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Intellectual Property in Industry 4.0. An analysis of the innovation system in a changing scenario

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1 Introduction. Theoretical framework and purpose of the thesis

The present thesis stems from the scholarship established by the Tuscany Region in the academic year 2019/20 for the PhD course in Business Economics and Management at the University of Pisa, University of Siena and University of Florence. The Pegaso scholarship - financed with funds from the POR FSE 2014/2020 (Activity C.2.1.3-A POR European Social Fund 2014/2020) - is tied to the theme of "Industry 4.0 and intellectual property protection in Tuscan companies". The scientific research project, in the strategic interest of the Tuscany Region, involved the collaboration with a local company (ErreQuadro srl), specialised in intellectual property and Industry 4.0. From May 2020, together with the partner company, the methodologies and research outputs of the scientific activities were defined and led to the construction of this dissertation.

The starting point of the research work is the Industry 4.0 (I4.0) prototype, created in Germany in 2011, which envisages the use of enabling technologies (IoT, Cloud Manufacturing, Additive Manufacturing, AI, Advanced Human Machine Interface, AR, VR, etc.) for the creation of a CPS (cyber-physical system) to manage integrated industrial production, logistics and marketing (Kagermann, 2015). Industry 4.0 is an industrial model based on technology to manage all elements of the smart factory: productive process, management and control, organisational structure and relations and communication with other companies and customers. It has emerged as a technological framework to integrate and expand manufacturing processes both at intra-organizational levels and inter-organizational levels (Xu et al., 2018). Built on hyper connections inside and outside the company, I4.0 aims to shape through technology an interconnected system and a shared value chain. To achieve this, it is necessary to adopt and develop advanced technologies embracing and integrating them into the company's systems. Companies need commitment and resources (economic and time) to be able to adopt the entire 4.0 industrial model: therefore, we speak of a 4.0 transition path.

Based on the development of new technologies, I4.0 require the ability to produce innovations (Kagermann, 2015). Therefore, the path of change that companies should face in order to conform to the new paradigm obliges them to develop the capability to innovate. The approach of constant innovation and growth on a technological basis links I4.0 to the "technology-based firm" - TBF defined by Professor O. Granstrand (Granstrand, 1998). The theory illustrates a typology of firm in which technology is the main element that guarantees its productive functionality and, at the same time, constitutes the main output of the production process. TBF theory considers technology as "*a body of knowledge, together with physical charateristics of its embodiments*" taking up the role of the entire company's core asset (Granstrand, 1998). Due to its structural characteristics, technology requires constant updating and expansion of its tangible and intangible components, leading the company to a process of technological evolution, which itself involves innovation and growth for TBF. The process of technological development has enormous economic potential: economies of scale, scope and speed (peace of a process), but it is linked to a constant increase in R&D and adaptive change expenses. Industrial R&D is an important source for innovation and diversification in the enterprise (Penrose, 1959), and it has the fundamental role of developing the knowledge necessary for the progress of the enterprise (Spender & Grant, 1996). Developing innovative capacity, therefore, is a priority for all kinds of TBF.

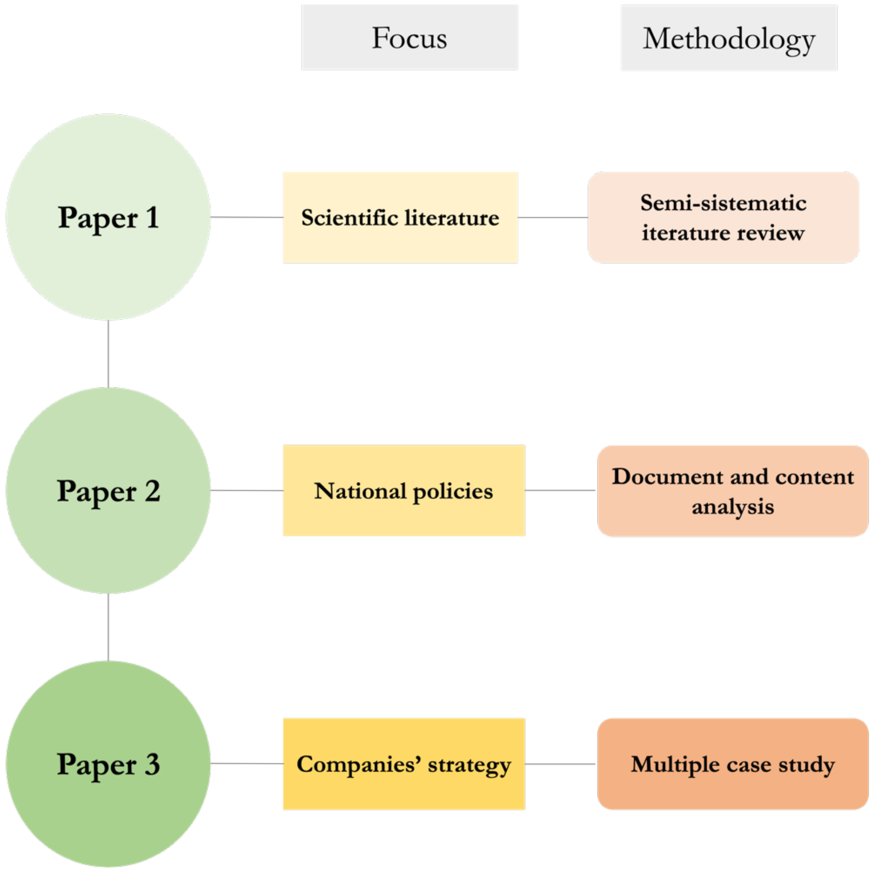
Also, referring to the contemporary context defined by the advent of the Fourth Industrial Revolution (4IR), the innovativeness of businesses assumes an important function. The term Fourth Industrial Revolution generally refers to the construction of a holistic development perspective through digitisation not only for the economy, but for society, government and the environment (Speringer & Schnelzer, 2019). It is a framework for complete and systemic change based on a combination of technological advancements to increase productivity, sustainability and growth nationally and globally (Skobelev & Borovik, 2017). Innovation is the key to finding solutions to complex problems with multiple levels of impact. In the current panorama of financial, environmental and social crisis, companies are called to constant internal and external innovation processes to be able to compete, survive and provide solutions. These dynamics have transformed skills and ideas into the asset to invest in and into the added value to offer, contributing to the knowledge-based economy (Powell & Snellman, 2004). This set of phenomena has outlined a new path of growth and development based on knowledge and the ability to make it marketable.

Starting from that, to adequately fulfil the objectives and demands dictated by contemporary times, companies must develop intellectual capital to empower their innovation capacity and build innovation strategies based on creativity and technology. To produce innovation, indeed, it is necessary to develop intellectual capital in its multiple components: research and development, knowledge, ideas, learning capacity, competences and skills, human resources, intellectual properties, strategic relations, etc. There is no doubt that the integration and exploitation of intellectual assets enable growth for companies (Noam, 2019; Teece et al., 1997). The literature has highlighted several effects resulting from the development of these elements: R&D investments increase the innovation capacity of companies in technology, giving them competitive and positioning advantages (Verbano & Crema, 2016); the creativity and collaboration of human resources strengthen the result-oriented commitment and motivation of workers (Nonaka & Takeuchi, 2007); Intellectual Property constitutes a new economic opportunity, providing different forms of economic exploitation of innovations and technological diversification (Al-Aali & Teece, 2013; Li et al., 2018; Teece, 1996).

Innovations, once generated, must be recognized in the competitive environment, protected and economically exploited. So, among these elements, intellectual property is of particular interest as a resource with multiple characteristics. It is an intangible asset based on an idea or innovation that allows legal recognition of its originality (patents, copyright, trademarks) and contributes to building competitive advantage based on innovations (North & Kumta, 2018; Porter, 1985). IP can be exploited economically in several ways: through its application in the company, the commercialisation of its content, its sale or temporary licensing, the definition of aggressive defence or massive acquisition strategies (Grzegorczyk, 2020; Palfrey, 2011; Germeraad, 2010). Given its great potential and the economic context, it is possible to assess IP as a primary asset to enable the functioning and growth of Industry 4.0. Therefore, the influence of IP in the design and implementation of Industry 4.0 should be substantial. In summary, IP should be the central strategic resource to be developed for (a) the implementation of the model, which is necessary to accompany the process of change of companies in the adoption of 4.0 systems; (b) for the growth of business, as a generator of technological innovations aimed at internal processes and the creation of products/services; (c) for the control and protection of technological innovations and the defence of its technical competitive advantage; (d) for the economic exploitation of innovations developed by R&D work.

Embracing a theoretical resource-based approach, it is possible to consider IP as the innovation-generating resource and prime mover behind technology-based enterprises (Delgado-Verde et al., 2016; Spender & Grant, 1996). The determination of intellectual property (IP) strategy and management must be implemented and developed through a focused and integrated approach by tech-based companies committed to Industry 4.0. Considering the innovativeness of the I4.0 model and its implications for the future in the socio-industrial scenario (Beier, Ullrich, Niehoff, Reißig, & Habich, 2020; de Sousa Jabbour, Jabbour, Foropon, & Godinho Filho, 2018) and determined the importance of IPs in the contemporary economy and especially in the technology-based production system (Granstrand, 2020), intellectual property will be investigated as a core asset to be protected and exploited at the basis of strategic change and innovation processes. If considered a strategic factor for the growth of I4.0, indeed, IP requires planning of its management in terms of creation, development and protection (Agostini et al., 2017; Conley et al., 2013). This research project aims to analyze the role of intellectual property in industrial 4.0 innovation processes e its strategic value in the Industry 4.0 model policy and application.

To conclude, this research project aims to investigate the relationship between these two elements: Industry 4.0 and intellectual property. Specifically, it aims to study and to verify the role that IP plays within smart factories in I4.0. The hypothesis that IP is the central factor for innovation and development of I4.0 as a technology-developer, human-based, innovation-enabler and security-insurer will be tested. In the light of this, it is important to understand how this dimension fits into the model defined by the fourth industrial revolution and its internal dynamics in terms of strategy and implementation. The research project aims to analyse how 4.0 companies (already evolved or undergoing transformation) are approaching the process of IP management into their 4.0 innovation strategy. The effects of the strategic management of the IP on the business 4.0 will be analyzed, outlining the practices for the creation, exploitation and protection of the IP. To do so, both the terms of priority defined at national level for intellectual property and the strategies implemented by the companies already active in this field will be considered, integrating socio-political and market dynamics. The ultimate goal will be the construction of a structured model capable of assessing ‘innovation 4.0’ state of art, evaluating the application in companies on 4.0 transitioning path.



The research will consist of 3 operational phases aimed at elaborating data and evidence of empirical origin on the topic and at achieving the objectives illustrated above. The first contribution is aimed at clarifying what has been elaborated so far in the scientific literature on the relationship between I4.0 and intellectual property through a semi-systematic literature review using a PRISMA approach. The second contribution focuses on the analysis of the national strategic policies through which the economic 4.0 model was launched and addressed in the G7 countries (UK, USA, France, Canada, Italy, Germany and Japan); a document analysis and content analysis were conducted to define the main themes and pillars in the 4.0 policies and to investigate the presence and role of intellectual property in these. Finally, an original assessment model was developed to understand the degree of implementation of the 4.0 innovation system in companies; the model was tested on a sample of 30 Tuscan companies through the multiple case study methodology. In this way, the focus of investigation will be in the first paper the scientific literature, in the second paper the policy-makers' national strategies and in the third paper the strategic choices of companies. The research aims to contribute to the scientific literature by deepening the issues related to: the innovation approach in Industry 4.0 and the role of IP in innovation strategies in the industrial context of I4.0. Based on the results and conclusions of the investigations carried out, the project aims to produce as final output an assessment model to measure the grade of innovation 4.0 achieved by enterprises. The usefulness of the research project is not limited to contributing to scientific knowledge and studies on the topic, but also aims to provide new insights and suggestions for practitioners.

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2 Paper 1 - The emerging connection between Industry 4.0 and Intellectual Property. A literature review

2.1 Abstract

In the scenario of the Fourth Industrial Revolution, technology and knowledge assume a strategic value. Intellectual property, as an intangible asset, is an indispensable resource in the knwoledge economy. Intellectual property enables both the protection and, at the same time, the economic exploitation of competitive advantage on an innovative basis. This research investigates the relation between the Industry 4.0 model and intellectual property within the scientific literature. The aim is to investigate which trend topics and study elements have been investigated in the academic literature about this relation. Using a semi-systematic literature review with a PRISMA approach, the study provides an overview of what has been stated by scholars to this day. In addition to a descriptive analysis of the body of literature, a cross-sectional matrix of interpretation is offered to summarise the review. By intersecting the study perspectives (Management, Context and Stretegy) and the three primary thematic elements of the relation (Trigger factors; Characteristics & dynamics; Effects & impacts), a guide is offered to identify themes and gaps in the literature on the relation between Industry 4.0 and IP.

2.2 Introduction

The expression fourth industrial revolution (4IR) refers to a new era based on the coexistence and collaboration of the physical world with its digital parallel, with far-reaching industrial, economic, and social impacts (Agrawal, Gans & Goldfarb, 2019; Schwab, 2017; World Economic Forum, 2016). In this context, the industrial model called Industry 4.0 (I4.0) has emerged, often with equivalent value of 4IR. Initially launched by a German government initiative (Kagermann et al., 2013), I4.0 has spread internationally by proposing a cyber-physical industrial system digitally interconnected internally and externally to the reality of the single firm: the fusion of advanced technologies (IoT, AI, additive manufacturing, etc.) and their interaction, enabling the creation of an "outher-than-human" intelligence that redistributes knowledge and optimizes choices (Benassi, Grinza & Rentocchini, 2020; Arthur, 2017; Gerbert et al., 2015).

The breadth of these changes has triggered a new kind of relationship between people and machines in the business context: technology has become an active agent, leading to a reduction in human dicision-making activities. The innovative relationship, now being established between people and technology, is changing organizational structure, work characteristics, corporate culture and value creation processes. The ability to innovate and produce technology turns out to be crucial for competing in the 4.0 environment (Frank et al., 2019), in fact, in order to develop and introduce innovations, it is necessary for the company to employ and exploit its knowledge (tacit and explicit) to produce new solutions and protect its competitive advantage; a company's intangible assets determine its ability to innovate and a large part of its value (Li et al., 2021).

Based on this, intellectual capital (IC) should take a central role in 4IR and would be a key element to be strengthened in adopting the I4.0 model (Mahmood & Mubarik, 2020). Under a resource-based perspective (Wernerfelt, 1984; Penrose, 1959), intangible assets determine an indispensable resource for creating, absorbing, producing, and exploiting innovations confirming the dynamics of the knowledge economy (Bogoviz, 2019). More concretely, intellectual property (IP), a measurable and marketable form of CI, is configured as a resource by the means of which firms manage, capitalize, and most importantly protect their innovations and consequently their competitive advantage and innovative activities (Wu, 2020; Chih-Yi & Bou-Wen, 2021). Although greater use of intellectual property tools has been noted with the advent of 4IR (Benassi, Grinza & Rentocchini, 2020), this strategic area still needs to be developed more by firms that have adopted the 4.0 model (Wankhede & Vinodh, 2022).

In this regard, the objective of this research paper is to produce a report of the recent scientific literature on the relationship between I4.0 and IP, in order to understand the evolution of studies on the topic and the level of in-depth study achieved of the dynamics and effects of this emerging connection. Based on previous research, although not constituting a gap in the literature, there is still no publication regarding a literature review on the topic. Consequently, it was decided to conduct this review to address an arising interest in both academic and industrial application contexts. The study has a double value: on the one side, it is intended to offer both a new perspective to scholars, deepening the analysis on dynamics and processes that may stimulate further investigation and providing guidance for research in this field; on the other side, the present paper may offer spits to managers and entrepreneurs for positive practices related to strategic choices and business processes to be triggered.

The paper is structured into 4 parts: the next section discusses the methodology adopted, why it was chosen, and the setting of the study; section 2 provides an extensive descriptive analysis of the body of literature and its main features; the third section contains a discussion of the review, sorted according to the themes emerging from the review of the content of the papers, which is followed by a systematization of the state of the art on the topic; and the fourth and final section sets out the conclusions of the paper, highlighting its primary contributions and limitations.

2.3 Methodology

2.3.1 *Setting and objectives of the review*

This section will explain the review methodology adopted: the methods, choices and process undertaken to compile the review of the scientific literature. Given the breadth and originality of the topics covered, the review methodology was chosen in a manner consistent with and appropriate to the topic of interest, the complexity of the topic, and its status as new to the academic debate. According to Synder (2019), the review method defined as semi-systematic was used. This approach differs from the classical systematic literature review by allowing the researcher to have an "overview research" produced by keeping track of the evolution of the academic discussion on the topic hinging on a "broader" research question. This methodology is adopted when there are topics covered by different disciplines with differing perspectives, which would make it difficult to apply the systematic review protocol (Synder, 2019). With a qualitative-quantitative approach, the researcher is called upon to define a development protocol for the review that is transparent and traceable and, at the same time, congenial to the type of material covered. In the present case, appropriately coordinating the time and resources available to the researcher, it was chosen to use semi-systematic literature review to map the field of inquiry, the state of the art in terms of research on the topic and identify recurring themes. It was chosen to deepen the review using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) method to organize and classify the contributions identified through the literature review (Liberati et al., 2009). This method-already used in analyses on Theme 4.0 (Rahman et al., 2022)-is set up to provide transparent, evidence-based results of the scientific literature review process.

The following section consist in the process of searching and selecting papers for the analysis of scientific contributions, with the aim of providing assurance regarding the rigor and reliability of the study and making it, eventually, repeatable (Yin, 2009). According to what the literature dictates (Massaro, Dumay, & Guthrie, 2016), starting with the research question, it is necessary to describe the steps of this process, detailing the choices made by the researcher. In the present case, the analysis was structured in 5 steps: 1) definition of the research object; 2) selection of scientific contributions on electronic database through the use of keywords, filters, and analysis of abstracts; 3) classification of scientific contributions; 4) analysis of papers; and 5) identification of issues and discussion.

In accordance with what has been explained above about the purpose of the study and the emerging and growing importance of the topic, it was chosen to formulate a research question that would be as inclusive as possible and would enable delineation of what has been concluded so far from the scientific literature, trends and the presence of any gaps and future developments. Consistent with this, three specific research questions were developed:

RQ a. How has the scientific literature developed up to now regarding the relationship between intellectual property and Industrial Model 4.0?

RQ b. What have been the main research trends and aspects most widely explored in the literature regarding the relationship between intellectual property and I4.0?

RQ c. What aspects should still be developed in the scientific literature regarding the relationship between intellectual property and I4.0, and in what direction might research on the topic turn in the future?

Combined, the three research questions aim to define the characteristics of the relationship between Industry 4.0 and intellectual property in terms of historical evolution (a), main issues explored in the subject (b), and gaps and future developments in the literature on the topic (c). By framing three dimensions (temporal, content and future developments), the answers to the research questions can provide a valuable contribution to the advancement of the state of scientific knowledge and a starting point for the next steps of scholars interested in the topic.

2.3.2 *The PRISMA method: criteria and screening*

After defining the objectives and research questions, the PRISMA method was applied for greater clarity and transparency of the process (Vimal et al., 2022; Rahman et al., 2022). The first step is the identification of the first macro-group of scientific contributions. To search for articles, a query was formulated to be entered within the databases' search engines including keywords and Boolean operators. Two groups of keywords were selected: the first related to Industry 4.0 and the second to intellectual property. In the first group, the terms Industr* 4.0, I4.0, fourth industrial revolution and 4IR were included; while in the second group, the words related to organizational and managerial terms affecting intellectual property in different business perspectives using the keywords: intellectual propert*, IP, patent*, R&D, "intangible asset(s)," "innovation capital," "structural capital" and "intellectual capital". Besides intellectual propert* and its abbreviation IP, the next three words are closely related to the theme: patents are the main product of intellectual property, central to the development of technologies for I4. 0; R&D is the abbreviation for the research & development department of companies engaged in innovative activities, designated to the production of intellectual property; intangibles asset is another common term by which intellectual property, among other things, is also referred to (Nichita, 2019; Vidrascu, 2013; Wyatt, 2008), as defined in the WICI (World Intellectual Capital Initiative) Intangibles Reporting Framework of September 2016 are non-material resources that, alone or in combination with other resources, can produce a positive or negative effect on the organization's value in the short, medium and long term.

For the other three terms in the group of clear words related to IP, the perspective of intellectual capital (Petty & Guthrie, 2000; Sveiby, 1997) - "knowledge that can be converted into profit" (Sullivan, 2000) - proposed by Ferenhof, Durst, Bialecki and Selig (2015) was adopted (Figure 1). Despite the constant enrichment of scientific debate, the proposed model is the most comprehensive on the topic of intellectual capital. According to that model, it consists of human capital (Bontis, 2002), relational capital (Roos et al., 2001) relating to the firm's relationships with customers, suppliers, and key stakeholders, social capital (Still et al., 2013) related to relationships with society, and structural capital (Marr, 2005) consisting of the organization's infrastructure and processes that enable human capital to cooperate and produce (Edvinsson & Malone, 1997; Choo & Bontis, 2002). In the adopted model, structural capital is divided into: organizational capital, capabilities, patterns and routines of the firm (Sonnier, 2008); technological capital, activities and functions of the technical and operational system (Sánchez-Cañizares et al., 2007); process capital, strategic processes and forms of cooperation (Marr et al, 2004); and finally, innovation capital referring to explicit organizational knowledge residing in intellectual property, business design, business process techniques, patents, copyrights, and trade secrets that enables organizations to build competitive advantage (Hsu & Mykytyn Jr., 2006). Based on this analytical approach to corporate intellectual capital, the keywords *innovation capital*, *structural capital*, and *intellectual capital* were included in a bottom-up approach.

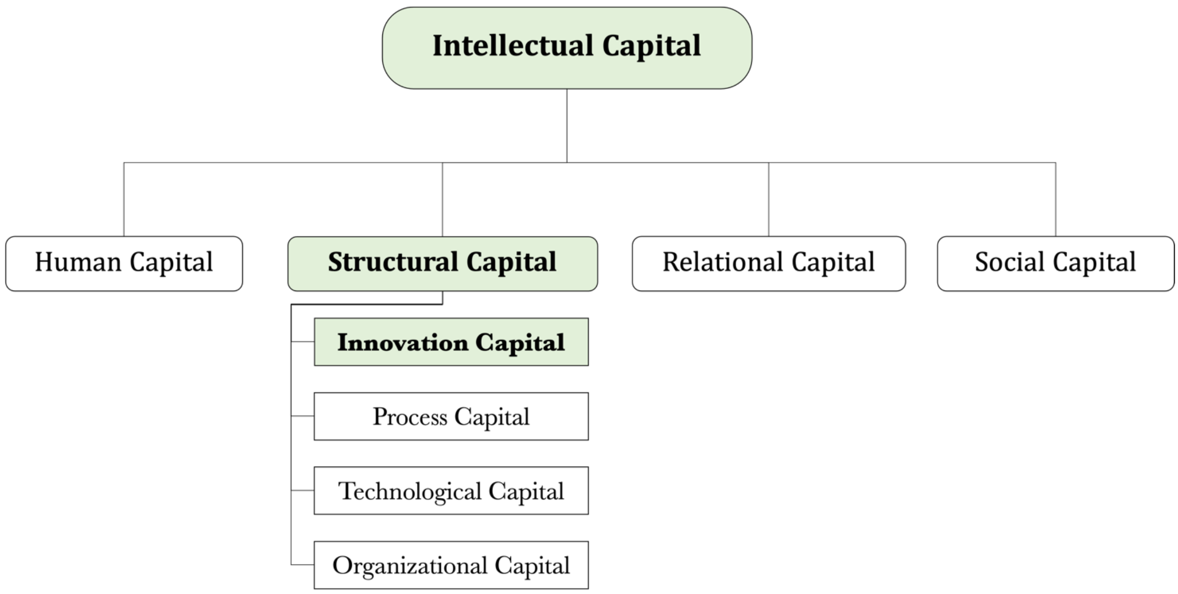

Figure 1 - Reconstruction of the model proposed by Ferenhof et al. (2015) used for choosing keywords included in the query for Scopus.

The combination of these keywords enabled the genesis of a query to identify as many scientific contributions as possible regarding the relationship between the industrial 4.0 model and intellectual property issues:

("Industr 4.0" OR "fourth industrial revolution" OR i4.0) AND ("intellectual propert*" OR ip OR patent* OR "intellectual asset*" OR r&d OR "innovation capital" OR "structural capital" OR "intellectual capital")*

It was chosen the electronic database Scopus, a citation database of the publisher Elsevier, which is periodically updated and includes journal articles, books, and conference proceedings, offering the possibility of consulting contributions that have undergone the peer review process in the scientific, technological, medical, and social fields. The choice of search tool fell on Scopus following the evaluation of other databases: Google Scholar and Web of Science were discarded as they returned fewer results available to the selected queries and always included the result set proposed by Scopus.

The first entry of the query into the Scopus database in the categories of Title, Abstract, and Author's keywords generated a total of 343 scientific contributions. So, four filters were included for further selection of results (Synder, 2019): 1) the search was limited to the time period between 2011 and February 2021, 2011 was chosen as the *post quem* date as the year of the first formulation of the Industrie 4.0 model in Germany; 2) only contributions relevant to the subject areas of business and economics were chosen, excluding those pertaining to other subjects of study (e.g. engineering, computer science); 3) only contributions written in English were chosen because of their implied greater dissemination and in view of the economic and time resources available for review that would not have allowed translation of articles into other languages. Also, papers present more than once were excluded. The implementation of this process returned a total of 129 articles.

Following the insertion of selectable filters directly within the database, further selection was carried out: as a qualitative criterion, only papers published by journals included in the ABS ranking list (2021) were chosen. At the end of this first selection stage, 47 scientific contributions were found to be consistent with the chosen criteria. As the second stage of filtering the results, a final assessment phase of the literature corpus was conducted: an analysis of the abstracts and contents of the literature contributions was carried out to check their actual relevance to the topic of investigation. Following this stage, a total of 21 articles were confirmed as the object of analysis.

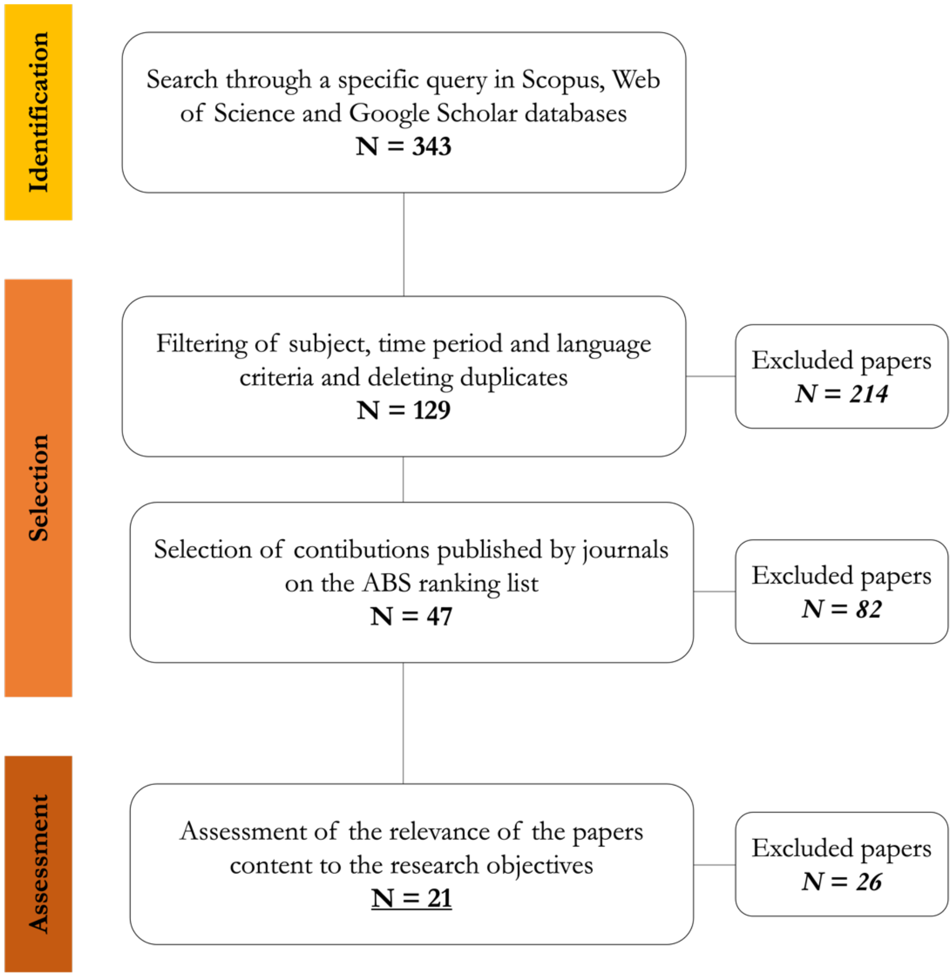

Figure 2 - PRISMA method used in the analysis

2.4 Descriptive analysis

In this section, an initial descriptive analysis of the 21 papers selected on the basis of specific criteria is proposed: the trend of publications over time, the journal to which they belong and the methodology used, bibliometric analysis, geographic origin, and the economic sector examined. The elaboration of these initial analytical results contributes to answering the first research question (RQ a) by reconstructing how the scholarly literature has developed over time and with what approach.

2.4.1 *Trend of publications over time*

The scholarly contributions under analysis were all published in the three-year period from 2019 to 2021, showing the recent and growing interest in the topic among academics (Figure 2). Considering that the present analysis takes place in the summer of 2021, it is indeed imaginable that more articles will be published before the end of the year.

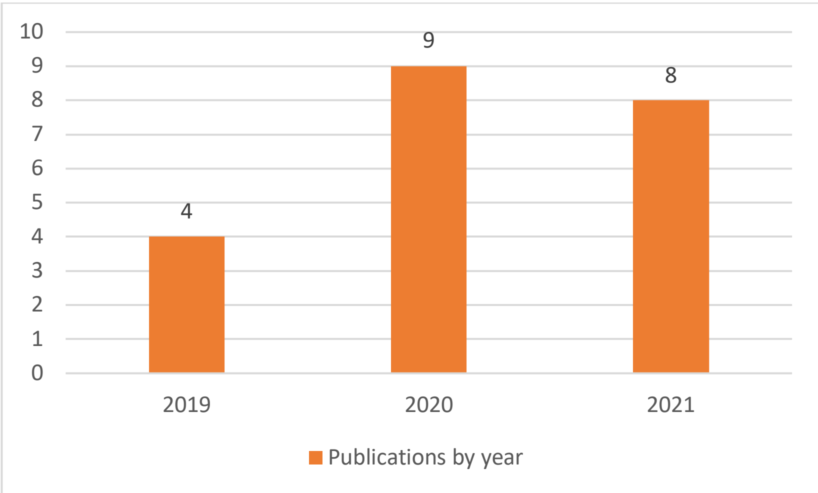

Figure 3 - Number of articles by publication year

2.4.2 *Source Journals*

Having imposed as a criterion the selection of only submissions from the list of journals in the ABS ranking (2021), all journals ensure an adequate level of objectivity and quality and a peer reviewed scientific approach. As visible in Table 1, of the 24 journals resulting from the setting of this selection criterion only 10 remained included in the literature review with a selection rate of 45%. According to ABS classification, the subject areas of the 10 journals are quite heterogeneous and refer to: Economics, Econometrics and Statistics (5, 14, 21), Innovation (20, 22), International Business (4), Operations and Technology Management (11), Sector Studies (12) General Management, Ethics, Gender and Social Responsibility (15) and Strategy (23). From this, it is possible to get a first idea of how wide a range of disciplinary approaches the topic has been approached from and, therefore, by how many academics it is perceived to be of interest for the development of scientific research.

N°	Journal name	ABS ranking	Present contributions	Selected contributions	Selection rate
1	Annals of Regional Science	2*	1	0	0%
2	Benchmarking: An international journal	1*	1	0	0%
3	Business Process Management Journal	2*	1	0	0%
4	**Competitiveness Review**	1*	1	1	100%
5	**Economics of Innovation and New Technology**	2*	1	1	100%
6	Economies	1*	1	0	0%
7	Foresight	1*	1	0	0%
8	IEEE Transactions on Engineering Management	3*	1	0	0%
9	International Journal of Productivity and Performance Management	1*	1	0	0%
10	International Journal of Social Economics	1*	1	0	0%
11	**International Journal of Technology Management**	2*	2	1	50%
12	**Journal of Cleaner Production**	2*	2	2	100%
13	Journal of Economic Policy Reform	1*	1	0	0%
14	**Journal of Industrial and Business Economics**	1*	1	1	100%
15	**Journal of Intellectual Capital**	2*	5	1	20%
16	Journal of Knowledge Management	2*	1	0	0%
17	Journal of Manufacturing Technology Management	1*	1	0	0%
18	Journal of Quality in Maintenance Engineering	1*	1	0	0%
19	Management Research Review	1*	1	0	0%
20	**R and D Management**	3*	1	1	100%
21	**Resources Policy**	2*	1	1	100%
22	**Technological Forecasting and Social Change**	3*	16	11	69%
23	**Technology Analysis and Strategic Management**	2*	3	1	33%
24	Journal of Legal Studies	3*	1	0	0%
Totale			**47**	**21**	**45%**

Table 1 - Selection of academic journals included in ABS ranking 2021 lists

2.4.3 *Bibliometric analysis*

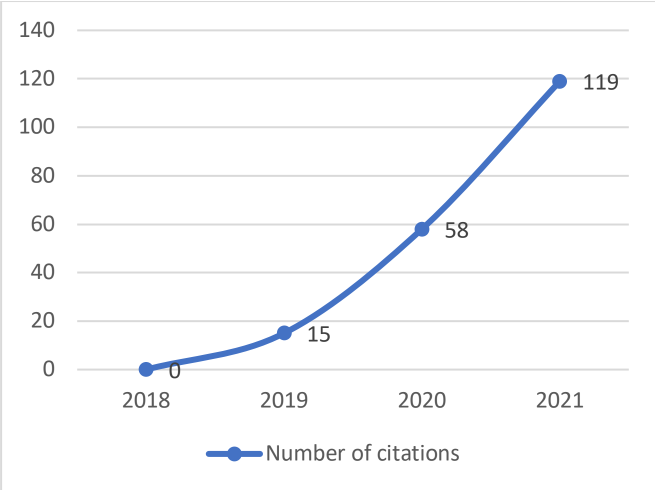

Figure 4 - Trend in number of paper citations over time

These are the 185 academic articles citing the 21 papers under analysis, which count (as of August 2021) a total of 192 citations. With an upward trend over time (as visible in Figure 3), the articles have stood out in a short time since their publication. In Table 2, the 10 most cited articles overall among the 21 selected are shown.

N°	Authors	Title	Year	Total
1	**Szalavetz A.**	Industry 4.0 and capability development in manufacturing subsidiaries	2019	**46**
2	**Tumelero C., Sbragia R., Evans S.**	Cooperation in R & D and eco-innovations: The role in companies' socioeconomic performance	2019	**29**
3	**Muscio A., Ciffolilli A.**	What drives the capacity to integrate Industry 4.0 technologies? Evidence from European R&D projects	2020	**22**
4	**Kahle J.H., Marcon É., Ghezzi A., Frank A.G.**	Smart Products value creation in SMEs innovation ecosystems	2020	**18**
5	**Mahmood T., Mubarik M.S.**	Balancing innovation and exploitation in the fourth industrial revolution: Role of intellectual capital and technology absorptive capacity	2020	**16**
6	**Wang K.-H., Umar M., Akram R., Caglar E.**	Is technological innovation making world "Greener"? An evidence from changing growth story of China	2021	**15**
7	**Rocha C.F., Mamédio D.F., Quandt C.O.**	Startups and the innovation ecosystem in Industry 4.0	2019	**12**

8	**Kim K., Jung S., Hwang J.**	Technology convergence capability and firm innovation in the manufacturing sector: an approach based on patent network analysis	2019	**10**
9	**Hu G.-G.**	Is knowledge spillover from human capital investment a catalyst for technological innovation? The curious case of fourth industrial revolution in BRICS economies	2021	**8**
10	**Li X., Nosheen S., Haq N.U., Gao X.**	Value creation during fourth industrial revolution: Use of intellectual capital by most innovative companies of the world	2021	**5**

Table 2 – The 10 articles with the most citations

Using the VosViewer software, a focus study was also conducted on the content of the abstracts and the trend of the most frequent terms within them over the three-year period. By setting as a word selection criterion a frequency of at least 4 times in total, the software returned the bibliographic network visible in Figure 4. The most frequent terms during 2019 focus on technical terms inherent to the product and business shape such as *start-up*, company, *smart produc*t, and AMT (i.e., *advanced manufacturing technology*); with the transition to 2020, the category to which the most frequent terms belong refers to the tools of IP-related 4.0 transformation such as *innovation*, *technology*, *study*, *r&d*, *development, and research*. Lastly, in 2021, impacts and effects seem to be more present with terms such as: *cluster*, *relationship*, *human capital*, *technological innovation*, *green growth* and *financial risk*.

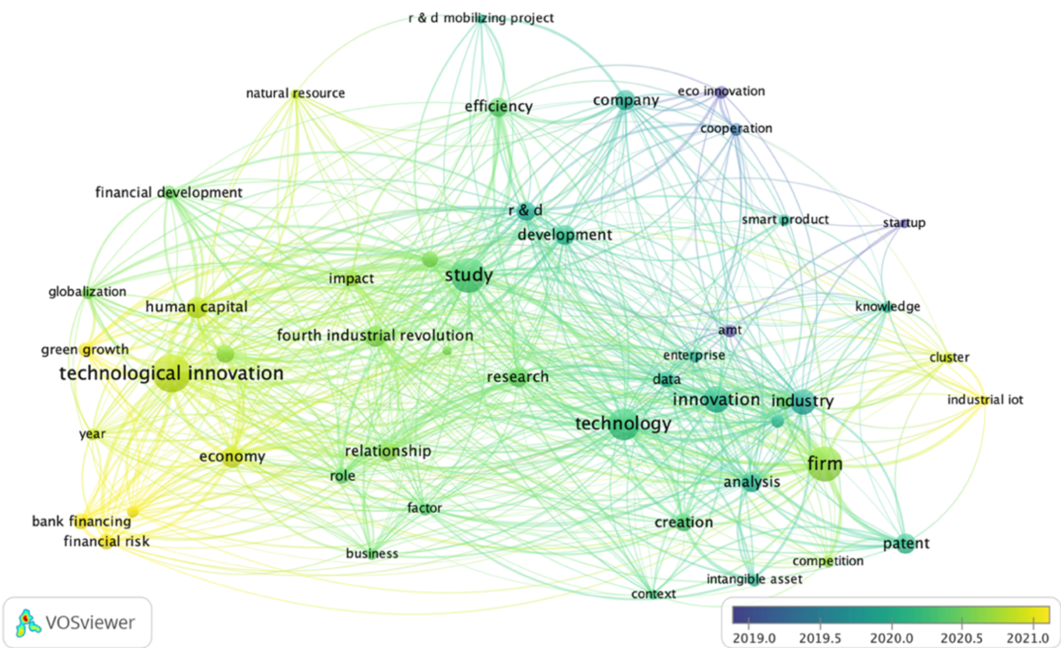

Figure 5 - Bibliographic network of the most frequent terms in abstracts

2.4.4 *Geographical setting*

Of the 21 articles analyzed, not all of them conducted studies exploring the reality of specific geographical areas: 4 papers did not refer to any particular nation or region. In the remaining 17, two groups can be identified: to the first belong the studies that chose specific international groups as their geographic target and to the second the studies that focused on a single nation. The first group has a total of 5 studies of which 2 are dedicated to the G7 (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States of America), one to the European Union, one to the E7 countries ('Emerging 7': China, India, Brazil, Mexico, Russia, Indonesia and Turkey) and one to the BRICS (Brazil, Russia, India, China and South Africa). The second group sees a majority of contributions dedicated to China and Brazil (3 each) and then a single study for Germany, Pakistan, Portugal, Spain, Hungary and the US. Figure 5 shows a map of the distribution of studies highlighting the areas most focused on by researchers. The map returns the interest in China and Brazil in particular, which, with 5 studies each, are the areas of greatest interest to academics regarding the topic of reference, followed by Germany (4 articles), France, Italy and the USA (3 contributions each).

