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Industrial Symbiosis, Networking and Innovation: The Potential Role of Innovation Poles

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Abstract: In the literature, there is much debate on how to make Industrial Symbiosis (IS) successful and on the factors that may potentially affect its implementation, including networking and innovation. They have so far found limited space for investigation in favor of other technical and economic aspects, such as the nature of the processes involved, regulatory issues, economic feasibility, and stakeholders involvement. However, in some cases, they may become relevant, especially when considered together and in their synergistic interaction. An interesting context to be considered in this respect is that of the Innovation Poles (IPs), which are government-sponsored consortia, created within EU programs with the objective of stimulating innovation within network of organizations and that promote the competitiveness in specific industries or value-chains at a local or regional level. In the present article, we firstly discuss how these topics have been so far addressed in IS studies, and then we analyze the main features of the IP model with the aim to understand if, and through which mechanisms, it can contribute to the development and spread of IS. A literature overview through desktop analysis and direct research, which particularly focused on the Italian IPs, provided the knowledge basis of the study. The results highlight the positive role that the IP model could play, both for its institutional activity of production and dissemination of knowledge and innovation, and, mostly, if considered as an applicative context for IS.

Keywords: industrial ecology; industrial symbiosis; innovation; networks; clusters; Innovation Poles

1. Introduction

Industrial Ecology (IE) deals with the impact of industry and technology and associated changes in society and the economy on the biophysical environment. Local, regional and global uses and flows of materials and energy in products, processes, industrial sectors and economies are investigated to highlight the potential reduction of environmental burdens [1–5]. Within IE, Industrial Symbiosis (IS) is an approach that promotes the engagement of communities of companies in improving their economic and environmental performance through collaborative strategies [3–6]. In the literature, there is still much debate on how to make the IS successful [7–9] and about the factors that affect its implementation, including technical and organizational aspects, regulatory issues, companies and stakeholders involvement, and economic feasibility [10–13]. Networking and innovation are also recognized as crucial aspects [9,14–16]. Networks of companies, due to the geographical proximity and the acquired tendency toward collaboration among the entities involved, in particular in the operating forms of industrial clusters or districts, are considered to be one of the most promising contexts for IS. Innovation is also considered a key aspect of the IS development, e.g., for providing new supporting technologies. Even though these aspects are often jointly discussed, especially in organization studies [17–19], in few cases this happens in an IS development perspective. An interesting

model to be investigated in order to fill this gap is that of the Innovation Poles (IPs). They are government-sponsored consortia, created within EU programs with the objective of stimulating innovation within network of organizations and promote the competitiveness in specific industries or value-chains at a local or regional level. Moving from the basic common features of industrial networking and innovation, in the present article, we investigate the role that IPs can play with respect to the development and dissemination of IS. The Italian territory is used as a source of regulatory and technical data on the IP model, which has found in this country a rapid and wide diffusion. The results of the study will contribute to exploring new spaces and possibilities for the development of IS in existing contexts, an area of research in which the authors have been involved for years, and they have conducted research on various forms of territorial agglomerations of companies, including clusters [13], local supply network [20], districts [21], and ecologically equipped industrial areas [22].

The article is structured as follows: the next sections outline the research methods used, and then the current spaces for innovation and networking within the IS studies is described in order to explain why these variables are considered relevant. In the second part of the article, the concept of IP and its main features are outlined and discussed to highlight its potential and limitations and the roles that this model can play with regard to IS. Finally, conclusions are drawn.

2. Research Settings

2.1. Conceptual Framework

The analysis conducted starts from three basic concepts, i.e., that of networking, innovation and IS; they are briefly presented below.

Networking and Inovation: Industrial networks can be considered as hybrid patterns of economic activity coordination that combine the advantages of the traditional governance mechanisms of vertical integration and market exchanges; they can take various forms and operate at different spatial scales [23]. According to the literature, innovation means changes introduced by companies in products, processes, and organization, in order to improve their own operational or market performance [24]. Organization studies demonstrate that these two concepts are closely related and that their interaction is capable of producing system changes. Many authors argue that companies belonging to networks are more innovative than isolated ones [17,25]; this is primarily due to the presence of relations that enable learning and knowledge sharing [18,19]. Geographical proximity often plays an essential role in generating and facilitating the diffusion of knowledge flows among network members, which in turn enhances the likelihood of innovation generation [26–30]. Moreover, it represents a powerful tool through which firms can interrelate [31]. Economic geographers have also contributed to this topic, pointing out that cognitive and organizational dimension, besides geographical proximity, are key elements in interactive learning and innovation within industrial networks [32].

