for end users to objectively verify such compliance. The paradoxical effect of hyper-regulation, which cannot be verified through clear and simple objective mechanisms, is an increase in distrust (a reduction in user trust). This, in turn, creates an even stronger barrier to digitally driven innovation within our supply chains. The net result is dichotomous: on the surface, Europe flaunts greater security thanks to its own regulatory productivity, but looking at market numbers the results are not supporting the optimism. The share of European data platform operators does not compete (EU 4%) with that of the two big giants (USA 74%, China 21%) grown, by the way, also thanks to a strong de-regulation in favour of data exploitation, and in open conflict with the European regulation (let's not forget that the CLOUD Act and the GDRP, the two data protection policies of US and EU, continue to be incompatible with each other, as well as with Chinese autocracy).

Figure 10.1 The EU share in the Platform Economy

In short, while Europe may be recognized by all as the world best referee in the digital game, we must remember that the referee never wins the match!

10.4 Ruling AI

10.4.1 Ruling AI: a regulatory asymptote

So if there is a "GDPR effect", as I call it - the risk of creating fear and mistrust in those who entrust their data to technology on the one hand, and fear of making mistakes and incurring penalties on the part of those who provide technology and services on the other, to the point of having slowed down, in many cases heavily, the migration to the cloud, the transformation of application technology parks, the reengineering of core processes and services of public administration and private enterprises. As a result, the race to innovate and create the digital economy has been hindered. What then could be the effect of a new AI Act that does not take these risks into account?

If artificial intelligence truly has endless applications, is pervasive, and it is virtually indistinguishable from any other algorithmic forms, it is in fact impossible to think of isolating it and regulating its behaviour effectively within AI powered services that are already active in thousands of platforms that we use daily.

Today we are suddenly discovering generative AI (as if we were amazed that our Golem has begun to speak) forgetting that LLM (Large Language Models) and GPT models have existed and been exploited for more than a decade, just as ML (Machine Learning) is based on mathematics from more than two centuries ago. However, what remains unseen is that AI is far more herpetic, so to speak, than we can imagine even in its most basic forms, such as RPA (Robotic Process Automation).

We remember how much RPA was demonized in the past decade because of the possible social impact caused by the reduction of jobs. Yet, during this time, the largest banks and insurance companies around the world have optimized their back office processes by automating 80% of them with RPA and adding more and more cognitive components over time (from OCR – Optical Character Recognition, to Speech2Text, to content extraction, meaning analysis, summarization, and more).

Imagine how many steps in a contract management, or customer relationship, and payment processes with an insurance, or a bank, or an ecommerce platform, already make extensive use of RPA and AI. These technologies streamline tasks that would otherwise be lengthy, burdensome, and prone to human error. Finally, let's imagine how these automata, which already replace us at work, converse with us through help desks and personal digital assistants on our phone, which widely and deeply interact with our life sometimes without our knowledge, would automatically take decisions on financial investments (affecting our savings), purchasing at the best price a product (favoring suppliers would who know how to make themselves appealing), to determine (or discriminate) the choice of a candidate for a job position by reading thousands of CVs (that would otherwise go unread), or to propose to us in an increasingly precise and profiled way, what we need to buy, how we need to plan our leisure time, selecting our partners and friends, and so on.

Yes, all of this is troubling, yet it is already our reality - a reality where algorithms, in effect, govern us. While we must certainly regain control, we can no longer live without them. Therefore, we should stop trying to document all possible cases in which technology can hurt and should instead define a simple and common way to see through technology behaviour transparently. This would empower us to make informed decisions and start harnessing technology to its fullest potential.

It seems difficult, if not utopian, to think of harnessing AI (as well as digital in general) within prohibitive rules and legal restrictions, because of the multitude of scenarios and use cases that are impossible to predict in its complexity. Even when specific issues are identified such as the AI Act's proposed ban on the use of facial recognition in public places for the purpose of personal profiling, it remains challenging to control such technologies comprehensively. You're absolutely right - none of us wants to be monitored by a "big brother". But if we are already using our faces to unlock dozens of applications that store data on hundreds of platforms scattered around the world, through a smartphone geolocated on a satellite network and local wi-fi, the situation becomes complex. By inferring metadata - legally, since it's anonymized - biometric characteristics, location, age, race, residence, occupation, social status, shopping preferences, web interests, interests in the physical surroundings by monitoring dwell times in front of establishments... Even if this doesn't involve AI and facial recognition directly, what's the real difference? Well, perhaps the difference lies in the consent we give to the use of our data, and the fact that we should have a lot more tools to understand who we are grating access to, and then make a conscious decision about what to do.