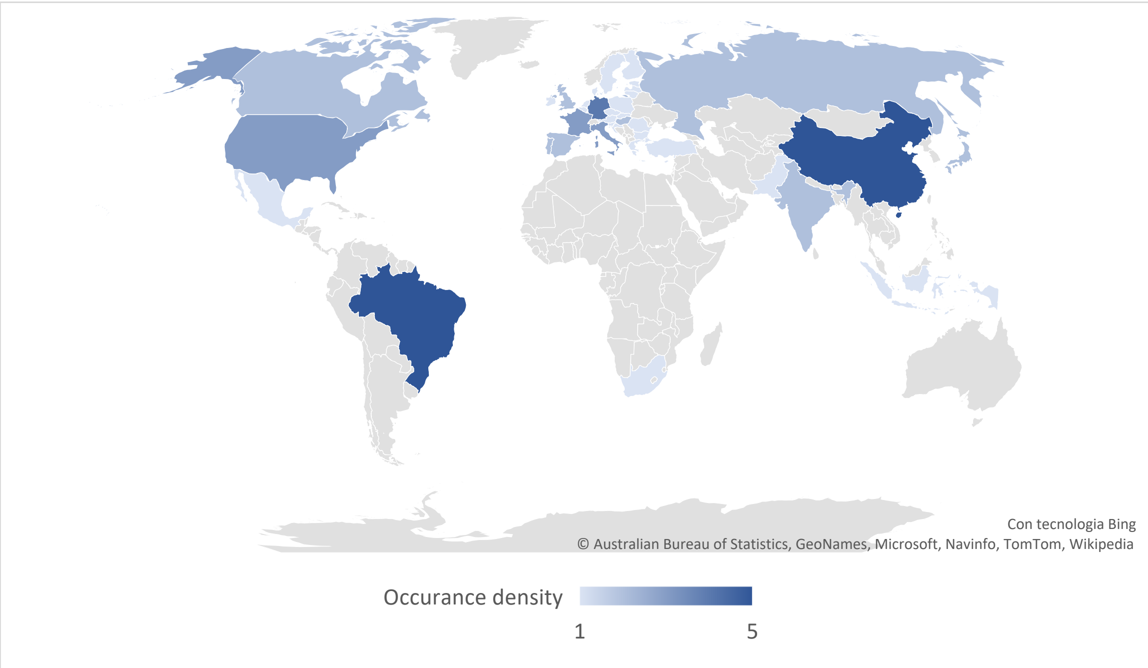

Figure 6 - Countries investigated in selected articles

2.4.5 *Economic sectors*

Although most of the selected papers do not claim to focus on any specific economic sector, 5 papers explicitly refer to one or more sectors (Figure 6). Specifically, 3 papers selected a single sector on which to focus their analysis: "Electrical and Electronic," "Communication industry," and "Ornamental stone." The remaining two papers, on the other hand, take a cross-industry approach by focusing on more than one sector simultaneously ("Electro-electronic and automation industrial" and "Semiconductor, automotive, telecommunication and broadcasting, medical device"). With the exception of the stone-processing sector (da Silva & Almeida, 2020), sectors related to electronics, communication, automation, and biotechnology make extensive use of intellectual property to protect and manage their innovations while simultaneously being more likely to adopt large-scale advanced technologies that enable more efficient and effective production (Zarzewska-Bielawska, 2012; Bongomin et al., 2020).

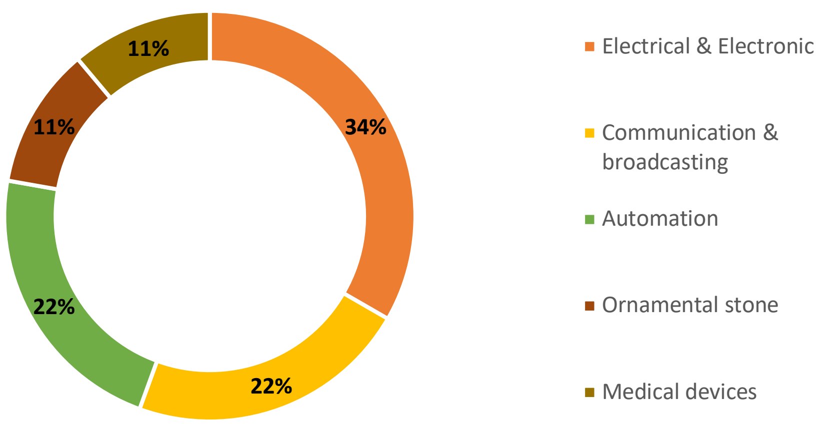

Figure 7 - Composition of economic sectors analyzed in selected articles

2.5 Discussion

To meet the challenges thrown up by the fourth industrial revolution, it is necessary for companies globally to engage in developing and enhancing their intangible and creative resources. The well-known ability of these types of resources to create shared value and positively influence financial and non-financial performance (Cheng et al., 2010) becomes even more critical in an era of constant technological change. Businesses of all sizes must develop innovative processes and products to achieve impacts on productivity while staying on track with technological advancements (Li et al., 2021). So, the connection between the need for continuous innovation and intellectual capital is strong: intellectual capital encompasses all the components necessary to ensure the maintenance and development of a firm's creativity (human capital, organizational structure, external relations). If, in the 4IR, the technological component of innovation is the central resource with which companies impose themselves on the market (Chih-Yi & Bou-Wen, 2021), it is normal that a need to affirm, protect, and exploit creativity is embodied in an increasing tendency to "patent" and use intellectual property tools from the early 2000s to the present (Benassi, Grinza & Rentocchini, 2020).

Within this framework, the discussion develops what has emerged from the analysis of selected papers from the literature review on the relationship between I4.0 and IP, divided into three sections: trigger factors, the triggers of this relationship and their activation; characteristics and dynamics, issues identified in the structure of the connection between the two elements; and effects and impacts, the consequences of the establishment of this relationship.

2.5.1 *Trigger factors*

- **Fueling R&D and growing HR**

At the root of any intangible resource and business innovation, it is imperative to consider R&D as central: whether it is more or less structured, it allows companies to recombine knowledge and spend time on developing new solutions (Engelen & Brettel, 2012). Therefore, it is not surprising that investment in **R&D** is one of the first elements identified in the literature review as essential for the implementation of the I4.0 model. The spending devoted to R&D has a great impact on technological innovation, as it is vital for the creation of new products and the competitiveness of enterprises (Yuan et al., 2021). According to several studies (Wang et al., 2020; Gu, 2021; Wang et al., 2021), a relevant and strategic investment in R&D is correlated with a higher chance of knowledge absorption and production of technological innovations. Since innovation depends on R&D (Wang et al., 2021), investment in this direction needs to occur at both the firm and national levels (He et al., 2021). Some scholars (Gu, 2021; Wang et al., 2020), in fact, identify the success and growth of innovation-based countries (primarily those in the G7) within the 4IR landscape as a consequence of continous investment in R&D. Other studies confirm this result by pointing to it as an indispensable factor for growth and performance improvement in different geographical contexts: E7 (Emerging 7 in Gu, 2021), BRICS (Hu, 2021) and China (Wang et al., 2021). According to Díaz-Chao, Ficapal-Cusí & Torrent-Sellens (2021), R&D activity, properly framed in a business model developed from a 4.0 perspective, is one of the elements that can enable companies to achieve better results in terms of sales, exports, productivity and EBITDA. Szalavetz (2019) suggests an additional dimension: not only, as seen, the investment in the department in charge of producing innovations enables the application and development of I4.0, but the introduction of 4.0 technologies in the company has in turn stimulated an increase in R&D activities to ensure appropriate management of maintenance, processing and resolution of new emerging technological problems.

In a digital economy, with the automation of many activities and tasks previously performed by employees, **human capital** must focus its specialization on the most creative and innovative tasks: the production of intangible assets and the sphere of R&D become the area of primary and exclusive human competence (Lobova et al., 2020). According to Szalavetz (2019), 4.0 technologies have freed human resources from time-consuming activities, allowing them to devote themselves to creative and value-adding ones, in which machines are relegated to a subsidiary role aimed at expanding their efficiency and pace of work (Lobova et al., 2020). In order to best establish this partition, companies must engage in the systematic development of human capital so that it is prepared and able to absorb the new knowledge required for the adoption of system 4.0 (Hu, 2021). Increasing the hard and soft skills of staff defines the starting point for creating an environment favorable to technological innovation (Gu, 2021; Wang et al., 2021). In fact, a targeted training plan makes it possible to enhance absorptive capacity (Cohen & Levinthal, 1989), that is the organization's ability to acquire, assimilate, transform, and profitably exploit information and knowledge (Zahra & George, 2002), to make human resources capable of profitably incorporating new knowledge for technological innovation (Hu, 2021; Wang et al., 2020). Some authors (Gu, 2021; Wang et al., 2021; Díaz-Chao, Ficapal-Cusí & Torrent-Sellens, 2021) have emphasized the complementary relationship between technological innovation in enterprises and human capital. Indeed HR, made more aware and competent through training, constitutes one of the indispensable determinants to produce innovation and compete in the 4.0 landscape.

- **Industrial policies and financial injection**

Another of the trigger factors in the emerging relationship between IP and I4.0 is the presence of targeted policies for investment in innovation. These, in fact, whether promoted by government agencies, chambers of commerce, or industry federations, guide national strategies and direct firms in their choices and investments. Benassi, Grinza, and Rentocchini (2020) showed that the greatest tendency to patent for I4.0 depends on strategic decisions made at the national level through **policies**. Policies guide firms by helping them improve their performance and become more innovative through guidance in terms of investment, management, and IP exploitation for 4IR (Wang et al., 2020). According to other scholars (Li et al., 2021; Muscio & Ciffolilli, 2020), economic policies make it possible to overcome the uncertainty of technological and organizational change such as that generated by the introduction of the new I4.0 model; they also promote learning, knowledge sharing, and cooperation, positively impacting both the intensity of business relationships and the ability to integrate innovative 4.0 technologies.

In order to generate innovation, the risks associated with it must be properly considered and managed. The **financial and banking sector**, the usual subsidizer of economic resources for firms, is not always well prepared to invest in R&D activities that could generate low economic returns or produce innovations useless to the market (Yuan et al., 2021). Financial risk should be curbed as it is one of the primary impediments to technological innovation: by disincentivizing banks from financing firms that are not certain of being able to repay their debts, risk alters the positive relationship between financing and technological innovation (He et al., 2021). The financial and banking sector is a vital factor in the creation of new products and the competitiveness of firms that facilitate their growth (Yuan et al., 2021; Gu et al., 2021). Some studies (He et al., 2021; Hu, 2021) have shown how external capital injections play a key role in promoting and accelerating the process of innovation and invention, especially in China and the BRICS countries. According to recent evidence, the international financial system and FDI (foreign direct investment) do not just provide capital, but are also able to positively influence enterprises by strategically allocating resources. They can transfer them from less productive sectors to more efficient and high-growth sectors in the 4.0 landscape, leading to the diffusion of knowledge and contamination as an additional externality (Gu et al., 2021; Hu, 2021; Wang et al., 2020).

- **Cooperation & international connections**

Relational capital is positively significant for enterprise value creation (Li et al., 2021), it is consistent with this that **international business relationships**, which foster knowledge exchange and technological contamination have been found to be an activating factor in the connection between IP and I4.0 in the scientific literature. Wang, Luo, Sari and Shao (2020) gave evidence of how, through globalized trade in goods and services, countries have been able to come in contact and influence each other in the development of technology. A more open trade structure and greater cooperation among firms underlies the processes that lead to increased innovation, in part because of the growth of international knowledge spillovers - "*investments in knowledge creation by one party produce external benefits by facilitating innovation by other parties*" (Jaffe, Trajtenberg & Fogarty, 2000) - which allow increasing absorptive capacity and stimulate greater patent activity (Grossman & Helpman, 1991; Aghion & Jaravel, 2015). Knowledge spillovers, closely related to FDI, pour information and knowledge into the territories linked, resulting a boost in R&D activities and human capital development of firms, which strengthen their capacity for technological innovation (Hu, 2021).

Cooperation between actors active in different geographic areas, with different specializations or degrees of development, allows a mutual contamination that promotes interdisciplinary research activity: in this way, it is possible to develop innovative 4.0 technologies based on diversity and contamination of knowledge, needs and solutions (Muscio & Ciffolilli, 2020). According to Tumelero, Sbragia, and Evans (2019), by disseminating more awareness, cooperation with different actors (similar companies, suppliers, stakeholders, research institutions, and even consumers) in R&D activities, fosters the creation and introduction of sustainable 4.0 innovations over time, in a perspective both technological (process and product) and organizational. Especially, cooperation in the R&D phase has a positive impact both in terms of image and efficiency, helping companies evolve in terms of innovation and sustainability in the process of adapting to the 4.0 model (da Silva & Almeida, 2020). This strategy proves invaluable especially for SMEs that do not possess all the resources and skills to produce 4.0 products or services: creating an innovation ecosystem in which players have complementary technological capabilities to each other enables them to develop the appropriate products for 4IR. Industry clusters designed in this way allow companies to share risks and costs by cooperating in order to stay updated and build opportunities according to market transformations (Kahle et al., 2020). Attention should also be paid to the size of collaborative clusters in the effect produced by AMTs on the IP output of firms. As an activating factor in the relationship between I4.0 and IP, a smaller cluster with more external connections manages AMTs more dynamically and positively mediates the effect of innovative technologies on the production of radical innovations, while a larger cluster has a positive effect on the relationship between AMTs and incremental innovations (Grashof et al., 2020). Different natures and sizes of clusters have different impacts on the ways and types of innovations that can be achieved, making it necessary for firms following a 4.0 innovation path to make strategic choices that are coherent with the circumstances in which they operate and their goals.

2.5.2 *Characteristics & dynamics*

- **Converging innovations**

In the evolving dynamics of the relationship between IP and I4.0, it is possible to outline general trends with which to analyze the phenomenon from a macro perspective. According to the analysis of EPO (European Patent Office) data conducted by Benassi, Grinza and Rentocchini (2020), since 1985, the number of patents filed in the European context has grown exponentially, reaching a quadrupling in 30 years, confirming the importance of IP in the context of the knowledge economy. Patents explicitly dedicated to 4IR (according to the canons defined by EPO) has seen an even larger growth increasing tenfold over the course of a decade. The geographic origin of patent applicants inherent to the fourth industrial revolution for 99 percent of applications is concentrated in 20 nations, headed by the U.S., Japan and Germany (with 27.5%, 25.1% and 13%, respectively). Intellectual property represents a unique asset that can be implemented and exploited in different areas and sectors and enriched by future knowledge. As reported by Chih-Yi and Bou-Wen (2021), a large and diversified IP 4.0 portfolio positively moderates the relationship between competitive initiative and firm performance, especially when reinforcing aggressive strategic choices; while a small and restricted portfolio limits the firm's competitive action, leading to negative effects on performance and loss of opportunities. These conclusions collide with the general trend that has seen only a few firms focus on more than one technological field, highlighting the strategy of **specialization** as the one most adopted (Benassi, Grinza & Rentocchini, 2020).

It is within this framework that technology convergence (Rosenberg, 1976) is outlined as a natural development of a system of interconnected technologies such as Industry 4.0. **Technology convergence** (TC) is the tendency for different forms of technology and innovation to intersect and converge into a common scope (Bhatt et al., 2021). This trend needs to be appropriately considered by companies operating under 4.0 because, as innovative technologies are both the core of the production process and the primary output, the company's own innovative and patenting capacity must be consciously and strategically directed. In their study, Kim, Jung, and Hwang (2019) argue that firms should strive to diversify their technologies by developing innovations different from those they already possess, riding the inevitable integration driven by TC. Tech hyperspecialization, based on the expansion of a technology strand, increases the applicability of the technologies possessed by the enterprise, but does not integrate with the development coordinates dictated by Industry 4.0 and TC.

- **Renovating and organizing**

The changes that have come from the adoption of I4.0 also require enterprises to manage the tradeoff between exploration (research and creation) and exploitation (application and capitalization) of innovation. **Organizational ambidextry** (March, 1991) consists of a firm's ability to be both able to exploit and benefit from what it has achieved, while retaining the ability to innovate and experiment by remaining flexible to internal and external changes (Durisin & Todorova, 2012). Intellectual capital plays a central role in facilitating firms to balance exploration and exploitation activities: strategic management of intellectual capital, optimized by the organization's ability to assimilate technology, enables it to build competitive advantage while simultaneously improving innovativeness and productivity (ambidexterity) (Mahmood & Mubarik, 2020).

Innovative capital is inextricably linked to the development of the 4.0 model by converting strategies, procedures and organizational structures through the digitization of processes. Intellectual property management itself is involved in this holistic digital transformation: innovative technologies have enabled the optimization and efficiency of IP-related activities and production steps. There is evidence showing that automation of processes in the creation of intangible assets for Industry 4.0 accelerates technological progress, increases the innovative activity of the business and improves its organization (Lobova et al., 2020). The use of robotics and AI have also proven to be useful in patent data processing, intellectual property registration processes, digital management of the operations area, and accelerating the testing phase of prototypes. IP management, from the testing phase to the protection phase, is part of the interconnected and digitized processes of the 4.0 universe, triggering a virtuous mechanism of interpenetration between IP and I4.0 (Lobova et al., 2020).

- **Resource or tool?**

From a strategic point of view, the literature has exposed itself on the role played by IP in 4IR. While it is possible to identify contributions that point to IP as an indispensable resource to be developed in the 4.0 scenario (Benassi, Grinza & Rentocchini, 2020; Li et al., 2021; Chih-Yi & Bou-Wen, 2021), some authors focus more on its instrumental character as a necessary element for the **protection** of competitive advantage. Wu (2020), examining the Chinese economic context, argues that the intellectual property protection system needs to be improved to respond to the dynamics of the Industry 4.0 environment. In a climate of constant technological innovation, intellectual property infringement creates serious economic, organizational and competitive damage. Enterprises must equip themselves with appropriate and effective tools to prevent a growing phenomenon in the knowledge economy: this can be achieved by defining modern IP protection models, by strengthening the knowledge and exploitation of IP-related rights, and by implementing a management strategy equipped with appropriate features to cope with the problems of the contemporary market and economy. Only through strengthening the effective protection of IP will it be possible to encourage innovation in businesses and ensure the adoption of the 4.0 model in companies (Wu, 2020).

But the IP domain is not just limited to being the *contidio sine qua non* enterprises succeed in protecting themselves and competing in the 4IR. Driving a paradigm shift in terms of innovation capability, efficient structural capital consisting of systems, databases, trademarks, and patents is a necessary resource to ensure the operation and growth of an innovation path within the 4IR scenario (Li et al., 2021). According to Chih-Yi and Bou-Wen (2021), the technological component of innovation is the central resource with which companies establish themselves in the market. Therefore, intellectual property plays the role of a **central strategic resource** underlying competitive advantage in order to compete in a 4.0 world. Companies feel the growing need to invest in IP and related activities: they resort more intensively to R&D enhancement, patenting and building an IP-based strategy (Benassi, Grinza & Rentocchini, 2020).

2.5.3 *Impacts & effects*

- **Competition and Open Innovation**

Inter-firm rivalry based on patent activity defines a new form of competitiveness in the 4.0 scenario. The rapid growth of 4IR technologies has made the patent field an important competitive arena for firms, changing known arrangements and promoting new players (Benassi, Grinza & Rentocchini, 2020). Chih -Yi and Bou-Wen's (2021) study showed that an **aggressive strategy** is profitable by ensuring greater chances of seizing business opportunities and securing the benefits. According to the authors, aggressive actions are particularly effective for companies with a diversified portfolio of tech patents, improving its value and related economic performance. Yet, a technologically highly advanced and populated environment mitigates the strength of an aggressive competitive strategy: this occurs because of a context characterized by the similarity of available resources and overlapping interests and markets (Chih-Yi & Bou-Wen, 2021). Whereas a system such as the one determined by I4.0, based on strong digitization, requires fast adaptation to the market's technological evolution.

Therefore, it is widely believed that a strategy based on **open innovation** (OI) allows for greater exploitation of the mutual relationship between I4.0 and IP, thus ensuring not only the survival but the growth of diverse actors in a complex and constantly changing economic environment. External agents, unrelated to defined internal processes and conditioned by different objectives and structures (such as start-ups or universities), are excellent sources of knowledge with which to enhance the cognitive, analytical, and relational capabilities essential for innovation 4.0 (Rocha, Mamédio, & Quandt, 2019). Lack of mutual trust, fear of knowledge loss, and difficulty in integrating systems and processes are major obstacles in realizing the goal of attracting and maintaining relationships with external firms and stakeholders over time and creating shared business opportunities; OI is able to overcome these impediments by eliminating 'project-based' cooperative dynamics and defining an integrated and structured system over time that enables all participants to remain productive and competitive in the 4.0 landscape (Kahle et al., 2020; Muscio & Ciffolilli, 2020). By acquiring inaccessible skills and obviating infrastructural limitations of impromptu collaborations, the OI strategy - both inbound and outbound - also guarantees further growth in the managerial and social elements needed to fuel innovation in the 4.0 model (Chih-Yi & Bou-Wen, 2021; Rocha, Mamédio, & Quandt, 2019).

- **Internal growth and performance improvement**

Innovation-driven business **growth** is at the heart of the 4IR concept. The creation of IP hinged on the exploitation of new knowledge makes it possible to improve and realize products or processes from scratch and is extremely beneficial for business growth. According to recent studies (Wang et al., 2020), technology innovation results in supply-side improvement, multiplying long-term results in terms of production and management efficiency. The fourth industrial revolution requires a paradigm shift in terms of operational excellence, ability to innovate products, technologies and solutions always in line with growing market expectations. Internal management is improved and positively affected on several fronts: energy efficiency (reduced consumption per product); raw material efficiency (less waste per product); evolution of soft skills (greater awareness and confidence in the future); and greater organizational effectiveness (improved corporate structure and staff working conditions) (da Silva & Almeida, 2020). To achieve an impact on productivity and business performance updated with technological advances, firms of all sizes must develop innovative processes and products. Efficient structural capital consisting of systems, databases, trademarks, and patents enables optimal **performance** and is essential to start a path of innovation within the 4IR scenario.

However, in order to exploit the potential of 4IR, it is necessary to transform the entire innovation process by working on the invested human capital that positively impacts the firm's performance through a process of efficiency (Li et al., 2021).

- **Social-economic impact and environmental sustainability**

In the context of 4IR, technological innovation is extremely positive for **national economic growth**. Western countries were the first to experience and benefit from the effects of the combination of IP and the 4.0 model, but the benefits have also been measured in other countries globally. Benassi, Grinza, and Rentocchini (2020) highlighted how applications for technology patents aimed at the 4.0 world have increased significantly in recent years and how some nations in particular are standing out in the 4IR scenario. In the international IP context, China plays a dominant role for 4IR and Canada and Taiwan are emerging, while the U.S. holds just under 30% of total patent applications (Benassi, Grinza & Rentocchini, 2020). International cooperation, knowledge spillovers and offshoring due to industrial globalization have enabled the spread of the 4.0 model around the world, concretely impacting national economies. Among the recognized leverages in the growth of BRICS economies, the development of technological innovation required to execute the models of the fourth industrial revolution plays a central role by ensuring a substantial increase in productivity (Hu, 2021). Moreover, according to Szalavetz (2019), the advent of AMTs has improved the capabilities of relocated subsidiaries, encouraging them to develop their own management skills and R&D activities. The 4.0 model has facilitated the collection of subsidiary capabilities needed to deal with the increased complexity of processing activities and new technological problems. Triggered by a new system thriving on constant updating and production of knowledge, industrial innovation, with a domino effect, determines sustainable growth in the economy of the country where it is adopted, improving living standards and balance with the environment (Wang et al., 2020).

Given the urgency of the climate issue, green growth is recognized as an issue of global importance, and the development of a more sustainable global trading system also depends on present technological innovation and upgrading of the production system. Through 4IR, research and development of new technologies has created solutions (both product and process) that repair and improve the **environmental impact** of modern economies (Wang et al., 2021). The technological innovations of I4.0 can promote efficiency while enhancing the environmental sustainability of firms, but these firms must necessarily invest in training and improving skills, resources, and organizational practices (Díaz-Chao, Ficapal-Cusí & Torrent-Sellens, 2021). As da Silva & Almeida (2020) point out, production logic 4.0 is linked to the circular economy, which involves cutting waste through renewed work organization and applying a sustainable management model that improves results and impact on the environment. The transformation promoted by I4.0 can help support sustainable growth within the industrial landscape also with reference to the goals defined by the 2030 Agenda (e.g., SDGs 12 and 13): I4.0 is an opportunity and guide in the long run due to its innovative practices and the boost caused by AMTs (Wang et al., 2021; da Silva & Almeida, 2020). Realizable through investments in R&D and HR, eco-innovations 4.0 not only make production processes more sustainable but also improve and accelerate the innovation process started with the fourth industrial revolution by positively influencing the social economic and environmental impact of firms (Wang et al., 2021; Tumelero, Sbragia, & Evans, 2019).

2.5.4 *The state of art about the connection between IP e I4.0*

From the content analysis of the selected papers, it was possible to bring out some common and cross-cutting elements in more than one contribution of the literature and build on this a content systematization that facilitates the understanding of scholars and practitioners. As explained earlier, the discussion of the review has been structured into three sections based on the subject matter of investigating the link between IP and I4.0 (4.1, 4.2, 4.3), showing which elements the scholarly literature has focused on most in studying the connection. It is possible to read those sections sequentially using the evidence they contain: the first section contains the elements needed to trigger the connection between IP and I4.0, the second the character and behavior of this relationship, and finally, the third and last what outcomes may result from it. To further explore the body of literature, the approach taken by the authors in conducting the studies was also examined. As visible Figure 7, three main perspectives were identified: management, relating to managerial and organizational aspects; context, inherent to the dynamics of the target competitive environment; and strategy, pertaining to the competitive approach to achieving goals. Most of the papers exploited an intersection between the three areas, although each contained at least one single-perspective contribution.

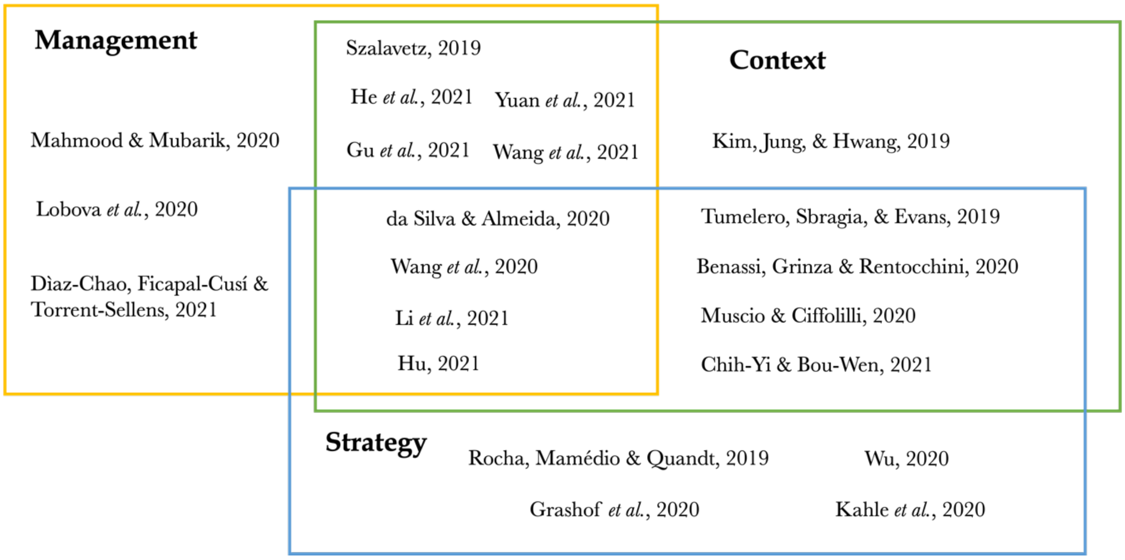

Figure 8 - Diagram of the division of authors by perspectives

By converging the two structures of analysis, thematic and perspective, it was possible to construct a matrix grid (Table 3) that systematized the findings from the literature in an organized and consistent manner. By integrating the three thematic elements and the three perspectives, a map was produced that could highlight the main findings reported in the reviewed contributions. Such a grid can provide a useful tool to orient and guide researchers in identifying points of primary research interest on this topic. This elaboration is intended as an initial contribution to the realization of a more full-bodied and three-dimensional analysis of IP and I4.0 connection.

	Trigger factors	*Characteristics & dynamics*	*Effects & impacts*
Management	**R&D investment** (Yuan et al., 2021; Wang et al., 2020; Wang et al., 2021; Gu et al., 2021; He et al., 2021; Hu, 2021; Dìaz-Chao, Ficapal-Cusí & Torrent-Sellens, 2021) **HR development** (Szalavetz, 2019; Lobova et al., 2020; Hu, 2021; Wang et al., 2021; Gu et al., 2021; Wang et al., 2020; Dìaz-Chao, Ficapal-Cusí & Torrent-Sellens, 2021)	**Digitalizing IP** (Lobova et al., 2020) **Organization ambidexterity** (Mahmood & Mubarik, 2020)	**Internal growth** (Wang et al., 2020; da Silva & Almeida, 2020) **Performance improvement** (Li et al., 2021)
Context	**Industrial policies** (Benassi, Grinza & Rentocchini, 2020; Wang et al., 2020; Li et al., 2021; Muscio & Ciffolilli, 2020) **Financial sector** (Yuan et al., 2021; He et al., 2021; Gu et al., 2021; Hu, 2021)	**Technology convergence** (Kim, Jung, & Hwang, 2019) **Portfolio diversification** (Benassi, Grinza & Rentocchini, 2020; Chih-Yi & Bou-Wen, 2021)	**Socio-economic impact** (Benassi, Grinza & Rentocchini, 2020; Hu, 2021; Szalavetz, 2019; Wang et al., 2020) **Environmental sustainability** (Wang et al., 2021; Dìaz-Chao, Ficapal-Cusí & Torrent-Sellens, 2021; da Silva & Almeida, 2020; Tumelero, Sbragia, & Evans, 2019)
Strategy	**International connections** (Li et al., 2021; Wang et al., 2020; Hu, 2021) **Cooperation** (Muscio & Ciffolilli, 2020; Tumelero, Sbragia, & Evans, 2019; da Silva & Almeida, 2020; Kahle et al., 2020; Grashof et al., 2020)	**Capitalizing** (Li et al., 2021; Chih-Yi & Bou-Wen, 2021; Benassi, Grinza & Rentocchini, 2020) **Protecting** (Benassi, Grinza & Rentocchini, 2020; Li et al., 2021; Chih-Yi & Bou-Wen, 2021; Wu, 2020)	**Aggressive strategy** (Benassi, Grinza & Rentocchini, 2020; Chih-Yi & Bou-Wen, 2021) **Open Innovation** (Rocha, Mamédio & Quandt, 2019; Kahle et al., 2020; Chih-Yi & Bou-Wen, 2021)

Table 3 - Orientation grid on themes and perspectives of the existing literature.

2.6 Conclusion

The scientific literature regarding the relationship between IP and I4.0 is still at an early stage, justified by the recent evolution of the topic and the effects and dynamics being defined. I4.0 is a recent industrial model (born in the late 2000s): its diffusion is far from homogeneous and widespread, and its adoption is still a work in progress even in companies that have chosen to engage in it early on. Studies on the 4IR phenomenon are rare and mostly focus on technical aspects of technological innovations and their application, neglecting to look at the phenomenon in a holistic way (Benassi, Grinza & Rentocchini, 2020). The total transformation imposed on businesses by the 4.0 model requires radical changes related to organization, processes, strategy and corporate culture, which are often challenging, costly and not immediate. Therefore, the in-depth study of the connection between a model that is still in the diffusion phase and IP management sins with an earliness that does not allow for a comprehensive and complete picture; this limitation is also reflected in the scientific literature that is still waiting to observe and collect data on the topic. The points of interest with which the orientation grid has been populated represent a first step in this direction and testify to the scholars' effort and interest in building a body of research on this topic.

What is undoubtedly appreciable from the literature reviewed so far are some general observations about research trends. First, many authors try to identify an optimal mix of factors to trigger and develop a two-way relationship between IP and I4.0. The literature, for the reasons stated above, focuses mostly on the a priori part of that relationship: on the research and creation phase of IP more than on that inherent to application and exploitation in the 4.0 context. Both the nature of the influences that I4.0 and IP have on each other and the assessment of the combined strategy that companies decide to adopt do not yet appear to be much explored. Although enough has already been written about the positive impact of cooperation, it is not yet possible to assess the dynamics and behavior of firms in an environment characterized by an ambivalence between cooperation and competition and the applicability of a coopetition strategy (Minà & Dagnino, 2016). Equipped with nourished data sets over a longer time frame, ruture research will have the capabilities to fill the gaps. In this way, it will be possible to enrich the literature with themes and perspectives and advance a structured framework for studying the connection between IP and I4.0, which can also be useful to practitioners.

The research presented here is not without its limitations: a literature review on such a new topic in the scientific landscape is itself limited by the small amount of scientific contributions to date; the semi-systematic review methodology, having fewer clear steps to follow, requires a process of customization by the authors according to the purpose of the project and therefore is not always endorsable (Synder, 2019; Wong et al., 2013). Nevertheless, the present study offers as a contribution an initial survey of the literature on the subject: an embryonic systematization of the areas of study and an input to produce new research on the topic that would allow for a full understanding of the IP- I4.0 connection.

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3 Paper 2 – Fourth Industrial Revolution in G7 countries: policy-driven innovation and the role of intellectual property

3.1 Abstract

The introduction of the 4.0 model in a geographical context requires structural changes at an economic, technological and social level. The Fourth Industrial Revolution is inextricably linked to the Science Technology Innovation (STI) policies through which it was first formulated and introduced. The 4.0 policies, indeed, enable to direct the strategies and actions for the implementation of a new economic model according to the macro-objectives defined by the socio-economic challenges of the present (scarcity of resources, climate emergency, demographic crisis, etc.). This paper investigates the process of introducing the new economic model through 4.0 policies, using the G7 countries as a reference sample. Using the dual methodology of content and document analysis, national 4.0 policies in the G7 countries are studied and examined in their fundamental aspects: pillars, priorities, strategies. A further in-depth study is devoted to the role of intellectual property within the above-mentioned 4.0 policies. As a strategic resource for the defence of competitive advantage on an innovative basis, intellectual property is examined under different aspects: its occurrence and the strategic role assigned to it. The study enriches the literature on the analysis of 4.0 policies through an in-depth study - so far absent - in the context of G7 countries.

3.2 Introduction

The advent of System 4.0 started a large-scale industrial revolution aimed at changing the nature and setting of manufacturing from the end of the first decade of the 21st century (Meniere et al., 2017). The industrial 4.0 model based on the full integration of ICT and enabling technologies to the manufacturing and business system has spread globally and has involved governments, businesses, institutions and researchers in a systemic change that responds to new social and economic needs (de Groot & Franses, 2009). In contrast to its predecessors, which were based on the dominance of certain innovative technologies within current production dynamics, the fourth industrial revolution stems from the will of government institutions (Schwab, 2017). Considering the history of the 4.0 model, it is relevant to note that its genesis was precisely due to a choice on the part of institutions to introduce structural change within the national context. The term "Industry 4.0" itself was introduced through an innovation policy (Borrás & Edquist, 2013) and then adopted across the board by companies, research organizations, and international consulting firms (McKinsey, 2015; BCG, 2015). A top-down dissemination that drives and coordinates a widespread and profound transformation of the business sector that responds to present-day social goals and challenges.

As defined by Kim (2018), Industry 4.0 should be regarded as a policy-induced meso industrial revolution to propel growth based on the development of science and technology. Embracing institutional theory, Reischauer (2018) formulates a new definition of the identity of the Industry 4.0 phenomenon, which he indicates as "*a policy-driven innovation discourse in manufacturing industries that aims to institutionalize innovation systems that encompass business, academia, and politics, an innovation system mode known as Triple Helix mode of innovation.*" Through a cross-social analysis, Reischauer explains that as a discourse I4.0 is configured as a communicative activity that shapes social reality through a frame of reference that enables coordination among actors with different prerogatives and interests. Thus, I4.0 does not simply propose technologies or techniques for innovation, but indicates to the different active actors (businesses, politicians, trade unions, academia, interest groups) the frame of reference through which to set up the innovation process, following the nature of each subject involved. This discourse is guided precisely through policy: policy makers have the key-role of shaping the reference frame, defining the governmental mechanisms that can make it emerge and keep it active. From this perspective, the ultimate goal of Industry 4.0 is to promote the innovation system in which business, policy, and academia participate in the mode of the Triple Helix (Leydesdorff & Etzkowitz, 1998). According to this model of innovation, the three players (business, policy, and academia) co-generate innovation on the basis of a bond based on cooperation and mutual influence, strengthening each other's capabilities and integrating projects, goals, and strategies (Etzkowitz & Leydesdorff, 2000). In this way, the main goal of Industry 4.0 is to make the Triple Helix innovation model an institution (Reischauer, 2018), that is, a permanent and integrated system of behaviors and structures that support and control the activities of the actors involved. The focus is not limited to introducing certain technologies or business models into the market by encouraging short- to medium-term strategies, but aims to make an integrated system for economic and social innovation persistent over time. The institutionalization of the

Triple Helix model through Industry 4.0 enables its legitimization among actors by encouraging its adoption and operation.

Policy-makers have an instrumental and strategic function in guiding this process and shaping a system by involving very different actors and shaping a shared and inclusive structure of the economic sector. In this scenario, it becomes crucial to understand when and how policy-makers have decided to fulfill this intent by achieving the ambitious goal of setting up and building a system of institutional innovation. It is of foremost importance to analyze and compare how the main policies of discourse 4.0 were structured, their nature, their interlocutors, and their main instances as defined by the key policy-makers. The purpose in investigating these documents is to capture common elements and differences of a model that has spread globally and is being declined in single national realities.

3.3 Science-Technology-Innovation Policy value in a socio-technical perspective

The process of policy-making makes it possible to set and determine an entity's course of action according to a certain vision or mission (OECD, 2006). The will of government entities assumes a central role in determining and imposing development choices and directions for society and the actors active in it. This approach is based on a structuralist economic view that, by placing less importance on the competitiveness of free markets and their ability to self-determine, promotes and relies on the competence and ability of governments to set and determine effective interventions in the economic field. In contrast to the neoliberal approach-which does not believe that deviations from optimality can nevertheless be effectively managed and remedied by governments-structuralists admit the fallibility of policy-makers' interventions but also support the ability of governments to efficiently improve and set up measures and instruments put in place to manage market forces that are found to be deficient or failing (Lall, 2003; Lall & Teubal, 1998).

In agreement with an approach that places trust in government entities as policy-makers, the area of intervention related to economic innovation is declined into an articulated multilevel system that unites issues related to the development of scientific knowledge and technological production. The latter underlie the cognitive and economic innovation that enables growth and the achievement of new socioeconomic horizons. Science - Technology - Innovation (STI) policies are central to directing and guiding the production system from a strategic perspective: STIs contribute to and ensure the sharing of sustainable growth objectives while simultaneously responding to political and social needs and challenges (sustainable energy, food security, climate change) (Ozkaya, Timor & Erdin, 2021). Given their key role, developed and developing countries are now focusing on establishing STI policies to increase and leverage their innovative capacity by targeting fast-growing markets (Thrope, 2007). Indeed, through science- and technology-based innovation, it is possible to work on sustainable goals based on a growing ecosystem. The complex and multidimensional nature of the system composed of actors involved in science and tech based innovation also determines the complex governance (multi-domain, multi-instrument, multi-level, multi-layer and multi actor) that requires planning and organization (Magro, Navarro & Zabala-Iturriagagoitia, 2014). In an international scientific environment characterized by strong globalization and increasing dynamics of open innovation (OI) and cross-cutting collaborations, new technologies and related knowledge are spreading rapidly, increasing the competitiveness and complexity of the global market, and the importance of STI increases accordingly (Ozkaya, Timor & Erdin, 2021). These enable countries to give order and shape to their internal dynamics and processes while remaining up-to-date and responsive in the global context.

Bernal (1939) was the first to identify government science policy as an area of strategic development: measuring R&D investment in England, he recognized the importance of national engagement in science policy, crediting it with the power to stimulate welfare and economic growth. This capacity has been the subject of several studies since then, leading researchers to define two main STI paradigms to describe the ways research and innovation are set to ensure long-term sustainable development. On the one side, transformative innovation policies are focused on major societal and environmental challenges (Weber & Rohracher, 2012; Schot & Steinmueller, 2018), and on the other side, mission-oriented innovation policies, which define a guide for frontier knowledge in order to meet specific common goals (Mazzucato, 2017).