Industrial Symbiosis: IS networks are considered as "complex adaptive systems", which can arise in different ways and evolve over time using their resilience [3,33–35]. An IS may incorporate different solutions (e.g., synergies within supply chains, synergies from shared use of utilities, synergies from local use of by-products, energy, or wastes); it may rely on new or existing entities and may evolve in a planned, facilitated, or spontaneous way [6]. Exchange relations are often enabled from a base of social relations, which find strength in trust and cultural elements. Some agents involved (individuals or organizations) play a decisive role (also as external facilitators) in defining the success of the IS. Over time, some forms of exchange and other cultural elements and values are progressively embedded by the participants, thus strengthening the awareness of its initial purposes. In the long term, IS can improve the socio-economic and environmental performances of the communities of companies involved as well as the territories in which it is established [36,37]. Despite its recognized potential, IS has found difficulty to spread operatively. By analyzing the diffusion rates, we see that in countries where it was possible to plan from scratch its development (e.g., China), its growth was

much faster [12]; in others, in which the development starts from existing industrial contexts, cultural problems and resistance to change may arise [13].

We move from the logical assumption according to which, if industrial networking and innovation are considered to be enablers of IS, other models that present these two elements can be investigated to understand whether, and how, they can facilitate the development of IS in their territories. The IP model represents in this sense a very promising case. Our research questions are therefore the following:

- How are the themes of innovation and networking addressed in the studies of IS?
- What are the main features of the IP model and what other elements are there in common between IS and IP?
- What are the mechanisms (if any) through which the IP can contribute to the development and diffusion of IS networks?

2.2. Methods

The article is based on a qualitative analysis of the scientific literature and secondary data. The role of networking and innovation in the field of IS is investigated through desktop and direct research with the use of up to-date and reputable sources. For the literature overview, the authors have defined a set of key-concepts (Industrial Ecology; Industrial Symbiosis; Networking; Innovation; Clusters; Regional System of Innovation; Innovation Poles) and combined the same for a keyword research. Data have been retrieved from the Scopus database. General information about IPs has been obtained by EU regulations, technical reports and official websites. The collection of operational data on IPs was made in reference to the Italian case, in which the model has had a rapid and wide diffusion. In addition, Italy has an important tradition in terms of local collaborations among companies, institutions and communities, inherited by the district model. This can thus imply a positive outcome also concerning the model based on IP. Data were obtained through public documents made available by the regional administrations. Empirical evidence emerging from recent studies conducted by the authors on the potential of IS development [13,20–22] was also used. The study applied the systemic approach of sustainability science and IE, encompassing a comprehensive analysis to the identification of potential areas for the theoretical, methodological and practical advancements of IS studies. Figure 1 shows a map of the research aims and the methodology performed in this study.

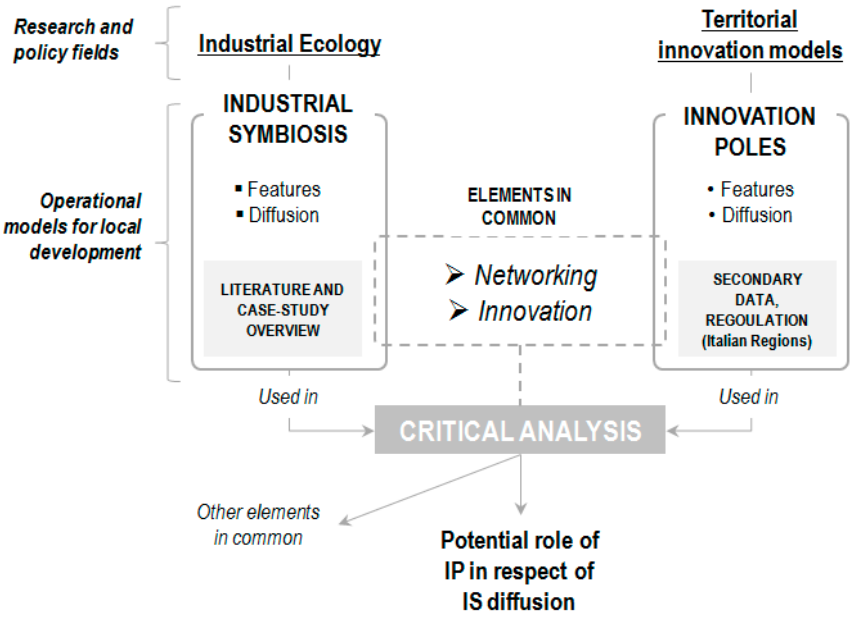

Figure 1. Map of the research aims and the methodology used.

3. Results

In this section, we will try to highlight how networking and innovation have progressively become relevant topics in IS studies and how they have been integrated in supporting EU policies and local development models. Later on, we will discuss the IP model and its potential role with regard to the IS development.