10.4.2 A new regulatory paradigm

This is where regulation and technologies need to converge and help us rebuild trust. For instance, preventing video-metric tracking at an airport, through cameras and facial recognition with AI algorithms like YOLO (You Only Look Once), might benefit individuals who want to conceal their identity, rather than most of the people willing to allow face tracking if this gives them more physical security in return.

I'm neither an anarchist nor a digital control enthusiast, but we must understand technology before regulating it. We must accept a certain amount of risk necessary to live with technology advances and innovation that can be dangerous but should not and cannot be eradicated or put under full control (like energy according to Lavoisier's famous postulate).

This should be approached with humility and starting from hard data, especially when one does not have the necessary expertise to make decisions. It's important to consider not just the risks, but also to the benefits that technologies, such as AI, can offer. These benefits include preventing accidents, improving diagnosis of diseases, reducing human fatigue, eliminating errors and injustices, retraining repetitive jobs, and increasing control and quality of our lives.

So, no need for regulation? Far from it! However, the challenge we face is addressing the real issue, akin to solving the Gordian knot of technology. The goal is to bridge the gap between desirable theoretical regulation and its practical verifiability. We need rules that are objective, measurable, and implemented through technological platforms. These regulations should avoid ambiguous legal interpretations, costly audits, and certification processes that create barriers to entry and benefit only the certifying authorities. I am convinced that the way forward today is the development of a common set of rules defining what digital trust is, and a common European platform, open to all and inclusive, for free verification of compliance with these rules. This would provide transparency to those who choose to be inspected, showcasing their level of compliance, and allow for a healthy comparison with those who choose not to.

Contrary to popular belief, trust does not equate to cybersecurity. Trust is about verifying the veracity of a service's descriptions, and the ability to control sources, destinations, usage, filtering types of data that can or cannot be processed. It involves monitoring and tracking access, ensuring compliance with approved data usage policies, verifying the compliance to the existing regulation, legally recognizing the identity of all actors in a transaction, and legally hold the provider accountable for the statements it makes through digital signatures, and more.

There is a Digital Market Act, a Digital Services Act, a Data Governance Act, a Data Act, a Cybersecurity Act (and many cybersecurity codes in member states that differ in name but not in substance). However, there is not yet a 'Digital Trust Act' that groups into a single code sub-assemblies of the rules already defined in the various regulations, and defines how their sum constitutes a sufficient level of transparency and auditability to be considered 'trusted.'

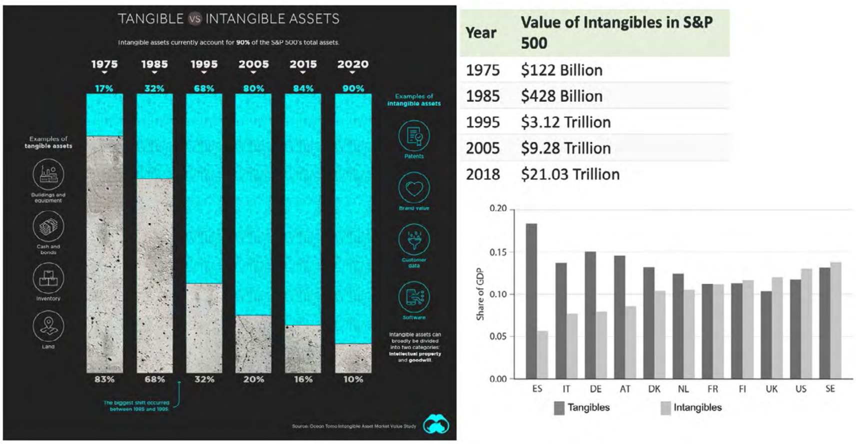
Verification of these rules can be achieved today through technologies, such as those underlying Web3 enablers, and projects such as Gaia-X with its Trust Framework.

What we need are transparency and controllability through a common set of rules, implemented on a decentralized and distributed technology platform, to enable informed decisions about whether to use a specific digital service. The creation of new regulations will not be sufficient, as there will always be a new Chat GPT coming around the corner and showing in a few days how to literally overturn every belief and written rule we think sufficient to feel in control of this new digital world.

