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Innovation 4.0 Policies in Italy: Strengths and Weaknesses of the Innovation Ecosystem of the "Transition 4.0" Plan from an International Perspective

Francesco Orazi [1,*] and Federico Sofritti [2]

[1] Department of Economics and Social Sciences, Polytechnic University of Marche, 60121 Ancona, Italy
[2] Department of Economics and Law, Faculty of Economics, University of Macerata, 62100 Macerata, Italy; federico.sofritti@unimc.it
* Correspondence: francesco.orazi@staff.univpm.it

Abstract: Innovation 4.0 is a strategic lever of industrial policies. That is the reason why, over the last decade, many European countries have introduced national plans to implement it in their economic fabric. Within this context, this paper focuses on the effects of Industry 4.0 policies in Italy and Europe by presenting the results of a research study on the national and continental ecosystems of innovation. In particular, the study was conducted by involving the main key bodies introduced by the "Transition 4.0" plan in Italy: Competence Centers (CCs), Digital Innovation Hubs (DIHs), and Punti Impresa Digitale (PID). The study adopted a qualitative–quantitative approach: an analysis of gray literature, semi-structured interviews, and a survey involving Italian and European DIHs were carried out. The results highlight an ambivalent scenario: on the one hand, the research suggests that the consolidation of the ecosystems of innovation is underway in Italy and relies on good organizational capacity; on the other hand, the international comparison indicates that the Italian system still suffers from a marked territorial and institutional fragmentation that needs to be addressed in the coming years.

Keywords: Transition 4.0 plan; Industry 4.0; innovation policies; Competence Centers; Digital Innovation Hubs

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1. Introduction

This paper focuses on the effects of Industry 4.0 policies in Italy and Europe by presenting the results of a research study on the national and continental innovation ecosystem.

The former "Industry 4.0" plan, launched in 2016 and subsequently named "Enterprise 4.0" and finally "Transition 4.0", has fostered access to and the development of new technologies in the Italian socioeconomic system and forms of innovation governance involving universities, research centers, public bodies, and companies.

Innovation 4.0 is a strategic lever of industrial policies, and in the last decade, many European countries have introduced national plans to implement it in their economic fabric. Despite their specificities, these policies have several points in common: integration between research and innovation; emphasis on the adoption of digital technologies in industrial processes; the promotion of investment in innovation among companies; and the mass customization of products as a new business model. These processes involve a form of innovation governance marked by a multi-actor approach that comprises local and national institutions, including universities and public and private research centers.

The systemic perspective adopted promotes territorial innovative culture [1–3] and technology diffusion in small and medium-sized enterprises [4], emphasizing public policies as tools to "govern" innovation processes and the competitive revitalization of national economies. In this sense, Europe is strategically targeting the diffusion of smart factories [5,6], characterizing them on three main technical–organizational functions: integration between physical and human resources through digital technologies and robotics;

integration between companies and between companies and external networks through information technologies; and the use of innovative sustainable strategies to reduce energy consumption and waste [7].

Compared with other countries, Italian policies addressed to promote technological innovation in manufacturing show a certain fragmentation of interventions and an often inconsistent governance of innovation. The same can be attributed both to the specific technical configuration of the production structure, which is characterized by pulverized supply chains of small and medium-sized enterprises, and to the polycentrism and socioeconomic differentiation of its localisms [8]. At the same time, the training system and labor market governance are not adequately coordinated, resulting in mismatch effects between supply and demand and "brain drain" patterns of skilled professionals due to the combined effect of low wages, insufficient demand for high-skilled jobs, limited institutional capacity to support innovative startups in their market debut, and inadequate venture capital [9]. This results in innovative technologies being allocated abroad, thus losing their ability to support innovation in the local contexts where they are tested and the costs are incurred [10].

The ambivalent trend in the governance of development processes is highlighted by the large and long-standing national literature. Several key aspects have been highlighted in the literature on technology districts: the first is the coordination of multiple stakeholders of different natures. Public agencies, enterprises, universities, and research centers must be managed so that they can cooperate with a view to local development. In this regard, it is important for public agencies to implement specific strategies and governance tools to promote the innovation processes of economic structures [11]. Territorial policies are crucial to enhancing the role of local leadership, which is essential to stimulating cooperative practices and horizontal exchanges among stakeholders to foster local development as a shared process [12].

Another key factor in the Italian local governance of innovation is represented by the marked socioeconomic differences between the northern and southern areas. This factor represents a historical criticality of the Italian economic and productive fabric, which significantly impacts innovative processes at the local and national levels [13,14].

The international literature also emphasizes the importance of regional innovation governance [15,16]. Innovation ecosystems are considered institutional means to foster bottom–up innovation processes, especially from the perspective of regional innovation systems [17,18]. In fact, innovation is fostered by collaborative activities among territorial entities of various natures (public, private, mixed) that lay the foundation for an atmosphere/setting conducive to Transition 4.0 practices [19]. The challenge is the digital conversion of small and medium-sized enterprises (SMEs), a complex process both due to their difficulty in innovating production processes consistently and because of the large investments involved [20]. The involvement of SMEs in 4.0 policies aims to develop innovation ecosystems at the local, national, and international levels [21], built on the assumption that innovation is often the result of the intertwining of traditional issues to be regulated with innovative and evolved governance strategies [22,23]. The aim is to configure innovative, collaborative, and inclusive environments capable of developing a culture of innovation through training initiatives and orientation to funding [24].

The 4.0 paradigm has been explored primarily in terms of the diffusion of the adoption of these technologies in firms and its overall impact on companies [25–27]. For example, market-related benefits were considered [28], as were dynamics related to technology transfer [29]. Also, research has focused on Innovation 4.0 processes in individual territorial contexts, as well as on the effects of regional innovation policies [16]. From this point of view, research has considered the local dimension through case studies on traditional industrial districts [30], also showing the relevance of the 'cognitive structure' sedimented historically in districts in the development of different approaches and mechanisms for implementing innovation 4.0 in the district dimension.