3.1. Industrial Ecology, Industrial Symbiosis and Innovation

Green and Randles [14], in the book entitled "Industrial Ecology and spaces for Innovation", brought to light the potential of interaction between studies on innovation and IE. According to the authors, innovation studies should consider how innovations transform socio-economic systems (including those changes involving natural environment), while IE should shape socio-economic systems "metaphorically" as ecological systems (through a set of concepts and techniques that includes technological and organizational innovations). They also acknowledge that the two fields have much in common and that innovation is central to achieving sustainable production and consumption, while studies on innovation were not systematically engaged in the IE community at that time. During the 2000s, the process of integration has gradually evolved, even due to some relevant contributions, such as the IHDP-IT Science Plan [38], which defined some practical trajectories of technological and organizational change in terms of the environment, the so-called "Industrial transformation". With regards to methodological aspects, important progress has been made considering the co-evolution of the perspectives of innovation studies (from individual initiatives, to innovations within companies and sectors, up to systems of innovation) and IE studies (from products, to processes, supply chains and whole economic systems). This holistic and systemic view, that now characterizes the two areas of study, led to the inclusion of the aspects of policy and governance of socio-economic development within common research themes [14]. Recently, some authors have focused their efforts on understanding how technological innovation can support IE. Sheel and Vazquez [16] propose a holistic framework and a model (named SWIT—Sustainable Wealth creation based on Innovation systems and enabling Technologies) which includes the use of appropriate technologies and their incorporation into innovative supply chains. Other authors emphasize the role of open innovation and business model innovation to place recycling activities at the center of strategic business management [39].

There are few scientific contributions that specifically investigate the link between innovation studies and IS, and have different perspectives of study. In 2011, Van Bommel [40] proposed a conceptual framework for analyzing sustainable strategies in supply networks from an innovation perspective. He emphasizes the role of the "focal" company, and proposes different strategies. Among the factors characterizing the power of that company, he includes: external orientation, transparency, learning capacity, leadership, autonomy and results orientation. The sharing of these strategies within the network is also enabled by trust, clear programs and an effective information system. Other studies test the use of innovative ICT methods and tools in the context of IS, both for modeling [41] and for the mapping of symbiotic networks or their optimization [42,43].

More recently, the famous case of the Kalundborg Symbiosis was the subject of a longitudinal study aimed at describing the innovative mechanisms that have driven its evolution [44]. However, for the purposes of the present article, there seem to be two perspectives that best link the concepts of IS and innovation. The first is attributable to the study conducted by Mirata and Emtairah [15] as part of the IS program hosted in Landskrona (Sweden). In a survey conducted among the managers of the companies involved in the program, the positive role of IS with respect to innovation activities carried out in the area, in particular, environmental innovations, was demonstrated. This occurred mainly in two ways: through aligning innovation activities in the search for environmental improvements, and in contributing to regional innovative capacity in general by means of enhancing inter-organizational collaboration and learning. The major contribution of this study was to emphasize the importance of the exchange of intangible resources and knowledge within IS network; this has paved the way for a number of research projects that have also drawn upon studies of organization and regional

development. The second perspective starts from the concept of "system innovation", defined by Geels in 2005 as a "transition from one socio-technical system to another" [45], i.e., innovations that are capable of producing systemic changes in both the social (values, regulations, attitudes) and the technical (technology, tools, production processes) dimensions of organizations [46]. Based on these constructs, IS has been subsequently included among systemic eco-innovations [47,48]. This is because the development of an IS in a given context can be interpreted as the adoption of multi-level changes within socio-technical systems. An IS may in fact include activities that can be integrated into existing processes, activities that can be built through the collaboration of two or more companies (sharing of resources, materials and expertise) and activities that require the involvement of other companies or external partners. Some of these activities do not require relevant economic or technological shifts and the organizational dimension of the systems is slightly involved; other solutions mostly impact the managerial and organizational dimensions, and marginally modify technologies; some improvement measures require a series of radical shifts, both on the products, processes and on the socio-economic dimension of the system that adopt the IS [20].

3.2. Industrial Symbiosis and Networking

The importance of the studies on industrial networks in relation to eco-industrial systems was first demonstrated by Cohen-Rosenthal and McGalliard [49]. In 2003, Gibbs [50] investigated the interactions of the economic, social and environmental aspects in the implementation of sustainable development strategies within local and regional networks. He highlighted the need of multidimensional approaches that draw upon economic geography and regional economics studies on some "untreated interdependencies" (based on trust, cooperation rules, and routines) that form the basis of the local specific assets. The relation between IS and the positive externalities deriving from co-located companies, the so-called "agglomeration economies", has also been the focus of an analysis conducted by Chertow et al. [51]; the authors discussed how particular industrial configurations are suited to different types of IS. In the same period, in a study involving the IS program in Rotterdam, Baas and Huisingh [52] enhanced the relevance of the interconnections between the techno-sphere and the social system dimensions in the study of IS. Networking, both social and material, is a common theme of several studies concerning the development of IS in existing contexts [13,20,53]. Some of them have deepened the role of tacit and explicit knowledge and ICT tools in order to enhance collaboration [54], others have focused on embeddedness, associated with the concept of trust [55] or proximity [56], for the application of Social Network Analysis (SNA). During time, several authors recognize the potential of IS to create new opportunities and add value to local production systems that find best expression in the model of industrial clusters or districts [11,57,58]. In this sense, networking can be seen not only as a prerequisite, or as an enabling element of IS, but also as an effect. Studies conducted within long-standing IS, as for example the Kalundborg case, demonstrate that symbiotic networks are capable of modifying themselves, thus creating new spaces for collaborations and relations among the companies involved [59].

3.3. Networking and Innovation in the EU Policies

Over the last 20 years, "territorial approaches" have played an important role in the innovation and knowledge economy. They have given rise to a vast array of literature. Starting from the traditional model of Industrial Districts (IDs), a number of new concepts and regional policies have progressively emerged; some of them still including the natural environment as a strategic variable.