With the advent of the 21st century and ground-breaking environmental and social changes, the role of science and technology becomes a priority in addressing the challenges of the present: transformative innovation policies enable transformative change toward a sustainable economy and society (Kuhlmann & Rip, 2018). The sustainable transition changes the role of research and innovation and assigns transformative policies to direct and organize science to help solve challenges and make the economy and society resilient and sustainable in the long run (Diercks et al., 2019; Schot & Steinmueller, 2018; Weber & Rohracher, 2012).

Differently, mission-oriented innovation policies are defined as a system of policies designated to achieve specific goals through mission-focused programs that define the allocation of resources and organization of research (Mazzucato, 2018): "*big science deployed to meet big problems*" (Ergas, 1987). These policies are aimed at creating technological responses to widespread problems categorized as medium-sized challenges. To do so, they provide direction to innovation efforts, determine collective actions, and establish funding instruments (Mazzuccato & Willetts, 2019). The ultimate goal is to push and stimulate radical innovations through the identification of strategic missions that can impact the social and productive structure of the country (Suárez & Erbes, 2021). In this case, the policy-makers' top-down approach allows them to guide and coordinate the combined actions of the different actors necessary to achieve the set goal (Mazzucato, 2018). Indeed, mission-oriented innovation policies must involve public and private actors active in different sectors and areas of society and production system, grasping the centrality of interlocking different skills and competencies. To ensure the accomplishment of this process, while directing and leading from the top, policymakers must simultaneously also encourage experimentation and a bottom-up approach to innovation that allows for a pattern based on two-way feedback (Mazzucato, 2018; Rodrik, 2004). The presence of different actors with different skills and needs is not only an opportunity for collective growth, but also results in a situation of complexity. The main obstacle to this policy approach is the difficult coordination of wills and instruments, the equitable distribution of powers, and the need to promptly manage and resolve multilevel conflicts (Arocena, 2018). To contribute to national competitiveness by responding to societal goals through the coordinated action of diverse actors, mission-oriented innovation policies aim to build an institutional framework to ensure the functioning of a national innovation system for stakeholder collaboration (Švarc & Dabić, 2021; Mazzucato, 2018). Such a systemic mode of intervention makes it possible to intervene by alleviating the problems and difficulties of structures dedicated to innovation within society, pivoting the integrated system on the basis of a holistic strategic vision. For this reason, a growing number of countries are implementing them to address national challenges (Larrue, 2021).

According to this view, the policies defined under the Industry 4.0 initiative belong to the universe of mission-oriented innovation policies. In fact, the purpose, intent, and manner of policymaking by which the 4.0 discourse is introduced is consistent with what has been outlined so far. Policy 4.0 aims to promote radical innovations and implement technological solutions by coordinating actors (public and private) from different sectors and organizing resources and collective actions in order to transform and institutionalize the national innovation system. The global dissemination and sharing of issues and goals related to the fourth industrial revolution has given rise in countries around the world to the need to build appropriate policies. Policy-makers internationally have responded appropriately, and mission-oriented innovation policies with a 4.0 theme have spread rapidly. The proliferation of 4.0 policies around the world since the end of the first decade of the 2000s emerges as an interesting phenomenon that allows scholars a cross-cutting analysis of policies with a common character. In this sense, it is possible to make a cross-sectional reading of the trend related to policies 4.0 by deepening its structure, themes and declinations at the international level. The following section outlines what has been highlighted in the academic literature on the topic so far.

3.4 The state of art of 4.0 policies studies

"*What begins as a national economic policy to face the challenges of ICTs for a country, ends up becoming nothing less than a new industrial revolution, it is said to be the fourth*": with these words Braña (2019) described the genesis and beginning of the innovation system materialized in the fourth industrial revolution. The term "Industry 4.0" itself originated in Germany during the famous industrial technology fair Hannover Messe in 2011 and was officially institutionalized through the German government's strategic plan "Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution" in 2013 (Büchi et al., 2020). Based on the same technological elements and strategic principles, several government initiatives of the same nature have emerged in the same years (Teixeira & Tavares-Lehmann, 2022; Mariani and Borghi, 2019; Liao et al, 2017):

the U.S. launched the "Advanced Manufacturing Partnership (AMP)" strategic plan in 2012, South Korea's "Manufacturing Innovation 3. 0 Strategic Action Program" in 2013, India′s "Make in India" in 2014, China′s "Made-in-China 2025″ plan in 2015, Singapore′s "Research, Innovation and Enterprise 2020 Plan" in 2016, Brasil developed the "Plano de CT&I para Manufatura Avançada no Brasil - ProFuturo" in 2017, Russia′s "Digital Economy 2024" in 2017, and South Africa launched the "Manufacturing Indaba" program in 2018.

Table 1 – Author's elaboration of national 4.0 initiatives worldwide.

Country	Initiative	Year
Germany	Industrie 4.0	2011
USA	Advanced Manufacturing Partnership (AMP)	2012
Denmark	MADE	2013
Belgium	Made Different	2013
South Korea	Manufacturing Innovation 3.0 Strategic Action Programme	2013
Australia	The next wave of manufacturing	2013
UK	Catapult – High value manufacturing	2014
Netherlands	Smart Industry	2014
India	Make in India	2014
Japan	Industrial Value Chain Initiative	2015
China	Made-in-China 2025	2015
France	Industrie du Futur	2015
Spain	Industria Conectada	2016
Italy	Piano Nazionale Industria 4.0	2016
Portugal	PRODUTECH	2016
Singapore	Research, Innovation and Enterprise 2020 Plan	2016
Canada	Innovation Superclusters Initiative	2017
Brazil	Plano de CT&I para Manufatura Avançada no Brasil – ProFuturo	2017
Russia	Digital Economy 2024	2017
South Africa	Manufacturing Indaba	2018

3.4.1 *4.0 Policies: an indispensable tool*

Policy 4.0 has played a primary role from the beginning, having the function of introducing the vision and dictating the forms to implement the innovation system. The metamorphosis of the international landscape under the influence of digital transformation and increasing globalization has changed the priorities and objectives with which institutions and policymakers address and determine the needs of a new reality. There emerges an urgency to develop proactive and targeted policies capable of encouraging the creation of an interconnected innovation system that provides support and tools to the areas involved (Romanova & Kuzmin, 2021). The organization and direction provided by a policy-based approach allows responding and reacting to a scenario shaped by overwhelming forces such as the technological development of 4IR and the increasing centrality of human capital in all social processes. The regulatory function of policy enables the fulfillment of complex content by making it explicit in relational structures, tools and objectives. Policy makers assume the role of "shapers of this reality" (Teixeira & Tavares-Lehmann, 2022), in which Industry 4.0 is recognized as a sociotechnical system for innovation with totalizing consequences for the economy, society and growth (Kumar et al., 2020). For this system to be properly introduced, adopted and exploited, it is necessary to develop a structured policy plan with a national focus that can activate the internal environment and define the relationships among the actors involved (Kumar et al., 2020; Devi et al., 2020). For this reason, policy-makers play a key role in the implementation of Industry 4.0, realizing the economic environment in which businesses, institutions, academia and civil society will have to operate (Teixeira & Tavares-Lehmann, 2022).

It is critical in planning for the 4.0 phenomenon to set effective regulatory guidance for its present and future players with the goal of ensuring proper and ethical implementation of its principles (Shayganmehr et al., 2021). According to the AIMA-KPMG Report (2018), government institutions act as enablers, facilitators and policymakers for the implementation of Industry 4.0. This confirms the close relationship: policies have formulated and launched the Industry 4.0 agenda, which is realized and implemented precisely through and thanks to the same policies (Castelo-Branco et al., 2019). The participation of the government in the role of policy-maker is crucial to the implementation of Industry 4.0, as policy-makers are the central stakeholders capable of ensuring the collaboration necessary to implement a new system (Kumar et al., 2021; Majumdar et al., 2021). Policies 4.0 enable government institutions to remove obstacles and ensure the functioning of a dynamic and articulated ecosystem by assuring that businesses remain competitive in a landscape of increasing complexity. Businesses are challenged to compete in a challenging and uncertain innovation-based arena and must derive guidance and means from policies to develop new skills and preserve their competitive advantage. By defining an open design and focusing on a long-term vision, Policy 4.0 becomes crucial in the innovation economy and must be embraced rigorously by managers (Li et al., 2021; Poma et al., 2020; Messeni Petruzzelli et al., 2022). For this to be guaranteed, the innovation ecosystem must have intermediaries to ensure that policies are translated into concrete acts and implemented at all levels of the national innovation system. The complexity of the sociotechnical transition and the interdependence that is generated within the system require a multilayered approach, which is essential to activate the processes necessary to realize the success of Industry 4.0. Intermediaries translate policies into actions by activating synergies and integrating heterogeneous competencies. Through their intercession, it is possible to make the process of stakeholder engagement more accessible and inclusive, minimizing marginalization and failure of systemic change (Prodi et al., 2022; Davies, 2015).

The absence of a 4.0 policy thus becomes a real barrier to achieving the Industry 4.0 model (Khanzode et al., 2021; Raj et al., 2020; Trappey et al., 2017). The lack of a governmental policy framework hinders the adoption and implementation of the Innovation 4.0 ecosystem. Policies 4.0 have the exact function of removing extrinsic barriers to systemic change and institutionalizing the action of the innovation model (Reischauer, 2018). Policies need to be formalized in order to build momentum for the adoption of Industry 4.0, to increase the performance of the industrial and research innovation ecosystem, consisting of entrepreneurs, universities, local governments, and labor unions (Chauhan et al., 2021). The absence of a tool aimed at defining a system reference architecture and managing regulatory issues with concrete and implementable plans is an insurmountable problem for the development of a common infrastructure to regulate the 4IR digital change process, especially in developing countries (Lee et al., 2020; Bogoviz et al., 2019). This situation allows us to identify policy as a key strategic resource to survive as a national 4.0 innovation system in a complex and constantly changing economic landscape.

3.4.2 *The concrete goals of 4.0 policies*

In order to get used to a context characterized by an increasing level of innovation, it is essential to proceed with the determination of rules, guidelines and restriction that will push in the right direction, limiting disputes and problems that may harm the organizations involved (Ahumada-Tello et al., 2021). Appropriate laws and regulatory instruments must be stipulated to create the ideal environment for the adoption of the 4.0 model. There are several contributions from scholars who have identified practical and overriding needs that policy-makers must address through policies 4.0.

First, Policy 4.0 needs to determine how the innovation system will be financed, whether through grants or direct funding for technology and business development, tax cuts and incentives for R&D investment (Dieste et al., 2022; Matt et al., 2021; Masood & Sonntag, 2020; Mir et al., 2020; Robinson & Mazzucato, 2019). From a regulatory and legislative perspective, it is highlighted that administrative processes need to be improved by reducing bureaucracy and harmonizing the new common legislation so that it solves current problems and does not require complex legal expertise (Dieste et al., 2022; Matt et al., 2021; Chauhan et al., 2021; Robinson & Mazzucato, 2019). In addition, common reference standards must also be defined for technology and infrastructure development with the dual purpose of facilitating cooperative projects and protecting the privacy of sensitive data and information (Dieste et al., 2022; Kumar et al., 2021; Matt et al., 2021; Chauhan et al., 2021; Zangiacomi et al., 2020; Robinson & Mazzucato, 2019). Policies must also act to protect human capital: by establishing appropriate labor regulations (Kumar et al., 2021; Mir et al., 2020), designing training programs to generate new skills for a new workforce prepared for change (Chauhan et al., 2021; Lepore & Spigarelli, 2020; Robinson & Mazzucato, 2019), and promoting the sharing of knowledge, best practices, and start-up culture (Mir et al., 2020; Zangiacomi et al., 2020). At the macro level, policies 4.0 are critical for arranging a reallocation of productive factors by attracting domestic firms located elsewhere and setting a new organizational dynamic among actors through structure agreements that resolve tensions and contrasts (Barbieri et al., 2022; Lepore & Spigarelli, 2020; Zangiacomi et al., 2020; Ozanne et al., 2016).

In general, there are many and different needs and issues to which policy makers must be receptive. In practical terms then, each individual country has specific dynamics and needs that policies 4.0 must take into account and set programs and solutions accordingly. The following section will provide a brief overview of the analyses produced so far in the academic literature regarding the main national policy 4.0 initiatives.

3.4.3 *The emergence of national 4.0 policies*

As illustrated above, since the launch of the German policy "Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution," several other nations have followed the example by implementing their own plans and programs to adopt an innovation system consistent with the principles of the fourth industrial revolution. Keeping Germany as a point of reference and influence, the U.S., U.K., China, Italy, France, Brazil and many others have engaged in the production and development of active national policy making. The national-level emergence of Industry 4.0 initiatives and policies around the world has become a topic of interest for researchers (Kosacka-Olejnik & Pitakaso, 2019). The topic, relevant in both business and social sciences, has become increasingly relevant to the scientific community as it is a widely spread phenomenon with fixed common characteristics.

Born inside of the European Union, it is inevitable that the phenomenon has involved the entire community. The European community has made Industry 4.0 goals and programs its own by institutionalizing them into community programs. The European Union's Strategies for *Smart Specialization-S3* plan defined for the period from 2014 to 2020, aimed at pushing competitiveness and innovation in member state economies, already includes among its objectives many features of Industry 4.0 (Lepore & Spigarelli, 2020). Although the EU abandoned the practice of instituting industrial policy in the 1990s, there have been several "soft" interventionist initiatives in the past 20 years that have enabled member states to support and direct the dynamics of economic development and innovation for businesses and industries (Tvaronaviciene, & Burinskas, 2020). In the European context, Industry 4.0 has become the strategic lever for digitizing and upgrading manufacturing and increasing the competitiveness of the business sector and workforce. The promotion of the deployment of the 4.0 model has then surged since 2016 with the European Industry Initiative of the European Commission, when member states began to implement internal policies based on European directives integrating innovative technologies and reconfiguring processes throughout the value chain-suppliers, manufacturers, distributors, and customers (Teixeira & Tavares-Lehmann, 2022; Ciffolilli & Muscio, 2018). The long-term goal of European countries' 4.0 policies is a transformation of the national and EU production system that enriches the eurozone by creating a strong local strategic advantage (Barbieri et al., 2022).

Aided by relative market and technology development, the opportunities provided by industrial competitiveness policies facilitate upgrading processes in both industrial powers or already highly industrialized countries (such as EU member states) and newly industrialized countries (Xu et al., 2018). Especially in developing countries (Lee et al., 2020; Bogoviz et al., 2019), the absence of the support and guidance provided by policies harms and slows down business digitization. Policies need to adapt to different levels of industrial and technological readiness of firms in different national realities. Indeed, the heterogeneity of country conditions impacts the different strategies for building and implementing 4.0 policies (Erro-Garcés & Aranaz-Núñez, 2020). The contingent needs to be addressed can be extremely diverse (integration with the post-pandemic situation, integration with sustainable social and environmental goals, prioritization of locals, workforce upgrading, poor public-private communication, coordination of plans and policies already in place), as shown by studies conducted on individual country situations- Russia (Popkova et al, 2021), Malaysia (Tay et al., 2021), Colombia (Parra-Sánchez et al., 2021), India (Krishnan et al., 2021; Wagire et al., 2021; Dutta et al., 2020), and Mexico (Casalet & Stezano, 2020). Considering individual situations and settings, policy-makers need to make sure to start with an accurate analysis of the initial state and consult all innovative actors in the process of defining and building 4.0 policies to ensure their feasibility and congruence.

3.5 What about the "role" of intellectual capital in 4.0 policies?

From a strategic point of view, in the context of a knowledge-based economy, intellectual capital is a crucial factor for firms' performance in the long run (Martín-de-castro et al., 2011; Hsu & Fang, 2009). Moreover, as was illustrated in the first contribution of this thesis, intellectual capital is intrinsically connected to and necessary for the development and operation of Industry 4.0, as much as when policies (Ahumada-Tello et al., 2021). Indeed, the three components of intellectual capital (relational, structural, and human) contribute to the innovation and growth of firms' technological capacity, enabling them to operate effectively in the Fourth Industrial Revolution landscape. The uncertain condition that enterprises face in the transformation process can leverage intellectual capital as an enabler and asset of innovation (Li et al., 2021). If the diffusion of 4.0 policies acts as a facilitator in the implementation of the Industry 4.0 model, then it is legitimate to expect them to devote space internally to elements related to the management and strategic approach of intellectual capital.

Intellectual capital has been the subject of some reflection within the contemporary debate on the 4.0 scenario, in its most concrete and economically explicit manifestation, intellectual property. Kamperman Sanders (2021) noted how the intellectual property system needs to be discussed and adapted in light of the sustainable development required by 4IR. Policies 4.0 must ensure that the results of the collaborative R&D activities they encourage are appropriately developed, tested, implemented, and economically exploited in the national innovation system (Casalet & Stezano, 2020). The process of institutional change that policies 4.0 seeks to activate must rest on a solid and functioning innovation cycle from research to implementation. As evidenced by the example of Thailand (Jutimongkonkul et al., 2021), policies must push for commercialization of the result of the innovation process, intellectual property, in order to take full advantage of a science and technology-driven economy. Policies are expected to enable innovations to be transformed into concrete products and processes to be sold and exploited in the marketplace by generating a shared strategic advantage and increase one's national competitiveness (Barbieri et al., 2022).

3.5.1 *Reserach setting and objectives*

From these studies and based on these premises, the thinking behind this paper is generated. The overall objective is precisely to understand and investigate how policies 4.0, a key tool for the adoption and implementation of Industry 4.0, has been designed in order to achieve an integrated national innovation system and what it has established regarding strategy and management for intellectual property. Initially, with a cross-cutting approach, national 4.0 policies will be investigated by comparing their approach, structure and content, taking into account the specificities of individual countries. Proceeding to a deeper level of analysis, it will be analyzed whether and how much space is devoted to intellectual property and its life cycle (R&D funding and process, IPR strategy, IP commercialization and exploitation) within 4.0 policies: what kind of "role" is attributed to it in the 4.0 change scenario. The academic literature has recognized the importance of this topic and the related need for further studies on it (Dieste et al., 2022;

Nazarov & Klarin, 2020; Li, 2018; Reischauer, 2018). Therefore, the present research aims to respond by contributing to building new knowledge on this topic.

For this study, it was decided to conduct an analysis in the context of the G7 countries (Canada, Germany, France, Italy, Japan, USA, UK,). This is the well-known intergovernmental forum of highly industrialized countries established in 1975 and institutionalized in 1986 when Canada joined the original Group of Six. Created to find common solutions to complex economic problems, the G7 organization aims to coordinate, discuss and monitor macroeconomic initiatives, programs and strategies. The G7 was chosen as a sample for analysis because of three elements: a) the shared industrial power status of its members; b) the periodic coordination at the macroeconomic and strategic levels; and, c) the high degree of digitization and innovation common to the members. According to OECD data (see Table 2), the G7 countries are global economic powers characterized by a high rate of industrialization and together hold 52.91% share of the World Wealth (Credit Suisse Research Institute, 2022). Within the organization, member countries hold a democratic structure based on constant updating and cooperation through annual summits between their respective prime ministers and economic ministers. In this way, the G7 takes a common approach to strategy setting and problem discussion and resolution by encouraging constant coordination. The meetings focus on economics and finance, development, and security policies, and include among the guests the president of the European Commission, the president of the European Council, representatives of international financial institutions, and representatives of developing partner countries (Argentina, India, Indonesia, Senegal and South Africa in the 2022 G7 Summit in Elmau, Germany). Great power at the economic level and a democratic and dialectical politics have resulted in a great influence of the G7's action with a very wide global reach. Also, in the area of sustainability, G7 countries demonstrate their annual commitment to reaching the Sustainable Development Goals set out in the UN 2030 Agenda (see Table 2). According to the latest data available from the 2022 Sustainable Development Report, G7 countries rank in the top quartile on overall performance in achieving the SDGs (Sachs et al., 2022).

Table 2 - Main national economic indicators of G7 countries.

	CA	FR	DE	IT	JP	UK	US
GDP [1]	1.989.624	3.447.940	4.857.465	2.723.375	5.400.596	3.286.242	23.315.100
Gross National Income [2]	51.651	47.294	59.618	46.453	44.673	48.450	64.475
Employment rate [3]	73.23%	67.25%	75.78%	58.25%	77.88%	75.13%	69.40%
Gross domestic spending on R&D [4]	1.7%	2.2%	3.2%	1.5%	3.2%	1.7%	3.1%
Share of the World Wealth [5]	2.67%	3.49%	3.77%	2.48%	5.54%	3.51%	31.45%
SDGs achievement performance [6]	29°	7°	6°	25°	19°	11°	41°

[1] Million of US $ in 2021 (OECD database) – [2] US $ per capita in 2021 (OECD database) - [3] % of working age population in 2021 (OECD database) - [4] % of GDP in 2019 (OECD database) – [5] Global Wealth Databook 2022 by Credit Suisse Research Institute – [6] Ranking of overall performance in SDGs achievement in the 193 UN member States (Sustainable Development Report 2022).

The key to the economic growth of G7 countries is related to achieving a high level of innovation and technological maturity. The advent of ICT and the resulting transformation of the economic sector have increasingly impacted the G7 economies. Technological innovation has changed the production dynamics and improved the economic performance of G7 countries. This has been possible thanks to heavy investment in R&D activities to support technical-digital innovation and process digitization. This path has improved G7 economies in terms of productivity, social change, and industrial development (Yuan et al., 2021: Ozkaya et al., 2021). The performance of G7 countries regarding innovation and technological maturity is represented in Tables 3 and 4, which illustrate through data and indicators their current status. Table 3 collects the Frontier Technology Readiness Index (FTRI) calculated by UNCTAD STAT (United Nations Conference on Trade And Development) relative to the year 2019. The FTRI "*includes technological capabilities related to physical investment, human capital and technological effort, and covers national capacities to use, adopt and adapt these technologies*." The calculation, based on five building blocks (ICT deployment, skills, R&D activity, industry activity and access to finance), places all 7 countries in the fourth quartile, giving evidence of their readiness for innovative technologies.

Table 3 - Frontier Technology Readiness Index by UNCTAD STAT (2019).

	CA	FR	DE	IT	JP	UK	US
ICT	0.89	0.84	0.84	0.68	0.91	0.88	0.89
Skills	0.71	0.72	0.74	0.64	0.53	0.79	0.74
R&D	0.70	0.73	0.79	0.68	0.74	0.75	0.94
Industry activity	0.70	0.79	0.82	0.70	0.79	0.81	0.76
Access to finance	0.86	0.82	0.76	0.75	0.94	0.88	0.96
Frontier Technology Readiness Index	**0.89**	**0.89**	**0.92**	**0.76**	**0.87**	**0.96**	**1.00**

Table 4 - Innovation and IP indicators from WIPO.

	CA	FR	DE	IT	JP	UK	US
Global Innovation Index (GII) [1]	15°	12°	8°	28°	13°	4°	2°
Patent applications [2]	34.565	14.313	62.105	11.008	288.472	20.649	597.172
Patents in force [3]	192.668	674.334	834.734	348.888	2.039.040	682.245	3.348.531
Trademark applications [4]	147.267	290.194	264.669	100.872	421.166	278.699	870.306
Industrial design applications [5]	7.530	31.196	40.638	25.364	31.650	32.731	50.743

[1] WIPO 2022 - [2] [3] [4] [5] In national offices (2020)

Table 4 shows some interesting data in terms of commercialization and exploitation of innovation elaborated by the World Intellectual Property Organization (WIPO). The Global Innovation Index (GII) annually ranks the most innovative economies based on performance and socio-economic indicators. The intellectual property registration offices in all G7 countries are among the 20 with the most patents applications and patents in force in the world. This achievement is even more remarkable when considered in light of the fact that the European Patent Office (EPO)-which falls within these 20 offices as an entity in its own right with 180.346 patent applications-has numerically damaged the performance of the offices in EU member countries (France, Germany and Italy) by offering broader geographic validity. In 2020 Germany, Japan and Italy also rank among the top 20 IP offices in the world for utility model filing. The same result is also recorded by the G7 IP offices on trademarks applications and industrial design applications.

Despite aligning on a common path, there are differences among the G7 countries with regard to the setting of internal economic and social structure. According to the classification proposed by Hall and Soskice (2001), later confirmed and expanded by Kim and Kim (2021), two different varieties of capitalism typical of developed economies can be distinguished within the Group of Seven: liberal market economies (LME) and coordinated market economies (CME). The first group - to which the U.S., U.K., Japan and Canada belong - is characterized by inter-firm relations defined by competitive dynamics and market hierarchies, in which the state takes a neutral approach and intervenes in order to de-regulate; while in the case of CMEs - as France, Germany and Italy - the relations are hinged on complex social structures and relations based on collaborative models, the state plays a mediating role and adopts an interventionist approach primarily to promote cooperation and sharing among social actors. These differences may be relevant with respect to the ways in which digitization and innovation within industries take place. It is crucial to understand how these aspects translate into directions and characteristics within the innovation policy discourse in individual countries (Reischauer, 2018). The Group of 7 has elements of commonality and diversity within itself, making it an appropriate and interesting object of study.
Considering the overall objective of the paper and the peculiarity of the chosen sample, the following three research questions have been prepared and will be answered throughout this paper:

RQ 1 - What are the main strategic policies introduced in the G7 countries for the introduction and adoption of the industrial 4.0 model?

RQ 2 - What are the main features of these strategic policies introduced at the national level?

RQ 3 - What role does intellectual property and its production cycle (R&D, protection and exploitation) play within the 4.0 policies of the G7 countries?

3.6 Research methodology

For the analysis aimed at answering the research questions, two qualitative, empirical, deductive methodologies were chosen: document analysis and content analysis by text mining. A review of the scientific literature on published studies with policies 4.0 as their subject (see Table 5) indicated these methodologies as the most adopted and effective for evaluating policies 4.0 with regard to our research questions.

According to Bowen (2009), document analysis is a qualitative research methodology based on the systematic review of documents. The process consists of three phases of study: skimming (superficial examination), reading (thorough examination), and interpretation, allowing the researcher to give an interpretation of the text within context. This technique is particularly valuable in the study of official documents, such as policies, whose drafting is the result of a structured and shared process. At the level of thematic analysis, document analysis is a tool for recognizing patterns and recurring themes through which to read the data (Karppinen & Moe, 2012; Fereday & Muir-Cochrane, 2006). Evaluation and discussion are produced based on re-reading and selection of analysis categories initially defined by the researcher. The creation of predefined elements and the examination of documents by reference with these ensures the reliability and credibility of the methodology. There are several advantages of this methodology: efficiency, cost-effectiveness, stability, coverage, exactness; and although the limitations are less insufficient detail and biased selectivity they must be managed and justified appropriately within the research. The second methodology adopted is content analysis, which is useful in providing an accurate overview of the material under study. The analysis produces quantitative indications regarding the frequency of certain terms and expressions selected a priori or emerging from the examination of the text. As a method, content analysis has the advantage of being a systematic measurement tool aimed at giving a quantitative and objective interpretation of the analysis of a text (Sivakumar, 2020; Prasad, 2008). The repeatable and verifiable interpretation of the result makes it possible to describe the characteristics of a text by going beyond impressionistic observations. This method of inquiry is particularly suitable for policy analysis and complementing the study of documentary information (Jauch et al., 1980). Problems related to semantics are a practical limitation to the application of content analysis, in addition to the lack of in-depth investigation of the meaning of terms and expressions with respect to their position in the text and the relationship between them. Content analysis was implemented using the text mining software NVivo-12, which provides a systematic process for searching for specific themes increasing the reliability of the study. Given the recent development of the topic and the sample of countries chosen for this research, it is necessary to apply methodologies that offer a comprehensive and inclusive comparative analysis that highlights similarities and diversities with respect to a set of criteria set in advance (Teixeira & Tavares-Lehmann, 2022). With the rigorous application of this dual qualitative methodology, the present research offers a cross-sectional and deductive approach to the analysis of 4.0 policies in G7 countries.

Table 5 - Literature review of scientific papers about 4.0 Policies.

Paper	Journal	Context	Methodology
Teixeira, J. E., & Tavares-Lehmann, A. T. C. (2022)	*Technological Forecasting and Social Chang*	European Union	Document systematic comparison
Bezerra Borges, D., Meyer Soares, P., & Santana Silva, M. (2021)	*Journal of technology management & innovation*	Brazil	Bibliographic research
Akman, A., Hürses, C., Yıldırım, N., & Gultekin-Karakas, D. (2021)	*Proceedings of the 30th International Conference of the International. Association for Management of Technology IAMOT 2021*	Turkey	Text mining
Asoba, S. N., Mcunukelwa, R. M., & Mefi, N. (2020)	*Academy of Entrepreneurship Journal*	South Africa	Document analysis
Wang, J., Wu, H., & Chen, Y. (2020)	*International Journal of Production Economy*	China	Document analysis; Reverse Quality Function Deployment
Lepore, D., & Spigarelli, F. (2020)	*Local Economy*	European Union	Content analysis – Document analysis
Romanona, O. A., & Kuzmin, E. A. (2020)	*Transactions on business and economics WSEAS*	Russia	Comparative analysis
Poma, L., Shawwa, H. A., & Maini, E. (2020)	*International Journal of Business Performance Management,*	Italy; United Arab Emirates	Document analysis
Kim, S. S., & Choi, Y. S. (2019)	*Foresight and STI governance*	South Korea	Document analysis

Majstorovic, V. D., & Mitrovic, R. (2019)	*International Conference on the Industry 4.0 model for Advanced Manufacturing*	European Union; UK; Swiss; Norway; USA; Canada; Mexico; Argentina; Brazil; South Africa; Japan; China; South Korea; Singapore; Malaysa; Thailand; Israel; India; Australia; New Zeland	Document comparative analysis
Li, L. (2018)	*Technological Forecasting and Social Change*	Germany; China	Document comparative analysis
Mukwawaya, G. F., Emwanu, B., & Mdakane, S. (2018)	*Proceedings of the International Conference on Industrial Engineering and Operations Management*	South Africa	Document analysis
Hemphill, T. A. (2014)	*Innovation*	USA	Document analysis

3.7 Results and discussion

The present section is organized as follows: initially a historical overview of the introduction of the 4.0 model in the G7 countries at the national level is offered; then the system of selecting the 4.0 policy for each country is explained, and the last three sections will describe the results of the study. Of the latter three: the first and second will report respectively on the document analysis and content analysis at the general level of the 7 policies for responding to RQ 2; the third will offer an in-depth look at the role of IP in policies 4.0 (RQ 3).

3.7.1 *The Fourth Industrial Revolution in G7 countries: historical notes*

Germany - As early as 2006, a full 5 years before the Hannover Messe Fair, Germany had already started working on an innovative development plan by launching the High-Tech Strategy 2020 action plan in 2012 with the aim of helping companies develop new technologies building on collaboration between industry and research. It was precisely at the Hannover Messe Fair in 2011 that led to the definition of the concept of Industry 4.0 in the speech given by Wolfgang Wahlster, director and CEO of the German Research Center for Artificial Intelligence, that the Plattform Industrie 4.0 was formed by the business associations Bitkom (digital industry), VDMA (mechanical engineering industry) and ZVEI (high-tech manufacturing), giving evidence of the participation of businesses in the process of change. Starting in 2011, the concretization of this mission takes the form of a project between Acatech - National Academy of Science and Engineering and the Industry-Science Research Alliance Promoting Committee. The working group publishes in 2013 the strategy program "Securing the future of German manufacturing industry. Recommendations for implementing the stretegic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group" signed by H. Kagermann, W. Wahlster and J. Helbig. After the definition of the pivotal principles in the document, the commitment of companies is consolidated and the four-year (2013-2017) *AUTONOMIK für Industrie 4.0* investment program is born. Germany continues its commitment to the deployment of the industrial 4.0 model, which is based on the ability of companies and institutions to network and cooperate together through projects such as 2015's *Smart Service World* for the digitization of services in German industry.

USA - In response to the radical technological changes taking place globally, the United States of America began working on a federal project to identify common opportunities and strategies for transforming the economy. In June 2011, the President's Council of Advisors on Science and Technology launched "Advanced Manufacturing Partnership" (AMP) to develop relationships between industry, academia and government that can lead to the development and investment of technology, policy and business partnerships. The stated goal is to harness technology potential to transform and "reinvigorate" U.S. manufacturing. In 2012, "Capturing Domestic Competitive Advantage in Advanced Manufacturing" is published to discuss the global strategic positioning of the U.S. at the industrial level. With the intent to strengthen domestic ties and encourage a coordination-based approach in 2013 the government's *Manufacturing USA - National Network for Manufacturing Program* (NNMI) is introduced, in 2014 the strategy is updated and enlarged with the *Revitalize American Manufacturing and Innovation Act* (RAMI Act), and finally, in 2018 comes the creation of the *Strategy for American Leadership in Advanced Manufacturing*. In order not to lose an industrial leadership position, the U.S., accustomed to a policy of minimal intervention in national industrial development, chooses to act through a series of policy instruments that can promote and drive for the creation of high-profile jobs and the use of innovative technology as a means to increase competitiveness.

UK - In 2007, the UK government founded Innovate UK, an entity to drive innovation across the country through targeted investment in particularly innovative projects and businesses. In 2011, *Catapult Network* is created, a network of multifunctional centers spread across the country and composed of entrepreneurs, institutions and researchers engaged in R&D, training and business support in radical change processes and commercialization of innovative ideas. Programming in this direction continued in 2012 with the construction of the government *Advanced Manufacturing Supply Chain Initiative Fund* and then, in 2013, with the *Future of Manufacturing* long-term industry action plan based on the principles of interconnection and cooperation with research institutions and business partners. Following the influences of the Industry 4.0 program and the circulation of ideas and goals related to them, in 2014 the government launched the national growth program "Our plan for growth: science and innovation," and in 2017 created the *Industrial Strategy Challenge Fund* to finance and support business and research by developing R&D. Again in 2017, the government issued a Green Paper "Building our Industrial Strategy" by which it builds an operational policy plan to direct national strategic industrial development. Similar to the U.S. strategy, Britain aims to increase business competitiveness by providing new and effective technology solutions across the manufacturing sector.

France - France's path into the fourth industrial revolution begins following the launch of Germany's Industrie 4.0 program. The influence of the German strategic program on the European territory was immediate and impactful. In 2013, the French government creates the "La Nouvelle France Industrielle" strategy to improve the positioning of companies by upgrading processes and increasing the skills of the workforce. In 2015, the "Factory of the Future" plan is established to support companies in the process of industrial transformation, to stimulate investment in research and the adoption of new enabling technologies. The same year, the *Alliance for the Industry of the Future* was created for the operational implementation of the plan, composed of professional and technological organizations, scientific and academic actors, financial organizations and companies. A year later, the Ministry with delegated responsibility for industrial policies creates the *Learning about Industry project* ("Osons l'Industrie") program for training and recruitment by linking human capital and students to job and employment offers related to the Industry of the Future program promoted by national companies active in strategic sectors. In 2016, the French government created the *Invest for the Future* program to fund education, research and innovation for businesses by creating a closer relationship between the world of education and research and the business world. Compared to the path of other national realities, the French strategy puts more focus on education, investment in research and development, and the placement of the national workforce.

Italy - After an initial national plan for industrial development dictated by the *Factory of the Future* project for the three-year period 2011-2013, Italy began to embrace the principles of Industry 4.0 in February 2016 when the Chamber of Deputies ordered a consultative study on the topic and the adoption of the principles of the fourth industrial revolution in the country. The document was presented in June of the same year by the 10th Commission on Productive Activities, Trade and Tourism under the title of "Industry 4.0 Fact-Finding: which model to apply to the Italian industrial fabric. Tools to foster the digitalization of national industrial supply chains," and identifies the strategic lines and initial operational proposals for the adoption of the 4.0 model in Italy. The plan outlines the pillars on which to build an Italian innovation strategy by removing obstacles and developing the potential of the national industrial context. Following the analysis of the survey results, in September 2016 the government and the Ministry of Economic Development presented the "National Industry 4.0 Plan" covering the period 2017-2020. The plan is structured on intervention guidelines of two types: key and accompanying guidelines that touch and involve all public and private actors, research, training and business. Monitoring of the plan's implementation is assigned to a steering cabin that includes in addition to public government institutions, public investment companies, universities and research centers, and organizations. In 2019, the Plan was renewed for an additional three-year period 2020-2022 with the launch of the "*National Transition 4.0 Plan*", with a focus on the themes of inclusion and sustainability.

Japan - The digitization and automation of the industrial sector in Japan has been the subject of several initiatives designed to support the economy and state competitiveness. In 2014, the state established the *Robot Revolution Realization Council* for industrial robotic upgrading, which was followed the next year by the publication of the New Robot Strategy strategic plan defined by the *Robot Revolution Initiative* (RRI) a consortium of 226 initial members including associations, companies, and individuals. The *Industrial Value Chain Initiative* (IVI) was launched as a project in 2015 that aims to integrate a collaborative ecosystem within the industrial scenario by putting together knowledge and technologies. IVI takes the form of a cooperative forum co-participated by the public and private sectors for industrial optimization through the organization of working groups and interactive platforms. The main target is to engage SMEs and the education system within the dynamics of industrial development by enabling them to access and use enabling technologies to generate new market opportunities. Also in 2015, the Cabinet Office adopted the plan "Society 5.0 - 5th Science and Technology Basic Plan 2016-2020" with the aim of creating an integrated system of innovation through the participation and connection of the government-industry-academia triad. Science and Technology Basic Plans are defined every 5 years by the Council for Science, Technology and Innovation (CSTI) chaired by the Prime Minister. The priority defined with Society 5.0 is to advance a more participatory and inclusive system that coordinates needs and goals at different levels (business, research and society) to put innovative and smart technologies (robotics, AI, Big Data and IoT) at the center of everyday life.

Canada - Canada's federal state structure assigns STI policymaking competence in the industrial sphere primarily to the governments of the states, entrusting the central government only with the coordination of national strategies and responsibility for funding. The autonomy and development of individual countries within Canada remains a key element of the nature and policies in industrial development with a cluster approach (Salazar & Holbrook, 2007). Industry 4.0 initiatives are no exception and have seen mostly regional guidance, coordinated lightly by the central government. Nonetheless, in 2017, the federal government of Canada through the National Research Council of Canada, Industrial Research Assistance Program (NRC IRAP) launched the *Innovation Clusters* project, which aims to strengthen sectors with the greatest potential for growth through a shared innovation process among companies, research centers, institutions, and nonprofits to strengthen the business sector. In 2018, an Industry 4.0 collaboration program was launched with the German government through a partnership and knowledge sharing plan that brought together key German and Canadian business players. The Cooperation Project was created with the aim of helping companies through an emulation and training approach for the application of innovative technologies and commercialization of research projects. The mission to launch the Project, which took place between February and March 2018, brought visiting Canadian managers, professors, and researchers to Germany's leading 4.0 players. The priority in Canada is primarily to advance the country's competitiveness and the common adoption of innovative technologies to establish a 4.0 innovation ecosystem at the cluster, state, and federal levels. To this end, 2017 saw the formation of the Economic Strategy Tables a forum for collaboration between industry and government, composed of industry leaders in six key sectors (advanced manufacturing, agri-food, clean technology, digital industries, health/bio-sciences and resources of the future) and federal Deputy Ministers. These worked on plans for innovation-led long-term growth for the Canadian economy to achieve ambitious goals for productivity and economic growth.

3.7.2 *Setting the G7 4.0 policies sample*

According to Bowen (2009), after identifying one's research questions, the researcher must determine the sample of documents to analyze based on their relevance to the analysis focus. The documents must meet several characteristics: authenticity, credibility and representativeness of the topic of investigation. Following Miedzinski (et al., 2022), criteria were defined by which to search and select policies for the present study:

a) Sourcing from central government agencies in the country, published and accessible on the country's official channels;

b) Direct reference to one of the following global frameworks: Industry 4.0, fourth industrial revolution, advanced manufacturing, innovation-based growth;

c) Publication not prior to 2010;

d) Strategic nature and multi-year time horizon;

e) Publication in English language, either original or in official translation.