For instance, Hervas-Oliver et al. [30] studied innovation policies in three traditional industrial districts with a qualitative approach and found that "one-size-fits-all policies" are not effective in promoting innovation at the local level. The best strategy seems to focus on the driving role of local actors capable of supporting bottom–up collective actions and based on co-design processes to implement targeted and shared local innovation.

Pagano et al. [22], by analyzing a traditional industrial district, came to similar conclusions, arguing that innovation is the result of a series of synergies between resources within the local context and external resources. Local development thus becomes the result of a combination of 'local buzz'—defined as learning processes taking place among actors embedded in a community by just being part of this context—and a 'global pipeline'—defined as knowledge attained by investing in building channels of communication to selected providers located outside the local milieu [22,31,32]. Some actors play the role of gatekeepers and are of pivotal importance for the diffusion of an innovative atmosphere in the local dimension; such actors can be leading firms, research centers, universities, business associations, and knowledge providers. The role of innovation policies is to promote public and private bodies to act as gatekeepers to prompt innovation in the local context [22]. These bodies act as intermediary agents as they are able to "filter" external knowledge and convert it into something understandable and useful for the local cluster.

However, innovation 4.0 has been less investigated from a macro perspective: Jiyu et al. [33], for example, focused on the outcomes of 4.0 policies to analyze the keys to the success of innovation 4.0 on different continents; in particular, they conducted a survey involving management figures from companies in all continents to provide a structural framework of the challenges and benefits brought by innovation 4.0.

Drawing upon this backdrop, there seems to be a lack of insight into the effects of innovation 4.0 policies at national and international levels, which is the focus of this contribution. The study aims to fill this gap by conducting an explorative qualitative study so as to frame the Italian case in the European framework.

The article will first provide an overview of the structures and activities of the Italian 4.0 system, providing an overview of the ecosystems of innovation introduced by the Transition 4.0 Plan in Italy: Competence Centers (CCs), "Punti Impresa Digitale (PID), and Digital Innovation Hubs (DIHs). Then, the Italian case will be addressed from an international perspective by conducting a comparison between Italian and European innovation policies. To this end, Section 2 focuses on an analysis of the national model of innovation governance, comparing it with the main European experiences, Section 3 describes the methodologies and research design, and Section 4 discusses the research results by ordering them on the basis of the multiple approaches used. Finally, the last section discusses the most relevant evidence from the survey.

2. Research Context: The Italian Governance of Innovation within the European Framework

The European strategy entitled "Digital Compass: the European way for the digital decade" (2021) identifies four goals to be achieved by 2030: on the human capital front, at least 80 percent of the adult population should have basic digital skills, and 20 million ICT specialists should be employed in the EU; 75 percent of enterprises should use cloud computing, big data, and AI services, and more than 90 percent of the EU's small and medium-sized enterprises should achieve a basic level of digital intensity; all households should have a fast Internet connection, and all populated areas should have 5G; cutting-edge, sustainable semiconductor manufacturing in Europe should account for 20 percent of world production; and finally, all the key public services should be available online.

Italy has started the digitization of the industrial sector, with a lower I4.0 investment budget than both France and Germany. In Germany, the annual investments in I4.0 applications up until 2020 amount to EUR 40 billion, with an estimated economic growth of EUR 153 billion. In France, in 2016, the Industrie du futur plan was endowed with a fund

of more than EUR 10 billion, with a focus on the development of innovative startups; the Station F project is considered the world's largest startup incubator [34,35].

The current Italian 4.0 governance model relies on two principles: innovative investment and skills. The first incentivizes private investment, increases private spending on research and development, and strengthens finance to support I4.0. The second spreads the 4.0 culture through training initiatives: the school–work transition, university paths, and innovative doctorates.

The governance of innovation is delegated to the "Impresa 4.0 national network," which consists of three instruments: Competence Centers, Digital Innovation Hubs, and Digital Enterprise Points.

Competence Centers (CCs) are innovation hubs that foster a climate of collaboration between the public and private sectors and between research institutions and enterprises, with a focus on SMEs. They are involved in promoting applied research activities, technology transfer, and training on advanced technologies.

Digital Innovation Hubs (DIHs) are organized by the most representative business associations nationwide. They are in charge of stimulating companies' demand for innovation, surveying their needs, and guiding them in I4.0 digitization opportunities through training activities and guidance on financing.

Digital Enterprise Points ("Punti Impresa Digitale"—PID) are service structures organized by the Chambers of Commerce and dedicated to spreading digital culture in micro-, small-, and medium enterprises (MSMEs) of all sectors. They offer digital skills assessments for companies, consulting firms, and training services (Table 1).

Table 1. The ecosystems of innovation introduced by the "Transizione 4.0" Plan.

Body	Promoting Bodies	Main Activities	Number
Competence Centre (CC)	Public–private partnerships	Applied research, technology transfer, and advanced training	8
Digital Innovation Hub (DIH)	Confindustria, Confartigianato, CNA, Confesercenti, Confcommercio	Mapping the digital maturity of enterprises Training for sector-specific advanced skills Orientation for digital transformation	269
Punti Impresa Digitale (PID)	Chambers of Commerce	Enterprise digital maturity mapping and digitization startup assistance with assessment/mentoring Basic digital skills training and guidance	88

Italy is in the process of digitizing many industrial sectors, but investment planning appears to be conditioned both by the territorial fraying of its development governance and by the structural limitations of the national production structure: modest investment in research, the excessive presence of SMEs below the threshold of technological innovation, the insufficient contribution of large enterprises to the innovation of production processes, the inadequate institutional coordination of public investment strategies, and the low capacity of the production system to absorb highly scientifically qualified labor. Overcoming these delays is necessary to accompany the country's social, economic, and administrative digitization, all the more so in accordance with its territorial differences. Italy's administrative digitization shows significant distances between the north and center–south, and in turn, the country's digitization is below the standard of many European competitors [25,26]. While social and economic digitization connects the most dynamic regions (Lombardy, Emilia-Romagna, Veneto, and part of Piedmont) to the European continental platform of development, it also rewrites/creates new fractures, peripheries, and inequalities of territorial development [8].