10.5 The relationship between cloud and European industrial policies?

10.5.1 Economics of data

The shift to a democratic web is far from hippy idealism. In fact, it's a response to a stark reality where 90 percent of the real economy is driven by intangible assets (S&P 500 index evolution data over the past 40 years); a level of enterprise adoption of infrastructure cloud (IaaS) for corporate data management below 20% (Eurostat data 2021); a significant increase in the cloud market, tripling from 2017 to 2020, in parallel with a collapse in the market-share for European players; and an extremely powerful and opaque technological offer, capable of challenging the objective verifiability of compliance with European regulations, from the GDPR (and the legal conflict with the American CLOUD Act), to the more recent Data Act (and the lack of sufficient reversibility and interoperability) and the future AI Act (and the lack of transparency on sources and destinations of data models).



Year	Value of Intangibles in S&P 500
1975	$122 Billion
1985	$428 Billion
1995	$3.12 Trillion
2005	$9.28 Trillion
2018	$21.03 Trillion

Figure 10.2 Tangible versus Intangible Assets

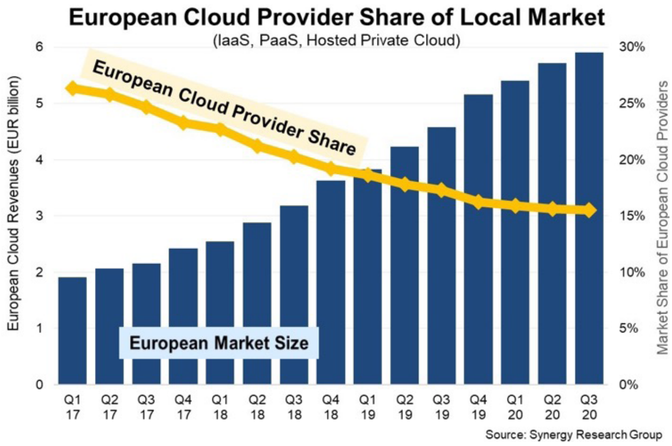


Figure 10.3 European Cloud Provider Share of Local Market

Without, therefore, a concrete alternative offering of 'trusted' services, the risk is that of a stalemate in the European real economy, and total subjugation to an oligopoly now of a very few data platform operators. The stalemate is caused by the dilemma between the fear of adopting technologies that are powerful but deemed 'insufficiently democratic,' and the fear of not keeping up with the innovation that the real economy requires, beginning to use data, pulling it out of the 'cellar' of on-premises data-centers and servers, and surrendering some of the intrinsic value to those foreign platforms managing it.

A dilemma then, in no small measure, driven by a data economy estimated in Europe by 2025 to be 830Bn Euro, about a 6% of European GDP, but which in fact represents only the tip of a submerged iceberg made up of the value induced by data to a new generation of products and services (in any sphere, from manufacturing to banking, transportation, etc.) where the market price is no longer proportional to the cost of production, but to a perceived value that is produced through the use of supply chain data (from applications to control a household appliance, to mobility services integrated into infotainment platforms, to integrations with payment systems, and so on).

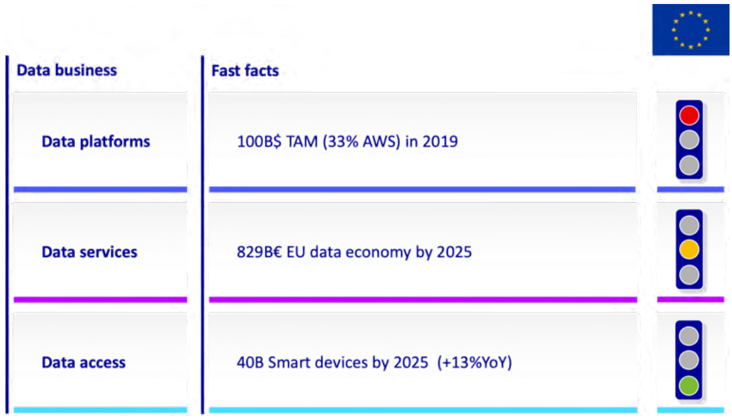


Figure 10.4 The data business

10.5.2 Data-gravity: decentralization and convergence of data platforms

Another physical phenomenon now visible to all is the so-called data-gravity, or the need to bring computing ever closer to where data is produced. This digital zero-kilometre requires a profound rethinking of cloud infrastructure. Instead of being hyper-centralized, proprietary, and isolated, cloud systems need to shift towards a federated, interoperable, and hyper-distributed model. This paradigm shift, results in the need for a continuum from cloud to Edge, and the consequent expectation to minimize data transfer, thus from data2compute to compute2data. Connectivity, in turn, becomes a hybrid of physical and virtual connection technologies, and a federation between networks and operators so that data can be accessed wherever it is generated or stored.