Although our goal is not to construct an exhaustive or representative sample of a global phenomenon, the defined selection criteria aimed to choose based on a principle of homogeneity. The different political, economic and social nature of the seven countries resulted in the consequent diversity of the way policies are defined, structured and written. The document selection process took this element into account and, consistent with the time and resources available, maintained an analytical and informed approach to selection (Creswell & Poth, 2016). The primary source for the research was the official websites of the central governments and primary Ministries of the G7 countries. Next, it was cross-checked with data on the EC-OECD STIP Compass, a database created by the European Commission and OECD for policy and STI policy data. Policies whose text version did not have a document structure (layout, chapters/paragraphs, and page numbers), such as slideshows, leaflets, or print advertising materials, were excluded (Schlogl et al., 2021). The choices that determined the selection of a particular policy for each country are discussed below (see Table 6).

Table 6 - G7 policies selected for the study.

Country	4.0 Policy	Year	Government
Germany	Industrie 4.0	2011	Angela Merkel
USA	A national strategic plan for Advanced Manifacturing	2012	Barack Obama
UK	Our plan for growth: science and innovation	2014	David Cameron
Japan	Society 5.0	2015	Shinzo Abe
France	Industry of the Future	2015	François Hollande
Italy	National Industry 4.0 Plan	2016	Matteo Renzi
Canada	Seizing opportunities for growth	2018	Justin Trudeau

For Germany, the policy choice was "Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group," which was the first to formulate the principles of the 4.0 model in a structured manner, serving as an example to the following and other countries. Published in April 2013, it is a report of recommendations and strategic objectives defined by the studies of the Industrie 4.0 Working Group: Communication Promoters Group of the Industry-Science Research Alliance (Prof. Dr. Henning Kagermann from National Academy of Science and Engineering, Prof. Dr. Wolfgang Wahlster from German Research Center for Artificial Intelligence and Dr. Johannes Helbig from Deutsche Post AG) and the acatech - National Academy of Science and Engineering. Another obligatory choice was the selection of the policy born after the "Advanced Manufacturing Partnership (AMP)": “A National strategic plan for Advanced Manifacturing. Launched in 2012 by the working group set up by the Obama government the previous year, this document gave the guidelines and initiated the construction of more specific policies in the following years. In the case of the UK, "Our plan for growth: science and innovation" published in December 2014 and commissioned by the Department for Business, Innovation and Skills was chosen. Despite having the same objective, the first 4.0 initiative launched, the Catapult innovation and research centers, was excluded because it constituted a concrete operational project for business development and competitiveness, and not a strategic programmatic plan. Initiatives aimed at developing a strategy for a single technology or sector were also excluded in Japan. The national policy "Society 5.0 - 5th Science and Technology Basic Plan 2016-2020" was chosen as the multi-year strategic plan most in line with the description of strategy for creating a "national innovation system." The choice for France and Italy fell on the national policies that constitute the declination of the Industry 4.0 plan defined in Germany and then approved by the European Commission as a community objective. For France, the "Industry du Future" policy published by central government in May 2015 was chosen, and for Italy the "National Industry 4.0 Plan" published in September 2016 by government and Ministry of Economic Development. Lastly, the federal situation of Canada and the great autonomy of Canadian countries in terms of industrial strategy complicated the choice of a policy that had national validity and met the criteria defined for selection. After an analysis of federal strategic documents, the strategic plan "The Innovation and Competitiveness Imperative. Seizing Opportunities for Growth. A Report from Canada's Economic Strategy Tables" was selected. It was published in September 2018 after the investigation and the Economic Strategy Tables' common goals setting.

3.7.3 *Document analysis of 4.0 policies in G7 countries*

- **National level**

This section will analyze the content of 4.0 policies individually, investigating their different aspects at the structure and content level. The goal is to understand by whom and how the strategic lines for an Industrial 4.0 model development, adoption and diffusion have been defined at national level. A chronological order has been adopted, starting with the analysis of Germany's 4.0 policy.

Germany - "Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group" is a document published in April 2013 and drafted by the same Working Group that first formulated the concept of "industry 4.0" announced at the 2011 Hanover Fair. The policy makers are composite in nature and involve public agencies (Federal Ministry of Education and Research), independent research organizations and advisory bodies serving public institutions (acatech National Academy of science and egineering and Forschungsunion Wirtschaft und Wissenschaft aka Research Union Economy and Science). The policy consists of 7 chapters: 5 central insights (corresponding to chapters 2 through 6) to which are added introduction and final outlook. With the goal of developing and securing a prosperous future for the German economy, the document offers a holistic and long-term view of the strategic path forward. The integration of the Cyber-Physical System (CPS) into production systems is not only an asset for the leadership and efficiency of the German business fabric but also offers a solution to the major challenges of the present (energy resource management, urban production, demographic changes, etc.) creating new opportunities for social value. New levels of interaction, pervasive services, and a new centrality of humans (both as citizens and workers) will make it possible to define new social infrastructures according to a mixed socio-technical approach to the new industrial 4.0 model. The dual strategy to be applied according to the document is to advance the deployment of CPS in the national industry and, simultaneously, the marketing of CPS products and technology through vertical and horizontal integration in order to "*becoming a leading market and supplier*."

Table 7 - Germany policy 4.0 main elements

Germany	
Title	**Recommendations for implementing the strategic initiative INDUSTRIE 4.0**
Policy-makers	Federal Ministry of Education and Research; acatech National Academy of science and egineering; Forschungsunion Wirtschaft und Wissenschaft
Structure	1) The vision: Industrie 4.0 as part of a smart, networked world 2) The dual strategy: becoming a leading market and supplier 3) Research requirements 4) Priority areas for action 5) How does Germany compare with the rest of the world?
Key point	Adoption of a socio-technical perspective that has an impact not only on the competitiveness of the industrial sector but on the whole society and its development, responding to the socio-demographic challenges and needs of the time. The improvement of conditions and the central position of people in the new paradigm -both as workers and citizens- is a primary goal in defining (human-centric) strategies.

The research is constituted as an indispensable tool to develop and implement such technology effectively to meet the challenges and build the 4.0 model. The priority areas for action identified in the document are: standardization of industrial processes in order to make them more replicable and adaptable, management of complex systems at the industrial and commercial level, national provision of a broadband IT infrastructure, safety in production and products, work organization and work design in the digital age, training and lifelong professional development, efficient use of resources (human, financial and raw materials), and a legal framework adequate to control the proper functioning of the model. From a global perspective, there is a final consideration to the international market for 4.0 technologies and developments of national strategies in countries such as China, the US, Russia, and India. International dynamics are carefully evaluated in order to monitor competitors but also assess possible strategic alliances and collaborations. The strategy document published by Germany as Policy 4.0 is wide-ranging and returns an interdisciplinary strategic vision with a long-time horizon. The German policy does not dwell at length on application or technical elements but provides guidelines and objectives not only industrial and technological but socioeconomic.

USA – The U.S. 4.0 policy "A National strategic plan for Advanced Manufacturing" was made public in February 2012 by the Office of Science and Technology Policy. The policy-makers who drafted its contents are: the National Science and Technology Council, which is responsible for developing research and development strategies, allocating funding and achieving national growth targets; Office of Science and Technology Policy, which articulates presidential science and technology policies and programs; and the Interagency working group on Advanced Manufacturing, which provides advice and guidance for all advanced manufacturing initiatives by identifying needs and conducting joint planning with other governmental and non-governmental stakeholders. The document has a strategic focus and consists of 8 chapters and 6 in-depth technical appendices.

The U.S. 4.0 plan declares 5 goals to be achieved in strengthening the industrial fabric by seeking to establish a virtuous system that places the entire life cycle of technology at the center. The plan is presented as a strategic innovation policy that can respond to the complexity of modern technologies for industry in both the public and private sectors. The plan also shows how the change that these new technologies bring can be managed.

Table 8 - USA policy 4.0 main elements

USA	
Title	**A National strategic plan for Advanced Manifacturing**
Policy-makers	President's Council of Advisors on Science and Technology (PCAST); Advanced Manufacturing Partnership Steering Committee
Structure	1) Advanced Manufacturing: patterns and trends 2) Principles and objectives of the National Strategy 3) Accelerating investment by Small and Medium-sized Enterprises 4) Strengthening workforce skills 5) Creating partnerships 6) Coordinating federal investments 7) Raising national investment in Advanced Manufacturing R&D
Key points	The stated goals are to set a new industrial strategy to be able to maintain global competitive advantage and a dominant position in a scenario of new players and thereby become an innovation economy. Accelerating investments, creating and supporting a collaborative innovation system and expanding the workforce are the main goals to secure for the USA a national economic growth based on technology exploitation.

The first stated goal is to accelerate advanced manufacturing technology especially for SMEs, and the federal actions defined to achieve it are: targeted public and private investments for crucial sectors and systematic procurement by federal agencies (especially military) of advanced manufactures in the scale-up phase. Expanding the workforce with skills adequate for advanced manufacturing and making the training and educational system more appropriate to market demand are the second goals. Here, the federal government operates programs in two directions: a) to ensure better continuing education for workers currently employed in advanced manufacturing and b) to define new training programs for future local workers specific to the technology industry of the present, enhancing STEM disciplines and skills and competencies most needed. The third goal of the plan is to create and support cross-cutting strategic partnerships (national-regional, public-private, government-industry-academia) to ensure greater investment and diffusion to advanced manufacturing. By the way, federal actions plan a boost for the creation of participatory clusters (integrating especially SMEs) and joint public-private investments to expand access to industrial commons and facilities. The fourth goal posed by the strategic plan is to optimize federal investments in advanced manufacturing by joining the forces and resources of the various active federal agencies. Through increased coordination, the federal purpose is to create a single portfolio of investments on advanced manufacturing by identifying and balancing priority needs, targets, processes and infrastructure. Four categories are selected for such investments: advanced materials, production technology platforms, advanced manufacturing processes and data and design infrastructure. In addition to these 4 previous objectives, to make the ultimate purpose of supporting and incentivizing U.S. advanced manufacturing effective, it is crucial to increase investment-public and private-in advanced manufacturing R&D (objective 5). Without this, it will not be possible to ensure development and take advantage of the new industrial system and ensure national economic growth. The federal actions established to achieve this goal are (a) a federal tax policy that incentivizes investment in Research & Experimentation accesible to all firms leading to large-scale innovation and (b) a federal budget for targeted investment in advanced manufacturing R&D aimed at growing the competitiveness of firms and the U.S. market.

UK - "Our plan for growth: science and innovation" is the policy published by the British government in 2014. The document was developed by public government agencies: HM Treasury (government department responsible for economic and financial policies), the Department for Business innovation & Skills (replaced in 2016 by the Department for Business, Energy and Industrial Strategy) and Minister of State for Universities, Science and Cities (now known as Minister of State for Skills, Apprenticeships and Higher Education). The policy is structured around 6 main pillars that correspond to the 6 chapters and outlines trajectories for making the UK a "*world-leading knowledge economy*." Right from the title, science and innovation are given the primary role for the growth of the UK economy: commercialization of scientific contribution and new technologies and ideas will ensure business development and progress of the national economy.

Table 9 - UK policy 4.0 main elements

UK	
Title	**Our plan for growth: science and innovation**
Policy-makers	HM Treasury; Department for Business innovation & Skills; Minister of State for Universities, Science and Cities
Structure	1) Deciding priorities 2) Nurtuirng scientific talent 3) Investing in scientific infrastructure 4) Supporting research 5) Catalysing innovation 6) Participating in global science and innovation
Key points	The primary intention is to set up a world leading knowledge economy through 5 key tools (agility, openness, excellence, collaboration and space) and the use of innovative technologies to develop products and services in different industries and sectors that can benefit the whole society.

The long-term economic plan involves 6 key elements. First, the policy sets priorities to succeed in meeting the major challenges of modern society through the identification of 8 Great Technologies (Big data and energy effiecient computing; Satellites and commercial applications of space; Robotics and autonomous systems; Synthetic biology; Regenerative medicine; Agri-science; Advanced materials and nano-technology; Energy and its storage). These 8 tech areas correspond to sectors with great potential for the UK and defined as central to the long-term national business strategy. The second pillar is Nurturing scientific talent to ensure competent and developed human capital capable of producing innovation. Systematic investment is planned in terms of training throughout the educational pipeline: increasing STEM teachers and projects from elementary school, loans and grants for higher and post graduate education, employment support and promotion of careers in science and innovation. Investing in scientific infrastructure and Supporting research are the third and fourth pillars, respectively. They define actions and investments to enhance the accessibility and capacity for scientific research and R&D-based innovation in the country, both at universities and research centers and within enterprises and innovation hubs (see Catapult project § 3.7.1 UK). Through activities aimed at enhancing collaboration and opening up new types of relationships, the policy aims to promote an interdisciplinary and multi-player approach to foster innovation and exploit research outputs and outcomes. The fifth pillar is Catalysing innovation and it leads actions aimed at increasing technology and industry clusters and ensuring the exploitation of patents and innovations produced. This section explains investments focused on creating virtuous circles based on the creation and exploitation of knowledge: securing funds for research, which attracts talent, generating innovative businesses that attract global businesses. Ensuring the protection and promoting the exploitation of intellectual property are defined by the policy as elements central to this goal. As in the case of Germany, the last pillar (Participating in global science and innovation) is devoted to the international perspective: by funding international research infrastructure, the UK aims to position itself as a key international partner by strengthening its global collaborative and economic relationships to drive a shared innovation strategy. Actions are defined to attract international investment and support trade with a global approach. Lastly, it is possible to conclude that in UK policy, explicitly based on the principles and values of excellence, collaboration, agility, place (physical spaces to connect) and openness, investment in knowledge and its economic exploitation are identified as the crucial challenges for business and the nation.

Japan - "Society 5.0 - 5th Science and Technology Basic Plan 2016-2020" is Japan's fifth national strategic plan for science and technology. Every 5 years, the Japanese government undertakes to formulate a 5-year strategy for the development of science and technology from the perspective of economic and social growth. It was drafted by the Ministry of Education, Culture, Sports, Science and Technology in 2015 and consists of 7 chapters. The four main pillars stated by the policy makers are: creating new value for the development of the industry of the future, addressing the economic and social challenges of the present, strengthening the national STI system, and building a virtuous circle by developing knowledge, funding innovation and human resources.

Table 10 - Japan policy 4.0 main elements

Japan	
Title	**Society 5.0 - 5th Science and Technology Basic Plan**
Policy-makers	Ministry of Education, Culture, Sports, Science and Technology
Structure	1) Acting to create new value for the development of Future industry and social transformation 2) Addressing economic and social challenges 3) Reinforcing the Fundamentals 4) Establishing a systemic virtuous cycle of human resources, knowledge and capital, for innovation 5) Deepening the relationship between STI and society 6) Enhancing functions for promoting STI
Key points	Central is society, player and target throughout the Japanese Plan. The objectives are achieving economic and social goals and creating value through a collaborative system for innovation and science based on the government-industry-academia collaboration.

In order to succeed in creating new value in the development of the industry of the future, Japan's plan configures a series of programs aimed at strengthening competitiveness and consolidating the use of key technologies (already a strength of the national economy) needed to build the "smart society." People, in fact, are at the center of a strong path of social transformation that makes it inevitable to integrate actions to enhance human capital and the creative activities dependent on it (R&D first and foremost). The plan develops the model to aspire to of a "super smart society" or "Society 5.0," which will bring prosperity to the population through the fusion of the physical and digital worlds, based on the increasing diffusion and exploitation of science and technology in all aspects of social and economic life. To achieve this model, the plan indicates as a priority to work on the major socio-economic challenges of the present (depopulation, hyper aging, resources, energy efficiency, etc.): it establishes to develop autonomous growth at the regional level and ensure the safety and security of decent and sustainable living conditions for citizens. Actions are aimed at ensuring the health of the environment, biodiversity and population, labor market, food, digital spaces, building infrastructure and strengthening services. Further key point of the plan is the strengthening of STI core elements. Being focused on knowledge creation and development, the plan focuses on empowering human capital with advanced training programs and promotion of intellectual professionals and pathways that foster mobility and diversity in the work environment. Promoting excellence in knowledge creation is crucial and sets out strategies to promote research activities (both public and private entities), reshape and upgrade facilities and infrastructure, and reform the funding system for researchers and universities. The fifth chapter focuses on creating a virtuous circle so that human resources, capitals and knowledge can lead to large-scale innovation results. By fostering cooperation between businesses universities and public agencies - from an open innovation perspective - business opportunities can be developed by clustering and incubating innovative SMEs and startups. The environment suitable for innovation will also be created according to the plan by reforming the regulatory framework and standardizing and promoting the strategic use of IP assets. The IP system is recognized in the plan as a key asset in an ICT-centered economy that is intended to be driven by constant innovation and co-creation.

France – French Policy 4.0 " New Industrial France" (Industry du Future) was written at the order of the central government by the Ministry of economy, industry and digitalization and published in 2015. It is composed of a first section presenting the crucial elements and macro-objectives of the industrial strategy and a second operational section on industrial "solutions" i.e., key sectors and markets to invest in and develop. It has a more technical and concrete format than the previously analyzed 4.0 policies, characterizing itself as an operational strategic plan.

Table 11 - France policy 4.0 main elements

France	
Title	**New Industrial France (Industrie du Futur)**
Policy-makers	Ministry of economy, industry and digitalization
Structure	1) Industry of the future 2) Nine French industrial solutions
Key points	The project is built on 5 pillars: developing cutting-edge technologies, supporting enterprises in the process of adapting to the new paradigm, cross-training workers, strengthening European and international cooperation, and promoting the industry of the French future.

The subtitle of the French strategic plan already declares the desire to modernize the production base and support enterprises in using digital technologies to transform business models. The priority is to update the production base in a world where technology has brought the industrial and service worlds closer together. Based on this, the plan defines 5 key pillars: develop cutting-edge technologies (AR, IoT, Additive manufacturing) to achieve European and global leadership; help companies to adapt with incentives and training programs; launch of employee upskilling training and industry research programs; promoting the Industry of the Future strategy and raise awareness in business communities; at last, reinforce cooperation at international and European level (especially with Germany) to strengthen influence and support French companies by developing *ad hoc* projects. To ensure the governance of the plan, there is set up a nonprofit association "Alliance for the Industry of the Future", composed by the state (Minister of the Economy, Industry and the Digital Sector), the regions, the National Council for Industry and trade unions, and research, training and educational institutions. The second part of the plan outlines nine "solutions" to respond more directly to new market needs and gain a stronger international dimension. With financial support from the state, these solutions bring together the priorities of the overall program in a more efficient and agile manner ensuring broader participation of local stakeholders and ecosystems. The first solution is to invest in "New resources," reconverting raw materials to bio and recycled materials to develop more sustainable production processes. "Smart cities" is the second solution identified for efficient management of primary resources (energy and water) and improving the quality and sustainability of the construction sector. Connected to the second, the third solution "Eco-mobility" and the fourth "Tomorrow's transport" strive to develop safer, cheaper, greener and more enjoyable and attractive mobility for citizens and businesses. "Medicine of the future" seeks to bring digital transformation (through the use of digital devices and biotechnology) within the health sector to make it more effective and lower cost. Solutions 6, 7, and 8 ("Data economy," "Smart devices," and "Digital confidence") define actions to develop extensive and widespread data management to a) ensure an economic ecosystem based on data analytics at all levels, b) to facilitate access to and adoption of smart technologies in all sectors and services, and c) to strengthen trust in technology and digital devices by ensuring security systems. Lastly, the "Smart food choices" solution supports the digital development of the food sector as a priority for its international competitiveness by investing in health, safety and sustainability.

Italy – The Italian 4.0 policy is the "Industria 4.0 - Italy's national plan for industry”, it was drafted in 2016 by the Ministry of Economic Development. As in the French case, the policy has an operational format and consists of a series of automatic economic measures available to companies to embark on a path of development and innovation in the 4.0 direction. The contents are divided into two sections: Innovation and Competitiveness. Its strategic value is inherent in the government investment and in the nature and purpose of the industry-wide measure: to digitalize and invest in innovation. The plan aims to improve the competitiveness of enterprises in every part of their development cycle: supporting investment, improving worker productivity, digitalizing processes, and developing new products, processes and skills. To cope with a new phase of the economy characterized by the centrality of globalization and digital, the government and businesses must act in a coordinated way to take advantage of the Fourth Industrial Revolution.

The first section, dedicated to Innovation, includes 5 measures: "Hyper and Superdepreation," which offers incentives to companies that invest in tangible and intangible goods and assets for digital transformation; "Nuova Sabatini," a renewed form of state coverage of interest on bank loans aimed at upgrading the production and technology sector of companies; "Tax credit for Research & Development," to encourage private investment in all R&D-related activities (hiring, agreements with universities, research centers, SMEs and startups, laboratory tools, intellectual property rights, etc.); "Patent Box," a special system of subsidized taxation for the use of intellectual property rights and attract and bring back the protection of intangible assets to the country; "Innovative startups and SMEs," is a model of state incentives and guarantees for innovative enterprises at all stages of their development in order to support the development of an innovative ecosystem based on teamwork and opening to international markets. The section on Competitiveness includes 4 state measures: "Guarantee fund for SMEs," a guarantee for enterprises and professionals with difficulties in accessing bank loans; "ACE Allowance for corporate equity," to strengthen the equity structure of enterprises; "IRES (Corporate Income Tax), IRI (Enterprise Income Tax) and Cash accounting," a reduction of up to 24 percent in the tax burden on enterprises that invest their profits internally; and "Productivity Wages," introduction of tax reductions for enterprises that integrate company welfare, correlate productivity to efficiency to wage increases and promote worker participation in the organization. To encourage planned digitalization and investment processes, state measures do not require prior assessment and are applied automatically and even cumulatively to eligible enterprises.

Table 12 - Italy policy 4.0 main elements

	Italy
Title	**"Industria 4.0" Italy's national plan for industry**
Policy-makers	Ministry of Economic Development
Structure	1) Strategic measures: innovative investments (stimulate private investments in tech I4.0, increase private expenditures in R&D, support innovative startups) skills (education and research in I4.0) 2) Complementary measures: support to enabling infrastructures and guarantee innovative investments
Key points	Seize the main benefits of the industrial 4.0 model: flexibility, increased speed, increased productivity, increased quality and enhanced competitiveness. Act in consultation with all knowledge carriers, enhancing the key role of excellent research centers and universities in developing innovations.

Canada – In 2018, the Canadian 4.0 policy "The Innovation and Competitiveness Imperative - Seizing Opportunities for Growth" was released. It was the result of the joint work of federal ministries and Economic Strategy Tables sessions (see Canada § 3.7.1). Providing policy guidance at the federal level, the document maintains a general and broad nature and a long-term horizon. It consists of 4 parts: starting with general challenges, then declining strategy and initiatives, and finally opening to future prospects. The stated goal is to activate Canada's potential by making it more competitive and attractive to talent and investors. The sectors identified in the plan that represent fertile ground for the nation are: Agri-Food, Resources of the Future, Health and Biosciences, Digital Industries, Clean Technology and Advanced Manufacturing.

Table 13 - Canada policy 4.0 main elements

Canada	
Title	**The Innovation and Competitiveness Imperative – Seizing Opportunities for Growth**
Policy-makers	Federal Government of Canada; Canada's Economic Strategy Tables
Structure	1) Canada's Growth Challenge 2) Industry-Led Strategies for Growth 3) Six Signature Initiatives 4) Just the Beginning
Key points	The focus is on competitiveness. Activate its potential through investment in innovation, cross-sector adoption of technologies, and intensive collaboration between government and industry. Six actions are identified to focus on: Brand Canada, Own the Podium, Agile Regulation, Infrastructure, Technology adoption and Skills and talent.

The challenge is to support and improve the quality of life in society by creating new job opportunities and increasing Canada's competitiveness through collaboration between society, government and industry. A brief analysis of the critical points and weaknesses of Canadian society (decreasing GDP, older population, transformation of the labor market, difficulties in the health and pension system) is presented as a reason for having to plan and act on a long-term strategy for the development and modernization of the country. It is stated that the digitalization of the economy and the resulting expected economic growth are linked to the development of society and the need to achieve and protect greater diversity, equality and inclusion. Industry will be responsible for driving and implementing strategies for growth, and public institutions will need to ensure an appropriate environment for this (investment, modern regulatory system, coordination, training). To achieve this goal, six initiatives are planned: support the best-in-class industry players (Own the podium), establish an agile modern regulatory system to attract foreign investment and protect competitive advantage (Agile regulation), finance education and training and promote a culture of lifelong learning (Skills and talent), ensure and encourage the adoption of technology in industries and public services (Technology adoption), build a national infrastructure network that integrates physical and digital resources (Infrastructure), strengthening international reputation and image of

Canada (Brand Canada). To make these initiatives effective and concrete, maximum coordination and alignment of industry and government (federal and national) actions is encouraged and required in order to achieve the best outcome for Canadian society in the long run. The document's target is divided into two main interrelated elements: industrial competitiveness and economic growth for the development of a more equitable society that can ensure the well-being of canadian citizens.

- **Aggregate level**

This section is devoted to deepening the document analysis at the aggregate level, the intent is to compare the 4.0 policies of the G7 countries with each other to appreciate their similarities and differences (as shown in Table 14). Each document has a defined structure in chapters related to the strategic plans' objectives or actions and focuses on formulating the results to be achieved in order to upgrade the national industrial system and economic sector in the medium to long term. Despite this common approach, some specific aspects are considered for comparison (Teixeira & Tavares-Lehmann, 2022; Reischauer, 2018): nature, target audience, implementation approach, time frame and funding. The diversities and similarities, linked to the economic and political specificities of the 7 countries, show a heterogeneous way of approaching and embracing the Fourth Industrial Revolution.

The nature of documents can be of three types: programmatic, operational and mixed programmatic and operational simultaneously. A programmatic-type policy strategically defines the vision and mission of the strategic plan and the priorities and objectives to be achieved based on an analysis of the status quo, needs and deficiencies; programmatic policy may outline in a general way the concrete actions to be implemented but does not define budgets or financial commitments, deadlines or the metrics for measuring results, unlike operational policy. Operational policies, on the other hand, focus on defining concrete actions complete with technical, time and monetary details. A policy with a mixed nature, both programmatic and operational, combines and integrates the two styles. In the sample we find two policies of a purely programmatic nature-Germany and Japan-constructed to define an all-round long-term strategy of the economic and social development of the country of reference. In contrast, the Italian policy is purely operational in nature, focusing on detailing tools and measures for the introduction and adoption of a 4.0 model in the national economic scenario. As for France, Canada, the UK and the US, the nature of their policies is hybrid: in addition to delving into analysis, strategies and objectives it also reports numerical data of planned investments, expected results, deadlines and tools for measuring results.

Table 7 - Comparison of 4.0 policies in G7 countries

	Nature	**Target audience**	**Implementation approach**	**Time frame**	**Funding**
CA	Mixed	Business Society	Hybrid	n.d.	Mixed
FR	Mixed	Business Society	Top-down	2015-2020	Public
DE	Programmatic	Business Academia Society	Hybrid	n.d.	n.d.
IT	Operational	Business	Hybrid	2016-2020	Public
JP	Programmatic	Business Academia Society	Top-down	2015-2020	n.d.
UK	Mixed	Business Academia	Hybrid	2015-2021	Public
US	Mixed	Business Academia	Hybrid	n.d.	Mixed

The second category of analysis is the target audience, which is the audience to which the policy refers as the intended public. The three target audiences usually identified for public policy are: business sector (industries, SMEs, large companies, etc.), academia and universities and civil society. Again, Germany and Japan share a similar direction: they address all three target audiences within their documents. The Italian 4.0 policy having an operational nature addresses only the business community. Lastly, while on the one hand France and Canada primarily target the business world and civil society, the UK and US take a pragmatic approach by addressing the direct agents of digital change, business and academia.

The third category concerns the implementation approach envisaged by 4.0 policy: top-down (imposed), bottom-up (voluntary) and hybrid. Here, except for France and Japan, which have planned primarily state implementation, the other 5 states have integrated bottom-up and top-down forms by providing a hybrid approach to their strategic plans. The time frame for application and implementation is not defined in the policies of Canada, Germany and USA. In the other countries, the common time horizon for applying actions and measures and measuring targets has been set to 2020, although some outcomes are expected up to 2030. The time horizon is on average 4/5 years, which is congenial for the application of a large-scale industrial strategy. The last category of comparative document analysis is the funding approach: public, private or mixed. Here Japan and Germany, with policies of a programmatic nature, do not state commitments in financial terms and leave the funding of the strategy unspecified in the document. UK, Italy and France have indicated within the 4.0 policies public funds (state and regional) to finance the measures and planned investments. In contrast, USA and Canada plan a mixed approach, public (federal and state) and private, in financing their strategic plans.

3.7.4 *Content analysis of 4.0 policies in G7 countries*

This second section reports the results of the content analysis done on the selected 4.0 policies. NVivo 20, a software for analyzing qualitative or unstructured data, was chosen for this analysis. The goal is to understand which themes and topics were the most discussed within policies 4.0 through the analysis of the most mentioned words. This section is divided into two parts: the first focuses on an analysis at the national level by reporting the most used words in each individual policy; the second focuses on the aggregate level by reporting and exploring a general wordcloud of the most used words in 4.0 policies.

- **National level**

Through illustrative tables 15 through 21, this section illustrates the 10 most frequently encountered words within the 4.0 polies for each nation. The stemmed words approach chosen in the NVivo setting included all similar words under one term, while also counting variants and synonyms (visible in the Similar word column of the tables). All irrelevant words were excluded: articles, conjunctions, prepositions, etc. For each term, the tables show the total count of the number of uses and the weight as a percentage of the total number of words. Each table provides an insight into the priorities of the corresponding policy and gives an idea of the main relevant issues. Accompanying the results of the document analysis, content focuses on vocabulary choices and language setting. To give an example in the case of Italian 4.0 policy, the most frequently used words are mostly technical terms such as tax, asset, benefit, income or depreciation. It is necessary to keep in mind when reading the results that the 4.0 policies analyzed have very different lengths and graphic settings. For example, while the Canadian 4.0 policy has only 24 pages but a considerable amount of text, in contrast, the French 4.0 policy consists of 58 pages where the text is very minimal and the graphics preponderant. These differences affected the frequency and percentage weight of words identified by the software. The words reflect the individual nature and purposes illustrated in the document analysis: Canada focuses on national competitiveness and global positioning (see Table 15); France on the future industrial developments of the various sectors (see Table 16); Germany aims at the integration of technology in the development of industry and production systems (see Table 17); the Italian policy focuses on financial and fiscal measures to encourage investment and industrial upgrading in the 4.0 perspective (see Table 18); the Japanese plan aims at social and national development based on the development of research and innovation (see Table 19); the UK looks at investment in science and research as tools for technological business innovation (see Table 20); and, finally, the U.S. policy focuses on investment planning and programs (at the federal level) for the technological advancement of the national manufacturing sector (see Table 21).

Table 8 - 10 most frequent words in Canada 4.0 policy

CA	Word	Count	Weighted %	Similar Words
1	innovators	100	1,44%	innovate, innovation, innovations, innovative, innovators
2	growth	91	1,31%	growth
3	global	76	1,10%	global, globally
4	competitiveness	72	1,04%	competition, competitive, competitiveness
5	need	69	0,99%	need, needed, needs
6	economic	66	0,95%	economy
7	technology	61	0,88%	technological, technologically, technologies, technology
8	opportunities	61	0,88%	opportunities, opportunity

9	sectors	61	0,88%	sector, sectoral, sectors, sectors'
10	firms	51	0,74%	firm, firms

Table 9 - 10 most frequent words in France 4.0 policy

FR	Word	Count	Weighted %	Similar Words
1	industry	150	2,90%	industrial, industries, industry
2	future	76	1,47%	future
3	new	66	1,28%	new
4	project	59	1,14%	project, projects
5	develop	49	0,95%	develop, developed, developing, development, developments
6	digital	48	0,93%	digital, digitization
7	technology	46	0,89%	technological, technologies, technology
8	markets	44	0,85%	market, marketing, markets
9	solutions	43	0,83%	solution, solutions
10	launch	41	0,79%	launch, launched, launching

Table 10 - 10 most frequent words in Germany 4.0 policy

DE	Word	Count	Weighted %	Similar Words
1	industry	527	2,43%	industrial, industrie, industries, industry
2	manufacturing	325	1,50%	manufacture, manufactured, manufacturer, manufacturers
3	production	238	1,10%	product, production, productive, productively, productivity, products
4	systems	199	0,92%	system, systemic, systems, systems'
5	technology	163	0,75%	technological, technologically, technologies, technology
6	working	160	0,74%	work, worked, working, works
7	development	148	0,68%	develop, developed, developers, developing, development, developments, develops
8	security	141	0,65%	secure, securing, security
9	processes	140	0,64%	process, processed, processes, processing
10	engineers	137	0,63%	engineer, engineering, engineers, engineers'

Table 11 - 10 most frequent words in Italy 4.0 policy

IT	Word	Count	Weighted %	Similar Words
1	tax	45	1,76%	tax, taxes, taxing
2	asset	45	1,76%	asset, assets

3	benefit	42	1,64%	benefit, benefiting, benefits
4	companies	35	1,37%	companies, companies', company
5	income	35	1,37%	income, incomes
6	investments	34	1,33%	invest, investing, investment, investments
7	depreciation	31	1,21%	depreciation
8	enterprises	28	1,10%	enterprise, enterprises
9	development	27	1,06%	development
10	business	25	0,98%	business, businesses

Table 12 - 10 most frequent words in Japan 4.0 policy

JP	Word	Count	Weighted %	Similar Words
1	technology	140	2,57%	technological, technologies, technology
2	society	92	1,69%	society
3	systems	70	1,28%	system, systemic, systems
4	science	67	1,23%	science, sciences
5	development	61	1,12%	develop, develope, developed, developing, development, developments
6	japan	59	1,08%	japanese
7	new	55	1,01%	new
8	promotion	53	0,97%	promote, promoted, promoting, promotion
9	innovative	53	0,97%	innovate, innovation, innovations, innovative
10	research	51	0,94%	research, researchers

Table 13 - 10 most frequent words in UK 4.0 policy

UK	Word	Count	Weighted %	Similar Words
1	research	290	1,67%	research, researchers
2	innovation	236	1,36%	innovate, innovation, innovations, innovation', innovative, innovators
3	science	214	1,24%	science, sciences, science'
4	business	162	0,94%	business, businesses
5	support	160	0,92%	support, supported, supporting, supportive, supports
6	funds	158	0,91%	fund, funded, funding, funds
7	investments	138	0,80%	invest, invested, investing, investment, investments
8	new	132	0,76%	new
9	development	123	0,71%	develop, developed, developers, developing, development, developments
10	technology	106	0,61%	technological, technologies, technology

Table 14 - 10 most frequent words in USA 4.0 policy

US	Word	Count	Weighted %	Similar Words
1	manufacturing	406	4,14%	manufacturable, manufacture, manufactured, manufacturers, manufacturing
2	advanced	277	2,83%	advance, advanced, advancements, advances, advancing
3	technology	169	1,73%	technological, technologies, technology
4	investments	134	1,37%	invest, invested, investing, investment, investments, invests
5	national	124	1,27%	nation, national, nationally, nations
6	federal	122	1,25%	federal, federally
7	industry	119	1,21%	industrial, industrialized, industries, industry
8	products	105	1,07%	product, production, productive, productivity, products
9	development	99	1,01%	develop, developed, developing, development, developments, develops
10	programs	87	0,89%	program, programs

- **Aggregate level**

The analysis at the aggregate level-as already mentioned-is composed of a wordcloud created with NVivo with the most frequent words among all policies 4.0 in the G7 countries. The wordcloud (see Image 1) shows in a central position and of a larger size the most frequently used words, as the words are found to be less present, they move outward with a smaller size. It is possible to observe that the three words with the highest absolute presence in the 7 policies are *manufacturing*, *industry* and technology. After these three, we see other key words emerge: *innovators*, *research*, *development*, *products*, *science* and *investments*. These words confirm the common goal and tools defined by the 4.0 policies of the G7 countries. Other shared terms also deserve reflection: *competitiveness*, *services*, *opportunities*, *network*, *educational*, *globally* and *challenges*. These words confirm a strategic direction focused on (a) increasing the competitiveness of the production and services system at the national level, (b) creating shared systems of education and partnerships, and (c) a vision of national development responsive to the challenges of the present and the globalized system in which countries nowadays operate.

Image 1 - Wordcloud of most frequent terms in 4.0 policies

3.7.5 *The role of intellectual property in G7 countries' policies 4.0*

This section offers a focus on intellectual property and its relative weight within the selected 4.0 policies for each G7 country. The methodology of content analysis using NVivo 20 software was again used. The difference is that in this case the search within the documents was done through the construction of an *ad hoc* vocabulary inherent to the topic of intellectual property. A targeted search for specific terms within a document provides insight into the presence and frequency of a particular theme within a text. Initially, a review was conducted of the scientific literature present on papers that used the same methodology with similar purposes (search and analysis of specific issues in documents and qualitative data). The results of this review were then restricted to papers that provided specific and already tested vocabularies of keywords suitable for the current research objective. In this way, the most effective vocabularies for content analysis reffered to IP and related topics were selected (see Table 22).

Table 15 - Literature review of IP and innovation keywords used

Paper	Keywords
Candelin-Palmqvist, H., Sandberg, B., & Mylly, U. M. (2012)	Intellectual property, Intellectual property right, IP, IPR, patent, industrial design, trademark, copyright.
Gök, A., Waterworth, A., & Shapira, P. (2015)	research & development, research and development, r&d, researcher, product development, technology development, technical development, development phase, development program, development process, development project, development cent, development facility, technological development, development effort, development cycle, development research, development activity, fundamental research, basic research
Héroux-Vaillancourt, M., Beaudry, C., & Rietsch, C. (2020)	patent, intellectual property, trade secret, industrial design, affiliation, collaboration, cooperation, partners, partnership, consorti, international consorti, global consorti
Wang, Y., Yang, N., Wang, Y., & Guo, M. (2021)	Innovation, Networks, Performance, Knowledge, Research and development, Product innovation, Empirical evidence, Impact, Dynamics, Open innovation

Table 16 - Keywords selected for thematic clusters

Themes	Keywords
R&D	research & development, research and development, r&d, product development, technology development, technical development, development research
Intellectual property	Intellectual property, Intellectual property right, IP, IPR, patent, industrial design, trademark, copyright, trade secret, intellectual property protection, intellectual properties exploitation
Innovation system	Innovation, innovation system, Knowledge, Open innovation, cooperation, collaboration, networks, innovation network

After a careful study of the keywords provided by scholars, a vocabulary was constructed for the deeper investigation of intellectual property in 4.0 policies. In order to be as inclusive and comprehensive as possible in the research and analysis in the text, the vocabulary was constructed by accompanying the words strictly related to intellectual property with the terms also relevant to the topics, such as research and development in science and industry and business innovation. This choice was made considering the main emerging issues related to the universe of the fourth industrial revolution and I4.0 and the complexity and heterogeneity of approaches in policies seen in the previous paragraphs (3.7.3 and 3.7.4). Therefore, the vocabulary developed for this analysis consists of three clusters of keywords related to the thematic categories of R&D, intellectual property and innovation system, as presented in Table 23.

The three keyword clusters created were submitted within the NVivo software for a search within the 4.0 policies of each of the G7 countries. The calculation of the frequency of each keyword cluster in the documents was reported in Table 24. By comparing the results by country, several observations can be made. The keyword cluster related to innovation system has many more terms than those related to IP and R&D. This result reflects what has already been found with the content analysis at the aggregate level: a greater focus of policies on the innovation creation and development system. UK ranks first for both Innovation system keywords and IP keywords: the sections in the English 4.0 policy dedicated to the knowledge creation and exploitation and the catalyzing of innovation show the priority nature of these issues for the English strategy. France, Canada, and the U.S. have the lowest number of appearances for IP keywords. This is due to the nature of the policies being more focused on creating programs, organizing investments and developing strategic markets; the absence or low presence of these keywords indicate a lack of interest in inserting specific strategies for IP in policies 4.0. This does not determine either positively or negatively what kind of vision and role IP plays in the 4.0 context in France and Canada. Future research is entrusted with the task of looking into application programs, measures and specific investments as these two countries addressed protecting and exploiting the rights to the products of innovation. Germany, Italy and Japan stand at a similar number of IP keywords; in fact, all three have dedicated specific parts within their policies. This demonstrates the three countries' recognition of a strategic role of intellectual property in the 4.0 transformation journey: IP is seen as a tool to protect and safeguard a competitive advantage in the technology landscape and knowledge economy.