Despite the highlighted limitations, Italy has a relevant entrepreneurial fabric that pursues a "high" path of development, focusing on technology, research, innovation, and

the enhancement of human capital. These are the 30 percent of companies that manage to move optimally in the design of innovative development and in receiving funding put in the pipeline by both I4.0 and the National Recovery and Resilience Plan—NRRP [36].

These companies manage to consistently decline their excellence within a knowledge economy in which intangible resources and assets become increasingly strategic. The prominence given by these companies to R&D as a strategic factor is much higher than the average Italian performance: 1.39 percent of GDP invested in 2018, which is lower than the 1.53 percent indicated as the minimum national target in the context of the Europe 2020 program, compared to the EU28 average of 2.11 percent [36]. The pace of R&D investment in Italy is also proceeding more slowly than in the rest of Europe: in 2018, national spending on intra-mural R&D grew by 3.3 percent compared to 2017, compared to the European growth of 5.2 percent. Similarly, total spending in this area has grown by 25.3 percent in Italy since 2010, which is far below the European average growth (35.9 percent). Moreover, in 2020, Italy suffered from a reduction in personnel engaged in R&D activities (−4.3%) in comparison with 2019.

At the national level, the Digital Economy and Society Index (DESI) 2022 places Italy 18th among the 27 EU member states [37].

The analysis of the Italian results shows an ambivalent scenario:

- More than half of citizens lack basic digital skills;
- Regarding connectivity, progress is observed in terms of broadband service deployment and network implementation;
- Sixty percent of SMEs have reached a basic level of digital intensity, with the use of cloud services growing significantly;
- The use of public digital services has shown considerable growth in the past two years, although only 40 percent of Internet users use them, compared to the EU average of 65 percent.

In terms of human capital, Italy ranks 25th out of the 27 EU countries. Only 46% of people possess basic digital skills, which is below the European average of 54%. The gap is narrower for people with more than basic digital skills (23 percent in Italy compared to 26 percent in the EU). The country has a very low percentage of ICT graduates: only 1.4% choose ICT disciplines, the lowest figure recorded in the EU. In the labor market, the percentage of ICT specialists is 3.8% of total employment, still below the EU average (4.5%). At the same time, only 15 percent of Italian companies provide ICT training to their employees, five percentage points below the EU average.

Finally, regarding the territorial distribution of supply chains and governance structures of technological innovation for economic development, the national innovation ecosystem shows ancient imbalances on the north–south axis but also surprising territorial realignments. Among the 680 structures surveyed by Unioncamere's Atlante I4.0, 50 percent are located in the north, followed by the south (28 percent) and the center (22 percent). And it is still the north that polarizes more than 60 percent of Competence Centers and Business Incubators and nearly 80 percent of technology transfer centers. This is also why the north has a higher presence of activities supporting research and experimental development projects. More evenly distributed throughout Italy, on the other hand, appears to be the network of Digital Enterprise Points (PID) set up by the Chambers of Commerce. This represents a reference for entrepreneurs who wish to start a digitalization path. The geographical distribution of DIHs and FabLABs (digital fabrication) also appears to be substantially balanced territorially. Technical high schools (Istituti Tecnici Superiori—ITS) are also quite widespread and are an important reference point for companies seeking highly specialized figures at the technological level.

From this composite ecosystem of national technological innovation, some patterns can be identified: 3D printing is more widespread, whereas blockchain and artificial intelligence-supporting SMEs are less adopted. Nearly one in three facilities provides support services for 3D printing, so-called additive manufacturing. But there is no shortage of centers that can support businesses in data management: 68 facilities deal with cloud

and 68 with big data and analytics. On the other hand, there is still room for improvement in supporting enterprises in "frontier" technologies: only 9 facilities provide assistance on blockchain and 16 on artificial intelligence.

Finally, the sums intercepted by the Italian innovation ecosystem should be added to those of the National Recovery and Resilience Plan (NRRP) amounting to 350 million over the period 2021–2026 to strengthen the innovation ecosystem. The goal is to rationalize and reorganize the innovation ecosystem, promoting a network of 60 centers (including CCs, DIHs, and PID) to stem the excessive fragmentation of the system. Operationally, four primary actions are planned: to improve the effectiveness and efficiency of existing CCs, to evaluate the possibility of creating new ones, to fund EDIHs selected by the Digital Europe program, and possibly to allocate additional funds to those that have been recognized as projects eligible for funding with NRRP funds.

3. Materials and Methods

To carry out the research, qualitative–quantitative techniques were adopted, which consisted of two levels: the first, based on semi-structured interviews with privileged witnesses, involved the heads of CCs; the second involved a survey among Italian DIHs and PID and DIHs in the European context.

The use of mixed methods is motivated by the exploratory nature of the study, carried out on an institutional fabric recently introduced. The qualitative approach of the first level is motivated by the need to delve into the object of study by interfacing with a privileged witness with the aim of obtaining a clear picture of the implementation of the investigated bodies at the time we carried out the research. These bodies were in fact newly established, and it was deemed important to use the interview because it could guarantee a greater level of depth, as well as better identify the analytical dimensions that would be fruitful to analyze with the web survey in the next phase. Twelve interviews were conducted with privileged witnesses: 8 with representatives of the 8 Italian CCs; 2 with directors of Italian PID and DIHs; and 2 with representatives of European DIHs. The privileged witnesses were chosen by consulting the organizational chart of the entities and are prominent representatives of the CCs who hold apex roles in its governance (mainly directors). Given their apex positions, these individuals were able to provide an insider's perspective on the status of implementation and deployment of the CCs and other entities. The interviews were preceded by a gray literature review based on the analysis of Italian and European policy documents; this was useful to reconstruct the research context described above as well as to describe the Italian CCs. Interviews involving components of Italian PID and DIHs and those with representatives of European DIHs were also conducted with senior figures and had a twofold aim: they were useful in making sampling choices and allowed for better identification of the dimensions of analysis for the subsequent survey. The interviews relied on a guideline aimed at investigating the following analytical dimensions: the state of implementation of the institutional entities; activities carried out so far; areas of specialization; institutional and governance features; partnerships; and networking and collaboration activities with other entities created by the Transition 4.0 plan.