3.3.1. Innovation Systems and Other Territorial Innovation Models

Within the studies on local and regional economy, the themes of innovation and networking are directly related to the concepts of Innovation Systems (or System of Innovation) and even more to the Regional Systems of Innovation. The Innovation Systems are a set of elements (local actors, institutions, networks of companies, and technological factors) linked to each other in order to create, share and

disseminate, innovation, knowledge and technological change in a specific area. They may have different spatial scales (national, regional, and local) or different spheres of interest (sectoral dynamics, or technological or organizational) and can include individuals from different contexts (public or private bodies, companies, research centers) or different levels of formalization (spontaneous, planned). Their performance in terms of innovation activity can be measured in different ways, e.g., through the number of registered patents, the number of ongoing projects, or investments in R&D [60]. In the literature, it is possible to find different versions of the concept of Innovation System. Some authors include them under the generic name of Territorial Innovation Models (TIM) [61,62]. The evolution of the traditional model of industrial districts or clusters towards territorial organizations with a strong scientific and technological connotations has led to a number of new concepts. In recent decades, the one that has become popular is that of *Regional System of Innovation* (RSI). In these systems, the spatial scale is the distinctive feature. They arise from the interaction of a series of constructs (economy, technology, districts, research, learning, knowledge, governance) related to industrial development at a regional scale. Their building blocks are typically companies, institutions, infrastructure, knowledge and a policy oriented towards regional innovation and are generally characterized by interactive learning (cross-fertilization), knowledge production, proximity (geographical closeness) and social embeddedness (in terms of role of social relations) [63]. A number of other operational models based on networks of companies, a territory and innovation activities have spread within the EU regions during the last decades, among them, the *Technological Districts* and the *Science/Technology Parks*. The *Technological Districts* are aggregations of competences on certain high-tech sectors, identified as priorities for a given territory. They are systems designed to transfer and connect knowledge in relation to the conditions that occur in a particular region. A further declination of the IDs in a technological way is represented by the *Science/Technology Parks* (STP), whose primary purpose is to promote the culture of innovation and competitiveness of enterprises and institutions that generate knowledge. To this end, the STPs encourage the flow of knowledge and technology amongst universities, R&D centers, companies and markets, facilitating the creation of innovative companies. Similar organizations are the so-called *Technopoles* and the *Technology Incubators*.

TIM represent useful tools to help industry benefit from innovations coming from research activities, contributing to the creation of multidisciplinary knowledge platforms and stimulating local economic growth [64].

3.3.2. Sustainable Innovations and Networks in EU

One of the first attempts to integrate the issues of networking and innovation with environmental sustainability dates back to 2000, when the WBCSD included industrial networking among the major enablers of such changes [65] in the analysis of drivers and barriers to sustainable innovation. However, an increasing attention to these issues has been recognized only in the period 2008/2012 (almost simultaneously with the start of the EU policy on Innovation Poles).

At this stage, the results of several studies, especially in the form of reports made by EU and international public and private observatories and agencies, were published. In 2008, in a report on eco-innovation, IS is in fact first cited as one of the policy options to support the development of "meso-level" eco-innovations (i.e., affecting product or service systems, supply chains, local settlements or regions) and a "natural partner" of the industrial cluster perspective [66]. This view was widely shared and expanded by the Organisation for Economic Co-operation and Development (OECD), which played an important role in the spread of this approach. In 2009, a study cited IE and the Kalundborg Eco-Industrial Park as examples of solutions to be included in a new, sustainable, industrial revolution [67]. In the same years, the closed-loop approaches and IE were first associated with the concept of "system innovation" (see Section 3.1) to indicate their ability to promote socio-economic changes. This new insight led to the inclusion of the Eco-Industrial Parks within the Systemic eco-innovations [68] and, more generally, to consider the IS as an innovative business model based on the reconfiguration of industrial networks [48].

From a more practical point of view, an interesting qualitative survey was conducted in 2011 by Barsoumian et al. [69], to understand to what extent these eco-innovative perspectives, in their various forms, had been incorporated at the level of cluster policies. The study, conducted in 27 EU countries, has highlighted how the phenomenon, especially in some Western countries (as shown in Table 1) was already quite consolidated, but none of the cases cite IS as an inspiration for the development of sustainable cluster policies. Instead, the picture outlined in a study conducted by Massard et al. in 2014 [70] is very different: throughout the whole report, starting from a perspective more oriented on eco-innovation parks, IS appears as one of the reference points for the development of collaborative and innovative strategies among companies.

Table 1. Eco-innovation clusters in the EU-27 member states.