Yes of course, the digital divide, bringing optical fiber everywhere, creating 5G antennas, and 6G, is crucial, but the effort must be contextualized in a future that requires a geographic hyper-distribution of compute, storage, and connectivity nodes. This requires a strong federation (and therefore trust) between distributed, potentially competing operators, and a convergence between compute, storage, and network resources. These elements must be developed in tandem to prevent disconnected progress in each area. After all, we wouldn't build highways where no cars travel or sell cars where there are no roads.

10.5.2 Data-Spaces – digitalization of value chains

Like every trend, today we live a moment of strong emphasis on the importance of data. But what to do with them, and why they are so important is still largely a mystery for the many.

Everybody accepted that data is the new gold, but likewise, gold cannot feed people, build houses, or power industries - its value is intangible, just like data.

But the real difference is that the data economy built with data produces tangible effects that are visible by all and will revolutionize the world we live in.

The last wave on this data hype, which began around 2016 and consolidated recently also through the European Data Strategy, the Europe 2030 Digital Decade plan, and the investments of the European Commissions, is the creation of common dataspaces.

But what are dataspaces? Despite the many, often confusing definitions, including those who use it as a synonym of data-pools, data-lake, or data-ocean, or else.

Dataspaces are simply a virtual common space around which individual subjects (typically business actors in a value chain of any type) decide to aggregate, or federate, and share data one another for their common good.

How this is accomplished is a technical issue, but understanding why they are valuable is a fundamental economic topic. If data is the new gold, the value of data, like for gold, is intangible. Gold in fact does not feed people, generate energy, or be used to build essential goods for our life. However, gold can be converted into currency producing tangible wealth. Similarly, to monetize data they need to be converted into measurable economic benefits: a) cost reductions, b) profit increase, c) market growth. The day may come when raw or refined data will be treated directly, like utilities, materials, or enterprise shares, in stock exchange markets will come. However, for now and the foreseeable future, the value of data can be found only in specific use cases where the traditional (non-digital) processes can be simplified in costs and produce higher revenues or margins.

This process requires business analysis and business re-engineering skills to redefine and invent new ways of conducting business, and cannot happen through a mere adoption of technology. The combination of business consulting skills (business subject matter experts, business owners, product owners, business analysts) together with technologist (data scientists, AI architects, cloud architects, SW architects) is required to operate any real data-driven effective business transformation.

In the context of future data-driven economy, the dataspaces are of critical importance as they essentially serve as the digital counterparts (or data-twins) of value chains. In a digitalized value chain, the interfaces between the actors are no longer products or materials but data. In this way the end-to-end (E2E) process is seamless across all the actors, making it possible to reduce or eliminate rework, mistakes, mismatches between requirements and final product. It also facilitates impossible E2E analysis, for example the calculation of the energy consumption, or the carbon produced to build a specific product or service.

Let's give an example in the day-by-day life of healthcare.

Without common dataspaces - A patient visits a physiatrist, who prescribes a specialist consultation and an echo scan. The patient then searches for the nearest hospital and books the exam through the hospital's booking system. After taking the exam, the patient waits for the report to bring back to the physiatrist. The physiatrist identifies the need for therapy and additional tests, and requests the patient to provide all previous test reports and medical records. Since the patient had previously lived in a different city and the records are not readily accessible, they must search through their personal records to gather the necessary information. The patient then returns to the physiatrist, who prescribes further tests, and the cycle starts anew.