In the first level, carried out between May 2020 and January 2021, in-depth interviews were conducted with privileged witnesses from the eight Italian Competence Centers. Given their possession of strategic information and expertise, apex individuals were interviewed: directors of CCs and members of management committees. The work was supplemented with participation in online events, such as webinars and pilot line presentations, organized by the CCs themselves. This allowed for continuous monitoring of the activities and actions taken by the CCs. Their small number made it possible to adopt a qualitative methodology as well as to survey the entire observed target population.

The exploratory approach adopted was along a continuum that, from the analysis of gray literature (reports and policy documents; analysis of official documentation found on CC websites such as bylaws and notices, etc.), culminated in the definition of the

semi-structured interview outline. The exploratory phase made it possible to identify the analytical dimensions to be further explored through the subsequent survey.

The second level consisted of a comparative web survey conducted in parallel between the Italian PID and DIH systems and the European DIH systems. In terms of sample selection, institutions were mapped by consulting official directories. For the mapping of Italian DIHs and PID, Atlante i4.0, a web portal for business digitization promoted by Unioncamere and the Ministry of Economic Development, was consulted. For the mapping of European DIHs, the European Commission's Smart Specialization Platform was used as a source. These databases enabled the creation of databases with the entire target population. Institutions were contacted by e-mail to fill out (free opt-in) the questionnaire; responses were then solicited by phone at a later date. This phase took place between March and September 2021.

Given the exploratory nature of the study, the sampling design was discussed with the representatives of the 8 CCs in the Italian case and those of the European DIHs. In the Italian case, the privileged witnesses agreed on our hypothesis of using reasoned sampling. The possibility of such a choice was motivated by the low numerosity of the statistical population considered (N = 200), an aspect that allowed us to use the procedure of theoretical saturation, for which we decided to suspend the increase in the empirical base when the contribution that could be obtained from the addition of another case might be zero.

However, in the case of the European sample (N = 150), our choice, based on the feedback from the privileged witnesses, fell on stratified sampling. Stratified sampling offers the advantage of dividing a population that would require a very large sample into relatively homogeneous strata that require smaller samples whose sum is less than the sample size we would have to extract from the total statistical population. In this way, we extracted a simple random sample from each stratum. The stratification of the sample was carried out by constructing three strata based on the economic size of the countries (total GDP, population, placement in the European Innovation Scoreboard).

Regarding the reliability of the samples, we accepted a margin of error of $\pm 10\%$, with a 95% confidence interval. The higher response rate found in the Italian sample (82/200 = 41% of the statistical population) than in the European sample (39/150 = 26% of the statistical population) makes the former more reliable. Although the low European coverage has limitations in terms of statistical adequacy, it seems to be significant on an exploratory level and fulfills the purpose of the survey to provide insights dealing with some trends involving DIHs in the European context. This study has an exploratory nature, and more extensive research will certainly be needed in the future.

The questionnaires administered, except for the differences regarding some institutional and operational aspects that differentiate Italian and European DIHs, were structured according to the following analytical dimensions: institutional profile of the institution; activities carried out and organizational configuration; staffing plan; available financial resources and procurement methods; target user profile; evaluation of national Industry 4.0 policies; and future scenario.

Eighty-two questionnaires covering Italian DIHs and PID and 39 European DIHs were collected. A descriptive data analysis was first conducted to allow the reconstruction of the Italian picture and its comparison with the European one. Then, a multivariate analysis set using a correlation framework between some variables was conducted to highlight the salient aspects that qualify specific phenomenologies of the observed processes.

A correlation plan was designed—after combining the Italian and European samples into a single database—considering the following variables: average employees of funded companies; amount of funds allocated to funded companies; size of funded companies (micro, medium, macro); most funded production sectors; prevailing production specializations of funded companies; networking capacity of funded companies; procurement of DIHs funds; collaboration with universities and research centers; and general adequacy of national I4.0 policies. As for the methodology adopted, the correlation coefficient used is

Pearson's. This coefficient can take values ranging from −1.00 (there is a negative perfect correlation between the two variables) and + 1.00 (there is a positive perfect correlation between the two variables). A correlation equal to 0 indicates that there is no relationship between the two variables. It is worth emphasizing that correlation does not include the concept of cause and effect but only that of a relationship between variables. Correlation allows us to understand that there is a systematic relationship between two variables, but not that one causes the other.

4. Results

This section consists of two parts: in the first part, the main results of the qualitative part focused on the Italian CCs are presented. Drawing on the findings of the analysis of gray literature and on the semi-structured interviews with privileged witnesses, the main features and structure of the Italian CCs are addressed. In the second part, the main findings of the web survey are provided; in particular, the Italian case is discussed from a European perspective.

4.1. The Italian Network of Competence Centers

The CCs were established from a 2018 Ministry of Economic Development call for proposals: eight entities, located throughout Italy, were awarded a total of EUR 72,770,000: about 43 million were earmarked for their establishment and structuring (from organizational aspects to those properly infrastructural), while about 28 million were earmarked for financing—through the publication of calls for proposals managed by the CCs themselves—innovative projects and the implementation of 4.0 technologies carried out by companies.

The overall objective of the CCs is to spread a culture of innovation through multiple channels: organizing calls for proposals to finance innovation and industrial research projects developed by companies; providing laboratories and demonstration spaces to be made available to companies willing to develop and experiment with innovative technologies; and providing training courses and consulting activities at a high level of specialization. With this in mind, since the aim of the CCs is to transfer know-how, technologies, and skills to the Italian industrial system, the composition of the partnership is crucial; in this sense, the idea is for large companies to act as a driving force for SMEs. In fact, partners are tasked with providing knowledge and expertise in such a way as to reach small and medium-sized enterprises, which are the main users of CC services.

The legal forms of CCs vary: they can be recognized associations, cooperative societies with limited liability (s.c.a.r.l.), consortia with external activities, and joint stock companies of a consortium nature (S.c.p.a.). The following table summarizes the main characteristics of CCs (Table 2).