Country	No. of Eco-Innovation Clusters	Years of Activity
Austria	>10	>10
Belgium	>10	>10
Bulgaria	none	-
Cyprus	none	-
Czech republic	1–5	>5
Denmark	>10	>10
Estonia	1–5	<5
Finland	>10	>10
France	>10	>10
Germany	>10	>10
Greece	6–10	>5
Hungary	6–10	>5
Ireland	1–5	>5
Italy	>10	>5
Latvia	none	-
Lithuania	1–5	<5
Luxembourg	1–5	>5
Malta	none	-
Poland	>10	<5
Portugal	-	<5
Romania	1–5	<5
Slovakia	none	-
Slovenia	1–5	>5
Spain	>10	>10
Sweden	6–10	>5
The Netherlands	6–10	>10
United kingdom	>10	>10

What emerges overall is that IE/IS, networking and innovation studies are strictly related; everyone can benefit from the experience of the others in terms of analytical approaches and policy development: IE scientists and practitioners could exploit methods and tools of innovation and organization sciences in order to understand the dynamics of the adoption and diffusion of IS; innovation and industrial policy, especially with a focus on system eco-innovations, could take into account IS in supporting sustainable local and industrial development or redevelopment.

3.3.3. The Innovation Poles

Concept and definition: IPs are government-sponsored consortia created within the EU regional policy guidelines 2007–2013 and specialized in one industry or in specific value-chains. Conceptually, they were conceived in the framework of TIM, which was presented above. Each Pole involves firms, SMEs, innovative start-ups and research institutions. A minority partnership in the Poles can also be extended to research institutions and enterprises that are not located in the same region or territory. They have the specific purpose of stimulating innovation activity, promote interaction

among organizations, joint use of research facilities, exchange of know-how, knowledge transfer and information diffusion.

Features of the model: In EU policies and strategies, innovation is considered a systemic process, embedded in specific socio-cultural and institutional contexts, and developing around clustered sets of production and research activities. These policies focus explicitly on concepts such as localized learning, generation of variety, structural change, technology transfer and innovation diffusion [71–73]. The EU regional policy guidelines 2007–2013 define innovation cluster as "groupings of independent undertakings—innovative start-ups, small, medium and large undertakings as well as research organizations—operating in a particular sector and region and designed to stimulate innovative activity by promoting intensive interactions, sharing of facilities and exchange of knowledge and expertise and by contributing effectively to technology transfer, networking and information dissemination among the undertakings in the cluster" [74]. In some EU member states, as in Italy, the concept of innovation cluster has been translated into IPs. Such Poles are being designed and implemented in several major Italian regions, mostly through a top-down identification of specific technological and territorial targets [75]. Since its adoption, the model of IP has been introduced in a number of ongoing regional-policy experiences in Italy, with the goal of fostering local networking, providing high-value services, shared facilities for innovation, as well as addressing the major technological and strategic challenges to be faced by the local industrial community. In particular, the Italian regional policies on IPs have focused on the formation or the development of strategic relationships among local firms and between firms and universities in given technological domains [76]. From an operational point of view, IPs are groups of organizations that share a common interest in different activities, from R&S to production and commercial phases. Their physical location can be a more or less wide industrial area, which includes infrastructures as offices, laboratories and production units [64].

The members of an IP are usually:

- production and/or services companies;
- local authorities;
- research infrastructures (linked to universities or other R&D centers);
- business incubators; or
- laboratories and testing centers.

The Italian experience: The Italian experience in the field of IPs has been initiated in 2008. The regulatory activities related to the establishment and functioning of the IPs has been entrusted to the regions. Some regional administrations have often created coordinating superstructures called *regional platforms* involving representatives from each IP, and from the regional administration. Such platforms are in charge of coordinating the IP activities, standardizing governance processes, coordinating workshops involving stakeholders and managing the IP participation in EU schemes in support of R&D and innovation activities. Despite having a common origin and similar structure, each IP has different evolutionary characteristics and dynamics. Since everyone benefits from different inputs available in the local economy, every territory or region has a specific potential for the absorption of the results from the IP activities, deriving from different historical traditions and specific needs. The role of public and private local stakeholders can also influence the development and growth paths of the IP. There are currently over 50 IPs in Italy. They bring together more than 7400 companies operating in strategic sectors [76]. Table 2 summarizes the characteristics of some of the most significant. Concerning the remaining Italian regions, it was not possible to find reliable data about operating IPs.

The regions considered in the analysis are representative of the whole Italian territory: there are four regions of northern Italy (Emilia Romagna, Liguria, Piedmont and Tuscany); three central regions (Abruzzo, Lazio and Umbria); and one (Calabria) southern region. The first regions to regulate the issue of IPs were Emilia Romagna, Lazio and Piedmont (2008); followed by Calabria (2009), Liguria, Tuscany and Umbria (2010); and, lastly, the Abruzzo region in 2012.

Table 2. IPs diffusion in some Italian regions.