Table 17 - Frequency of cluster keywords in policy documents

Country	R&D keywords	IP keywords	Innovation system keywords	
Canada	8	1	123	*132*
France	7	0	50	*57*
Germany	35	14	237	*286*
Italy	20	19	28	*67*
Japan	52	15	131	*198*
UK	66	43	392	*501*
USA	82	5	94	*181*

As in the case of the IP word cluster and for similar reasons, there are few references to words related to research and development activities in the Canadian and French 4.0 policies. The number of terms goes up in the case of Germany and Italy, which refer to research and development as the main drivers of business and technological innovation. Research activity is also prodromal to the registration and exploitation of intellectual property, and therefore a strategic activity to be defended in the 4.0 universe: this is highlighted in the Japanese, Italian and English policies. Both UK and Japan count a higher number of words related to R&D right after the US, which ranks first. In the U.S. policy an entire strategic objective (Objective 5) is devoted to funding and strengthening for R&D (both public and private) for manufacturing development and increasing national competitiveness. The last word cluster is related to innovation system and contains words about cooperation and shared knowledge creation and production systems. The Italian policy and the French policy report the lowest numbers for this cluster: the former has a very technical character and is not explicit about organizational and collaborative strategies for the creation of an innovation system; the latter maintains a more general profile and is limited to defining solutions and sectors to be strengthened. USA, Japan and Canada record similar numbers for innovation system wordcluster, all three encouraging collaborative change management and knowledge creation. Germany ranks second, emphasizing that an effective approach to innovation must arise primarily from the cooperation of actors with different responsibilities, skills and needs. Lastly, UK, first among all by number, also distances Germany by a wide margin with a massive presence of words from this group. As seen above, the UK 4.0 policy devotes three chapters to the topic (Investing in scientific infrastructure; Supporting research;

Catalysing innovation), confirming the strategic priority of establishing and growing the innovation ecosystem to increase the country's technological and industrial competitive power.

3.8 Conclusion

The initial objective of this study was to understand the development of 4.0 policies in the introduction of the Fourth Industrial Revolution at the national level. The undisputed usefulness of policies in the introduction of radical economic and technological transformations (§ 3.3. and § 3.4.) confirms the relevance of the policy examination during the change path driven by the introduction of the 4.0 model. Technological change and the socio-economic challenges of the 21st century have called for a new way of thinking about the manufacturing and industrial sector, entrusting them with a new role in society. Tech-based advanced manufacturing does not only increase business competitiveness but reflects an overall change in the way nations look to the future. The G7 countries, the chosen analysis sample, are a collection of highly industrialised and developed countries that periodically update their economic and social goals and strategies. The policies issued by the central bodies in the national context over the past 15 years clearly reflect the awareness of the structural change required by the 4IR.

This paper set three research objectives: to identify the main 4.0 policies in the G7 countries (RQ 1), to establish what are the main elements and themes contained in the identified strategic policies (RQ 2) and what space and importance intellectual property has within them (RQ 3). By analysing the history and strategic stages, it was possible to indicate a policy inherent to the Fourth Revolution universe for each of the G7 group states. In order to deepen their structure and answer research questions RQ 2 and RQ 3, a document and content analysis was conducted. Following the analysis of the results, common underlying strategic lines and traits can be recognized: a medium to long term perspective, a strong incentive for innovation, technology as a tool for entrepreneurial and social development, and industrial transformation as an engine for national growth. Despite a common vision, differences in the approach and structure of the G7 policies were also highlighted: focus, target audiences, priorities, implementation, time frame, funding. In this way, it was possible to appreciate the different ways of approaching 4.0

innovation among nations with coordinated and related economic and political systems. Going deeper, in line with the objective of this thesis, further investigation was devoted to the role and space dedicated in 4.0 policies to intellectual property and its creation, protection and exploitation process in strategic terms. In this perspective, intellectual property is only one element of a complex innovation system based on process integration and multi-level cooperation. Its role depends on the strategic priorities and the approach chosen by policy makers in each case, but there is an undisputed view of IP as a strategic tool for protecting innovation-based competitive advantage. Despite this, it is not a primary element to be developed for all countries in the process of deploying the industrial 4.0 model.

The paper offers several contributions in terms of scientific literature. Firstly, an initial analysis of the 4.0 policies of the G7 countries is presented, which is not yet available in the literature. Thus, a first overview is given at a global level (on three continents) of countries aligned with each other historically and economically. Moreover, Canada, given its federal nature with extensive regional autonomy in economic aspects, had never before been the subject of analysis for its 4.0 policies. The study contributes both to broadening the literature on the analysis of national STI policies with strategic significance and to deepening the topic of intellectual property in STI policies. Intellectual property is usually most studied as a performance evaluation measure and as an intellectual capital asset of companies. The analysis of strategic value within national 4.0 policies is a further contribution to expanding the literature on the topic.

The study is not without its limitations, of course. Qualitative methodology is certainly a valid tool to approach complex qualitative data such as policy texts. Despite this, it must be emphasized that content analysis and document analysis have several structural limits in the rendering and interpretation of the results that have already been discussed in § 3.6. Regarding future research, it is suggested to integrate a quantitative methodological approach to guarantee a more comprehensive comparison of 4.0 policies. In this way, an analysis of planned investments and an evaluation of the effectiveness of the measures in the policies could be provided. The impact and effectiveness of 4.0 policies in national economies would deserve specific studies and research from a wide-scale qualitative-quantitative point of view. Another critical element concerns the target of the analysis: the chosen sample - although strategically aligned - is limited both numerically and politically speaking (consisting of seven democracies). Broadening the focus of the analysis to more heterogeneous groups of nations with more diversified economies would be beneficial. Studies in this direction could allow a greater understanding of the phenomenon of STI policies in the 4.0 landscape and a broader comparison of the new role of IP in this scenario.

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4 Paper 3 – "In.Ac.Re. Innovation System 4.0" assessment model. An evaluation of Tuscan firms' approach to innovation for Industry 4.0

4.1 Abstract

With the deployment of the Industrial 4.0 model, companies have embarked on a long and challenging journey of transition and change. To track and monitor progress in the change process, assessment models are an important and effective tool. The scientific (and non-scientific) literature has devoted several contributions to the construction of 4.0 maturity models, either general on readiness or vertical on specific topics. However, to this date, an assessment model for the innovation system 4.0 is still missing. Innovation is a central factor in the strategy defined by worldwide national 4.0 strategic policies; those require companies to develop various elements to generate an innovative system (training, R&D, patenting, etc). This study provides, for scholars and companies, a first assessment model of the innovation system 4.0 based on the measurement of three dimensions (Investments, Activities and Relations). Using the multiple case study methodology, the assessment model developed was tested on a sample of 30 companies active in Tuscany region in Italy. The analysis of the implementation of the integrated innovation system 4.0 and its constituent factors represents an original contribution to the literature on 4.0 assessment models and a first step towards the definition of a framework on innovation in the context of the Fourth Industrial Revolution.

4.2 Introduction

The spread of the Fourth Industrial Revolution (4IR) is leading companies on a challenging transformation path. The industrial 4.0 model requires the adoption of advanced technologies (adaptive robotics, AI, AR, big data analytics, cloud, IoT, etc.) in production and management processes and the consequent adaptation of the entire business system. Transition 4.0 does not only imply an adaptation to a more efficient industrial system but a total paradigm shift (Flamini & Naldi, 2022). As national 4.0 policies have largely indicated, the goal of 4IR is set much higher than a manufacturing transformation, it addresses the great social, sustainable and economic challenges of the present - such as the demographic crisis, resource scarcity, globalisation, climate emergency - (Prause & Weigand, 2016; de Groot & Franses, 2009). Only through this process of transformation - which cannot be avoided by businesses that must contribute - is it possible to trigger a radical holistic change that pushes in the direction of progress and greater sustainability (Rayna & Striukova, 2016).

The change journey is not easy to follow and organisations can often struggle to understand their level of progress. This has resulted in the need to develop specific assessment models to help organisations understand their stage of adoption and development in the 4.0 transition journey (Schwab, 2017; Proença & Borbinha, 2016; Becker et al., 2009). Since the 1970s, assessment models have been a management tool that can accompany companies on the transformation path and in achieving their goals in the short and long term (Pöppelbuß & Röglinger, 2011). Several models have been developed to provide companies with an assessment tool for the process of adoption and maturity in relation to the Industrial 4.0 model. The 4.0 assessment models developed in the literature have investigated both entire geographical contexts and the individual company; in some cases with a general approach to readiness to the Industry 4.0 model, in other cases with a specific focus on certain elements of the model (advanced technologies adoption, supply chain management, circular economy, etc.).

However, despite the proliferation of Industry 4.0 assessment models, specific assessment to the element of innovation in the context of the Fourth Industrial Revolution is absent. Innovation capacity, as already seen in Paper no. 2, plays a central role within this new scenario of change (Nowacki & Monk, 2020). In the 4.0 context, innovation contributes both to enhance competitiveness and to improve the market positioning of companies. The Triple Helix innovation paradigm is confirmed in national strategic policies for the introduction of the I4.0 industrial model (Temple et al., 2019). In fact, 4.0 policies promote the growth of companies and the economic system through the creation of knowledge and the development of ideas in a cooperative manner between business, academia and government (Matulova et al., 2018). The innovation dimension acts as a glue between several central factors that enable the adoption and development of Industry 4.0 such as investments, training, R&D, patenting, etc. (Czvetkó et al., 2021). In this sense, it is possible to consider innovation in the 4.0 context as a system of independent but interconnected and mutually influenced elements. With this paradigm of reading and interpreting innovation for Industry 4.0, it is possible to analyse dynamics and strategies implemented by companies. In this sense, assessing the innovative capacity of companies in the 4.0 scenario is an interesting yet unexplored topic of investigation. This research aims to cover this gap in the literature and produce a first assessment model of the innovation system within the context of Industry 4.0.

This study is divided into 5 sections: section 4.3 provides a review of the scientific and non-scientific literature on the main assessment and maturity models produced for Industry 4.0, with a focus on innovation issues; section 4.4 illustrates the assessment model built to measure the degree of implementation of the innovation system 4. 0 in businesses, its dimensions and the method of deployment; section 4.5 explains the chosen methodology and illustrates the selected sample of businesses; section 4.6 illustrates the results obtained from the testing of the assessment model in the sample of businesses; finally, section 4.7 illustrates the conclusions of the research.

4.3 Evaluation and assessment models for Industry 4.0

From the very beginning, Industry 4.0 has attracted considerable attention in the scientific and non-scientific literature about the topics of measurement and evaluation. An industrial revolution based on the integration of specific processes and technologies requires maximum attention from companies and practitioners in the field of application. The process of change and adaptation to the new industrial model, both at the individual company level and at the systemic level, is not immediate. Scholars and experts have immediately attempted to develop tools capable of measuring and reporting the level of maturity achieved by companies with regard to Industry 4.0. There are already contributions in the scientific literature dedicated to reviewing all the assessment and maturity models formulated over the last decade (Flamini & Naldi, 2022; Hajoary, 2020; Simetinger & Zhang, 2020). This paper will not devote itself to expanding and supplementing the reviews of the literature already present; it will merely acknowledge some of the most widely adopted models and highlight the breadth of scientific contributions on the topic, in terms of both approaches and themes. In this section, therefore, the content and focus of the literature on maturity and evaluation models created to measure the performance of companies in the 4.0 environment will be briefly discussed.

Table 1 - Most frequently used assessment/maturity models for Industry 4.0.

Assessment model 4.0	Year	Authors
IMPULS Industrie 4.0 Readiness Model	2015	VDMA association
SIMMI 4.0	2016	Leyh, C.; Schäffer, T.; Bley, K.; Forstenhäusler, S.
PwC Maturity Model Industry	2016	PwC
Industry 4.0 Maturity Model	2016	Schumacher, A.; Erol, S.; Sihn, W.
Industrie 4.0 Maturity Index	2017	ACATECH
Singapore Smart Industry Readiness Index	2017	Singapore Economic Development Board
Smartness Assessment Framework for Smart Factories	2017	Lee, J.; Jun, S.; Chang, T.W.; Park, J.
Maturity and Readiness Model for Industry 4.0	2018	Akdil, K.Y.; Ustundag, A.; Cevikcan, E.
Smart SME Technology Readiness Assessment (SSTRA)	2021	Saad, S.M.; Bahadori, R.; Jafarnejad, H.
I4.0 Maturity Assessment Framework	2021	Scremin, L.; Armellini, F.; Brun, A.; Solar-Pelletier, L.; Beaudry, C.

Table 1 shows the most frequently used assessment models in the scientific literature (Flamini & Naldi, 2022). This includes not only scientific publications but also models developed by public bodies, industry associations, private research organisations and consulting firms that have also been widely used in the academic world: IMPULS Industrie 4. 0 Readiness Model from the VDMA association (the association representing the German mechanical engineering industries), PwC Maturity Model Industry from the consultancy firm of the eponymous name, Industrie 4.0 Maturity Index from acatech (the German Academy of Science and Engineering, which took part in the process of creating the 4.0 model) and Singapore Smart Industry Readiness Index developed by the Singapore Economic Development Board of the central government. Regardless of the authors, all 10 models aim to measure the readiness or maturity level of companies about the 4.0 model. Considering the length of the publication time span (2015 to 2021), it is possible to state how building assessment frameworks has persistently remained a need over time. Although more frequently used, the models in Table 1 are not the only ones developed.

The maturity model 4.0 approach can be found in numerous publications: Ávila & Gil Herrera, 2022 (with a focus on SMEs); Dantas & Barbalho, 2021; Wagire et al., 2021;

Santos & Martinho, 2020; Rafael et al., 2020 Sassanelli et al., 2020; Bibby & Dehe, 2018; Sjödin et al., 2018; Ganzarain & Errasti, 2016. The same happens with models for assessing the readiness of firms, measured both in general (Tripathi & Gupta, 2021) and with specific insights. As is the case in the publication by Shqair & Altarazi (2022), which define 4 criteria - readiness, maturity, drivers and barriers - for the assessment of Jordanian SMEs; and in the assessment study developed uniquely for oil and gas companies (Beisekenov et al., 2022).

Another frequent topic in measurement models for 4.0 is undoubtedly the technology sphere: inclination, adoption, implementation, adaptation and security. In 2019, Adres et al. developed IMAM (Industrial Maturity for Advanced Manufacturing) to assess the degree of maturity and ability of companies in the implementation of advanced manufacturing technologies and their adaptation to business processes. The same model was then also used by Zonnenshain (et al., 2020). Two years later, another model was defined to measure the degree of implementation of 4.0 technologies with a case study on the Spanish region of Murcia (Gonzalez et al., 2021). Another case study was proposed in 2022 by Hrbić and Grebenar on the estimation of the inclination of companies in Croatia towards 4.0 technology, with an in-depth examination of the advantages, risks and limitations associated with the technological leap. The topic of 4.0 security for SMEs has also been the subject of other publications, see the study on identifying risks related to the adoption of Industry 4.0 for SMEs (Snieška et al., 2020) and the cybersecurity assessment model (Emer et al., 2021). The measurement of the maturity and readiness of companies in technology implementation and problem management is also complemented by assessment models focusing on the operational side of operations and the supply chain. With this aim, the evaluation models of Asdecker and Felch (2018), Caiado (2021), and Alamsjah and Yunus (2022) were developed.

The measurement of maturity in the 4.0 universe in the literature has also addressed the topics of quality (Glogovac et al., 2022) and sustainability of technologies and their impact on business management (Bai et al., 2020). Sustainability and the impact of production processes have considerable relevance within the Fourth Industrial Revolution. Therefore, the emergence of evaluation models with a specific focus in this direction is consistent with the general approach of the 4.0 model. This may be observed in the contribution of the three-level self-assessment model - beginner, ongoing and performing - of the integration between Circular Economy and Industry 4.0 (Belhadi, et

al., 2022) and the SCSC (Smart Circular Supply Chain) model on the integration between supply chain, circular economy and I4.0 (Kayikci et al., 2022).
Finally, the assessment model 4.0 also addressed the transformation path the companies were on. Scremin (2018) developed an assessment framework to understand the change process of companies adopting the 4.0 model by submitting it to 10 companies in Canada and Australia. Delving further, capabilities and competencies are important elements to be developed in order to lead and manage the 4.0 transformation process. Some academic contributions are focusing on the construction of assessment models for competencies (Dzwigol et al., 2020) and capabilities (Gökalp & Martinez, 2022; Lookman et al., 2022; Lin et al., 2020) necessary for smart manufacturing.

4.3.1 *Innovation assessment model in Industry 4.0*

In this paper, the literature review of assessment models for Industry 4.0 was pushed to a deeper level with the search for innovation-related elements. The creation of innovations, their exploitation and protection plays a key role in the model built by Industry 4.0. Investing, promoting and developing an innovative environment in companies is a fundamental precept of all national policies examined in the second paper of this thesis and, previously, found in the literature of the first paper. Research and development, cooperation between companies, universities and society, production and protection of intellectual property, realization and participation in creative and innovative networks are frequent and essential aspects of the economic model outlined in the Fourth Industrial Revolution. Being able to develop a strategy in this regard and build processes to create innovations and exploit and protect them through appropriate tools are fundamental precepts for the 4.0 enterprise. Therefore, measuring the degree of maturity and assessing how companies are doing in defining and applying a 4.0 innovation model is crucial. It is the task of scholars to develop appropriate assessment frameworks that are targeted or integrated into overall assessments of the degree of maturity of companies in the 4.0 transformation. As analysed, there is no vertical framework on the topic in the literature, but references are made within multidimensional and general frameworks. These contributions are briefly analysed in this section, starting with the assessment models in Table 1.

The IMPULS Industrie 4.0 Readiness Model, published in 2015 by the German VDMA association, offers an assessment of six degrees of enterprise maturity (from 0 outsiders to 5 top performers) based on six dimensions to be measured. One of these is dedicated to Strategy and Organisation and related to innovation in the enterprise: the ability to integrate innovative strategy and structural organisational change in a 4.0 perspective. To measure this dimension, criteria relating to the ability to invest internally and manage innovation are taken into account.
The SIMMI 4.0 maturity model (Leyh et al., 2016) was built on the measurement of four dimensions (Vertical integration, Horizontal integration, Digital product development and Cross-sectional technology criteria) to define five stages of development. The first category refers to creating and integrating an internally integrated communication system to connect the different business areas and with a two-way exchange of information. Horizontal integration, on the other hand, is the dimension related to the creation of and collaboration with different value networks to foster cooperation at the information and process coordination level.
The PwC Maturity Model Industry of 2016 defines an assessment matrix for companies with four development levels and seven dimensions. The dimension 'Digitisation and integration of vertical and horizontal value chains' connects to the topics of participatory innovation and the building of cooperation networks with external partners, as well as internal investment in the harmonisation of processes and internal communication. Other elements also emerge in the dimension 'Organisation, employees and digital culture': internal collaboration as a value and a culture of sharing between employees.
In the Industry 4.0 Maturity Model (Schumacher et al., 2016), nine dimensions are evaluated and innovation 4.0 is mentioned in: Operations (interdepartmental collaboration, interdisciplinary), Culture (open-innovation, cross-company collaboration, knowledge sharing), People (competencies and capabilities), Governance (protection of intellectual property).
Also, in the following Industrie 4.0 Maturity Index, developed by acatech in 2017, there are some hints referring to the 4.0 innovation ecosystem. In constructing an indicator for measuring the maturity level of 4.0 companies, acatech set six value-based 4.0 development stages based on four 4.0 capabilities categories (Resources, Information Systems, Organisational Structure and Culture). Among the essential capabilities related to “Resources" identified by the Index, the digital capabilities mention the need to defend strategic information for the enterprise through the use of the intellectual property.

Furthermore, there are also references to the creation and production phase of innovations in the section on "Organisational structure": constant and participative cooperation with the value network is recommended in order to integrate competencies and be able to generate new products and processes. The Industrie 4.0 Maturity Index confirms the importance of building an innovation system for the company. In this model, in fact, elements relating to the measurement of the 'innovation' dimension linked to the Industrie 4.0 model are visible in a dual dimension: the production and sharing of knowledge through the construction of a value-network and the protection of strategic competitive advantage through the use of intellectual property.
The indicator developed by the Singapore government in 2017 hinges on three macro-areas: Process, Technology and Organisation. Regarding innovation topics, the former contains references to both vertical integration for process coordination and horizontal integration for supply chain collaboration; while the latter area assesses the development and training of human capital internally and, externally, cooperation with other companies.
The Maturity and Readiness Model for Industry 4.0 (Akdil et al., 2018) inserts several 'innovative' criteria to be measured in companies: in the dimension 'Smart business processes' among 'Smart Productions and Operations' are R&D and product development; among 'Supportive Operations' human resources development; and in the dimension 'Strategy and Organisation' there are references to investment in technology and development of strategic partnerships.
The I4.0 Maturity Assessment Framework (Scremin et al., 2018) is structured on three axes: strategy, maturity and performance. Among these it is possible to recognise some elements related to the innovation system of Industry 4.0. At the strategic level, the model includes as a central factor the measurement of the ability to network and integrate knowledge and skills ("Networking and Integration Indicator"). Maturity, on the other hand, includes the training system and knowledge management system ('Absorptive Capacity Indicator') among the factors to be assessed. Also in this model, the creation and enhancement of competencies, the management of new knowledge capabilities and the definition of networking strategies are intrinsically linked to the implementation and functioning of the industrial 4.0 model.

Beyond the most widely used and well-known models for assessing the maturity of the 4.0 model in companies, other references to measuring the 4.0 innovation dimension were searched for in other scientific publications. Firstly, Biegler's (2018) Factory of the Future assessment model of the level of adoption and implementation was found. The assessment model is based on a system of mixed qualitative and quantitative KPIs aimed at examining different aspects. In particular, among the transversal critical success factors in the industrial 4.0 context taken into account, some are particularly relevant to the IP and innovation landscape for the Factory of the Future: a) CSF 3 - Capacity for innovation, capabilities and competences regarding R&D activities; and, b) CSF 4 - Ecosystems support for innovation, on the creation of a fertile environment for digitisation through networks, collaborations with external firms, research institutes and universities.

The ASME Model proposed by Oztemel & Ozel (2021) for the evaluation of SMEs within the contemporary 4.0 context is another example of an assessment model that integrates elements of the 4.0 innovation system. It consists of five components to be assessed: Technological competency, Financial competency, R&D and innovation competency, Strategic competency, Intellectual competency. The objective is to measure the level of competency in each of these aspects in order to be able to define the overall status of the analysed enterprise according to six Competency Levels based on a score range from 0 to 100. The final level is obtained from a sum of the scores obtained in each of the five competence areas according to their weight values. It is necessary to dwell on the two components of interest in this study: 'Intellectual competency' and 'R&D and innovation competency'. The first takes into account the aspects concerning knowledge management and utilisation: Information management, Education level, Career management, Process and improvement, and Generation of new ideas. On the other hand, 'R&D and innovation competency' relates to the issues of opportunity creation and productivity enhancement: commercialisation, R&D and innovation culture, and R&D potential and structure. Thus, this model, tested on a Turkish SME in the metal industry, also delves into the more operational dimension of innovation starting with the department responsible for new ideas (R&D), its structure and the commercialisation of its output (IP, products, etc.).

4.3.2 *Research settings and objectives*

There is no doubt that the literature - both scientific and non-scientific - has shown interest in the construction of specific assessment models for Industry 4.0. The number of

assessment and maturity models has grown over the years, as well as the different insights and focuses that have been proposed. Innovation issues in the 4.0 context have been an integral part of several of these models. The development of human resources and the development of an integrated organisational system, the management of the R&D department, the use and exploitation of intellectual property, the creation of inter-company cooperation systems and networking are the main elements that were repeatedly included in the assessment models. These elements have been widely identified as foundational factors for Industry 4.0 not only by the assessment model literature but also by national strategies defined through 4.0 policies (§ Paper no. 2). Despite this, an assessment model with a vertical focus on innovation and intellectual property issues in the context of Industry 4.0 has not yet been developed.
Given this, the aim of this study is to investigate and understand how to measure and evaluate the ability of companies to implement an innovation system that meets the needs of Industry 4.0. To achieve this objective, it was decided to design, create and test a specific assessment model to understand the level of maturity of companies in integrating and implementing the 4.0 innovation system, specifically answering the following research questions:

RQ α - How can the level of implementation of an innovation system be assessed in companies transitioning to Industry 4.0?

RQ β - Which dimensions and factors should be included in an evaluation model of the degree of implementation of an innovation system in the context of Industry 4.0?

The construction of the assessment model will be based on the results of the two previous papers of this thesis - the literature review on the relationship between intellectual property and Industry 4.0 (§ Paper no. 1) and the analysis of 4.0 policies in G7 countries (§ Paper no. 2) - and what has been observed on the maturity models already developed for Industry 4.0. The first part of this paper will be devoted to illustrating the model, its characteristics, the dimensions and factors included within it, the measurement calculation of scores and the resulting levels of development.

After this, in order to give concreteness to the model and test it, a second phase of the study envisaged the submission of the model to a sample of companies committed to the transition to Industry 4.0. Specifically, it was decided to focus on companies active in

Tuscany Region. There are several reasons for this choice. Firstly, this thesis stems from a grant from the Region of Tuscany for research projects related to Industria 4.0 aimed at the development of the regional economic fabric. Furthermore, since 2016 (the year in which the National Industry 4.0 Plan was launched in Italy), Tuscany Region has constantly defined several programmes and investments to facilitate companies active in the territory to undertake a path of change in a 4.0 perspective. The regional government has identified the Industry 4.0 model as a strategic priority for the local economy by developing not only *ad hoc* policies and funding (both for specific sectors and for specific categories of companies) but also competency centres, university research projects, staff training and refresher courses, and business coordination platforms (as can be seen in https://industria40.regione.toscana.it/). In addition to this, the scientific literature on assessment models for Industry 4.0 has several times taken Italy as an object of analysis. Table 2 gives a brief overview of the publications of maturity/assessment models related to I4.0 in which the object is companies either generally Italian or belonging to specific Italian regions, and the relevant research methodology used. As can be seen, although there are models tested on companies of individual regions, Tuscany Region has never been specifically studied, but only as part of a larger sample. The research here adopts a vertical analysis approach on Tuscany Region, which has been absent until now, and will analyse a sample of enterprises from the same territory. According to a study about the 4.0 readiness level of regions in Europe (Czvetkó et al., 2021), Tuscany Region is among the most advanced regions in Italy (after Latium, Lombardy and Emilia Romagna) regarding the implementation of Industry 4.0. The comparison between samples of enterprises from different Italian regions was excluded due to a lack of available resources, both economic and time related. The selection criteria and process and the characteristics of the sample in particular are illustrated later in section § 4.5.1. This approach of the research project led to the formulation of a third research question:

RQ γ - What level of implementation of the innovation system 4.0 is present in the Tuscan companies transitioning to Industry 4.0?

Table 2 - Articles on Industry 4.0 assessment/maturity models set in Italy.

Paper	Journal	Geographical focus	Methodology
D'antonio, G., Macheda, L., Sauza Bedolla, J., & Chiabert, P. (2017)	IFIP International Conference on Product Lifecycle Management	Piedmont Region	Survey (33 companies)
Pirola, F., Cimini, C., & Pinto, R. (2019)	Journal of Manufacturing Technology Management	Bergamo province in Lombardy Region	Multiple case study (2 companies)
Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M., & Pinto, R. (2020)	Journal of Manufacturing Technology Management	Italy (no further specification)	Multiple case study (10 companies)
Rauch, E., Unterhofer, M., Rojas, R. A., Gualtieri, L., Woschank, M., & Matt, D. T. (2020)	Sustainability	Italy (no further specification) with Austria, Slovakia, and the United States	Field study (17 companies)
Tortora, A. M., Maria, A., Iannone, R., & Pianese, C. (2021)	Procedia Computer Science	Campania Region	Survey (77 companies)
Lepore, D., Micozzi, A., & Spigarelli, F. (2021)	Sustainability	All 20 italian Regions	Multivariate analysis
Rossini, M., Cifone, F. D., Kassem, B., Costa, F., & Portioli-Staudacher, A. (2021)	Journal of Manufacturing Technology Management	Italy (no further specification)	Multiple case study (19 companies)

4.4 "In.Ac.Re. Innovation System 4.0" assessment model

This section describes the criteria for the construction of the assessment model, its dimensions and factors under assessment and the functioning and interpretation of the results. The definition of a model for the assessment of the innovation system 4.0 is based on the integration of the results of previous studies and the literature analysed previously. Building a vertical model with a specific focus in the context of the Fourth Industrial Revolution required a phase of mediation and comparison of the different elements emerging from the international scientific literature and the economic and industrial strategies and policies formulated at national level. Despite the variations and different approaches to the topic illustrated, the model developed from those factors that are constant and transversal in the different academic and policy formulations.

- **Purpose and design**

The objective of the assessment model that this study aims to produce is to measure the degree of implementation and proactivity of companies regarding innovation in the context of Industry 4.0. As a first step, a series of characteristics to be considered and attributed to the assessment model were defined during the design phase of the model. First of all, adaptability: the model must adapt to companies of different sizes and active in different sectors; it must not be a specific tool for a certain type of company or economic sector. Second, comprehensiveness: the model must include all the elements previously recorded in the scientific literature on the subject of innovation in the 4.0 context; it must be as complete and exhaustive as possible. Third, modularity: the model must be defined by thematic blocks capable of measuring specific dimensions, built on the basis of a classification of the elements that make up the innovation 4.0 ecosystem. Lastly, simplicity: both in construction, the model must contain a strategic and not too high number of key dimensions and factors to be taken into account in order to ensure transversal applicability; and in application, the model must be an effective and easy tool to apply and to provide a result easy to understand.

One of the first evidences revealed by the literature analysis is that the prototype introduced by Industry 4.0 is an integrated model whose elements - subjects, processes and tools - are strongly interconnected. In this context, actions, choices, operational models require multi-level integration (company, inter-company, sector, state). It is possible to describe it as a system. From its earliest definitions, the system is understood as a group of different elements and the relationships these elements have with each other (Dosi et al., 1988; Boulding, 1985). This can be observed not only at the macro level in the multiple presentations of the Industry 4.0 model, but also in the analysis of the role of innovation in the Industry 4.0 model. From this comes the choice to define an 'innovation system' as an interconnected structure of multiple aspects. The results of Paper no. 2 showed that in national 4.0 policies, innovation is seen as a goal to be achieved and, at the same time, a process to be developed through the coordination of a set of interconnected elements (networking, cooperation, training, investments, etc.). For this reason, the assessment model was constructed with the objective of measuring the degree of integration and implementation of an innovation system 4.0, incorporating all the elements recognised as belonging to and contributing to this system. In order to give a structure to the system and the assessment model, all inputs and elements related to it were collected from: literature review (Paper no. 1), 4.0 policies (Paper no. 2) and the innovation related elements of the assessment/maturity model 4.0 (§ 4.3.1). Once collected, the elements were systematised into 3 macro-areas: Investments, Activities and

Relations. The first dimension concerns the investments in the process of adopting the 4.0 innovation model, the second dimension the innovative activities and operational choices in the 4.0 context, and the third comprises the relational aspects included in the 4.0 model. More details are provided later. These categories correspond to the three measurement dimensions of the new innovation system 4.0 assessment model and address the need to develop a modular model.

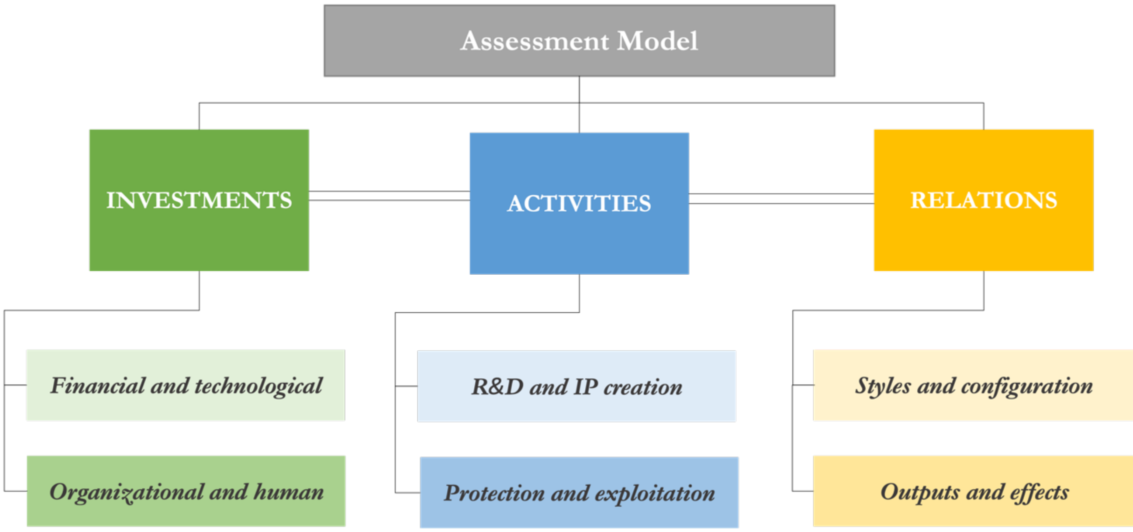
One of the objectives in building an assessment model is also to integrate and overcome the limitations of previous assessment models (Pirola et al., 2019). As there are currently no vertical studies on innovation system 4.0 assessment, the literature review was useful to identify the various elements included in the other assessment models on Industry 4.0, categorising them into the three dimensions mentioned above. By contrast, this made it possible to identify absent elements to be integrated into the new assessment model. The aim is to build an all-inclusive model capable of contributing to a coherent assessment of the innovation system 4.0, without leaving out any item. In this way, the comprehensiveness criterion is to be addressed. In Table 3 the assessment models analysed in § 4.3.1 are presented, for each of them the elements that populated the different areas in the innovation 4.0 assessment model are highlighted.

The construction of the model was designed from the three identified areas representing the measurement dimensions. Each of them, for the sake of clarity and completeness, was in turn subdivided into its main topics with the aim of distinguishing and analysing the main elements that make them up. The structure of the assessment model is configured as a tree (see Figure 1): the object of analysis is divided into three assessment areas, which in turn comprise the specific measurement topics, each of which comprises several specific factors (for the complete structure of the model see Appendix B). The dimensions and related topics are briefly described below to explain the issues covered and the factors included.

Table 3 - Elements of previous assessment models incorporated into the 'Innovation System 4.0' assessment model.

	Innovation 4.0		
IMPULS Industrie 4.0 Readiness Model	Investing in innovation	Defining an innovation strategy; Innovation management	--
SIMMI 4.0	Vertical integration	--	Horizontal integration
PwC Maturity Model Industry 4.0	Vertical integration; Collaboration culture;	--	Horizontal integration
Industry 4.0 Maturity Model	Interdepartmental collaboration; Competencies	Protection of intellectual property	Open-innovation; Cross company collaboration; Knowledge sharing
Industrie 4.0 Maturity Index	Digital capabilities	IP utilization	Network cooperation
Singapore Smart Industry Readiness Index	Vertical integration; Workforce learning and development	--	Horizontal integration; Inter and intra company collaboration
Maturity and Readiness Model for Industry 4.0	Technology investments; Human resources	R&D and Product development	Strategic partnerships
I4.0 Maturity Assessment Framework	Training system	Knowledge management system	Networking and integration
Factory of the Future assessment model	Competencies	R&D activities	Networking and innovation ecosystem
ASME Model	Education level; Process and improvement	Generation of new ideas; R&D and innovation culture; R&D potential and structure; Commercialization	--
	Investments	**Activities**	**Relations**

Figure 1 - Macro-structure of 'Innovation System 4.0' assessment model.



- **Dimension 1: Investments**

The first area is dedicated to measuring investment. This includes all financing and investment activities that a company defines in the process of adopting and developing the 4.0 model within its own organisation. Companies need to develop and integrate into their internal environment a set of tools and processes that can assist them in implementing the 4.0 innovation system. Investments give a measure of the commitment and effort the company puts into the implementation of an innovation ecosystem. Innovation system 4.0 investments have been grouped into two main types corresponding to the two topics:

Technological and financial - Financial and technological investments are the technical investments that the company makes to implement the 4.0 path. First and foremost, the use of and access to differentiated forms of financing (equity capital, bank loans, European/national/regional funding and calls) to guarantee sufficient liquidity to implement the path of change and equip itself with the appropriate organisational and technological structures. The greater and more differentiated the forms of financing, the greater the ability to manage a complex path adequately and produce innovations (He et al., 2021; Hu, 2021). Thanks to these, it is possible to reduce the risks associated with the research path and increase the competitiveness of enterprises (Yuan et al., 2021; Gu et al., 2021). From a technological perspective, the adoption of advanced technologies and their integration into production processes aimed at improving the management and planning of activities are evaluated. This makes it possible to relieve human resources from activities that can be automated, simplify decision-making processes and increase the efficiency and effectiveness of the production process.

Organizational and human - The second topic analyses the organisational and human perspective of the investment. Here, the focus of investment is divided between organisational change at the company structural level and the development of human capital. Integrating the skills necessary for the implementation of the 4.0 model and its proper functioning is the first factor assessed in this topic, companies must find ways to equip themselves with trained and effective human resources. This can be done through a strategy of targeted recruitment or staff training. Staff development is aimed both at improving absorption and learning capacity and at producing new knowledge (Wang et al., 2021; Becciu et al., 2022; Zahra & George, 2002). In addition to this, reorganisation must take place through a form of vertical integration of business processes and departments: the flow of data and constant cooperation between areas has the function of ensuring fluent and constant communication. A digitally connected internal environment is one of the necessary elements for the establishment of a proactive and innovative system. This is one of the core elements of the industrial 4.0 model and is embedded in many of the maturity models analysed above (see Table 3).

- **Dimension 2: Activities**

The second dimension focuses on innovative activities. Many of the elements found within the 4.0 policies of the G7 countries are concentrated in this section. Innovative activities are understood as all those strategic and operational choices - oriented internally and externally - aimed at building the competitive advantage of the enterprise on an innovative basis. The production (in the narrowest sense) of innovations with a 4.0 approach is measured within this section. This, in fact, includes activities related to intellectual property and its entire management process within the enterprise (from creation to exploitation). The dimension has therefore been divided into two topics:

R&D and IP creation - The first topic focuses on: research and development and intellectual property creation in companies on the path of Transformation 4.0. The focus is on the first part of the innovation creation process, characterised by the management of creativity, idea development processes and the intellectual property design process (Pedota & Piscitello, 2022). The first factor considered is the presence of an specific department dealing with research activities in the company. This department and its optimised functioning are a sign of the importance attributed to creative activities in the company (with dedicated staff and budget). Besides the presence of an R&D department, the structure of the innovation process is also important in this dimension. The innovation process within the company may be more or less structured or even completely unstructured, depending on the case. The more structured the process, the more effectively planning, management and supervision and control can act and limit the risk of errors and losses in the short and long term. On the intellectual property side, planning an appropriate strategy for the creation and management over time (protection and exploitation of intellectual property) is another priority in an industrial 4.0 context. This determines the choice of intellectual property result goals to be achieved and the planning of actions to achieve them. At this stage, intellectual property can already take on an instrumental function: the use of IP-related tools and information offer strategic support to the innovation development process. As a last factor, the sustainability perspective was considered: this has been repeatedly emphasised as the reason and goal of 4.0 innovations both in the scientific literature and in 4.0 policies (Wang et al., 2021; da Silva & Almeida, 2020; Tumelero et al., 2019).

Protection and exploitation - The second topic of the dimension about innovation system activities deals with the protection and exploitation of intellectual property with strategic purposes. The regular and habitual use of legal instruments to protect innovations and ideas ensures the protection and recognition of intellectual property as a strategic business asset. Intellectual property is mentioned in several national 4.0 policies as a key tool for securing competitive advantage at both company and national level. Encouraging companies to protect their innovations through legal mechanisms is also a guideline to ensure international market recognition of economic and competitive value. As Industry 4.0 is a digital and automated business model, the protection of innovations must also be ensured at the IT level, through 4.0 tools. Cyber security is a key element to be developed to protect the knowledge, ideas, information and data of companies in an IT environment. Three main factors related to competitive strategy, economic exploitation and instrumental use are included in the perspective of intellectual property exploitation. Specifically, the use of intellectual property can be exploited to determine aggressive competitive strategies (such as hyper-patenting, massive acquisition of IP, etc.) and impose itself in the knowledge economy 4.0 (Chih -Yi & Bou-Wen's, 2021; Benassi et al., 2020). The parallel of this strategy is the economic exploitation of IP based on the sale or temporary licensing of intangible assets. Both strategies make it possible to fully capitalise on the investment made in IP registration and maximise profits from the 4.0 innovation process. Finally, the last key factor is the strategic use of IP-related information, in this case not aimed at the development and creation process, but at defining strategic market choices, positioning, risk reduction and maximising knowledge of the competitive arena.