Considering the CCs as a whole, there is substantially homogeneous institutional governance: each entity has a Governing Council and a Technical Scientific Committee. The organizational structure can be more or less branched: some CCs have a more centralized structure (such as Made and CIM 4.0), while others have branches in various territories (such as Artes 4.0 and SMACT). In general, it is possible to see a tendency for metropolitan cities to have an organizational structure that is more centered on their lead agency (Milan, Turin, Genoa), although even in these cases, the initiatives go beyond the regional dimension (especially with regard to training and funding calls for innovative projects). Nevertheless, other entities in northeast, central, and southern Italy tend to have more nodes and more centers of reference.

Management is also mixed; in some cases, the director is a representative of academic institutions and in others of companies. This confirms the public–private nature of these institutions, although the composition of the boards tends to be mostly corporate, confirming the supporting role of the academic system.

Table 2. Overview of the Italian CCs.

CC	Leading Institution	Areas of Specialization	Partnership	Governance
Artes 4.0	Scuola Superiore S. Anna (Pisa)	Robotics, enabling digital technologies	35 founding members (13 universities and research institutions; 1 national institution; 16 companies; 5 foundations and third sector entities) + 92 ordinary, affiliate, and supporting members	Ramified
Made	Polytechnic of Milano	Additive technology; collaborative robotics; industrial cybersecurity; AI and big data analytics; internal logistics and traceability	4 universities, 1 public body and 42 companies	Centralized
CIM 4.0	Polytechnic of Turin	Additive manufacturing 4.0 and digital factories, automotives, and aerospace	2 universities and 23 companies	Centralized
Start 4.0	CNR (National Research Council) of Genoa	Strategic infrastructures, digital twins, security, and optimization	6 public bodies and 33 companies	Centralized
Cyber 4.0	"La Sapienza" University of Roma	cyber security core services, aerospace, automotives, e-health	8 public research bodies, 1 public body, and 35 companies	Ramified
SMACT	University of Padua	Digital platforms and apps, advanced analytics and big data, cloud computing, Internet of Things	8 universities, 4 public bodies, and 30 companies	Ramified
Bi-Rex	University of Bologna	Big data and mechatronics	5 universities, 7 public bodies, and 34 private bodies (27 companies and 17 service providers)	Centralized
Medi-tech	"Federico II" University of Naples and Polytechnic of Bari	Space, agrifood, energy, transport, and construction	8 universities and 22 companies	Ramified

Considering institutional relations with other entities, those formalized with regional governmental bodies are rather rare (in only one case is a formal agreement with a municipal entity noted), while those with other entities created by the original Industry 4.0 plan (especially the DIHs of Confindustria) are more widespread. In some cases, there is regular discussion with regional institutions. There is a fruitful and continuous relationship of collaboration and interchange among the eight CCs through a national coordination table.

Within the scope of the realized and planned activities, CCs enjoy a certain degree of legal autonomy and have their own budget to be used for their organizational and institutional purposes. However, CCs must disseminate processes and cultures of innovation, fostering the development of progressive and gradual virtuous circles: the dissemination of innovative culture, training and orientation activities aimed at businesses (webinars, specialized training courses), and the creation of their own spaces, laboratories, and equipment in partnership with universities.

Some territorial differentiations should be noted, partly reflecting the country's socioeconomic inequalities: in fact, some CCs in the central–south started their activities late compared with CCs in the north–central and northeastern regions, although at present there is a significant realignment.

From a funding perspective, all the respondents stressed an insufficiency. The CCs were then refinanced as part of the NRRP measures with a Ministerial Decree of 16 February 2023 until 2025; the planned allocation is EUR 113.4 million from mission 4 (component 2, investment 2.3) of the NRRP, which concerns the "thematic and territorial strengthening and

extension of technology transfer centers for industry segments". This decree also provides for the creation of a Steering Committee aimed at monitoring activities and promoting the coordination of these entities.

The role of CCs has been central to the European Digital Europe program, which, for the period 2021–2027, aims to support the digitization of the European economy and society through five strategic areas: high-performance computing; artificial intelligence; cybersecurity and trust; advanced digital skills; deployment; optimal use of digital capacity; and interoperability. This program partially replicates that of the 2016 Digitising European Industry (DEI) initiative.

Despite the structural difficulties of the Italian innovation system in accessing European funds for technological innovation, as many as 37 Italian projects have passed the European selection process to become European Digital Innovation Hubs. Of these, 13 will be fully funded under the Digital Europe program (50 percent from Europe and 50 percent from Italy), while the other 24 (17 received the seal of excellence after the first call, the remaining 7 after the second restricted call) will receive 50 percent co-funding from Italy. The total amount requested as funding from these projects is EUR 73.8 million—the highest amount in Europe, followed by 50 million from Spain's 23 above-threshold projects and 48 million from Germany's 19 above-threshold projects.

This result, as well as a potential qualitative leap in the widespread governance of innovation processes, signals a certain degree of resilience in the Italian manufacturing system, especially that composed of those companies, mainly the medium-sized ones, that have been able to move with flexible logic and a culture of innovation in global ecosystems of development [38]. In many ways, this figure also explains Italy's lower pessimism than Europe's in terms of the perceived adequacy of national I4.0 policies. So, Italy comes out in many ways well rewarded at the European level and with a positive assessment of its governance of technological development, despite the criticalities highlighted by the DESI index.

In the European Commission's vision, European Digital Innovation Hubs (EDIHs) will function as "one-stop shops that will help companies respond dynamically to digital challenges and become more competitive". They will do this by providing access to technical expertise and experimental innovations, as well as the opportunity to "test before investing." EDIHs will thus be expected to help companies improve business/production processes, products, or services using digital technologies. Among the other activities they will carry out will be financial advisory services, training, and skill development needed for digital transformation. They will also be expected to help companies address environmental issues, particularly energy consumption and low carbon emissions. EDIHs will also be a kind of "agency" through which the EU can allocate additional resources to support the digitization of SMEs. Their activities will thus include the following: testing and experimentation services; digital assessment and technology brokerage; identification of public and private funding; and staff training services.