Regions	Industry (Area of Interest)
Abruzzo *Resolution No. 248 of 23 April 2012*	Advanced services; Agrifood; artistic craftsmanship; automotive; chemicals-pharmaceuticals; civil economy; energy; fashion; furniture; ICT & electronics; internationalization; logistics and transport; sustainable construction; textile and footwear; tourism.
Calabria *Resolution No. 194 of 20 April 2009*	Agrifood; Cultural heritage; Energy and environment; Fisheries resources; Health technologies; ICT; New materials; Transport, Logistics, Processing.
Emilia Romagna *Resolution No. 736 of 19 May 2008*	Agri-food; Biotechnology and environment; Chemicals-pharmaceuticals; Construction; Energy and environment; ICT and design; Informatics-Electronics; Life sciences; Mechanical and food engineering; Mechanics and materials; Techno-Medical.
Lazio *Resolution No. 611 of 5 August 2008*	Logistics; Nautical; Photovoltaics; Strategic raw materials.
Liguria *Resolution No. 177 of 5 February 2010*	Biotechnology and biomedical; Environmental and sustainable development monitoring; Intelligent automation Network, security, intermodal transport; Renewable energy and smart grid; Systems for ship and boat building, marine environment; Technologies to improve the lives of seniors and persons with Disabilities.
Piedmont *Resolution No. 25-8735 of 5 May 2008*	Agrifood; Biotechnology and biomedical; ICT; Mechatronics and advanced manufacturing systems; New materials; Renewable energy and biofuels; Renewable energy and mini Hydro; Systems and components for renewable energies; Sustainable chemistry; Sustainable construction and hydrogen; Textile.
Tuscany *Resolution No. 1040 of 6 December 2010*	Automotive and mechanical engineering; Boat and port facilities; Energy and green economy; Fashion; Interiors and design; Life sciences; Marble and ornamental stones; New materials; Railway; Photonics, Optoelectronics, Robotics, Telecommunications, ICT and space; Smart city-Tourism-Cultural Heritage; Paper.
Umbria *Resolution No. 226 of 15 February 2010*	Advanced mechanics and mechatronics; Energy efficiency and renewable sources; Life sciences; Special metallurgical materials, micro and nanotechnologies.

4. Discussion

The analysis conducted makes clear that collaborations (guaranteed by the network) and changes (i.e., innovations) have become relevant in IS studies; it also indicates that these two elements have been placed based on the EU territorial innovation models and therefore of the IPs. For these reasons, we believe that IPs represent interesting contexts to be investigated with regard to IS. Indeed, a number of elements have emerged in support of this and they are explained below.

It should first be noted that, among the Italian IPs, the environmental variable has been recognized as a key element in almost 15 cases (highlighted in bold in Figure 2). Some of them are located in regions already involved in the development of territorial solutions for the environmental sustainability (e.g., Tuscany with the CLOSED project (Closed Loop System with Eco-Industrial Districts) [77]; Piedmont with the development of the Scientific and Technological Park named Environment Park [78]; and Emilia Romagna with the promotion of the so-called Ecologically Equipped Industrial Areas [22,79]). However, no explicit references to the concept of IS in connection with IP projects are registered.