- **Dimension 3: Relations**

The last dimension included in the innovation model concerns relations. Enterprise relations were mentioned as a key element in all 4.0 policies analysed in Paper no. 2. Innovation in the 4.0 industrial model is closely linked to the ability to cooperate and collaborate in order to disseminate and exchange knowledge and thus increase the creative capacity of the enterprise. This dimension concerns, therefore, the cooperative approach to the innovation system 4.0 and the sphere of the company's external relations. Whereas investments focused on internal practices, and activities on both internal (R&D and creation) and external (strategies) practices, this dimension focuses only on external practices and their effects. The Relations dimension is divided into two topics:

Styles and configurations - The first topic focuses on the way corporate relations are defined and organised. The first factor to be assessed is undoubtedly the presence or absence of strategic alliances and/or collaborative projects for the innovation generation. According to the industrial 4.0 model, it is not only important to be open to cooperation, but also to differentiate one's relations by extending them to less structured and highly innovative companies (primarily start-ups) and to universities and research centres. Interdisciplinarity and mutual contamination with different realities promote research activities and assist the creation of innovations that lead to solutions to complex problems (Muscio & Ciffolilli, 2020; Tumelero et al., 2019). Moreover, through cooperation, companies are able to create solutions that are more attractive on the market by sharing the necessary risks and resources (Kahle et al., 2020). Sharing resources and knowledge is a fundamental part of the cooperation process in innovation system 4.0. Mutually sharing know-how, knowledge, information and knowledge strengthens reciprocal trust and increases the possibilities to innovate. The structure and hierarchy of collaborative relations also play a role. Innovation in System 4.0 should be as open as possible, without limits and barriers to access between mutual parties (Chih-Yi & Bou-Wen, 2021; Rocha et al., 2019). Therefore, an open and equally cooperative relation structure is more appropriate for a 4.0 innovation context, although more complex to manage than a relation structure with a defined hierarchy.

Outputs and effects - The second topic of the dimension is devoted to the results and effects of innovative relations. The primary goal of 4.0 realations is the production of innovations and their shared exploitation. Co-operation that does not bring any concrete benefit to companies is meaningless. The first factor measured is the actual achievement of the objective: the production of innovations. Secondly also the actual form of involvement in the innovation, the registration of intellectual property and the eventual sharing of it. Of course, it is also important to understand whether the shared innovation process has nourished the system by producing innovations (especially technological innovations) aimed at extending and managing the 4.0 model. Co-operation in the 4.0 perspective can also start an integrated system with actors outside the company. Horizontal integration in the context of Industry 4.0 refers to this: a digital compenetration of processes and activities between companies in the same production chain or the same technology sector. The fusion and coordination of specific activities arise from a digitally based cooperation process planned and implemented through agreements between different actors.

4.4.1 *Functioning and interpretation of results*

The functioning of the model in operational terms and the interpretation of the results are now briefly described. It was necessary to define a linear structure and a mechanism capable of fulfilling the *a priori* defined construction criteria, in particular adaptability and simplicity.

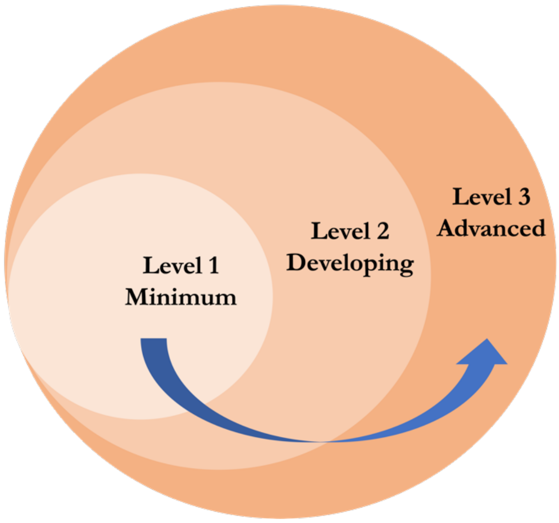
Regarding adaptability, the first assumption was not to define a hierarchy among the dimensions to be measured. In the absence to this day of a specific reference framework for the innovation system 4.0, it was not possible to rely on already tested and validated models and schemes. Furthermore, from an empirical point of view, it can be seen that the choice of innovation strategies and practices is strictly individual and varies considerably depending on the sector and size of the company. The great heterogeneity of companies converting to Industry 4.0 does not allow for a subjective criterion to be chosen, leaving companies to assign weights according to their own perceived priorities. To ensure that the model retains a transversal adaptability character, it was decided not to assign hierarchical weights to subordinate dimensions and topics. The aim of not assigning specific weights to the different areas was not to define the importance and priority of one over the other. The same weight was attributed to each dimension and to the two topics of each dimension by normalising the factors composing them (3 factors for both topics of the Investments and Relations dimensions and 5 for both topics of the Activities dimension), as can be seen in Appendix B. It is thus possible to determine a single value scale based on measurement domains all having the same weight. These will then be distinguished in the discussion of the results. In order to also meet the criterion of simplicity, we wanted to create a model that is convenient in its application not only for academics but also for practitioners. Its aim is to give a measurable degree of progress and development of an innovation system 4.0. Therefore, the model is developed on a summation of scores given by the calculation of individual factor measurements for each topic of each dimension. Thus, it is possible to have an overall synthetic value, but also sub-values to be analysed both for each dimension and for each topic. The assessment model is intended to offer itself as an easy-to-implement and easy-to-read tool capable of returning a general guideline value. The constructed model was submitted to the judgement of colleagues (E.S.; E.B.; A. C.) who validated it and the research approach.

Table 4 - Scores and levels of 'Innovation System 4.0' assessment model.

	Level 1 – Minimum	**Level 2 - Developing**	**Level 3 - Advanced**
Investments	0 - 7	8 - 13	14 - 20
Activities	0 - 7	8 - 13	14 - 20
Relations	0 - 7	8 - 13	14 - 20
In.Ac.Re. Innovation System 4.0 Assessment (Overall)	**0 - 21**	**22 - 39**	**40 - 60**

Like a litmus paper, the elementary implementation of the model and the reading of the results must be immediate and clear. As mentioned, the model is based on a numerical score obtained from the sum of the scores of all the factors to be evaluated. The sum of the scores obtained is on a total scale ranging from a minimum of 0 to a maximum of 60 points. Reflecting the criterion of modularity, each of the three dimensions provides a maximum of 20 points, based on the sum of the scores of both topics which can range from 0 to 10 points in total. Based on this approach, three levels of progress in the development of an innovation system 4.0 were set: minimum, developing, advanced (see Table 4). In addition to determining the overall degree of assessment, three levels are also reflected in the scores of the three individual dimensions, allowing a horizontal reading of the company's performance in the innovation system 4.0. The three chosen levels are defined with an incremental approach: according to a nesting principle (Figure 2), from the first level one moves on to the second as the score increases as the factors entered are more satisfied. In a nested assessment system, each level covers the characteristics of the lower levels (Oztemel & Ozel, 2021).

Figure 2 - Nesting levels of the 'Innovation System 4.0' assessment model.



To guide the reading of the results, an interpretation matrix was also compiled, allowing the levels related to the scores to be read descriptively (see Table 5). The matrix can be read both vertically by levels and horizontally by dimensions. It offers a map of the company's performance with respect to all chosen dimensions, showing the general company situation and the aspects that can be improved. Considering that the overall score gives a general measure of performance, it is useful to look deeper and analyse the scores obtained in the individual dimensions. In particular, it should be emphasised that

- regardless of the level at which a company is ranked through the overall score - the individual dimension scores may fall into different levels. By looking at the detail of these, it is possible to have a precise reference of which dimensions are deficient and need to be addressed and developed in the future.

Table 5 - Interpretation matrix of 'In.Ac.Re. Innovation System 4.0' assessment model results.

	Level 1 Minimum	**Level 2 Developing**	**Level 3 Advanced**
Investments	Low level of investment in the adoption of 4.0 tools and technologies and underdeveloped organisational environment	Progressive integration of multiple technological and financial investments and development of an appropriate organisational structure	Maximum differentiation of technological and financial investments and definition of a developed, interconnected, and trained organisation
Activities	Low design creative processes, low strategy definition and poor protection of innovations and intangible assets	Progressive structuring of a R&D process and identification of targets for innovation; systematic protection of competitive advantage through IP	Planning of the innovation development process and planning of an IP strategy; innovation protection integrated programmes and definition of exploitation policies
Relations	Minimal commitment to relationship building and insufficient resource and risk sharing	Initial development of collaborative relationships with external actors through the definition of agreements and objectives	Creation of a cooperation network with different external actors and integration and sharing of objectives, risks, activities and results (output and outcome)
In.Ac.Re. Innovation System 4.0 Assessment (Overall)	**The innovation system 4.0 is still at a premature stage and does not support the structural and strategic change of approach to innovation in I4.0. More investments and a proactive attitude to the creation of an innovation system are needed.**	**The innovation system 4.0 is formed and begins to function through the development of strategies and programs and the integration of processes. Greater coordination between the elements and better system management are required.**	**The innovation system 4.0 is structured and functions through constant planning, optimal innovation process integration, full exploitation of intangible resources, participative collaboration and networking and protection of competitive advantage.**

4.5 Methodology

This section is dedicated to methodology and is divided as follows: the first part describes the methodologies used in the testing phase of the developed assessment model, the second part outlines the identification procedure and the criteria for selecting the research sample and, finally, the third part describes the sample on which the assessment model was tested.

4.5.1 *Multiple case study*

In order to adequately answer the research questions formulated, a qualitative methodology was identified. As reported in section 4.3.2., the most common methodology for testing and developing assessment models is the empirical case study methodology, specifically with a multiple case typology. The present study adopted this methodology and applied it to a selected sample. According to Pirola, Cimini and Pinto (2019), this method is particularly appropriate for developing and testing an assessment tool. In fact, the case study is a methodology that allows the observation of a subject's actions and practices regarding certain topics (Yin, 2009; Meredith, 1998) in order to understand the dynamics of a specific phenomenon. The case study succeeds in describing a context and providing an understanding of how or why certain situations occur; thanks to the researcher's participatory approach - conducting interviews - it is particularly useful in studying complex phenomena (such as digitisation or innovation) that have nuances or multiple levels of interpretation. The co-presence of multiple elements and dimensions to be grasped and studied suggests a qualitative and holistic approach such as the case study (Eisenhardt, 1989). The adoption of Industry 4.0 falls into this group of complex phenomena characterised by major changes in the technological and managerial sphere and the case study method can help to capture it effectively (Pirola et al., 2019). Another appreciable and useful feature of the case study is that it is consistent with studies of an exploratory and descriptive nature (Oliver & Kandadi, 2006).

The choice of a multiple case study approach is justified by its design that "*allows the researcher to explore the phenomena under study through the use of a replication strategy*" (Zach, 2006). Whereas in the single case study the uniqueness of the individual object is explored, in the multiple case study it is possible to look at individuals and simultaneously at differences and similarities in the group (Baxter & Jack, 2008). In this way, it is possible to provide the literature with a strong empirical basis to discuss the analysis of phenomena and the deepening and evolution of theories, thanks to strong and reliable evidence (Vannoni, 2015; Eisenhardt & Graebner, 2007). In addition to its advantages, this methodology has several critical aspects. Firstly, the greater the number of case studies the less time the researcher can devote to each one (Gustafsson, 2017; Gerring, 2004). Not only can the multiple case study be extremely time consuming and costly (Baxter & Jack, 2008), but it may be less effective in observing a phenomenon, causing less data to be collected and limiting the researcher's perspective compared to the depth of analysis of a single case study (Siggelkow, 2007). The richness of the contexts analysed and described, however, compensates depth with numerosity and comparison. Despite the various limitations, the multple case study makes it possible to (a) analyse a phenomenon in a cross-sectional manner, (b) move the literature forward by comparing differences and similarities, (c) provide clear and reliable evidence by answering broader research questions, and (d) formulate discussions and conclusions (Gustafsson, 2017). For these reasons, the multiple case study was chosen as the methodology for the present study. Each integrated case study was conducted from the prerequisite of voluntary participation. For each subject included in the sample, an analysis consisting of several stages was conducted: 1) documental research on the company (through analysis of financial statements, reports, website, social), 2) first contact and acquaintance with the company, 3) semi-structured interview (in presence, via web or telephone) for the collection of an in-depth narrative, accompanied by a visit to the company when possible; 4) eventual further discussion and confirmation of data and information.

4.5.2 *Sample settings and criteria*

A multi-criteria approach was chosen for the definition of the population of companies to test the constructed assessment model. In addition to the geographical location in the Tuscan regional territory (§ 4.3.2.), in order to obtain appreciable results, two necessary characteristics were established for the selection of the companies under analysis. On the one hand, it was necessary that the enterprise had at least begun the transformation path towards the 4.0 model, regardless of the degree of maturity achieved. On the other hand, the companies had to have some interest in protecting their competitive advantage on an innovation basis and to have demonstrated that they were committed to protecting their ideas and innovations strategically. In order to be able to define a population of companies with the above mentioned characteristics, a cross-criteria approach was chosen.

Initially, companies that had embarked on a 4.0 change path were identified. As previously outlined, the Region of Tuscany has planned several initiatives and programmes aimed at supporting and developing companies active in the 4.0 direction.

With this objective, the Region has defined over the years a series of funded measures to develop the capacities of enterprises and their skills in the 4.0 sphere. Through the study and analysis of the participants in the main funded initiatives and calls for applications for Industria 4.0 of the Region of Tuscany, an initial group of enterprises (902) was defined. All calls for proposals available on Tuscany Region website, open or closed, with a consultable list of participants were selected. The selected calls for applications are 8 and have different focuses and objectives, as can be seen in Table 6 where the purpose and year of launch of the call for applications can be found. The sample was identified, filtered and excluded freelancers and public entities. No discrimination was made between successful and unsuccessful companies: the willingness to participate in initiatives aimed at developing their capabilities and competence for I4.0 was defined as a sufficient criterion for selection.

Table 6 - Funding calls launched by the Region of Tuscany on Industry 4.0 topics.

	Purpose of the calls	Year
1	Facilitating the realization of investment projects in industrial research and experimental development, encouraging business innovation.	2017
2	Supporting and increasing investments in machinery, equipment and intangible assets in Tuscany to accompany reorganization and restructuring processes, in line with national and regional Industry 4.0 strategies	2017
3	Stimulating investments in innovation, supporting industrial research and experimental development activities of enterprises, by financing industrial research and experimental projects carried out by large enterprises in cooperation with Micro, Small and Medium Enterprises, with or without Research Organizations	2017
4	Funding for innovation consulting aimed at implementing the Industry 4.0 paradigm	2018
5	Funding for training projects related to retraining and outplacement actions for workers linked to company restructuring and industrialization plans for Industry 4.0	2018
6	Support and increase investment in the territory of Tuscany in machinery, equipment and intangible assets to accompany reorganization and restructuring processes in line with the Research and Innovation Strategy for smart specialization in Tuscany	2018
7	Funding for strategic industrial research and experimental development projects carried out by large companies in cooperation with micro, small and medium-sized enterprises (micro and SMEs), with or without research organizations	2020
8	Funding for training interventions aimed at strengthening the capacity and skills of workers and enterprises to anticipate and support technological and economic changes in the markets and production systems in which they are located, accompanying the paths of innovation and competitive modernization of production processes	2021

The PATSTAT database was used to identify Tuscan companies engaged in building and defending a competitive advantage based on innovations. PATSTAT is the Worldwide Patent Statistical Database of the European Patent Office and contains patent data from different countries. A search identified all Tuscan companies with at least one registered patent in the last 20 years (regardless of where the IP was registered). In this way, a second group of companies (588) was identified. By cross-referencing the two groups it was possible to identify a reference population of 80 companies currently active in the Tuscan regional territory. The enterprises were contacted by e-mail and telephone and invited to participate in the study and 30 companies agreed to be interviewed and take part in the research project (participation rate of 38% of the initial defined population).

4.5.3 *General presentation of the sample*

This section presents the sample resulting from the above selection process. The 30 companies that joined the project participated in the research and were assessed using the elaborated assessment model. Below we briefly describe the characteristics and composition of the sample in order to appreciate its heterogeneity, as can be seen in Table 7. Although it is not a representative sample of the population of the enterprises engaged in the 4.0 change in the territory of the Region of Tuscany, it offers an introductory basis to test the assessment model and gives an initial measure of the behaviour of the enterprises with respect to the 4.0 innovation ecosystem. The limits of a circumscribed sample analysed by means of qualitative methodology (semi-structured interviews and multiple case studies) do not allow to give statistical value to the results of this research. Future studies will have the opportunity to expand the reference sample by extending its number and characteristics. Given the strategic and confidential nature of the information provided by the 30 companies, their names will not be disclosed and each company is indicated with a sequential number (e.g. business1 = B1).

The 30 enterprises vary in size. Using the classification defined by the European Union, enterprises with <50 employees were identified as small, medium-sized 51< 250 employees, no more than €43 million balance sheet total and large enterprises >250 employees (OECD Report, 2013). The 40% of the sample consists of small enterprises, 20% of medium-sized enterprises and the remaining 40% of large enterprises. The prevalence of SMEs within the sample reflects the composition of the national and regional economic structure. The legal status of the enterprises is split almost in half: 57% are limited liability companies (S.r.l. in Italian) and the remaining 45% are joint stock companies (S.p.A in Italian). Only 27% of companies have a multinational profile. A total of 67% focus on a business-only market, while only 33% offer products and services for both businesses and individual consumers. The plurality of sectors represented makes the sample extremely heterogeneous. Nevertheless, some of the most numerous groups are discernible: 23% of the companies are in biotech, 17% in mechanical engineering, 10% ICT, 10% pulp and paper industry, 7% chemical industry, 7% electrical engineering, 7% leather industry, 7% metallurgical industry. Specialisation in these sectors requires not only a high level of knowledge, continuous training and updating, but also (incremental and radical) product and process innovation.

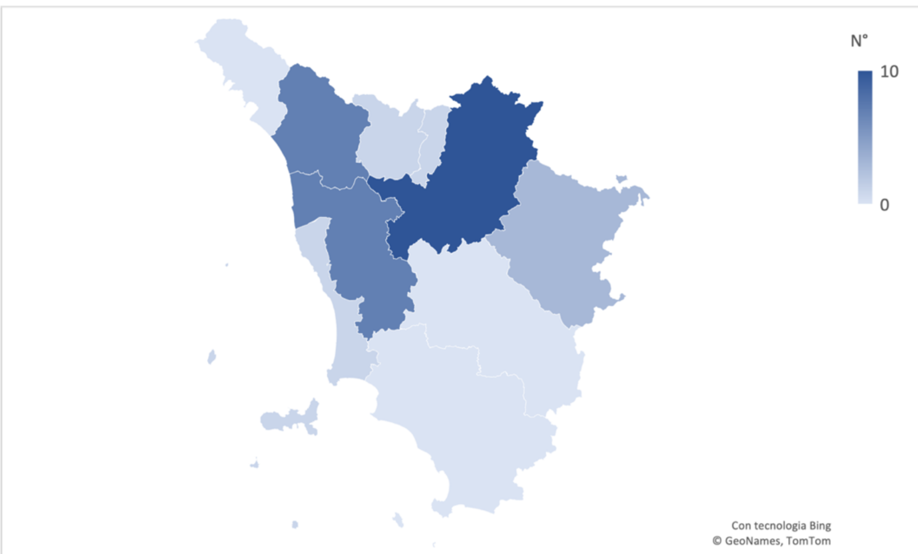
Table 7 - General characteristics of the companies' sample assessed through the developed assessment model.

	Economic sector	**Size**	**Legal nature** [1]	**Ownership**	**Market**
B1	Mechanical engineering	Small	Srl	National	B2B
B2	Waste management	Large	SpA	National	Both
B3	Leather industry	Medium	Srl	National	B2B
B4	Chemical industry	Large	SpA	Multinational	B2B
B5	Metallurgical industry	Small	SpA	National	B2B
B6	Fashion	Small	Srl	National	B2B
B7	Biotech	Medium	Srl	National	B2B
B8	Leather industry	Small	Srl	National	B2B
B9	Biotech	Medium	Srl	National	Both
B10	Biotech	Small	Srl	National	B2B
B11	Textile industry	Medium	SpA	National	Both
B12	Mechanical engineering	Large	SpA	Multinational	B2B
B13	Biotech	Small	Srl	National	Both
B14	Chemical industry	Large	SpA	Multinational	Both
B15	Biotech	Large	SpA	Multinational	B2B
B16	Mechanical engineering	Large	Srl	Multinational	Both
B17	Agriculture & food	Small	Srl	National	Both

B18	Metallurgical industry	Large	Srl	National	B2B
B19	Pulp & paper industry	Large	SpA	Multinational	Both
B20	ICT	Medium	Srl	National	B2B
B21	ICT	Medium	Srl	National	B2B
B22	Electrical engineering	Small	Srl	National	B2B
B23	Biotech	Small	Srl	National	B2B
B24	Mechanical engineering	Large	SpA	National	B2B
B25	Biotech	Small	Srl	National	Both
B26	Pulp & paper industry	Large	SpA	Multinational	Both
B27	Mechanical engineering	Small	Srl	National	B2B
B28	Pulp & paper industry	Large	SpA	Multinational	B2B
B29	Electrical engineering	Large	SpA	National	B2B
B30	Engineering	Small	SpA	National	B2B

Geographically, some peculiarities also emerge. Within the regional territory, the enterprises are not homogeneously distributed among the 10 provinces of which Tuscany Region is composed (see Figure 3). No participating enterprises belong to the three provinces of Siena, Grosseto and Massa-Carrara, while 33% of the enterprises are located in the province of Florence. Following in numerical terms in the sample are the provinces of Pisa and Lucca (23% each), the province of Arezzo (10%) and the provinces of Pistoia, Prato and Livorno (3% each).

Figure 3 - Map of the geographical distribution of the sample in Tuscany.



Within this introductory section, two further presentation features were chosen. These two elements refer to the development framework of the Industry 4.0 model in the company. During the interviews, companies were asked how long they had been on the transformation path towards Industry 4.0 and at what stage of implementation of the model they considered themselves to be (between early, intermediate and advanced). Both elements, which were excluded from the assessment model, only allow to better frame the sample and illustrate its characteristics in the path of change towards Industry 4.0. From a time perspective (see Figure 4), there are some companies in the sample that started to adopt the Industry 4.0 model even before the launch of the Italian national strategic plan (in 2016). These are structured companies, aimed at a mainly international market and with strong ties abroad; this justifies the earlier adoption compared to the timing of national development. Beginning in 2016 with the definition of the Italian national 4.0 policy, the number of companies increased over the years, with a peak in the following year. The year 2020 saw another peak in the number of adoptions, with many companies stating that the pandemic emergency due to Covid19 pushed them towards adopting a more digitised and computerised model. The second question asked for a subjective self-assessment by companies on their degree of progress in the transformation to Industry 4.0. They were offered three options: early stage, intermediate, advanced stage. A total of 63% of the sample stated that they felt they were in an intermediate stage, 27% in an early stage and only 10% in an advanced stage (see Figure 5). This indicates that the majority of companies still consider themselves to be in the middle of the transformation process and are still implementing processes and tools to become smart manufacturing.

Figure 4 - Year of start of the 4.0 transition path in the analysed sample.

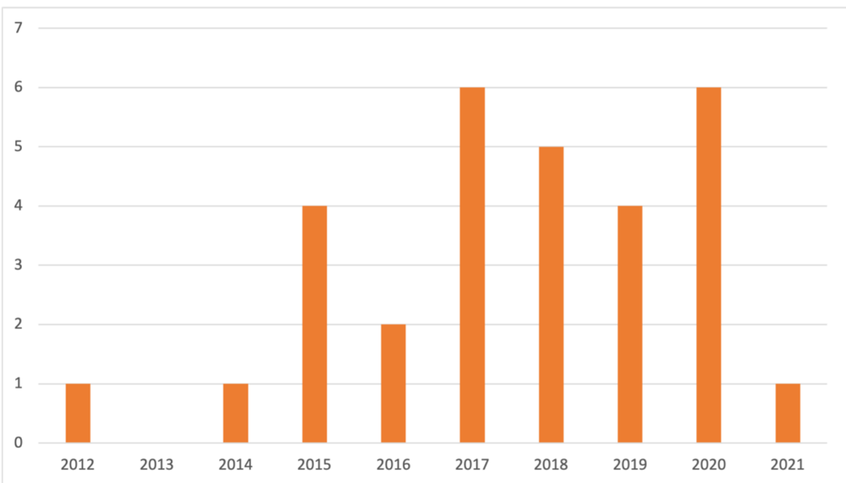
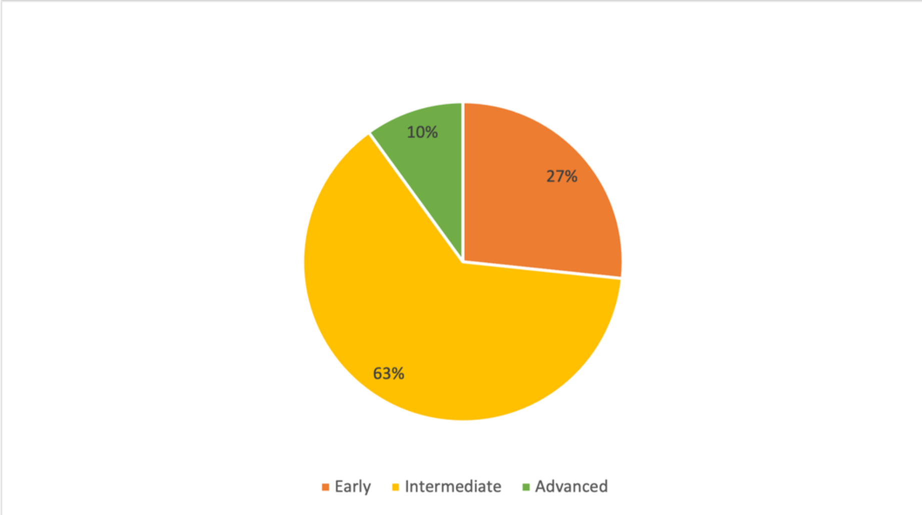
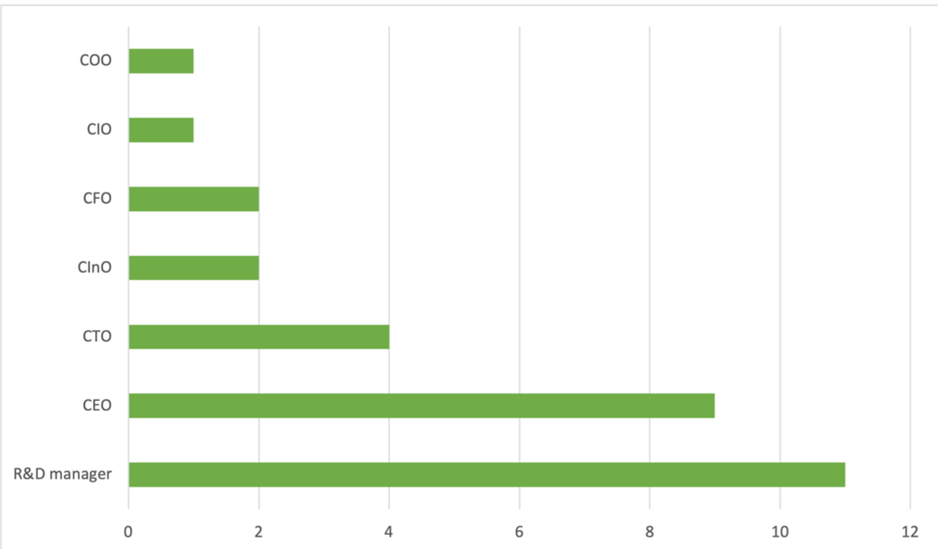


Figure 5 - Stage of progress in the 4.0 transformation path according to companies' self-assessment.



Finally, some elements on the participation in the interviews are worth mentioning. The semi-structured interviews were carried out in different ways depending on the availability of the company: face-to-face, via web, via telephone. The companies internally identified the most appropriate person to answer the questions on Industry 4.0 and innovation topics according to specific responsibilities and strategic competence. The role played by the respondents is highly differentiated (see Figure 6). In absolute terms, the highest frequency was covered by employees with the role of R&D manager (37%) and CEO (30%), followed by CTO (13%), CFO and Innovation Office (7% both) and CIO and COO (3% both).

Figure 6 - Role played by the interviewed employees of the companies in the sample.



4.6 Results and discussion

This section discusses the results obtained from the implementation of the assessment model to the thirty companies in the sample. Descriptive statistics were used to complement the qualitative approach of the multiple case study through which the data were collected (Pirola et al., 2019), as explained in § 4.5. In general, a great variety of situations can be observed within the sample. As can be seen in Table 8, there are different circumstances within the companies with regard to the assessment of the different dimensions measured. It is not possible to formulate general reading criteria across the three dimensions and the absence of a constant pattern can be observed in the companies. This indicates that each enterprise has formulated its own innovation strategy, defining specific priorities and associated policies of action. However, macro-observations can be made at an aggregate level (see Table 9). The majority of the enterprises are on Level 2 - Developing (67%), with an average value of 31.16 just over half of the total achievable score of 60. This means that more than half of the sample is at a more than elementary level of implementation and proactivity in the innovation system 4.0. Although there are still several aspects that can be improved, in most of the companies innovation system 4.0 has been triggered and is starting to function smoothly thanks to a good level of strategy, processes and policies conducted. Having been on a transition path for quite some time (in 47% of the sample since before 2018) justifies being at a more developed level than the minimum. In the remaining sample, only four companies are at Level 1 - Minimum (13% of the total, with an average value of 16.44): three of these are small companies with fewer resources at their disposal and the fourth is a large company that only started the path in 2020. At the highest Level 3 - Advanced lies 20% of the sample under analysis (6 companies in total with an average value of 43.54). The composition of this group is varied: three large companies that have invested a lot of resources in the 4.0 transition (B14, B16, B18), two medium-sized companies that adopted the industrial 4.0 model early on (B7, B11), and a small, recently founded company with advanced technologies production that quickly integrated 4.0 processes and tools (B22).

Table 8 - Results of the In.Ac.Re. Innovation System 4.0 assessment model in the sample tested.

	Investments	Activities	Relations	In.Ac.Re. Innovation System 4.0 Overall	
B1	14,2	13,33	0	**27,53**	**L2 - Developing**
B2	11,32	8	11,64	**30,96**	**L2 - Developing**
B3	9,54	14,33	11,64	**35,51**	**L2 - Developing**
B4	9,87	9	3,33	**22,2**	**L2 - Developing**
B5	8,98	12	13,31	**34,29**	**L2 - Developing**
B6	4,99	7	11,65	**23,64**	**L2 - Developing**
B7	15,98	13,83	16,64	**46,45**	**L3 - Advanced**
B8	5,65	2	0	**7,65**	**L1 - Minimum**
B9	7,87	12,83	14,97	**35,67**	**L2 - Developing**
B10	4,99	12,5	6,65	**24,14**	**L2 - Developing**
B11	12,43	14	13,31	**39,74**	**L3 - Advanced**
B12	9,76	14,67	13,31	**37,74**	**L2 - Developing**
B13	11,76	10,5	14,98	**37,24**	**L2 - Developing**
B14	14,2	18	14,97	**47,17**	**L3 - Advanced**
B15	7,77	13,33	11,65	**32,75**	**L2 - Developing**
B16	14,2	14,67	13,31	**42,18**	**L3 - Advanced**
B17	10,54	11	0	**21,54**	**L1 - Minimum**
B18	14,65	12,17	16,64	**43,46**	**L3 - Advanced**
B19	10,65	13,17	8,31	**32,13**	**L2 - Developing**
B20	10,87	10,33	8,32	**29,52**	**L2 - Developing**
B21	13,09	11	8,31	**32,4**	**L2 - Developing**
B22	13,76	13,5	14,98	**42,24**	**L3 - Advanced**
B23	6,1	7,5	8,31	**21,91**	**L2 - Developing**
B24	12,43	8,67	0	**21,1**	**L1 - Minimum**
B25	8,43	7,5	13,31	**29,24**	**L2 - Developing**
B26	13,54	13	11,64	**38,18**	**L2 - Developing**
B27	5,65	9,83	0	**15,48**	**L1 - Minimum**
B28	9,1	8,67	8,32	**26,09**	**L2 - Developing**
B29	11,87	13	11,65	**36,52**	**L2 - Developing**
B30	9,76	14,17	11,65	**35,58**	**L2 - Developing**

It is interesting to note that all 6 of these companies when asked the self-assessment question on the degree of adoption of I4.0 answered that they were at an intermediate (and not advanced) stage, showing awareness of the areas for improvement and development that are still feasible. All companies that answered 'advanced' to the previous question were classified in Level 2 - Developing by the results of the In.Ac.Re. Innovation System 4.0 assessment model.

Table 9 - Summary of the results of the In.Ac.Re. Innovation System 4.0 assessment model by level and dimension.

	Level 1 – Minimum		**Level 2 - Developing**		**Level 3 - Advanced**	
In.Ac.Re. Innovation System 4.0 Assessment	*13%*	**4**	*67%*	**20**	*20%*	**6**
Investments	*17%*	**5**	*63%*	**19**	*20%*	**6**
Activities	*13%*	**4**	*63%*	**19**	*24%*	**7**
Relations	*23%*	**7**	*57%*	**17**	*20%*	**6**

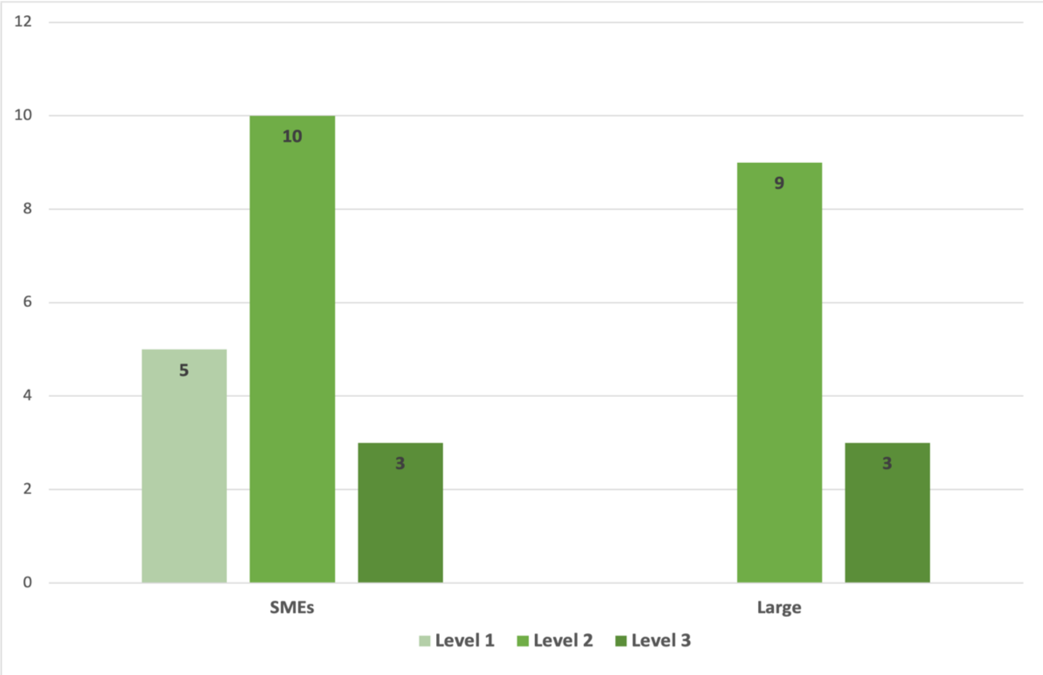
The composition of the levels of the three dimensions (Investments, Activities, Relations) constituting the total value reveals some remarkable aspects. Within the sample, 40% of the enterprises present a homogeneous level of assessment for all three dimensions: two enterprises are at Level 3 Advanced in all three dimensions (B7 and B14), nine enterprises register at Level 2 Developing (B2, B4, B15, B19, B20,B21, B26, B28, B29), only one enterprise at Level 1 Minimum (B8). The number of enterprises with at least one dimension at Level 3 Advanced is twelve (40% of the sample): this gives evidence of the growth path that a considerable group of enterprises in the sample is undertaking. Each of these twelve companies has an overall assessment that places them all at Level 2 Developing and Level 3 Advanced. On the other hand, only four companies recorded a Level 1 Minimum in maximum two dimensions (13% of the sample), which is slightly lower than the number of companies recording a Level 1 Minimum in maximum one dimension (5 companies, 17% of the sample). This shows that there is a growing general push towards the integration of innovation system 4.0 elements. Looking deeper into the individual dimensions, it is possible to make more detailed conclusions on the degree of advancement of companies in the innovation system 4.0. The three dimensions have a separate assessment system based on the same three levels as the overall assessment: each company can score from 0 to 20 for each dimension (reaching together the maximum score of 60 of the overall assessment) and reach the corresponding level according to what it has achieved as shown in Table 9.

Therefore, in the following sections, the results and assessments obtained by the sample companies in each of the three dimensions are briefly presented. Taking advantage of the distribution of companies between SMEs and large companies (60% - 40%), a comparison of the scores of the two groups is presented with respect to both the overall dimension and the two specific topics that make up each assessment dimension.

4.6.1 *"Investments" dimension assessment*

The first dimension concerns Innovative Investments. The assessment of the companies in this dimension reflects the overall values: 17% of the companies register a Level 1 Minimum, 20% of the companies are on Level 3 Advanced and the majority (63%) on Level 2 Developing. The average value of the scores of the thirty companies in this section is 10.46, a score in the middle of the overall scale. The full detail of each company's score for each factor of each topic in the Investments dimension can be found in Appendix C. Analysing by company size (see Figure 7), more than half (55%) of the SMEs are concentrated in Level 2 Developing, 28% in Level 1 and only 17% in Level 3. In contrast, among the large companies, none are in Level 1, 75% are in Level 2 and the remaining 25% in Level 3. In the case of the companies that recorded a Level 1 for the size of innovative investments, there are five small companies that have recently started their transformation journey; therefore, it is not surprising that the level of investment is minimal.

Figure 7 - Distribution of the sample companies across the three progress levels for the Investments dimension of the assessment model, grouped by size (small-medium and large enterprises).



Going deeper, looking at the composition of the Investmentes dimension it is possible to make distinctions between the topic 'Financial and technological' and the topic 'Organisational and'human'. Each company could score from 0 to 10 in each of the two topics composing the dimension. In the first topic, the average value achieved by the sample is 6.02, while in the topic 'Organisational and human' it is 4.44. Certainly, technical investments are more immediate and frequent in the 4.0 transition than the more complex organisational investments. Changing the internal corporate structure, updating processes, integrating and upgrading personnel requires a more demanding effort in terms of time and resources. As can be seen in Figure 8, only 7 out of 30 companies do not reach the median value of 5 on the scale and these are SMEs. In contrast, in the second topic (Figure 9), 50% of the sample is below the median value and of these, one third are large companies.

Figure 8 - Distribution of companies' scores for the topic 'Financial and technological' of the Investments dimension.