This new opportunity will be key to bridging the diffuse innovative capacity of researchers and entrepreneurs and making them interact in an ecosystem of innovative development integrated with more structured business supply chains. The goal is to make institutional opportunities for supporting development and innovation actionable, starting with a more systematic policy of supporting SMEs, startups, and spin-offs, overcoming the fragmentation of industrial policies and the unclear vision of innovation as a shared process of governance for widespread development.

4.2. The Italian Case from a European Perspective

The results of the study on DIHs and PID seem to confirm the greater fragmentation, from a European perspective, of Italian governance for innovation processes. Table 3 highlights that the average number of employees in the DIHs studied is less than one-tenth of that in other European countries, as is the allocation of funds for innovation 4.0. It should be noted that the largest size of these funds (over EUR 500,000) in Italy affects

only 7.4 percent of companies compared to 24.3 percent of European companies; the reverse is true for the smallest size. These Italian peculiarities are associated both with the size of companies (there is a clear gap between Italy and the EU in the involvement of medium-sized companies) and in terms of networking capacity and therefore the level of internationalization.

Table 3. Italian PID and DIHs and European DIHs—comparative framework.

		Italy	Other EU Countries
Employee Average		3.8	41.1
Funds for companies	Up to EUR 50.000	47.1%	24.3%
	More than EUR 500 thousand	7.4%	21.6%
	EUR 51.000–100.000	17.6%	21.6%
	EUR 101.000 to 200.000	16.2%	10.8%
	EUR 201.000 to 300.000	4.7%	9.1%
	EUR 301.000 to 400.000	4.5%	6.9%
	EUR 401.000 to 500.000	2.5%	5.7%
Company target	Micro and small	89%	63.2%
	Medium	11%	34.2%
	Big	-	2,6%
International networking		20.7%	69.2%

Table 4 shows the gap in the technical–organizational configuration between the Italian and European models.

In terms of the services provided, Italian DIHs have predominantly basic assistance and guidance activities (43.9%), while European DIHs predominantly (69.2%) concentrate on ecosystem building, scouting, brokerage, and networking activities. These activities are instrumental in the implementation of technologies in production processes and indicate superior technological development. This appears consistent when looking at the professional figures employed in European DIH-funded projects, which show the massive presence of ICT specialists and engineers; in Italy, in contrast, there is a greater presence of marketing experts and trainers. The latter are employed as external experts by European DIHs in the same way as engineers in the case of Italian DIHs. All of this suggests that while Italy is largely in a phase of promoting a culture of technological innovation, from a European perspective, there seems to be a more advanced and consolidated level of technological innovation in the entrepreneurial fabric.

Differences between Italian and European DIHs also emerge in the prevailing sources of resource sourcing: the share of national ones is similar, while there is a greater propensity for private sources among Italian DIHs (42.7 percent) than European ones (21.1 percent). In contrast, Italian facilities are less able to grab European funds (10.6% vs. 28.1%). This finding is consistent with the one regarding the international networking capacity of the investigated facilities.

The manufacturing and service enterprises involved constitute the main targets of both samples, with a notable difference in terms of production specializations. In Italy, in contrast to Europe, traditional sectors prevail, and higher-tech services are scarce. There is also little demand for product innovation, which in European DIHs, in contrast, constitutes nearly 3 out of 10 types of innovation demanded by firms. In Italy, the large number of small and medium-sized manufacturing firms in often traditional manufacturing sectors mainly drive process innovation. Moreover, although about three-quarters of Italian DIHs cooperate with the university system, in the EU, all those studied cooperate with universities.

Table 4. Italy–EU comparative framework by activity profile, professionalism, funds, and production specializations.

Variables		Italy	EU
Main activities		1. Basic assistance and guidance (43.9%)	2. Ecosystem building, Scouting, brokerage, and networking (69.2%)
		2. Digital assessment (32.9%)	2. Collaborative research (38.5%)
Employed Professionals		1. Marketing experts (53.9%)	1. Engineers (48.7%)
		2. Trainers (46.4%)	2. IT experts (43.6%)
External consultants		1. Trainers (58.7%)	1. IT experts (61.3%)
		2. Engineers and IT experts (52.4%)	2. Trainers (45.2%)
Funding supply	National	46.7%	50%
	Private	42.7%	21.1%
	European	10.6%	28.9%
Sectors	Manufacturing	58.5%	51.4%
	Services	40.2%	40.5%
	Agricolture	1.3%	8.1%
Productive specializations	Traditional Manufacturing	49.4%	28.9%
	Commerce	26.6%	7.9%
	Tourism	6.5%	-
	High-tech manufacturing	4.7%	15.8%
	Technological services	4.8%	31.6%
	Others	8%	17.8
Prevalent type of innovations required by companies		1. Process innovation 40.7%	1. Process innovation 33.3%
		2. Digital marketing 22.2%	2. Product innovation 28.2%
Collaborations with universities		72.5%	100%

Finally, regarding the evaluation of 4.0 policies in their national context, 72.2 percent of respondents from Italian DIHs believe that their activity is penalized by the inadequacy of available resources; this share is lower in the case of European ones (60.5 percent). However, half of the latter complain that the quantity of institutions deemed necessary is undersized compared to what was found among Italian ones (the quantity is insufficient only for 15.5 percent). This figure reflects the greater number of entities expected in the Italian context; while it favors a widespread presence, especially at the local level, it also raises questions about the excessive fragmentation of the 4.0 ecosystem. From the point of view of the diffusion of a culture of innovation, significantly high shares say they are fairly (67.1 percent) or very (15.9 percent) satisfied in Italy; this is consistent with what emerged at the European level (71.8 percent are fairly satisfied, 5.1 percent are very satisfied).