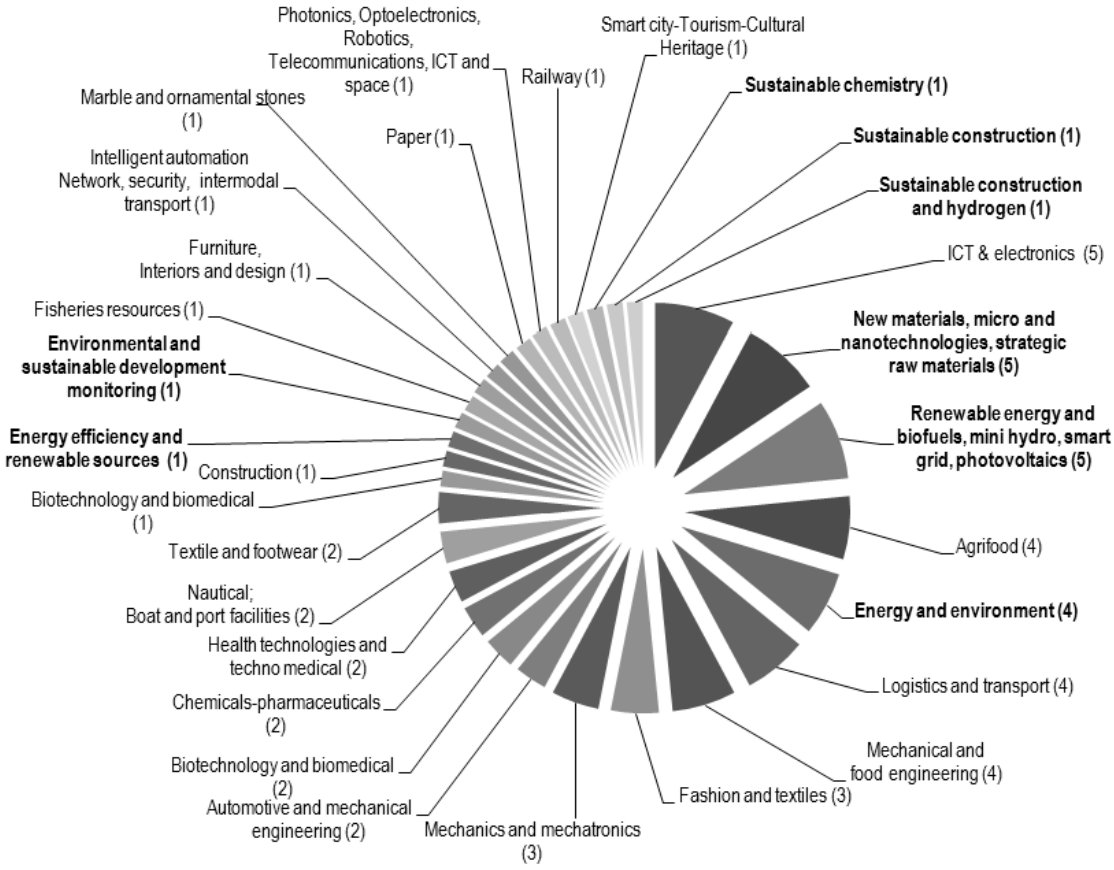

Figure 2. Areas of interest of the current Italian IPs.

Considering the role that IPs could play with respect to the development of IS, the conducted analysis reveals that they can be involved in at least two ways: (i) in a supporting role; and (ii) as a "facilitator" and as an applicative context.

(i) IP as an incubator for innovations and as a vehicle for spreading IS: Surely the IPs, in their institutional role, present within their own members, the knowledge and skills that are capable of developing product or process innovations which are useful for the development of an IS, such as substitute materials, technologies for materials recovery and recycling, waste and wastewater treatment and energy recovery, which could be adopted in other contexts or in an existing IS. In such cases, the regions (through the top-down approach), consultants, or groups of local businesses (through

the bottom-up one) who are interested in the development of IS, may involve the IP as a carrier of theoretical and applied knowledge for solving technological and production problems. In addition, a further supporting role that could be played by IPs concerns the diffusion of models inspired by IS, in two ways: acting as promoters of best practices using network communication channels and giving the opportunity to the various involved companies to replicate or reproduce the model in their local settlements (for example the IPs that have a regional or supra-regional spatial dimension, as for the Abruzzo region).

(ii) IP as a context of IS: The most ambitious role that IPs can play is to act as applicative contexts for the IS development, that is, promoting the establishment of symbiotic relations among the members of the IP itself. The presence of networking and innovation may act in favor of such kind of initiatives; nevertheless, the influence of other elements should be deeply analyzed. Among them, those emerged as most significant, are: sectoral specialization, spatial scale, social relationship and trust, local actors and institutions, and regulatory aspects.

Sectoral specialization. By definition, IPs are constituted by companies and entities belonging to the same supply chain or industry, which implies a certain level of homogeneity in terms of processes, materials and products manufactured in the network (as emerging in the Italian context). This aspect, analyzed in relation to the potential of IS development, highlights positive and negative areas for reflection. According to the literature [80], a certain level of internal homogeneity ensures the availability of materials useful to IS (such as by-products, waste) in a higher amount, as produced from a higher number of companies, and this can help to overcome some "scale" limitations. Other positive elements are represented by the possibility of knowledge sharing and the development of common management solutions to two or more companies. On the other hand, a high level of internal homogeneity in the network can reduce the chances of input/output matching, since the involved organizations in the IS have similar flows [80]; indeed, in some cases, a certain level of diversity among the involved firms is fundamental to allow symbiotic exchanges [81]. Some of the limits connected to the sectoral homogeneity could be addressed by promoting inter-IPs synergies. In this case, the intervention of a coordinating body (or knowledge-sharing among the IPs managers) would be necessary in order to facilitate the initiation of interactions among the involved companies.

Spatial scale. The scientific literature as well as empirical cases show that companies in an IS must not be necessarily co-localized [11,82]. However, as IS is based on exchanges of low value-added flows (e.g., wastes), long-distance transfers can generate extra costs, as well as additional environmental impacts. Therefore, proximity, in general, plays in favor of a great efficiency of IS exchanges; nevertheless, some results suggest that, dealing with recovery and recycling issues, is not possible to assign any particular spatial scale a priori, because economic transaction reasons often prevail [83,84]. Other studies show that a "local" scale is able to offset some trade-off (such as those between the "technological and organizational competences" and the "degree of personal affectedness") [85]. The data collected show that IPs can have a variable spatial scale. At a minimum size level, they may overlap existing industrial clusters or districts (e.g., as in some cases of the Tuscany region), or may involve companies belonging to the same region or even beyond regional boundaries (e.g., as in some cases of the Abruzzo region) and then operate transversely to existing industrial sites.

Social relationship and trust. According to some authors, IS is strongly rooted in these two elements, which may adversely affect its development even in the presence of positive technical requirements [86]. In a local network of companies, relations are an important aspect. They can be structured at different levels (institutional, professional, informal) and can positively influence innovation capacity [24]. In the case of the IPs, the existence of a stable relational basis represents an element of interest in the IS perspective, at least for the instrumental role that they could play in enabling trust and collaboration among their members, thus making them aware of being part of a network that is oriented to change. This would represent a fundamental prerequisite for sharing innovative solutions and strategies, such as the IS.