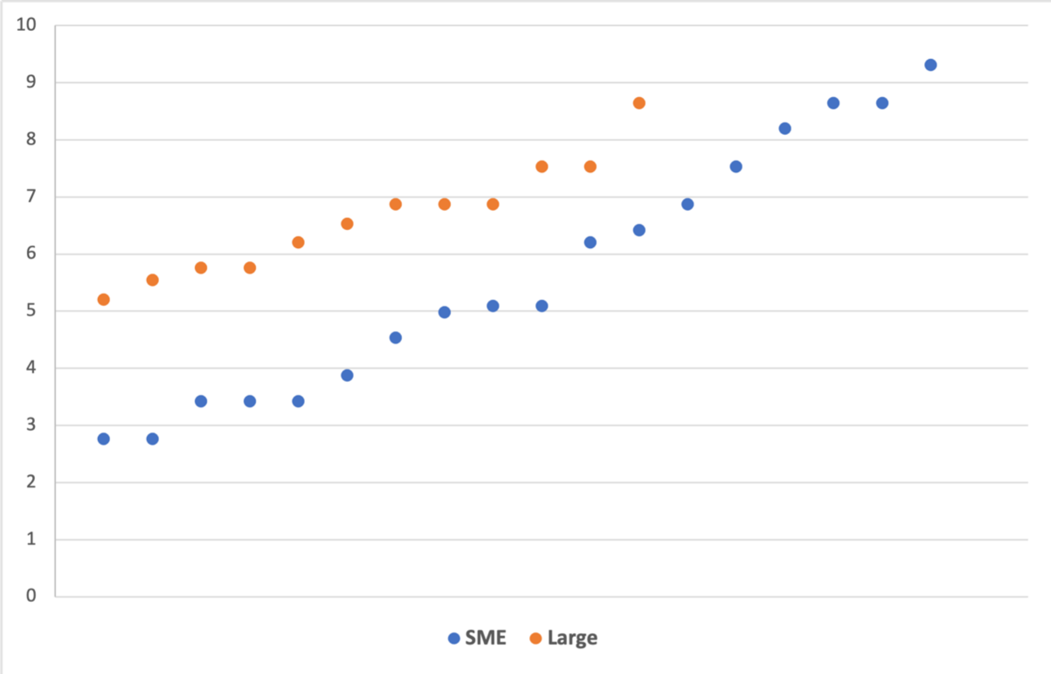
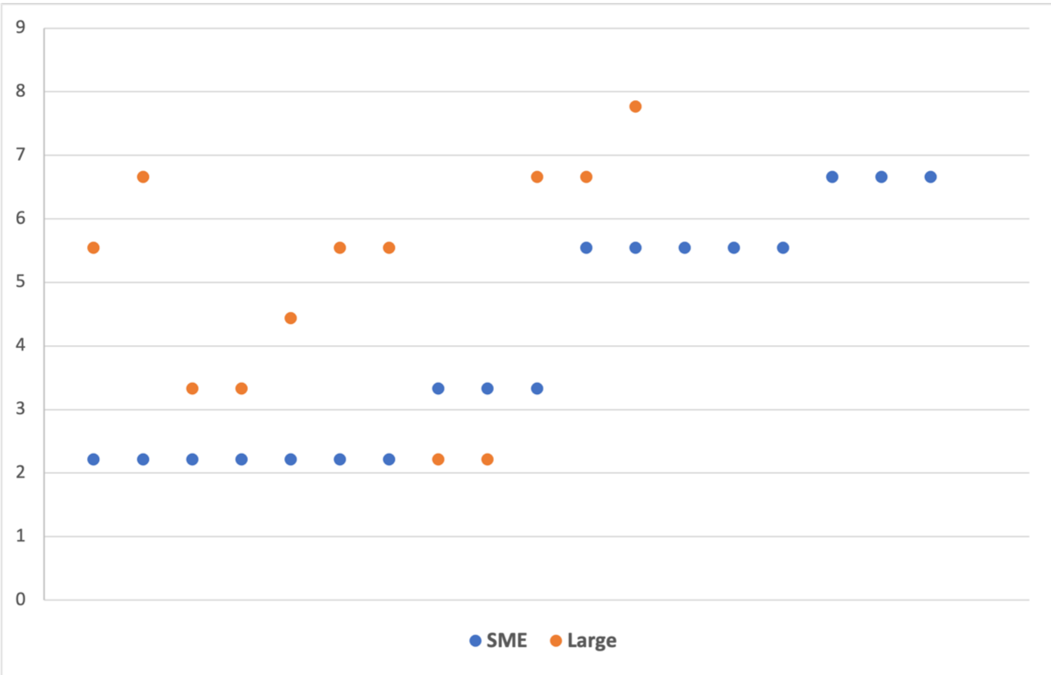


Figure 9 - Distribution of companies' scores for the topic 'Organizational and human' of the Investments dimension.

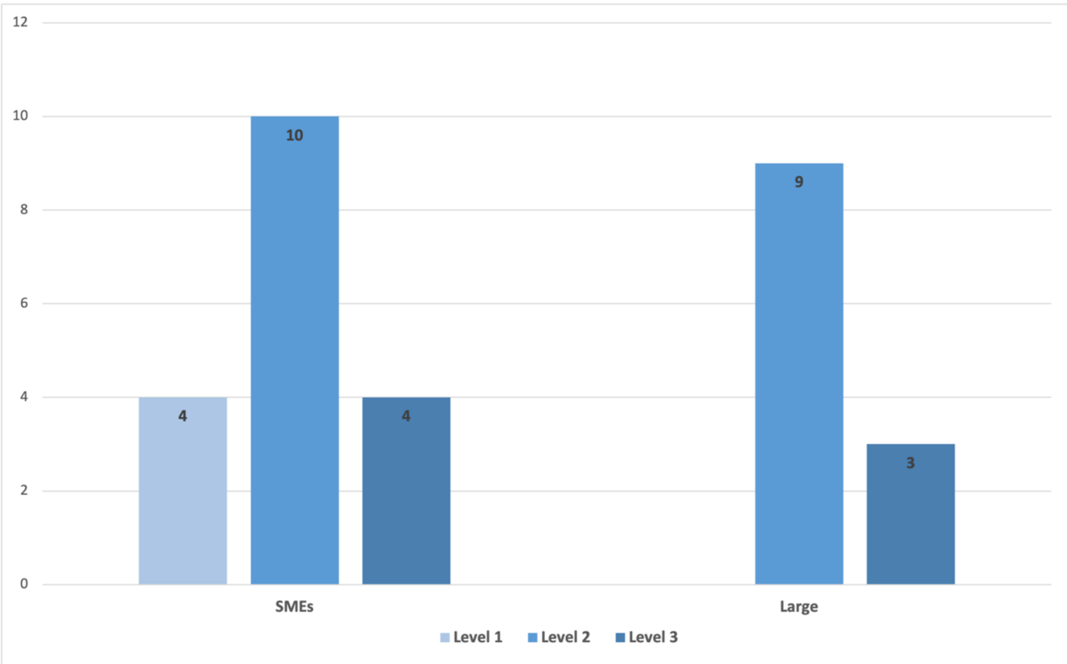


4.6.2 *"Activities" dimension assessment*

The second dimension concerns Innovative Activities in the 4.0 context. In this case, the average value of the sample rises by one point compared to the Investments dimension to

11.45. In this case, the distribution between levels remains almost unchanged from the previous dimension, with only one change to the advantage of Level 3 Advanced. The latter comprises 24% of the companies analysed, while Level 1 only 13% and Level 2 remains static at 63%. Also in this dimension, there are no large enterprises included in the Level 1 Minimum, which is again composed only of SMEs. With the exception of one enterprise (B25), these are the same small enterprises that had also achieved a Level 1 in the Investments dimension. Continuing the analysis by company size (see Figure 10), more than half (56%) of the SMEs are in Level 2 Developing, only 22% in Level 3. In the large companies, 75% are in Level 2 and the remaining 25% in Level 3. A complete detailed list of enterprise scores for all topics and factors of the Activites dimension can be found in Appendix D.

Figure 10 - Distribution of the sample companies across the three progress levels for the Activites dimension of the assessment model, grouped by size (small-medium and large enterprises).



The two topics of the Activities dimension are 'R&D and IP creation' and 'Protection and Exploitation'. The average values in the two topics are 7.28 and 4.16, respectively. Activities related to the creation and production of innovations are much more widespread and implemented by companies than those related to the protection (legal and tech) and exploitation of innovations. The creation of competitive advantage on an innovation basis occupies a strategically more preponderant space than its defence and/or exploitation. The two images of the distribution of the values obtained by the companies for the two topics (see Figure 11 and Figure 12) confirm this interpretation.

In the first topic only five companies (17% of the sample) are below the median value of the scale, while in the second topic twenty companies (67% of the sample) are below the median value of the scale. Interestingly, in the topic 'Protection and Exploitation', of the remaining ten enterprises above the median value eight are SMEs. Small and medium-sized enterprises showed a greater interest in implementing activities for the protection and exploitation of their innovations, in order to be able to benefit as much as possible from the investment made. Whereas with regard to the topic 'R&D and IP creation', large companies were at the highest level of the median value (10 out of 12 companies), with only five companies (B12, B14, B15, B16, B26) reaching the absolute maximum of the assessment (10/10) for the topic.

Figure 11 - Distribution of companies' scores for the topic 'R&D and IP creation' of the Activites dimension.

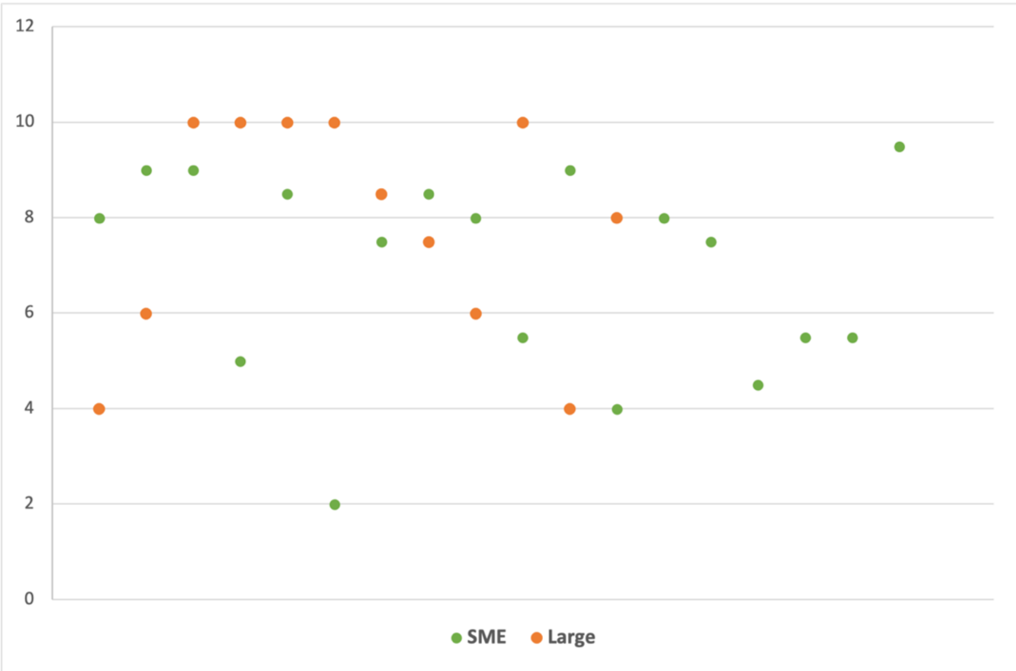
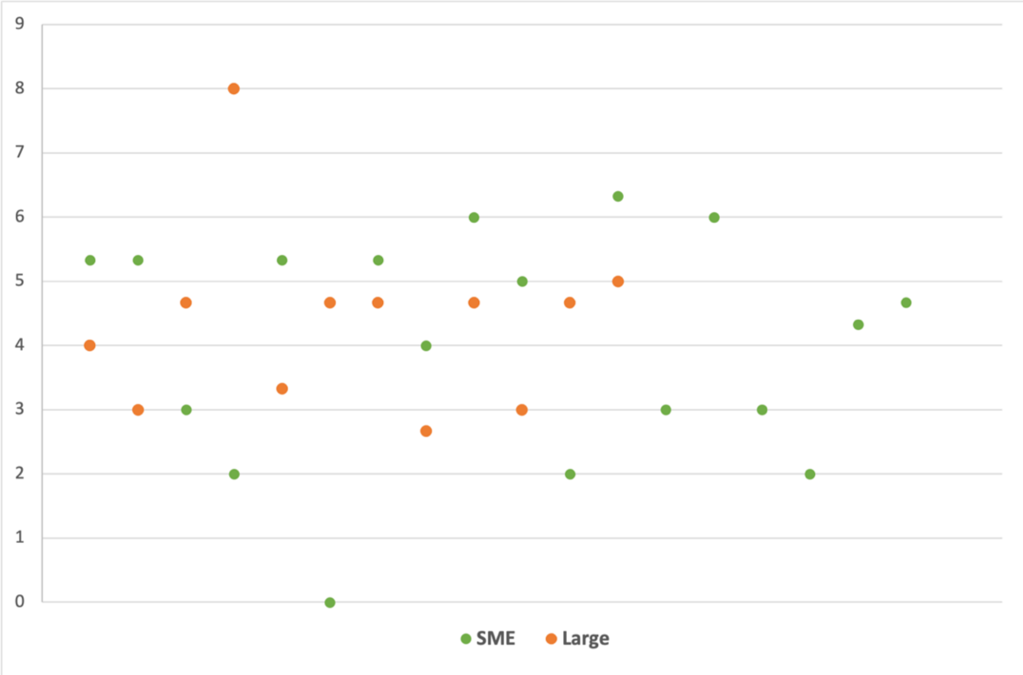


Figure 12 - Distribution of companies' scores for the topic 'Protection and exploitation' of the Activites dimension.

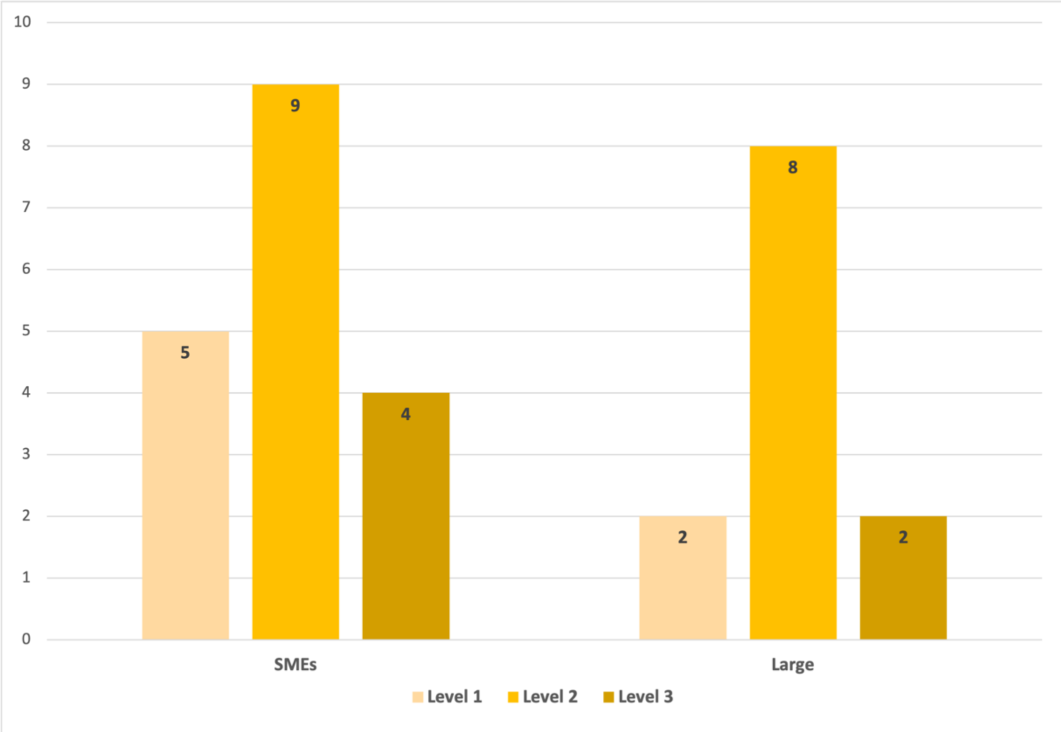


This dimension contains six key factors relating to intellectual property, which are the subject of the present thesis. In the first topic 'R&D and IP creation', the following factors were evaluated: a) *Periodic formulation of a dedicated IP strategy* and b) *IP-related tools and information that the company uses in the product/service development process*. The first factor was well confirmed, with only 23% of the companies in the sample not periodically formulating a dedicated IP strategy. In the second factor, at least 67% make use of at least one piece of patent information in the innovation (product/service) development process, demonstrating the common practice of using IP-related information as a tool for training and strategic proficiency. In the second topic 'Protection and Exploitation', four factors were evaluated. For the factor *Regular use of legal instruments for the protection of innovations and intellectual property*, only one company (B8) stated that it does not make regular use of these instruments for economic barriers that do not allow constant investment in this protection form; on the contrary, only one company (B11) confirmed the factor *Formulation of competitive strategies based on aggressive IP-related policies*. The third factor *Sale or temporary licensing of IP* recorded a low number of confirmations (23%), underlining how this strategy of economic exploitation of IP is still not very common. Lastly, the factor *Exploitation of IP information in innovation process or for strategic decisions* - on the other hand - showed how IP enabled companies to guide their strategic choices, with 70% of the sample confirming that they use at least two IP data in their decision-making processes.

4.6.3 *"Relations" dimension assessment*

The third dimension Relations measures the innovative relationships of the company, its ability to build a network to co-operate with and commonly manage processes. Here, the distribution of the sample across degree levels changes considerably. In this dimension, a greater number of companies are placed at Level 1 Minimum (23%), the number of companies recording a Level 2 falls (57%, compared to 63% in the other two dimensions) and the part of the sample that reaches Level 3 stands at 20%. In fact, the average score value in the sample is 9.76, lower than both previous ones. In Level 1, companies of different sizes can be found: 5 companies are small (of which three B8, B10 and B27 had achieved a Level 1 in at least one other dimension) and 2 are large enterprises (both B4 and B24 had achieved a Level 2 Developing in the other two dimensions). This shows that it is possible to encounter a reticence to cooperate and share resources and strategic knowledge, regardless of the size of the enterprise. However, 50 % of the SMEs settled on Lelev 2 and only 22 % on Level 3 (two small B13 and B22 and two medium B7 and B9 enterprises never fell below Level 2 in any dimension). In contrast to the other dimensions, for the first time a group (17%) of large enterprises is recorded on Level 1, the same percentage of the group is recorded for Level 3, and the majority (67%) for Level 2. A more detailed overview of the enterprise scores for the Relations dimension, its underlying topics and individual factors can be read in Appendix E.

Figure 13 - Distribution of the sample companies across the three progress levels for the Relations dimension of the assessment model, grouped by size (small-medium and large enterprises).



The Relations dimension comprises - like the others - two topics: 'Styles and configurations' and 'Outputs and effects'. The average values recorded in the sample of companies for the two topics are 5.32 and 4.43 respectively. The first topic relates to the modes of cooperation undertaken by the analysed companies. In this case, looking at the distribution of the companies' scores (Figure 14), it can be seen that one third of the total sample ranks below the median value of the score scale (0 to 10). Of this group, six enterprises (four small and two big enterprises) score the absolute minimum by placing themselves at 0, as they do not engage in any relations of cooperation with other external parties. Of these, five (B1, B8, B17, B24, B27) also achieve the same score in the second topic (see Figure 15), demonstrating the total absence of interest in the creation of a network of relations. In the topic 'Styles and configurations', more than one third of the sample (eleven enterprises: four large enterprises, five small enterprises and two medium enterprises) score above 8. This shows a great polarisation in the behaviour of companies regarding the choice of strategic alliances. In the second topic, 'Outputs and effects', almost half of the sample (47%) is below the median value on the score scale, 23% is on the median value and the rest (30%) above. Of the nine companies scoring above 5, one is at 6.66 (B22), seven companies score above 8 (four large enterprises and three medium-sized ones), and one small company (B13) achieves the highest possible score for the topic (10/10), demonstrating how a strategy based on cooperation can enhance the innovative capacity of companies with fewer resources and more freedom.

Also in this dimension, there is a factor directly related to intellectual property. In the topic 'Outputs and effects', the factor Registration of intellectual property on co-produced innovation was assessed. In addition to the possibility that no intellectual property on the co-produced innovation had been registered, the possibility that it had been registered exclusively by one partner or jointly was assessed during the survey. In this case, only four enterprises (B10, B20, B22, B29) stated that they had not registered any kind of industrial property with respect to the co-produced innovations, excluding the six enterprises that had not entered into any strategic alliances aimed at cooperation. Of the remaining enterprises, 53% of the sample registered the intellectual property exclusively without the participation of the partner; whereas only four enterprises (B6, B13, B15, B30) registered the rights to the co-produced innovation in a shared and participatory manner.

Figure 14 - Distribution of companies scores for the topic 'Styles and configurations' of the Relations dimension.

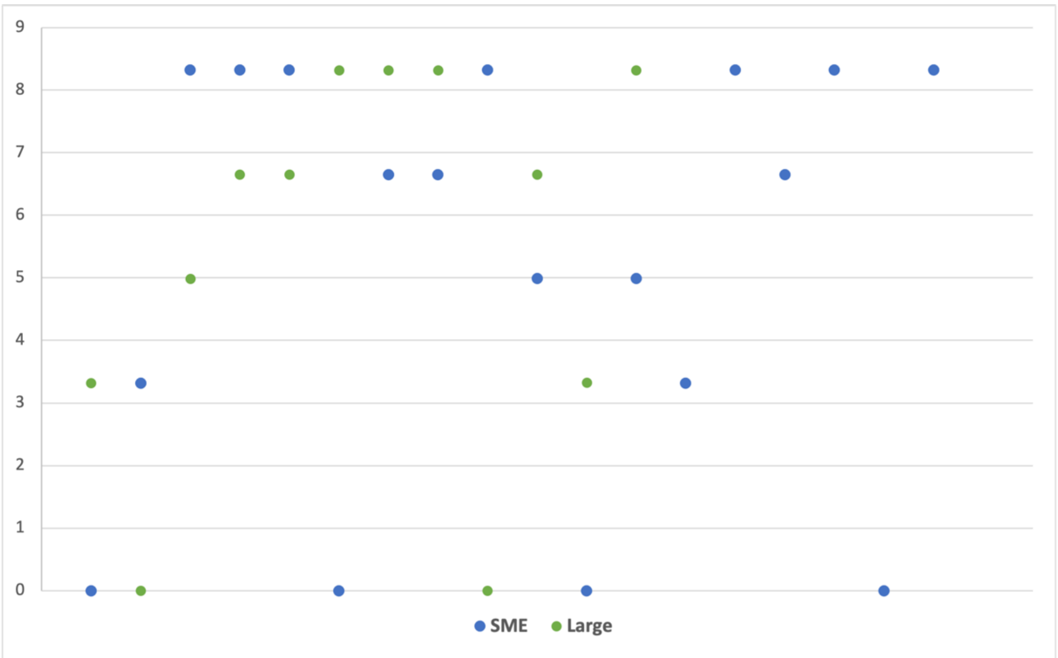
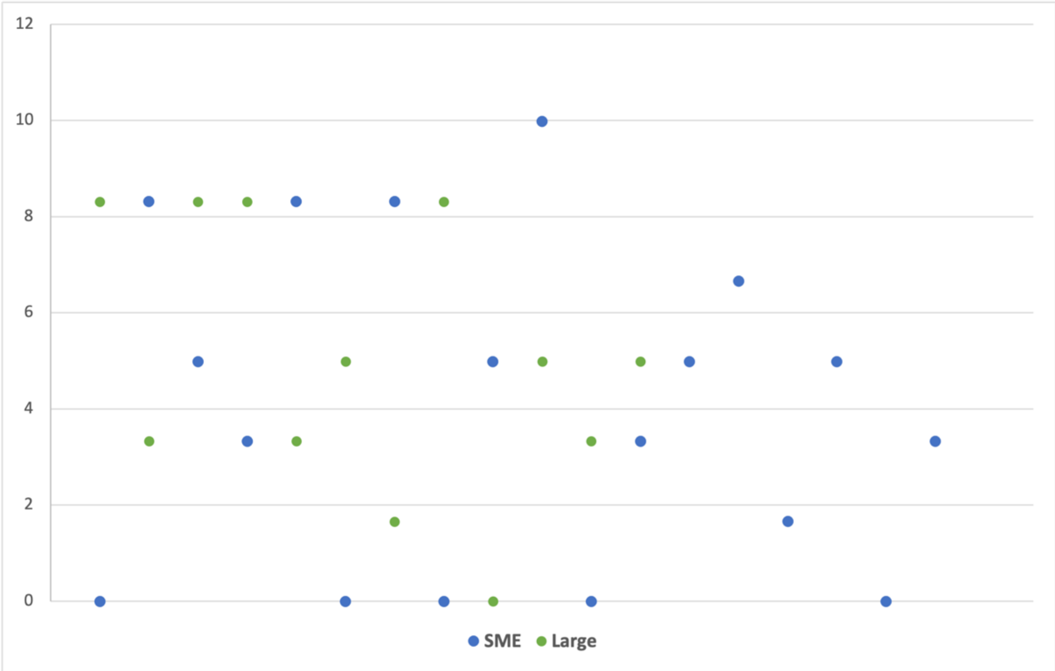


Figure 15 - Distribution of companies scores for the topic 'Outputs and effects' of the Relations dimension.



4.7 Conclusion

The aim of this paper was to analyse the implementation of the innovation system in companies within the context of Industry 4.0. Understanding how companies behave with respect to an innovation system integrated into an industrial model is an important building block for academic and entrepreneurial knowledge. This study aimed to offer the scientific literature the construction of an integrated assessment model on the topic, which is still absent to date. Using an empirical approach, it was possible to develop an assessment model based on the assessment of three dimensions of innovation in Industry 4.0. The three dimensions were defined starting from the analysis of the scientific literature on the topic of innovation in the 4.0 context and the study of national strategic 4.0 policies. The investigation of previous assessment and maturity models built by scientific literature and practitioners around the world provided an example and a prototype on which to build a *ex novo* model. Establishing general objective and design criteria, the architecture of the innovation system 4.0 assessment model was built based on three primary dimensions: Investments, Activities and Relations. Each of these dimensions was implemented with the primary innovation factors found in the literature and national 4.0 policies. Each of these dimensions, while independent, is closely linked to the others, forming an interconnected and integrated innovation system 4.0. The assessment model "In.Ac.Re. Innovation System 4.0" allows to assess each of these dimensions and compose a total score for the identification of the implementation level of the innovation system 4.0. Thanks to the model it is possible to assess companies, regardless of size, and place them in one of three predefined development levels (Level 1 - Minimum, Level 2 - Developing, Level 3 - Advanced) according to a score on a scale from 0 to 60.

The present development of a specific assessment model is the first attempt to assess companies on the vertical topic of innovation in the context of Industry 4.0. The developed tool provides an analysis of the state of continuous innovation in companies and gives an indication to managers and scientists on the degree of progress in the innovation system 4.0. The In.Ac.Re assessment model serves as an easy-to-use and quick-to-interpret tool. These features allow it to be integrated and accompanied by the other 4.0 assessment and maturity models building a 360° assessment of the enterprise in the 4.0 transition path. A further contribution of this research was the testing phase of the assessment model on a sample of 30 Tuscan companies engaged in transformation 4.0. Through a multiple case study, it was possible to analyse the degree of progress in the 4.0 innovation system implementation by this sample of enterprises and to confirm the degree of progress parallel to the integration of the industrial model 4.0. Moreover, this study constitutes the first in-depth study on the behaviour of Tuscan companies regarding 4.0 issues. Although Italy has often been the subject of similar analyses, Tuscany Region has never been the central focus of any study, despite the fact that funding and strategic projects in the 4.0 direction have been a key point of regional policies in recent years.

Although not statistically valid, the sample analysed showed that the companies were at a good level of progress in the development of the 4.0 innovation system, working differently on the three dimensions. Each company chose which factors to focus on based on its sectoral specialisation and on the level of maturity in the adoption of I4.0. The mix of factors and their combination constitutes an original element in each company and reflects the objectives set. Companies have demonstrated an understanding of the strategic value of the intellectual property, adopting it and investing in the creation of a specific strategy. Despite this, the management of IP and especially its economic exploitation (both in terms of commercialisation and in terms of aggressive strategy) shows considerable margin for improvement. During the interviews, companies often mentioned the economic factor and the high maintenance costs as the main obstacle to a greater use of IP as a strategic resource. However, cooperation is not seen as a possible solution. A form of scepticism about sharing ownership and strategic knowledge is widespread. Nevertheless, sharing costs and resources between companies could be a valuable solution to the economic problem and contribute to enhancing each other's innovation capacity.

Despite the various contributions this study offers, the paper is not without limitations. The constructed assessment model needs further integration, testing and validation. It is necessary for the scientific literature - through its critical mass - to contribute to a more detailed frame work on innovation system 4.0. Only through this process will it be possible to integrate the proposed thematic assessment model, currently in its first version. Regarding the testing and validation phase, a broadening of the reference sample and a differentiation of the geographical contexts under analysis is recommended. Although this constitutes the first study on a sample of Tuscan companies, in order to validate the robustness of the test it is advisable to enlarge the sample and test the model in other regions. The criteria for selecting the reference population may also be less strict in order to multiply the number of enterprises that can access this instrument. It is also possible and necessary to assess the degree of implementation of the 4.0 innovation system in companies that have not applied for regional 4.0 calls or do not have at least one registered intellectual property. By doing so, it would be also possible to integrate the reading of these results on the topic of innovation 4.0 with results of other more general maturity models 4.0. Finally, it should be pointed out that a qualitative methodology, although appropriate and effective for the purpose of this research, lacks statistical validity. Enlarging the sample or proposing comparisons with companies from other regions or states (e.g. using the matching pair technique) may provide an opportunity for future studies to integrate data on the financial performance of companies and also use quantitative methodologies. The hope is that future research will cover the limitations of the present study and enrich the literature by contributing to the construction of a framework on innovation system 4.0.

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5 Conclusions: summary of results, contributions and potential future research agenda

The aim of this doctoral thesis was to investigate the relationship between Industry 4.0 and intellectual property. Specifically, the different steps of the research wanted to examine the role of the latter as a central factor in the innovation system required in smart factories. A multidimensional analysis of IP was constructed to understand what space was dedicated to this element into the production model defined by the Fourth Industrial Revolution. The subject of the analyses of the three contributions were mainly the strategic choices regarding IP in the context of I4.0 with a threefold focus: the scientific literature, national 4.0 policies and the strategic choices of companies.

The first paper '*The emerging connection between Industry 4.0 and Intellectual Property. A literature review*' focused on the findings and suggestions in the scientific literature regarding the relation between Industry 4.0 and intellectual property. Through a semi-systematic literature review with a PRISMA approach, what scholars have produced over the last decade was analysed. Although still at an early stage, the present literature is increasing and shows a growing interest in the topic. The approaches and perspectives from which it has been explored are various. To one side, it was possible to identify three main thematic focuses: trigger factors, of the relationship and their activation; characteristics and dynamics of the relationship; and effects and impacts, the consequences of the establishment of this relationship. On the other, the perspectives with which the relationship was looked at were: Management, coordination practices; Strategy, the strategic choices and implications; and Context, factors relating to the competitive environment. In order to summarise and provide easy guide on the topic to scholars, a cross-matrix of perspectives and themes was created to categorise the contributions analysed. There are several aspects considered in the literature, but the element of strategy is central either as a primary focus or as a secondary cause or effect of another focus. Further investigation of the topic is necessary, especially considering the recent emergence of the I4.0 model (early 2010s). The contribution offered by the first paper is therefore limited to a summary of the first steps of research on the topic; a framework is thus provided to stimulate debate and to direct future research.

The second paper (*Fourth Industrial Revolution in G7 countries: policy-driven innovation and the role of intellectual property*) changes perspective and focuses on policy choices at national level. Specifically, the policies established at the national level to introduce and guide the adoption of the 4.0 model were analysed. In fact, the smart manufacturing model was born thanks to the introduction of Science Technology Innovation policies, so much so that I4.0 is considered a policy-driven breakthrough. Starting from this assumption, the analysis focused on the specific 4.0 policies promulgated by central governments (or at their behest). The aim was to a) identify the strategic priorities and central topics defined at national level for I4.0 and the innovation system 4.0; b) to investigate how much space and what role was dedicated to intellectual property in 4.0 policies. The group of G7 countries (USA, UK, Germnay, France, Italy, Canada and Japan) was chosen as the analysis sample due to the high level of industrialisation and economic alignment of the participating countries, despite the heterogeneity of macroeconomic structures. For each country, the 4.0 policy enacted was chosen based on a set of criteria that made them comparable. The analysis was carried out first by document analysis and then by content analysis using NVivo software. Despite the number of differences between the documents, their structure and primary focuses, the framework defined in the G7 4.0 policies is common and concurring. The stated priority is to build an integrated innovation system based on the cooperation of different actors (companies, academia, society, government) to address contemporary socio-economic challenges by developing a new production system. In the setting of the different state priorities, the intellectual priority has been indicated in most of the 4.0 policies. This confirms its strategic character in a system strongly geared towards innovation. Its absence or lesser presence in some cases certainly depends on the different level of depth of the 4.0 policies, the specific approach, and also the amount of freedom left to companies in the implementation of the strategies. The analysis of 4IR policies offers an extension of the literature on the topic of STI policies in the contemporary context and the first in-depth look at the topic in relation to the group of G7 countries.

Finally, the third paper *("In.Ac.Re. Innovation System 4.0" assessment model. An evaluation of Tuscan firms' approach to innovation for Industry 4.0*) offers an analysis perspective focused on companies. The purpose of the contribution is to understand how 4.0 companies (already evolved or undergoing transformation) are approaching the 4.0

innovation strategy and what space IP management strategy has in this. The ultimate goal was the construction of a structured model capable of assessing 'innovation 4.0' state of art, evaluating the implementation in companies on 4.0 transitioning path. The model was built from the innovation factors found in the literature, the elements highlighted in the 4.0 policies and other assessment models on I4.0. From these factors, three main dimensions were defined to be considered in the assessment of the innovation system 4.0: Investment, technological and in human and organisational capital; Activity, creation, protection and exploitation of innovations and IP; and Relations, strategic alliances aimed at innovation cooperation. Each of these dimensions, composed within themselves of different factors, constitutes an element that is independent and, at the same time, interconnected to the others. Through these dimensions, the choices and the strategies implemented by the companies already active in this field will be examined. Also, the effects of the strategic management of the IP on the business 4.0 will be analysed, outlining the practices for the creation, exploitation and protection of the IP. The assessment model provides both a general development value and a development value for each of the three dimensions, based on three stages (Level 1 Minimum - Level 2 Developing - Level 3 Advanced). The assessment model was tested, through the use of the multiple case study, on a sample of 30 Tuscan companies engaged in the 4.0 transition process. Although not statistically valid, the test on the enterprises demonstrated the validity of the model in assessing the progress in the implementation of the innovation system and the different strategic approaches. On a general level, most of the Tuscan companies evaluated are at a development level in the implementation of the innovation system 4.0. The Investment and Activity dimensions register good scores, in contrast to the Relation dimension, showing a strategy less oriented towards cooperation and sharing. More in depth, with regard to intellectual property, the companies showed that they recognise its strategic value for the defence of competitive advantage, but the low economic exploitation was evident and the definition of an aggressive IP-based strategy was absent. The main barrier to IP utilisation is economic (maintenance costs, legal fees, etc.), aggravated by the low propensity to share. The study offers a first assessment model of the innovation system 4.0, which did not exist until now, and a multiple case study on a sample of Tuscan companies, which to date have never been the subject of 4.0 maturity analysis in the scientific literature. In this way, it contributes to the advancement of knowledge about innovation in the 4.0 context.

The research thesis presented here brought to the general attention some elements on the relation between Industry 4.0 and intellectual property. Thanks to an analysis on three sides (academic, national strategy and corporate behaviour), it was possible to build an initial picture of the dynamics that are being defined in the contemporary stretegic context. All three domains highlighted the importance of the issues of developing an innovation system in the 4IR scenario and protecting competitive advantage on an innovation basis. On the one hand, governments have built policies to guide companies in the path of developing and activating the integrated and innovative system that the I4.0 model requires; on the other hand, companies are beginning to build the new business model by implementing ad hoc tools and processes. The academy has begun to explore the phenomena related to these issues from a variety of perspectives, keeping track of developments and changes in the international economic landscape. Indeed, the dynamics related to innovation 4.0 are still being defined and specific strategies are emerging over the past few years.

What is clear from examining the results of the three papers is that innovation is configured as a system in the 4.0 context: the integration of different factors and actors is necessary in order to achieve the construction of the industrial 4.0 model as originally designed. Industry 4.0 is not simply the sum of its technological elements, but rather flourishes from the integration in an interconnected system at intra- and inter-organisational level. Equally, it is not possible to merely study a single innovative factor or strategy, but it is crucial to consider and study the 4.0 innovation issues in an aggregate manner. Intellectual property is generally confirmed as a fundamental resource for the development of I4.0, but it only assumes a key value if it is managed and integrated in a set of systemic actions and strategic choices. It is no coincidence that its potential in companies that have not yet developed strategic alliances or specific strategies is not fully exploited and exploitable. It is in this direction that future research on the subject must develop: investigating an interconnected innovation system 4.0, the relations of the different factors that it comprises and the effects on performance at an aggregate level (company, sectoral, regional and national).

This thesis, therefore, offers as a theoretical contribution a preliminary analysis of the current status of studies on the topic of innovation 4.0 and of the first empirical evidence on the definition of strategic dynamics observable at national and company level on the topic. What has been briefly summarised here provides guidelines for the future construction of a framework on innovation in the context of Industry 4.0. On a practical level, the primary contributions are: firstly, the mapping of the first 4.0 policies and national strategic priorities, useful for the definition of further 4.0 policies in the future; secondly, the construction of a (self-)assessment model for companies on the topic of innovation in the 4.0 context, a practical and easy tool for understanding the level achieved and areas for improvement. The thesis is not without limitations. Within the single papers, the limitations concerning the chosen samples and methodologies have already been described. In general, the thesis has an empirical and explorative character by approaching - with qualitative methodologies - a situation that is still under development. The results, therefore, are circumscribed and do not have statistical validity. However, the contributions of this doctoral thesis are useful to build a first overview on the topic and aimed at providing a solid starting point for the construction of a structured framework on innovation system 4.0.