The respondents also offered us some "mood" assessments of the DIHs and entrepreneurial networks with which they interact. This is a shared, satisfied mood regarding the diffusion of innovation culture. However, among the vast majority of European respondents, there is a general negative opinion towards innovation 4.0 policies: 46.2 percent of respondents find they are in fact inadequate, while 76.9 percent of Italian respondents have a generally positive opinion of the policies implemented. A final figure of interest is the scenario regarding the labor-killing effects of technological innovation: only 12.2% of Italian respondents say they are concerned, while this share is much higher (63.1%) among Europeans.

In the second step, a multivariate analysis was carried out with confirmatory intentions concerning what emerged from the descriptive analysis. The analysis, which has a specific focus on the Italian case, shows the significance (a correlation above 0.6) of four aspects.

First, networking activity is positively correlated with the procurement of European funds. This result indicates the extent to which a substantial part of Italy's productive and institutional fabrics show a lag in the ability to activate international collaborative networking and how penalizing this is in terms of resource procurement capacity. The research showed that, for the "chain" of innovative governance for innovation ecosystems 4.0, the value of funds drawn from European projects stands at 10.6 percent, compared to 28.9 percent for European DIH. Similarly, Italian 4.0 ecosystem entities do international networking in only 20.7 percent of the cases analyzed, compared to a European average value referring to our sample that stands at 69.2 percent. It follows that a crucial objective to increase the competitiveness of our innovation process governance hubs in the industrial field lies in the development of professional profiles and skills related to a European design.

A second significant correlation concerns the size of DIH user companies and membership in international networks; in particular, medium-sized companies show a higher correlation with membership in international networks. This finding also confirms the Italian difficulty in international networking, especially considering that the medium-sized companies that make up the Italian DIH user base amount to 11 percent, while this share stands at 34.2 percent in the rest of the European sample. A user base of small and micro-enterprises prevails in Italy, a fabric of diffuse manufacturing economies that together are the wealth and limitations of the Italian manufacturing production system.

A third aspect is the positive correlation between the agricultural sector and Green-Tech as a specialization of user companies, in the presence of a generic underestimation of the involvement of the agricultural sector in the 4.0 ecosystem. The issue of Green-Tech, especially concerning the funding devoted to it by the NRRP, is one of the limitations of the Italian innovation system. Among the farms that turn to DIH, the Italian ones are significantly smaller than the European ones we surveyed (1.3 percent vs. 8.1 percent). This is moreover confirmed by the data on European-funded EDIHs: of the 13 Italian projects funded in full, only one has any relevance to the agricultural sector. This result is rather modest for a context in which the agriculture and food sectors show considerable potential. Among the other 17 projects (EDIHs) considered of interest by the EU but not co-funded, none, on the other hand, relate to the agricultural sector, showing the marked prevalence of the manufacturing sphere.

A final significant correlation concerns the presence of efficient national innovation ecosystems and the recognition of the adequacy of Industry 4.0 strategies to innovate firms. This result underscores the relevance of advanced innovation governance systems and related development support policies for the enhancement of innovative fabrics and their competitiveness. As far as the Italian case is concerned, the data can be read in a chiaroscuro way: on the one hand, the outcome of EDIH funding shows the good organizational capacity of these innovative ecosystems; on the other hand, the territorial and institutional fragmentation highlights deep discrepancies between the productive and territorial fabrics capable of engaging these innovative environments and those realities that are displaced and deeply delayed in the reconversion of their technical–organizational configurations, showing the endemic territorial differentiation that characterizes the Italian socioeconomic structure [39,40].

5. Discussion

This study focused on the effects of innovation 4.0 policies at national and international levels. In this strand, research has mainly focused on two aspects: on the one hand, the effects on the economic–organizational performance of enterprises; on the other hand, the effects of innovation 4.0 in local development contexts (industrial districts, regional innovation systems).

This research is in the second strand, seeking to fill the gap in the scientific literature on the outcomes of the 4.0 paradigm in terms of policy and governance quality. This choice is motivated by the fact that many studies have focused more on the local dimension and less on outcomes in terms of institutional performance. For these reasons, an exploratory qualitative–quantitative approach was adopted to contextualize the Italian case in the European framework.

The study is also in the line of inquiry of a study by Trigilia [39], who emphasizes the role of political, national, and local action as a function of improved economic performance and reduced inequality. In this sense, the institutional fragmentation highlighted by the research concerns PID and DIHs, generated by each trade association, responding to the typical centrifugal logics of the many localisms and particularisms that characterize the Italian socioeconomic context [40].

The Italian production structure, characterized by the widespread presence of small and medium-sized district enterprises, confirms the importance of effective innovation governance. In this sense, the literature highlights the role of key actors, such as gatekeepers, capable of facilitating innovative cultures and the diffusion of production technologies [22]. From this point of view, strengthening innovation 4.0 ecosystems can improve Italian innovation governance by bringing about potential gatekeeper actors such as CCs and EDIHs. These entities, in fact, aim to spread a culture of innovation in the territory through the involvement of public bodies, SMEs, universities, and research centers [21,22,41,42]. However, the comparison with European DIHs showed that Italian 4.0 ecosystems suffer from several limitations: a lower international networking capacity, limited techno-organizational configurations, especially regarding the staff employed, and the critical financial mass available.

Despite these limitations, the study suggests that an innovation ecosystem is being consolidated in Italy; this is evidenced by the 13 projects that have passed the European assessment to become EDIHs and the additional 24 projects that have received the Seal of Excellence. In this sense, the traditional north–south territorial divide appears to be mitigated by the geographic distribution of EDIHs, which shows both territorial variability and manufacturing specializations, and the funding of several initiatives implemented in the center–south of the country.