Local actors and institutions. A number of studies indicate that one of the key factors to greater success in planning an IS lies in the involvement and active participation of a number of local stakeholders, such as political bodies, associations and communities of individuals [87,88]. As showed in Table 1, the governance of IPs belongs directly or indirectly to the regions, but also involves authorities, associations and other entities of the local economy. This can be a positive precondition for the IS development in these contexts. Local actors' engagement can also play a positive role both in data collection, and in promoting initiatives that can support the development of the IS over time [10].

Regulatory aspects. Environmental standards, rules and regulations have emerged as one of the most critical factors for the development of the IS in a specific area or region [49,89]. In some cases they can act as promoters (for example through the introduction of dedicated action plans, funding measures, etc.), in others they may block or limit its development (as in the case of too restrictive rules concerning the use of by-products). Watkins et al. [90] stated that at present, some of these problems originate locally and must necessarily be addressed locally. Currently in Italy, the regions often address IPs as partners for the definition of initiatives and funding in support of business and also for a pre-selection of their proposals and projects. This role as intermediary would also be very useful for the coordination of IS initiatives in specific areas or industries.

Governance and Policy Implications

In the light of what discussed above, it can be reasonable to assume that IPs could play a positive role in the development and diffusion of IS in a given territory, both for their institutional activity of production and dissemination of knowledge, and also if considered as applicative contexts for IS. The potential benefits for the territory deriving from a large implementation and diffusion of the IS model would be numerous. Environmental benefits may derive from a more efficient use of materials and energy and from a reduction of pollutant emissions; the social dimension could also improve as a consequence of a growing rate of employment, a greater integration and territorial cohesion and a renewal of the site public image; the economic dimension could get better due to reductions in raw materials and resource costs; reductions in waste management expenses; additional income deriving from higher values of by-product and waste management [9,48,49]. In some areas, an operating IS could be useful in order to increase the attractiveness of territories that otherwise would hardly be chosen as a location by external companies, especially considering the recent trends toward globalization and delocalization of production. The presence of these positive elements should strengthen the belief of local and regional government bodies on the effectiveness of such solutions, thus including IS among their policies.

However, the use of the IP model as a context of IS development could present some criticalities. A first critical aspect is that the IPs have not been designed in order to promote IS. This could be addressed by modifying the model in a way to perform this role. However, this would also require legislative and regulatory changes and will be feasible only in the long run. Effective synergies could arise by putting the IPs in connection with other sustainable local development approaches and tools that are already operating in some territories. In this perspective, an interesting example is provided by the Emilia Romagna region that has promulgated a regional law on circular economy in 2015 [91], and where the model of Ecologically Equipped Industrial Areas [22,79] became the referential and mandatory model for any form of new local industrial systems established in the region [92].

In addition, IS is recognized as a phenomenon that, in order for it to be successful, the total involvement of the participants is required. This is often related to the spontaneous and progressive establishment of synergistic solutions (e.g., in the Kalundborg experience), while many of the top-down projects have failed. IPs are designed and implemented as planned organizations (as confirmed by the Italian experience), arisen through a top-down approach in which the local government authorities have an important role in decision making activities and in the identification of specific technological and territorial targets. The strong presence of the local governments and an excessive planning and bureaucracy, which is typically related to a top-down approach, can adversely affect both the thrust

and motivation and the proactive and collaborative atmosphere that is necessary for the development of durable IS projects. More effective could be an approach in which the IP governance body plays a role of facilitator (also supported by universities or research centers), encouraging and supporting initiatives and increasing the awareness that IS can be an element of strategic competitive advantage and growth for the whole territory.

5. Conclusions

In the present article, moving from the common features of industrial networking and innovation, the potential synergies and critical issues between the two models of local development of Industrial Symbiosis (IS) networks and Innovation Poles (IPs) have been investigated. A literature overview and direct research provided the knowledge basis of the study. The Italian territory has been used as a source of regulatory and technical data on the IP model, which has found in this country a rapid and wide diffusion. Firstly, it was found that networking and innovation are considered as two critical aspects in IS studies; it was also confirmed that they have been poorly used as a common basis for IS development, but are placed at the basis of the EU territorial innovation models, including precisely the IPs. The positive role that IPs could play in the development and diffusion of IS in a given territory can be related both to their institutional activity of production and dissemination of knowledge and innovation, and mostly (if considered as applicative contexts for IS) to the promotion of the establishment of symbiotic relations among their members. In respect of this, some aspects have emerged as relevant, i.e., the sectoral specialization, the spatial scales, the existence of social relations and trust, the role of stakeholders and the regulatory issues. A number of policies and managerial implications for local development were also highlighted. Firstly, the potential benefits for the territory deriving from the diffusion of the IS model would be numerous and this should be deeply considered by the regions and local administrators. Secondly, given the fact that the IPs were not conceived for this aim, relevant synergies could arise connecting the IP model with other approaches and tools for the local sustainable development. Concerning the limitations of our study, it should be pointed out that they are related to the scale of the study (the sample is limited to Italian IPs) and the availability of data, since the IP model is still poorly studied, and examples of its practical application are too recent to draw a significant picture of their functioning. Our future efforts will be directed to find additional operating contexts in which to deepen and test our results.

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