6 Appendix A

List of publications with related abstracts selected for Paper 1 literature review

<table>
<tr><th>N°</th><th>Autore</th><th>Titolo</th><th>Source</th><th>Year</th><th>Keywords</th></tr>
<tr><td rowspan="2">1</td><td>Kim K., Jung S., Hwang J.</td><td>Technology convergence capability and firm innovation in the manufacturing sector: an approach based on patent network analysis</td><td>R and D Management</td><td>2019</td><td>/</td></tr>
<tr><td colspan="5">Abstract - As a consequence of the convergence between manufacturing technology and the foundation technologies of Industry 4.0, it is becoming more important for firms to formulate an innovation strategy for their technological capabilities. In this context, the present study measures firm-level technology convergence (TC) capability using patent network analysis. A firm's TC capabilities are measured using three centrality indices pertaining to a patent network, which is constructed based on the relationship between patents and their international patent classification. For the empirical analysis, panel regression is conducted to observe the effect of TC capabilities on innovation for the top 30 firms in four manufacturing industries. We find that the TC degree positively influences the firms' overall innovation, namely their total number of patents, and negatively influences their convergent innovation, calculated as the ratio between the number of TC patents and the total number of patents, while the effect of TC betweenness is the opposite. These findings imply that while concentrating on similar technologies may promote quick technology application, it could hamper the enhancement of a TC's potential. To promote TC, a firm should thus develop technologies more likely to be involved in TC.</td></tr>
<tr><td rowspan="2">2</td><td>Startups and the innovation ecosystem in Industry 4.0</td><td>Startups and the innovation ecosystem in Industry 4.0</td><td>Technology Analysis and Strategic Management</td><td>2019</td><td>digital innovation; industry 4.0; innovation ecosystem; Startups</td></tr>
<tr><td colspan="5">Abstract - The article identifies how collaborations with startups can influence digital innovation in Brazilian manufactures. The theoretical basis relates the concepts R&D collaboration, open innovation and Industry 4.0. A qualitative multiple case study was carried out with four startups incubated at C2i, International Innovation Center, located in the south of Brazil. The results indicate that the sources of knowledge and innovation from partnerships with companies, universities, government development agency, and C2i incubator, characterise the intense use of open innovation practices by startups. It has also been found that: the complexity of the startups innovation ecosystem is seen as a strategic asset; and the nature of these collaborations is characterised by informal management, coupled with a still low maturity stage of startups. This study contributes to evidence of the nature, dynamics and consequences of startups collaborations in the development of digitalisation in Brazil, and to demonstrate the Industry 4.0 difficulties and challenges.</td></tr>
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<tr><td>3</td><td>Szalavetz A.</td><td>Industry 4.0 and capability development in manufacturing subsidiaries</td><td>Technological Forecasting and Social Change</td><td>2019</td><td>Capability development; Hungary; Industry 4.0; Manufacturing subsidiary; Upgrading</td></tr>
<tr><td></td><td colspan="5">Abstract - This paper investigates whether advanced manufacturing technologies (AMT) can modify the patterns of upgrading in manufacturing subsidiaries operating in FDI hosting factory economies. Does the digital transformation of local manufacturing engender the accumulation of local technological and R&D capabilities, or the beneficial impact of AMT remains confined to production capability? Analysis is based on primary data collected through in-depth interviews with a sample of high-flying manufacturing subsidiaries in Hungary, complemented with interviews with AMT providers. We find that AMT have spectacularly improved all components of production capability. AMT redefined the boundaries of production activities and incited a fusion of selected technological activities in production activities. AMT deployment has automated selected tacit knowledge-intensive technological activities, making the related subsidiary-level capabilities obsolete. Conversely, other local technological activities have become more knowledge-intensive than before. AMT propelled the upgrading of subsidiary-level R&D capabilities by supporting specific R&D activities and by acting as enabler of innovation collaboration. AMT created an integrated development environment and thus reduced the risks related to the decentralisation of R&D. Altogether, AMT adoption contributed to subsidiary R&D capability becoming ‘revealed’ and further upgraded through learning by doing.</td></tr>
<tr><td>4</td><td>Tumelero C., Sbragia R., Evans S.</td><td>Cooperation in R & D and eco-innovations: The role in companies’ socioeconomic performance</td><td>Journal of Cleaner Production</td><td>2019</td><td>Cooperation; Eco-innovation; Research and development; Socioeconomic performance; Sustainability; Triple Bottom line</td></tr>
<tr><td></td><td colspan="5">Abstract - In this study, the principles of sustainable development motivated the validation of an original model, in which cooperation in R & D and the green route of eco-innovations satisfactorily explain companies’ socioeconomic performance. Data were collected from 221 electrical and electronic manufacturers operating in Brazil and processed via SmartPLS®3 using the Structural Equation Modeling technique. We originally demonstrated that the knowledge synergies released from cooperation in R & D with heterogeneous agents are advantageous to the introduction of multidimensional types of eco-innovations, including both technological (product and process) and organizational. We also succeeded in covering a gap in the literature that stems from the fragmented investigation of the well-known Triple Bottom Line paradigm. We filled this gap by showing that eco-innovations, which could be considered the environmental line, are able to positively influence both the social and economic performances of companies. These findings reverse the logic that companies must first have leftover profits to invest in environmental sustainability. Further, our novel contributions allow us to suggest that cooperation in R & D does not have the ability to influence companies’ socioeconomic performance, which confirms our departure model premises in that, although the relation between cooperation in R & D and socioeconomic performance does not directly exist, it is mediated by the introduction of eco-innovations. Future studies may investigate how biomimicry could inspire radical eco-innovations and how</td></tr>
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	digital transformations, such as Industry 4.0 and IoT could boost the efficiency of eco-innovations.				
5	Benassi M., Grinza E., Rentocchini F.	**The rush for patents in the Fourth Industrial Revolution**	Journal of Industrial and Business Economics	2020	EPO; Fourth Industrial Revolution; Industry 4.0; Matched patent-firm data; Patent applications
	Abstract - Our paper provides a novel and in-depth analysis of the technological trends, geographic distribution, and business-level dynamics of the Fourth Industrial Revolution (4IR) in the European Union from patent- and firm-level perspectives. We do so via the analysis of patents filed at the European Patent Office between 1985 and 2014. We employ a new matched patent-firm data set provided by the Bureau Van Dijk: ORBIS-IP. We find evidence of a surge in the patenting activity related to the 4IR in the past three decades, particularly in networked devices. Our results also suggest that firms filing 4IR patents have become progressively younger on average. At the same time, we find a steady growth in the average number of 4IR patent applications filed yearly by each company. Further variance decompositions show that the surge in 4IR patent applications is mainly explained by incumbent firms filing more 4IR patent applications over time, rather than new entrants progressively populating the 4IR world. Finally, we uncover a general trend emerging at the firm level, whereby firms tend to specialise in a few technological areas and avoid differentiation.				
6	da Silva A., Almeida I.	**Towards INDUSTRY 4.0 | a case STUDY in ornamental stone sector**	Resources Policy	2020	AEC; Industry 4.0; Innovation; Lean thinking; Optimization; Ornamental stones; SDGs
	Abstract - A movement to mobilize the Portuguese Ornamental (OS) sector to reduce waste and improve flexibility began in 2004. Boosted by R&D Mobilizing Projects in consortium and fostered by two of the Sustainable Development Goals (SDG9 and SDG12), this mobilization resulted in a new generation of technologies, concepts and innovative practices, matching the needs of Portuguese OS companies, stressing an integrated approach to European Competitiveness that should be fostered by a sustainable industrial policy, combined with innovation and skills. Bearing in mind that the Sustainable Development Goals (SDG) are the blueprint to achieve a better and more sustainable future for all, and considering the importance of following the goals and guidelines of SDGs 9 and 12 in the industrial processes optimization achievement in the Portuguese OS sector, the following research question arises: What is the impact of the R&D Mobilizing Projects on the efficiency and image of Portuguese OS companies? The objective of this research is to conceptualize an empirical framework based on a mixed methodology, to assess the efficiency and image benefits resulting from participation in these R&D Mobilizing Projects. Through applying the empirical framework to two case studies, it was concluded that for companies that since 2004 have been part of R&D Mobilizing Projects, the evolution in terms of improved energy and raw-material efficiency, soft skills and improved facilities is more positive than in other OS companies. Moreover, there are potential gains in efficiency and image of 9.62%, compared to companies that have never participated in this type of project. This results match with the EU's integrated climate and energy policy and an integrated approach to the sustainable management of natural resources, the protection of biodiversity and ecosystem services. The sustainable production and consumption revealed in the Portuguese OS sector are among the drivers for achieving objectives under both the SDG and the Lisbon strategy.				

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<tr><td>7</td><td>Grashof N., Kopka A., Wessendorf C., Fornahl D.</td><td>Industry 4.0 and clusters: complementaries or substitutes in firm's knowledge creation?</td><td>Competitiveness Review</td><td>2020</td><td>Advanced manufacturing; AMT; Cluster; Incremental; Incremental innovation; Industry 4.0; Innovation; Radical; Radical innovation</td></tr>
<tr><td></td><td colspan="5">Abstract - Purpose – This paper aims to show the interaction effects between clusters and cluster-specific attributes and the industrial internet of things (IoT) knowledge of a firm on the innovativeness of firms. Cluster theory and the concept of key enabling technologies are linked to test their effect on a firm's incremental and radical knowledge generation. Design/methodology/approach – Quantitative approach at the firm-level. By combining several data sources (e.g. ORBIS, PATSTAT and German subsidy catalogue) the paper relies on a unique database encompassing 8,347 firms in Germany. Ordinary least squares (OLS)-regression techniques are used for data analysis. Findings – Industrial IoT is an important driver of radical patents, mediated positively by firm size. For incremental knowledge, a substitution effect occurs between a cluster and IoT effects, which is bigger for larger firms and dependent on cluster attributes and firms' outside connections. Research limitations/implications – The paper opens up new research paths considering long-term disruptive effects of the industrial IoT compared to short-term effects on the innovativeness of firms within clusters. Additionally, it enables further research enriching the discussion about cluster attributes and how these affect ongoing processes. Practical implications – Linking cluster theory and policy with Industry 4.0 raises awareness for being considerate in terms of funding and scrutinising one-size-fits-all approaches. Originality/value – Connecting the concepts of a cluster and advanced manufacturing technologies as a proxy for industrial IoT, specifically focussing on both radical and incremental innovations is a new approach. Especially, taking into account the interaction effects between cluster attributes and the influence of industrial IoT on the innovativeness of firms.</td></tr>
<tr><td>8</td><td>Kahle J.H., Marcon É., Ghezzi A., Frank A.G.</td><td>Smart Products value creation in SMEs innovation ecosystems</td><td>Technological Forecasting and Social Change</td><td>2020</td><td>Capabilities; Cooperation; Industry 4.0; Innovation ecosystem; Internet of things; Smart Products</td></tr>
<tr><td></td><td colspan="5">Abstract - Technological innovations are increasing the opportunities to develop technically and economically feasible Smart Products. However, the development of Smart Products requires knowledge and capabilities that single companies usually do not possess, thus creating new opportunities for cooperation through the establishment of innovation ecosystems focused on Smart Products. Hence, this study aims at understanding possible configurations for these ecosystems by considering the required characteristics they should display to allow the development of Smart Products from their early stages. We conducted a case study in an electro-electronic and automation industrial cluster of 120 small and medium-sized enterprises (SMEs), based on 37 interviews with key participants in the ecosystem: 15 SMEs executives, 8 academics, 2 R&D center representatives, 8 large manufacturing customers, 3 business associations and 1 state government representative. As a result, we developed a conceptual framework that presents the required characteristics of an innovation ecosystem to offer Smart Products, and discloses the relationships among these characteristics.</td></tr>
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9	Lobova S.V., Alekseev A.N., Litvinova T.N., Sadovnikova N.A.	**Labor division and advantages and limits of participation in creation of intangible assets in industry 4.0: humans versus machines**	Journal of Intellectual Capital	2020	AI; Competition; Creation of intangible assets; Human intellectual capital; Humans; Industry 4.0; Intellectual capital; Labor division; Machines
	Abstract - Purpose –The purpose of the work is to solve the set problem and to study the competition and perspectives of division of labor of humans and machines during creation of intangible assets in Industry 4.0. Design/methodology/approach – The research is performed with the help of regression and comparative analysis by building regression curves and with the help of the qualitative structural and logical analysis. Findings – The authors perform an overview of the factors that determine the advantages and limits of participation in creation of intangible assets in Industry 4.0, determine the perspectives and compile recommendations for division of human and machine labor during creation of intangible assets in Industry 4.0. Originality/value – The results of the performed research confirmed the general hypothesis that machine technologies allow improving the innovative, marketing and organizational and managerial activities and activities in the sphere of R&D through automatization of certain stages of the process of creation of intangible assets. The authors determine the factors that define the contribution of machine technologies in this process and their competitive advantages as compared to human intellectual capital during creation of intangible assets. These advantages prove the possibility and expedience of division of human and machine labor during creation of intangible assets.				
10	Mahmood T., Mubarik M.S.	**Balancing innovation and exploitation in the fourth industrial revolution: Role of intellectual capital and technology absorptive capacity**	Technological Forecasting and Social Change	2020	Fourth industrial revolution (Industry 4.0); Innovation; Intellectual capital; Organizational ambidexterity; Structural equation modeling; Technology absorptive capacity

	Abstract - Industry 4.0, which features the Internet of things (IoT), cloud computing, big-data, digitalization, and cyber-physical systems, is transforming the way businesses are being run. It is making the business processes more autonomous, automated and intelligent, and is transmuting the organizational structures of businesses by digitalizing their end-to-end business processes. In this context, balancing innovation and exploitation—organization's ambidexterity — while stepping into the fourth industrial revolution can be critical for organizational capability. This study examines the role of intellectual capital (IC)—human capital, structural capital and relational capital—in balancing the innovation and exploitation activities. It also examines the role of technology's absorptive capacity in the relationship between IC and organizational ambidexterity (OA). Data were collected from 217 small and medium enterprises from the manufacturing sector of Pakistan using a closed-ended Likert scale-based questionnaire. The study employs partial least square-Structural Equation Modeling (PLS-SEM) for data analysis. Findings indicate a profound influence of all dimensions of IC, both overall and by dimensions on organizations' ambidexterity. Findings also exhibit a significant partial mediating role of technology absorptive capacity (TAC) in the association of IC and ambidexterity. The findings of the study emphasize the creation of specific policies aimed to develop IC of a firm, which in turn can enable a firm to maintain a balance between innovation and market exploitation activities. The study integrates the TAC with the IC-OA relationship, which is the novelty of the study.				
11	Muscio A., Ciffolilli A.	**What drives the capacity to integrate Industry 4.0 technologies? Evidence from European R&D projects**	Economics of Innovation and New Technology	2020	European NUTS 2 regions; Framework Programme; Industry 4.0; Smart specialisation; technological integration
	Abstract - Industry 4.0 is a word that identifies innovative technologies, processes and products, typical of a Fourth Industrial Revolution characterised by a massive and pervasive use of interdependent digital technologies the rise of cyber-physical spaces or smart factories. European Member States are committed to adapting their innovation systems in order to be able to benefit from Industry 4.0 and the European Commission is also facing the challenge of putting less advanced regions in a position to do so, However, little is known about the drivers of the capacity to compete in the domain of Industry 40 by integrating different enabling technologies at the regional level. On the basis of data on regional participation in the 7th European Framework Programme for research and technological development, we investigate the factors underlying the capacity to compete by integrating Industry 4.0 enabling technologies. The evidence shows that EU funding, centrality in research networks and interregional cooperation all play a significant role in technology integration, and these results have important policy implications.				
12	Wang L., Luo G.-L., Sari A., Shao X.-F.	**What nurtures fourth industrial revolution? An investigation of economic and social determinants of technological innovation in advanced economies**	Technological Forecasting and Social Change	2020	Economic globalization; Financial development; G-7 countries; Human Capital; R&D; Technological innovation

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<tr><td></td><td colspan="5">Abstract - The Fourth Industrial Revolution is characterized by technological transformations, artificial intelligence, and the digital revolution. The technological innovation in the Fourth Industrial Revolution is expected to be a supply-side miracle, with long term gains in the efficiency, as well as production. The widespread variability in the innovation performance of countries has led to the development of many underlining theoretical explanations. These explanations primarily revolve around the role of international trade, research and development, foreign direct investment, human capital, and the financial development in the Fourth Industrial Revolution. Previous studies, however, have only looked at the micro-level determinants of technological innovation. Also, previous studies have tended to ignore the cross-sectional dependency among countries, and the heterogeneity in analysing the issues that pertain to technological innovation. This study examines the macroeconomic indicators of technological innovation in G-7 countries from the year 1996 to 2017. The results show that globalization, R&D, GDP, financial development, and human capital are important factors in explaining technological in-novation. Furthermore, the results of the panel causality test suggest that there is bidirectional causality from economic globalization, financial development, human capital index, research and development expenditure, and real GDP to technological innovation, and vice versa. The findings from this study may be helpful when designing policies that are related to globalization, financial development, and innovation.</td></tr>
<tr><td>13</td><td>Wu C.</td><td>Qualitative analysis of intellectual property forgery in manufacturing enterprises in Industry 4.0 environment</td><td>International Journal of Technology Management</td><td>2020</td><td>Evaluation system; Forgery; Intellectual property; Legal regulation; Manufacturing enterprise; Qualitative analysis</td></tr>
<tr><td></td><td colspan="5">Abstract - In order to avoid the situation of economic development, enterprise competition and resource waste caused
by intellectual property counterfeiting in manufacturing enterprises under
the environment of Industry 4.0, this paper makes a qualitative analysis on the intellectual property forgery that most affects the development of enterprises. Based on the existing laws and regulations, this paper puts forward some suggestions to improve the legislation of intellectual property forgery in manufacturing enterprises, and constructs an intellectual property protection model to realise the best protection of intellectual property rights and ensure the economic level and social welfare level of the country. To avoid economic losses caused by intellectual property counterfeiting, and to improve the manufacturing enterprises' intellectual property research and development enthusiasm, improve the overall competitiveness of manufacturing enterprises.</td></tr>
<tr><td>14</td><td>Chih-Yi S.,
Bou-Wen L.</td><td>Attack and defense in patent-based competition: A new paradigm of strategic decision-making in the era of the fourth industrial revolution</td><td>Technological Forecasting and Social Change</td><td>2021</td><td>Network position; Open innovation; Patent-based competition; Technological diversification</td></tr>
</table>

	Abstract - The fourth industrial revolution, characterized by hyperautomation and hyperconnectivity, is accelerating the pace of innovation and rapidly reshaping the competitive landscapes of firms. Firms are increasingly competing to secure key resources, such as patents. Patent-based competition, e.g., patent litigation, is increasingly fierce and has been largely used as a strategic weapon against rivals. It is crucial to explore the conditions under which firms can improve their performance when taking action to address patent-based competition. We suggest that the effectiveness of different types of actions is contingent on technological diversification, open innovation, and network position. Using data from the U.S. communications equipment industry on patent infringement lawsuits, we find that firms pursuing attacks perform better. These positive effects are amplified when firms have a more diversified technological portfolio, whereas the adoption of outbound open innovation weakens the positive effects. Furthermore, although defenders are adversely affected when they are attacked, these negative effects are mitigated when firms can utilize inbound open innovation or operate in a less crowded environment. Our study contributes by extending the competitive dynamics literature to the context of patent-based competition.				
15	Díaz-Chao Á., Ficapal-Cusí P., Torrent-Sellens J.	**Environmental assets, industry 4.0 technologies and firm performance in Spain: A dynamic capabilities path to reward sustainability**	Journal of Cleaner Production	2021	Circular economy (CE); Dynamic capabilities; Environmental assets; Firm performance; Industry 4.0.
	Abstract - The consolidation of industry 4.0 (I4.0) as a new innovative ecosystem has generated high expectations about its economic and environmental effects. In this study, we investigate whether Industry 4.0 technologies can reinforce environmental assets management in achieving firm results. We intend to contrast the existence of reward mechanisms for being green. Using a panel of 1028 Spanish industrial firms in 2009–2016 period, the research has obtained three main results. First, environmental assets, the use of robots and the adoption of flexible production technologies generate individual and two-complementarity marginal effects in the explanation of sales, exports and labour productivity. Second, environmental assets and I4.0 technologies do not generate any individual or complementarity marginal effect that positively explains gross operating margins. And, third, however, we have found a business model that generates significant total effects on the four firm results, especially on profitability, through the combination of environmental assets, I4.0 technologies, R&D expenditure, production flexibility and human capital management. Implications for the circular economy and ethical business models are also discussed.				
16	Gu J., Gouliamos K., Lobonţ O.-R., Nicoleta-Claudia M.	**Is the fourth industrial revolution transforming the relationship between financial development and its determinants in emerging economies?**	Technological Forecasting and Social Change	2021	E7 economies; Financial development; Fourth industrial revolution; Natural resources; Technological innovation

	Abstract - The fourth industrial revolution has been significantly affected by different economic sectors, including the Financial sector. The financial sector has dramatically changed the way it works and hence, providing new opportunities to investors. The advancement of new technologies in information and communication has a strong association with financial sector performance, profitability, and development. This study examines the impact of technological innovation and natural resources on financial development across seven emerging economies (such as China, India, Brazil, Mexico, Russia, Indonesia, and Turkey) from 1990 to 2017. The results of the cointegration test indicate that there is a long-run relationship between financial development and its determinants in all three models. The results further show that natural resources, technological innovation, income, human capital, and research and development (R&D) expenditures are important variables affecting financial development in the long run. We found that human capital strengthens the technological innovation led financial development nexus in E7 countries. In terms of implication, human capital, technological innovation, and continuous investment in R&D can shift the curse into a blessing by transferring natural resources into other productive sectors of the economy.				
17	He X., Xiong D., Khalifa W.M.S., Li X.	**Chinese banking sector: A major stakeholder in bringing fourth industrial revolution in the country**	Technological Forecasting and Social Change	2021	Bank financing; China; Financial risk; Industrial revolution 4.0; Non-bank financing; Technological Innovation
	Abstract - The industrial revolution 4.0 has caused an abrupt change in society and has changed the way we live. The importance of banking finance in affecting technological innovation is a topic of great interest in recent years. This endeavor empirically examines the impact of bank financing and financial risk on technological innovation in the case of China from 1990 to 2017. We use Maki cointegration and Bayer-Hanck cointegration to serve this purpose and the estimation cointegration regression (FMOLS) method. The results show that bank financing, non-bank financing, real GDP, research and development (R&D), and Financial Risk Index (FRI) are important to explain technological innovation in China. Our results further show that an increase in financial risk alters the relationship between bank financing and technological innovation. High financial risk is a big hurdle in bank financing, leading to technological innovation in China. Moreover, we find an increase in financial risk alters the relationship between non-bank financing and technological innovation.				
18	Hu G.-G.	**Is knowledge spillover from human capital investment a catalyst for technological innovation? The curious case of fourth industrial revolution in BRICS economies**	Technological Forecasting and Social Change	2021	BRICS; FDI; Human capital; Knowledge spillover; R&D; Technological innovation
	Abstract - The issue of knowledge spillovers, and technological innovation has received immense importance, particularly in the Fourth Industrial Revolution. In this context, this endeavor to carry out this study aims to empirically examine the determinants of technological innovation of Brazil, Russia, India, China, and South Africa (BRICS) countries, using the data that spans from the year 1990 to 2017.Moreover, this study further aims to investigate the role of human capital in mediating the relationship between the spillovers, through imports, foreign direct investment, and the technological progress that will prevail. This study is confined to the employment of the Westerlund (2007) cointegration and augmented mean group (AMG) method for the analysis. The cointegration method outcomes show that there is a stable, long-run equilibrium relationship among the variables in all the five models that have been				

	considered. The results of the AMG method show that in the long run, an increase in the gross domestic product, human capital, research and development expenditures, and the foreign direct investment spillovers, increases the technological innovation in BRICS economies. The results also suggest that an improvement in the human capital strengthens the relationship between technological innovation and the spillovers. Hence, the knowledge spillovers and the developed human capital are more likely to affect the total technological innovation.				
19	Li X., Nosheen S., Haq N.U., Gao X.	**Value creation during fourth industrial revolution: Use of intellectual capital by most innovative companies of the world**	Technological Forecasting and Social Change	2021	Firm's performance; Fourth industrial revolution; Innovative companies; Intellectual capital; Value addition; Value creation
	Abstract - This study investigates the impact that intellectual capital (IC) and value creation have on a firm's performance, in relation to the leading innovative firms in the world, at the start of the Fourth Industrial Revolution. An analysis is based on the top 100 innovative companies from different countries and sectors, as indexed by Forbes in 2016, for the period between 2011 and 2015, by using the pooled OLS regression model. The Fourth Industrial Revolution characterizes the fusion of technologies, and is blurring the boundaries between physical, digital, and biological spheres. The study reveals that capital employed efficiency and human capital efficiency have a significant positive impact on a firm's performance, whereas, the relational capital efficiency and structural capital efficiency are not related to it. Findings also suggest that relational capital efficiency is positively related to the value creation of innovative firms, while all the other mechanisms of intellectual capital and Modified Value-Added IC (MVAIC), are not associated with the value creation of innovative companies. The study advocates that innovation policies are critical, and require a rigorous review from the top management in order to meet the challenges of the Fourth Industrial Revolution, that is heavily innovation-based, and requires overwhelmingly new competencies.				
20	Wang K.-H., Umar M., Akram R., Caglar E.	**Is technological innovation making world "Greener"? An evidence from changing growth story of China**	Technological Forecasting and Social Change	2021	China; Economic globalization; Green growth; Human capital; Industrial revolution 4.0; Technological Innovation

	Abstract - Countries around the world are making efforts to transform f their industrial and economic structures in order to promote green growth, and environmentally adjusted multifactor productivity growth, that relies on cleaner and sustainable energy sources. With the Fourth Industrial Revolution coming into play, eco-friendly technologies have significantly improved and repaired the environmental conditions in modern economies. Many studies on the determining factors of green growth have attracted researchers and policymakers across the globe. However, thus far, no single study has reported the role of technological innovation, in the promotion of green growth. Therefore, this study examines the impact of technological innovation on green growth, in the presence of economic growth, globalization, research & development expenditures, and human capital between the periods of 1990 to 2018, with a multivariate framework in China. By using cointegration approaches, the results suggest that in the long-run, green growth depends on technological innovation, GDP, human capital, economic globalization, and R&D expenditures. Moreover, technological innovation is found to have a positive effect on green growth. On the policy side, any initiative that targets technological innovation, globalization, R&D, and human capital shall affect green growth. These policies should take approximately more than one year to start functioning.				
21	Yuan S., Musibau H.O., Genç S.Y., Shaheen R., Ameen A., Tan Z.	**Digitalization of economy is the key factor behind fourth industrial revolution: How G7 countries are overcoming with the financing issues?**	Technological Forecasting and Social Change	2021	Business finance; Digitalization; G7 countries; Industrial revolution 4.0; R&D expenditure; Technological innovation
	Abstract - The digitalization role in economy has increased over the years, particularly after the arrival of the industrial revolution 4.0. This paper aims to examine the impact of digitalization in the economy on technological innovation in the presence of business financed R&D expenditures, income, and financial risk for G7 economies for the time period 1990 to 2017. This endeavor uses recently developed econometric approaches, which are superior to traditional first-generation econometric methods. The results show a long-run stable relationship between technological innovation and its determinants (such as digital economy, bank financing R&D expenditure, GDP, and financial risk). Moreover, the digital economy, bank financing R&D expenditures, and financial risk are important factors responsible for technological innovation in G7 countries. This study has meaningful policy implications for decision-makers in designing their policies related to the digital economy, bank financing, and technological innovation in G7 countries. The cost of innovation is significantly high, for which bank finance is sufficiently required. However, due to the high financial risk firms, banks often reluctant to finance innovative ideas. Hence, for nurturing technology through digitalization in economy and business financed R&D expenditure, financial risk must be minimized.				

7 Appendix B

"In.Ac.Re. Innovation System 4.0" assessment model developed in Paper 3

Areas	Topics	Factors	W.	Answers	Score	W.	Min	Max
INVESTMENTS [20]	*Financial and technological [10]*	Investment types adopted to address the path of innovation and change for I4.0	**3,33**	Equity capital	1	**1,11**	0	3
				Bank loans	1	**1,11**		
				European/national/regional funding	1	**1,11**		
				None	0	**0**		
		4.0 technologies adopted within the company	**3,33**	None	0	**0**	0	2
				1	1	**1,66**		
				2+	2	**3,33**		
		Planning and management control phases on which data collection and analysis using 4.0 tools and models have had the greatest impact	**3,33**	None	0	**0**	0	5
				Strategic planning	1	**0,66**		
				Budgeting	1	**0,66**		
				Feedback collection	1	**0,66**		
				Reporting	1	**0,66**		
				Performance evaluation (economic-financial, accounting, organisational, individual, process, product)	1	**0,66**		
	Organizational and human [10]	Integration of the necessary I4.0 skills into the workforce	**3,33**	Recruitment	1	**1,11**	0	3
				Training	1	**1,11**		
				Interprofessional funds	1	**1,11**		
				None	0	**0**		
		Skills covered by HR training and development activities	**3,33**	Deepening the 4.0 model	1	**1,11**	0	3
				Hard skills (e.g. technological tools competences)	1	**1,11**		
				Soft skills (e. g. problem solving, team work, emotional intelligence)	1	**1,11**		
				None	0	**0**		
		Implementation of Vertical Integration 4.0	**3,33**	Yes	1	**3,33**	0	1
				No	0	**0**		
ACTIVITIES [20]	*R&D and IP creation [10]*	Presence of an in-house R&D department	**2**	Yes	1	**2**	0	1
				No	0	**0**		
		Structuring level of the internal innovation process	**2**	Unstructured	0	**0**	0	2
				Partially structured	1	**1**		
				Defined and established procedure	2	**2**		
		Periodic formulation of a dedicated IP strategy	**2**	Yes	1	**2**	0	1
				No	0	**0**		
		IP-related tools and information that the company uses in the product/service development process	**2**	Technology mapping at the beginning of the development phase	1	**0,5**	0	4
				Preliminary search before the end of the development phase	1	**0,5**		
				Background search before placing on the market	1	**0,5**		
				Analysis of implementation freedom at the beginning of the development phase	1	**0,5**		
				None	0	**0**		
		Prioritising sustainability in R&D and IP creation processes	**2**	Yes	1	**2**	0	1
				No	0	**0**		

ACTIVITIES [20]	*Protection and exploitation [10]*	Regular use of legal instruments for the protection of innovations and intellectual property	**2**	Yes	1	**2**	0	1
				No	0	**0**		
		Formulation of competitive strategies based on aggressive IP-related policies (e.g. over-patenting)	**2**	Yes	1	**2**	0	1
				No	0	**0**		
		Adoption of 4.0 protection mechanisms (e.g. cyber security) to protect the innovations developed	**2**	Yes	1	**2**	0	1
				No	0	**0**		
		Sale or temporary licensing of IP	**2**	Yes	1	**2**	0	1
				No	0	**0**		
		Exploitation of IP information in innovation process or for strategic decisions	**2**	To identify possible development trajectories	1	**0,33**	0	6
				To reduce the risk of counterfeit products of competitors	1	**0,33**		
				To obtain technical information	1	**0,33**		
				To identify potential partners or suppliers	1	**0,33**		
				To identify geographical areas and/or markets of interest	1	**0,33**		
				To identify possible properties to protect	1	**0,33**		
				None	0	**0**		
RELATIONS [20]	*Styles and configurations [10]*	Setting up strategic alliances or cooperation projects for the production of process and/or product innovations	**3,33**	None	0	**0**	0	2
				Yes, with universities or other research organisations	1	**1,66**		
				Yes, with companies or start-ups	1	**1,66**	0	
				Yes, both with other companies/start-ups and with universities/research institutes	2	**3,33**		
		Defining and establish a structure and hierarchy for cooperation	**3,33**	No	0	**0**	0	2
				Yes, one entity maintained a position of coordination, management and decision-making	1	**1,66**		
				Yes, under equal management and decisions conditions	2	**3,33**		
		Programming shared training activities for cooperation	**3,33**	No	0	**0**	0	2
				Yes, organised by a third company	1	**1,66**		
				Yes, based on mutual knowledge sharing	2	**3,33**		
	Outputs and effects [10]	Registration of intellectual property on co-produced innovation	**3,33**	No	0	**0**	0	2
				Yes, in an exclusive form	1	**1,66**		
				Yes, in a shared ownership	2	**3,33**		
		Coordinated production and management of innovations for the 4.0 model (technologies)	**3,33**	Yes	1	**3,33**	0	1
				No	0	**0**		
		Implementation of Horizontal Integration 4.0	**3,33**	Yes	1	**3,33**	0	1
				No	0	**0**		

8 Appendix C

Detail of enterprise scores in the Investments dimension in "In.Ac.Re. Innovation System 4.0" assessment model

	Investments [0 - 20]								
	Financial and technological [0-10]				*Organizational and human [0-10]*				
	Investment types adopted to address the path of innovation and change for I4.0	4.0 technologies adopted within the company	Planning and management control phases on which data collection and analysis using 4.0 tools and models have had the greatest impact	***Tot***	Integration of the necessary I4.0 skills into the workforce	Skills covered by HR training and development activities	Implementation of Vertical Integration 4.0	***Tot***	**TOT**
B1	3,33	3,33	1,99	**8,65**	3,33	2,22	0	**5,55**	**14,2**
B2	1,11	3,33	1,33	**5,77**	1,11	1,11	3,33	**5,55**	**11,32**
B3	2,22	3,33	0,66	**6,21**	1,11	2,22	0	**3,33**	**9,54**
B4	2,22	1,66	2,66	**6,54**	1,11	2,22	0	**3,33**	**9,87**
B5	1,11	1,66	0,66	**3,43**	1,11	1,11	3,33	**5,55**	**8,98**
B6	1,11	1,66	0	**2,77**	1,11	1,11	0	**2,22**	**4,99**
B7	3,33	3,33	2,66	**9,32**	1,11	2,22	3,33	**6,66**	**15,98**
B8	1,11	1,66	0,66	**3,43**	1,11	1,11	0	**2,22**	**5,65**
B9	2,22	1,66	0,66	**4,54**	2,22	1,11	0	**3,33**	**7,87**
B10	1,11	1,66	0	**2,77**	1,11	1,11	0	**2,22**	**4,99**
B11	2,22	3,33	1,33	**6,88**	2,22	3,33	0	**5,55**	**12,43**
B12	2,22	3,33	1,99	**7,54**	1,11	1,11	0	**2,22**	**9,76**
B13	1,11	3,33	0,66	**5,1**	1,11	2,22	3,33	**6,66**	**11,76**
B14	3,33	3,33	1,99	**8,65**	2,22	3,33	0	**5,55**	**14,2**
B15	2,22	3,33	0	**5,55**	1,11	1,11	0	**2,22**	**7,77**
B16	2,22	3,33	1,99	**7,54**	3,33	3,33	0	**6,66**	**14,2**
B17	3,33	1,66	0	**4,99**	1,11	1,11	3,33	**5,55**	**10,54**
B18	2,22	3,33	1,33	**6,88**	2,22	2,22	3,33	**7,77**	**14,65**
B19	2,22	3,33	0,66	**6,21**	2,22	2,22	0	**4,44**	**10,65**
B20	3,33	3,33	1,99	**8,65**	1,11	1,11	0	**2,22**	**10,87**
B21	1,11	3,33	1,99	**6,43**	2,22	1,11	3,33	**6,66**	**13,09**
B22	2,22	3,33	2,66	**8,21**	1,11	1,11	3,33	**5,55**	**13,76**
B23	2,22	1,66	0	**3,88**	1,11	1,11	0	**2,22**	**6,1**
B24	2,22	3,33	1,33	**6,88**	1,11	1,11	3,33	**5,55**	**12,43**
B25	1,11	3,33	0,66	**5,1**	1,11	2,22	0	**3,33**	**8,43**
B26	2,22	3,33	1,33	**6,88**	1,11	2,22	3,33	**6,66**	**13,54**
B27	1,11	1,66	0,66	**3,43**	1,11	1,11	0	**2,22**	**5,65**
B28	1,11	3,33	1,33	**5,77**	2,22	1,11	0	**3,33**	**9,1**
B29	2,22	1,66	1,33	**5,21**	2,22	1,11	3,33	**6,66**	**11,87**
B30	2,22	3,33	1,99	**7,54**	1,11	1,11	0	**2,22**	**9,76**

9 Appendix D

Detail of enterprise scores in the Activities dimension in "In.Ac.Re. Innovation System 4.0" assessment model

	Activities [0-20]												
	R&D and IP creation [0-10]						*Protection and exploitation [0-10]*						**TOT**
	Presence of an in-house R&D department	Structuring level of the internal innovation process	Periodic formulation of a dedicated IP strategy	IP-related tools and information that the company uses in the product/service development process	Prioritising sustainability in R&D and IP creation processes	***Tot***	Regular use of legal instruments for the protection of innovations and intellectual property	Formulation of competitive strategies based on aggressive IP-related policies (e.g. over-patenting)	Adoption of 4.0 protection mechanisms (e.g. cyber security) to protect the innovations developed	Sale or temporary licensing of IP	Exploitation of IP information in innovation process or for strategic decisions	***Tot***	
B1	2	2	0	2	2	**8**	2	0	2	0	1,33	**5,33**	**13,33**
B2	2	0	0	0	2	**4**	2	0	2	0	0	**4**	**8**
B3	2	1	2	2	2	**9**	2	0	2	0	1,33	**5,33**	**14,33**
B4	2	1	2	1	0	**6**	2	0	0	0	1	**3**	**9**
B5	2	1	2	2	2	**9**	2	0	0	0	1	**3**	**12**
B6	2	0	2	1	0	**5**	2	0	0	0	0	**2**	**7**
B7	2	2	2	0,5	2	**8,5**	2	0	2	0	1,33	**5,33**	**13,83**
B8	2	0	0	0	0	**2**	0	0	0	0	0	**0**	**2**
B9	2	1	2	0,5	2	**7,5**	2	0	2	0	1,33	**5,33**	**12,83**
B10	2	1	2	1,5	2	**8,5**	2	0	0	2	0	**4**	**12,5**
B11	2	1	2	1	2	**8**	2	2	0	0	2	**6**	**14**
B12	2	2	2	2	2	**10**	2	0	2	0	0,67	**4,67**	**14,67**
B13	2	1	2	0,5	0	**5,5**	2	0	0	2	1	**5**	**10,5**
B14	2	2	2	2	2	**10**	2	0	2	2	2	**8**	**18**
B15	2	2	2	2	2	**10**	2	0	0	0	1,33	**3,33**	**13,33**
B16	2	2	2	2	2	**10**	2	0	2	0	0,67	**4,67**	**14,67**
B17	2	2	2	1	2	**9**	2	0	0	0	0	**2**	**11**
B18	2	1	2	0,5	2	**7,5**	2	0	2	0	0,67	**4,67**	**12,17**
B19	2	2	2	0,5	2	**8,5**	2	0	2	0	0,67	**4,67**	**13,17**
B20	2	1	0	1	0	**4**	2	0	2	2	0,33	**6,33**	**10,33**
B21	2	1	2	1	2	**8**	2	0	0	0	1	**3**	**11**
B22	2	1	2	0,5	2	**7,5**	2	0	2	2	0	**6**	**13,5**
B23	2	1	0	1,5	0	**4,5**	2	0	0	0	1	**3**	**7,5**
B24	2	1	2	1	0	**6**	2	0	0	0	0,67	**2,67**	**8,67**
B25	2	1	0	0,5	2	**5,5**	2	0	0	0	0	**2**	**7,5**
B26	2	2	2	2	2	**10**	2	0	0	0	1	**3**	**13**
B27	2	1	2	0,5	0	**5,5**	2	0	0	2	0,33	**4,33**	**9,83**
B28	2	1	0	1	0	**4**	2	0	0	2	0,67	**4,67**	**8,67**
B29	2	1	2	1	2	**8**	2	0	2	0	1	**5**	**13**
B30	2	2	2	1,5	2	**9,5**	2	0	2	0	0,67	**4,67**	**14,17**

10 Appendix E

Detail of enterprise scores in the Relations dimension in "In.Ac.Re. Innovation System 4.0" assessment model

	Relations [0-20]								
	Styles and configurations [0-10]				***Outputs and effects [0-10]***				**TOT**
	Setting up strategic alliances or cooperation projects for the production of process and/or product innovations	Defining and establish a structure and hierarchy for cooperation	Programming shared training activities for cooperation	***Tot***	Registration of intellectual property on co-produced innovation	Coordinated production and management of innovations for the 4.0 model (technologies)	Implementation of Horizontal Integration 4.0	***Tot***	
B1	0	0	0	**0**	0	0	0	**0**	**0**
B2	1,66	1,66	0	**3,32**	1,66	3,33	3,33	**8,32**	**11,64**
B3	1,66	1,66	0	**3,32**	1,66	3,33	3,33	**8,32**	**11,64**
B4	0	0	0	**0**	0	0	3,33	**3,33**	**3,33**
B5	3,33	1,66	3,33	**8,32**	1,66	0	3,33	**4,99**	**13,31**
B6	3,33	1,66	3,33	**8,32**	3,33	0	0	**3,33**	**11,65**
B7	3,33	1,66	3,33	**8,32**	1,66	3,33	3,33	**8,32**	**16,64**
B8	0	0	0	**0**	0	0	0	**0**	**0**
B9	1,66	1,66	3,33	**6,65**	1,66	3,33	3,33	**8,32**	**14,97**
B10	1,66	1,66	3,33	**6,65**	0	0	0	**0**	**6,65**
B11	3,33	1,66	3,33	**8,32**	1,66	3,33	0	**4,99**	**13,31**
B12	3,33	1,66	0	**4,99**	1,66	3,33	3,33	**8,32**	**13,31**
B13	1,66	3,33	0	**4,99**	3,33	3,33	3,33	**9,99**	**14,98**
B14	3,33	1,66	1,66	**6,65**	1,66	3,33	3,33	**8,32**	**14,97**
B15	3,33	1,66	3,33	**8,32**	3,33	0	0	**3,33**	**11,65**
B16	3,33	1,66	3,33	**8,32**	1,66	3,33	0	**4,99**	**13,31**
B17	0	0	0	**0**	0	0	0	**0**	**0**
B18	3,33	1,66	3,33	**8,32**	1,66	3,33	3,33	**8,32**	**16,64**
B19	1,66	1,66	3,33	**6,65**	1,66	0	0	**1,66**	**8,31**
B20	3,33	1,66	0	**4,99**	0	3,33	0	**3,33**	**8,32**
B21	1,66	1,66	0	**3,32**	1,66	0	3,33	**4,99**	**8,31**
B22	3,33	1,66	3,33	**8,32**	0	3,33	3,33	**6,66**	**14,98**
B23	1,66	1,66	3,33	**6,65**	1,66	0	0	**1,66**	**8,31**
B24	0	0	0	**0**	0	0	0	**0**	**0**
B25	3,33	1,66	3,33	**8,32**	1,66	3,33	0	**4,99**	**13,31**
B26	3,33	1,66	1,66	**6,65**	1,66	3,33	0	**4,99**	**11,64**
B27	0	0	0	**0**	0	0	0	**0**	**0**
B28	3,33	0	0	**3,33**	1,66	3,33	0	**4,99**	**8,32**
B29	3,33	1,66	3,33	**8,32**	0	0	3,33	**3,33**	**11,65**
B30	3,33	1,66	3,33	**8,32**	3,33	0	0	**3,33**	**11,65**