With a common dataspace - The patient visits the physiatrist, who determines the need for specialized tests, starting with an echo-scan. The doctor accesses the national healthcare ecosystem platform, which connects all partner facilities and shares their availability for diagnostic tests. The system retrieves the patient's medical records and identifies the nearest lab. It also notes that the patient had been treated at a hospital in a different city and prompts the doctor to confirm or update the location preference. The doctor then books the test directly through the system. The following day, the patient undergoes the echo-scan, and the report is automatically sent to the doctor. An AI engine, analyzing millions of scans, detects a potential cancerous anomaly and sends a real-time alert to the doctor. Receiving the notification on his mobile device, the doctor reviews the image and authorizes an in-person consultation with a specialist with a simple click. While the patient waits in the hospital's waiting room, they are promptly taken to the specialist, who orders additional tests to complete the triage. The patient's entire medical history is stored and analyzed in correlation with past data. The physiatrist, having a comprehensive view of the situation, contacts the patient to discuss the next steps, which are automatically prescribed through the platform.

One may might argue that the difference is just a matter of systems integration, but the real difference lies in the approach. In the traditional model, the patient runs around the healthcare ecosystem trying to join the dots of a broken chain. In contrast, the digitalized value chain, is a whole healthcare ecosystem that is interconnected thanks to a common dataspace. Here, the patient data is at the centre of it.

The digitalization of value chains through the creation of common dataspaces is not only a way to optimize and improve existing processes and products. It represents a crucial transformation to increase the resilience of physical, geographically dispersed value chains, where a single broken ring can disrupt the full chain (as evidenced by the pandemic's impact on the automotive industry in Europe).

Common dataspaces therefore produce stronger, more competitive, more efficient, and more resilient value chains, where the cost of production, or delivery of a service, is reduced or optimized, and the margins increase proportionally to the level of seamless integration and the depth of information exchanged by the participants.

The question then comes naturally: why has this not already been accomplished? It is not a lack of technology at all (we do have data exchange technologies since decades). Rather, it stems from a substantial lack of a common definition of trust, and a common and easy way to verify that the data exchanged respect the data usage and access policies defined by the data owners. In absence of common trust rules, value chain actors will restrict the amount of data shared scared of losing competition or intellectual property, and not leveraging the power data (keep the money under the pillow).

Still the solution is only one: a new generation of trustworthy and sovereign services.

10.5.3 A new role of leadership for Europe in the future of digital economy

Whether we are talking about artificial intelligence or digital technologies in general, we must understand that we are facing discoveries now comparable to the nuclear fusion or genetic manipulation, that can transform the entire humanity - either destroying it or protecting it depending on their use.

We should therefore first encourage and incentivize a healthy, controlled but profound phase of experimentation, to understand the benefits as well as the risks, and refine later, based on the data collected and in a continuous improvement process. And we must seek for a more effective regulation, focused more on the achievement of trust (transparency and control), and less on specific prohibitions, which are de facto already regulated by other existing codes and laws.

In the final analysis, I believe Europe is at an important crossroads. On the one hand, the choice to harness technology in hyper-regulation, hoping to force a radical (and global, since technologies have no borders) change in the way digital technologies and services are developed, delivered, sold, and enjoyed. On the other, the opportunity to translate its regulatory and legislative capacity, recognized by the world, into a huge business opportunity by developing a trust platform capable of objectively measure and verify the compliance of services with its rules.

The opportunity is thus to create a marketplace of services that can truly be defined as sovereign, fostering a new and globally competitive market. This would stand in contrast to the current dominant, often opaque solutions. By doing so, Europe could position itself as the world's leading exporter of this new generation of trustworthy technologies. This approach would align with the European Union's foundational principles of an open market, human centricity, and freedom of choice, reflecting the values of true democracy.

Conclusions

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1. What this book has accomplished

The interplay between digital transition and on European industrial policy was at the core of this book. Digital transition was framed as a challenge occurring at differences levels:

a. The changes in B2B and B2C relationships triggered by digital platforms;
b. The implementation of the Digital Market ACT (DMA), which came into force in May 2022 bringing about new relationships among consumers and companies;
c. The transition from 4G networks to 5G networks, which can impact significantly on energy consumption;
d. The increasing role of the cloud and edge computing;
e. The highly debated topic of Artificial Intelligence (AI), and the associated issues of the increasing need for data storage and energy consumption.

The book investigated digital transition with an interdisciplinary approach, relying on different academic disciplines - economics, management, computer science and statistics - but also on contributors from business and institutions.

Many industrial aspects are influenced by the digital transition. We limited our attention to i) changes in value chains and ii) the new technological infrastructures needed to deal with this important challenge.