Drawing on this evidence, it seems useful to discuss I4.0 policies within the Italian macroeconomic context. As pointed out by Orlando and Rodano [43], the Italian economy appears to be characterized by a marked undercapitalization of its firms and a massive presence of zombie firms. These are indebted firms, no longer able to meet debt repayment through their operating income [44]. In 2019, they accounted for 3 to 5 percent of all Italian companies, showing a greater likelihood of experiencing liquidity deficits, default risks, and market exit [45]. In this sense, undercapitalization often anticipates going out of business; about 60% of undercapitalized companies go out of business within 3 years. Orlando and Rodano [43] show that in 2018, there were about 48,000 firms in a state of crisis (7.5 percent of the total). This number would have risen in 2020 to 94,000, but government policy interventions (extraordinary measures against the covid-19 emergency) reduced it to 82,000. Still, this figure appears worrisome: it is, in fact, 12.4 percent of active enterprises, employing nearly one million workers. The most undercapitalized enterprises are the smallest and youngest. At the sectoral level, the greatest vulnerability concerns the food and accommodation sectors; at the territorial level, it affects the central and southern regions.

As for the world of innovation 4.0 ecosystems, despite their profound heterogeneity, the companies that make up the ecosystem show greater dynamics of access to credit and financial strength, as well as a good ability to implement tax benefits for innovation. For example, the access to credit for innovative startups and SMEs through the Guarantee Fund for Small and Medium Enterprises—a public fund established in 2012 to facilitate SMEs' access to credit—founded in the second quarter of 2022 the activation of 15,829 operations, with the total amount of financing mobilized exceeding EUR 2.9 billion. Access to these

sources of credit shows clear territorial imbalances, confirming the deep north–south gaps that characterize the Italian socioeconomic structure.

This positive dynamic of financing widespread innovative companies is related to one of the most important macroeconomic effects of Italy's I4.0 strategy: tax incentives for technological innovation. In the four-year periods 2008–2011 and 2012–2015, the total Italian use of Computer Numerical Control (CNC) machinery stood at about 70 billion for each of the two four-year periods, averaging about 17 billion annually. With the introduction of super-amortization under the former Industry 4.0 plan, in the four-year period 2016–2019, CNC machine consumption rose to 98 billion. In the four-year period 2020–2023, the Italian consumption of new industrial machinery is estimated to reach 112 billion. A comparison of the value of CNC machinery consumption between the four-year period 2020–2023 and that of 2012–2015 shows a growth of 59 percent, a dynamic to which the Industry 4.0 plan has contributed substantially [46]. The Italian production structure proves particularly receptive to industrial robotics. In the decade 2011–2021, it went from 5091 robots sold to 14,083, registering the highest percentage change in growth (176.6%) among the world's leading economies. Contextually, the IOT market reached EUR 8.3 billion in 2022, with +13% growth over 2021 (Digital Agenda). As has been noted [47], the share of small and medium-sized companies aware of I-IoT solutions has risen to 87%, marking an increase of +41% compared to 2021, while for large companies, this share is 98%. Furthermore, 77% of large companies and 58% of SMEs have decided to start at least one project. For both types of companies, however, a lack of skills is still the main factor limiting project startup (44% large companies and 38% SMEs). In light of this, it is interesting to note the positive impact that the NRRP will be able to generate on innovation ecosystems by providing for investments of about EUR 7 billion until 2026 in the integration of the IOT and energy sectors. The NRRP also envisages investments of another 25 billion in favor of the innovation of production systems (smart factories, EUR 14 billion), the digital transition of cities (smart cities, 7 billion), and the activation of home care programs (assisted living, 4 billion).

These data are part of an economic context in which capital productivity is returning to growth after the most acute phase of the pandemic crisis [48]. In 2021, the value added of the sectors producing market goods and services grew strongly (+8.5 percent). The factor productivity of production also followed a similar trend, with the exception of labor productivity, which decreased by 0.7 percent. Capital productivity has grown by 7.7 percent, after being −10.7 percent in 2020. Growth in added value is also helped by an increase in total factor productivity (+2.0%) after a decline in the first year of the pandemic (−1.2% in 2020).

Drawing on this evidence, it seems that the I4.0 policies implemented in Italy have fostered an important process of industrial innovation that is still ongoing; its dynamics need to be investigated from a medium-term perspective.

6. Conclusions

This paper focused on the short- and medium-term effects of Innovation 4.0 policies in Italy, starting with the main evidence from a study conducted on the innovation ecosystems introduced by the former Industry 4.0 plan in Italy. In particular, the aim was twofold: to provide some insights into the development and consolidation of the Innovation 4.0 ecosystem in Italy and to contextualize the Italian case from a European perspective.

This study, based on qualitative–quantitative techniques, investigated both the national articulations of I4.0 (the CCs) and the local ones (PID and DIHs). In addition, it involved European DIHs in order to contextualize the Italian case from an international perspective. What emerged was an articulated and complex reality, which confirms the traditional contradictions and criticalities of the Italian socioeconomic system but also lays the groundwork for significant improvements in the future. The main criticalities detected have to do with the organizational conformation of innovation ecosystems. In this

regard, 4.0 policies have highlighted two endemic issues: institutional fragmentation and the re-proposition of traditional territorial divides.

The fragmentation of interests seems to reflect Italian polycentrism, which has a twofold nature: on the one hand, it represents a valuable resource for local development; on the other, it raises issues of coordination, generating significant territorial inequalities and distortions in the territorial governance of development [40]. This is a crucial factor [49,50], especially in the most critical areas, in fostering the 4.0 transition of institutional and production chains. It should be noted, however, that 4.0 policies, especially with regard to the identification of EDIHs, show an attenuation of national territorial disparities.

This research study suffers from some limitations; the first one has to do with the transitional phase in which it was conducted. At this stage, the bodies investigated had just been created (or were in the process of being created), so a study at a greater temporal distance from the establishment of innovation ecosystems could provide additional insights and update the findings of this work. Secondly, the sample of European DIHs appears to be small, as what was sought was a broad frame of reference with which to compare trends in the Italian case.

Finally, the study opens up a number of further questions, which future research should focus on. From a national perspective, there is a need to respond to the challenges of an environment that is still lacking in terms of digital skills and the overall digitization of socioeconomic fabrics. It would be very useful for future research to investigate not only the state of implementation of 4.0 ecosystems but also their level of effectiveness in terms of responding to innovation challenges. Finally, at the international level, the challenge for the Italian innovation ecosystem is to align with the European critical mass in both technology and organization, building an increasingly integrated system between territories and supra-regional production systems.

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