2. Digital transition for value chain re-organization

Digital transition encompasses several technological innovations related to the organization of value chains, such as AI, Big data, cloud computing, Internet of Things, augmented reality, blockchains and B2C and B2B platforms. The functioning of these technologies asks for changes in the business organization and logistics, inducing new relationships between suppliers and service providers and companies at all the stages of the global value chains.

Adjustments in real time, made by possible new technologies, allow companies to deal with the necessity of facing changes and sudden shortages in energy and raw materials procurement. The re-organization of supply chains is an extremely urgent, due to the recent world-wide disputes, such as wars and geopolitical repositioning at the world-wide level. The impact of digital transition on value chains was analyzed from many important and diversified point of views: the structure of the Italian manufacturing sector; the challenge for the statistical identification of value chains; the important implications for business and managerial reorganizations; the relationships between large and small companies, the metaverse challenge.

The need for rapid decision-making can be easily satisfied by digital data. The ability to process data quickly allows to adapt their decisions and strategies in presence of an increasing number of destabilizing factors around the world, both in the geopolitical and economic dimensions. Moreover, blockchain technology can be easily adopted to guarantee the traceability of exchanges between business and consumers. This capability will become increasingly important with the anticipated implementation of the digital European passport regulations in the coming years.

From an industrial policy point of view, the identification and redefinition of value chains across Europe can be an important issue. We know that Europe present a lack of companies of remarkable size at the world-wide level. In order to face this issue, we have three possible solutions: improving the global legal, bureaucratic environment to facilitate companies to grow; investing on the managerial and capabilities culture of companies to promote growth; and improving the relationship among companies of different sizes in the same global value chains, as the digital and green transition for small and medium sizes companies can be facilitated by larger companies.

What are other European industrial policy goals? Which sectors should be incentivized without adopting a top-down approach, if there is broad agreement on this? How can be re-shoring processes incentivized inside the Europe, in order to reduce dependence on raw material from China and to face the increasing competition from United States and China, which adopt a strong and aggressive industrial policy? The challenge is to reconcile the EU's competition policy with its industrial policy needs, and the key is determining how to achieve this balance.

3. Digital transition and technological infrastructures

The second part of this book examines the digital transition and the technological infrastructures that facilitate the implementation of various challenges. As the amount of data generated by AI increases, the role of cloud and edge computing becomes crucial for data storage. The book explores the debate around the need for significant infrastructures to store these vast datasets.

The digital transition presents a significant opportunity for many companies, but its potentially disruptive impact cannot be ignored. The focus of this part of the book is not solely on Big Data per se, but also on the importance of having certified-quality datasets and the necessary infrastructure to store them. It is crucial to recognize that wealth is not just derived from data, but also from the infrastructures that store it.

Europe's reliance on foreign tech giants like Google, Apple, Facebook, Amazon, and Microsoft (GAFAM) poses a challenge for European companies and industrial policy, raising concerns about digital sovereignty. The book identifies the issue and discusses several approaches to address it, including market-based solutions, public infrastructures, or hybrid governance models.

To build sovereign cloud computing systems, Europe needs to tackle challenges related to interoperability, open source, standardization, and modularity. These principles are essential for regulating digital infrastructure and fostering a new industrial policy. One option is to establish a European supranational entity, similar to the European Space Agency, to counter the dominance of international tech giants. This entity could partner with existing public and private organizations and require substantial funding. Alternatively, Europe could pursue market solutions, such as the GAIA-X or Dynamo projects, to create a European cloud technology stack and reduce reliance on non-European platforms. Participants in these projects would need to ensure transparency, control, and interoperability, avoiding platforms that rely on opacity and client dependence (lock-in). A third option involves a mixed approach, combining public and private sector involvement. The book aims to promote an interdisciplinary debate on these issues by engaging companies, academia, and institutions.

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Digital Transition and the European Industrial Policy

Edited by **Maria Letizia Giorgetti and Lorenzo Zirulia**

Industrial policy has become central in the public debate after several years of neglect. Relying on contributors with different backgrounds, from academia to the public and private sectors, the book emphasizes two topics that are crucial to inform and motivate industrial policies in current times, expecially at the European level. The first part of the book touches several points related to global value chains, and how these are undergoing reorganizations due to factors related to digital transition. The second part of the book, instead, is dedicated to the role of infrastructures to store data for business, with a particular focus on cloud computing.

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