



Inter-firm cooperation and local industrial ecology processes: evidence from three French case studies

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Abstract

In this paper, we are interested in industrial and territorial ecology (ITE), whose aim is to optimize the management of material and energy flows between local economic players by drawing inspiration from the cyclical nature of natural ecosystems. The organizational elements, specifically the forms of coordination between actors, appear to be central in the setting out of these processes. This is why methodological devices promise to respond to the chronic difficulty of implementing local inter-firm relations conducive to cooperation. The work presented here, based on social network analysis, aims to determine their validity through three case studies. First, we examine the need to consider the spatial dimension of ITE approaches to understand the conditions for the emergence of inter-firm cooperation and sustainable development, and we present the methodological elements of our work. Then, we proceed to the case studies and identify inter-firm relations and study their evolution over time. We conclude with an assessment of the devices studied, the intermediary role of facilitators, and the difficulty of perpetuating these types of cooperative relations, which raises serious questions about the modalities of the implementation of sustainable territorial development processes.

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1 Introduction

The linear functioning of our industrial society is increasingly generating important impacts. Natural resources are being depleted. The climate is changing and getting warmer, and pollution caused by human activities is accumulating and damaging natural ecosystems as well as the services they can provide. These phenomena are raising concerns about the current and future populations' well-being and are gradually affecting all regions and states, even the most prosperous ones (MEA 2005; IPCC 2019).

In response to these issues, the circular economy is an interesting avenue for action that puts an end to the harmful effects of society's linear functioning (Gregson et al. 2015). Promoting the circular organization of production and consumption methods, it originates in Boulding's (1966) work, which highlights the inconsistency of the linear economic model that mobilizes unlimited flows of resources with limited stocks. The environmental question, often considered as a constraint, then becomes an opportunity to develop the economy (Bocken et al. 2014). The circular economy promises to present potential for concrete actions to make production and consumption patterns more sustainable in territories, through reliance on organizational and technological innovation and green growth (Baldassarre et al. 2019). This is why many countries have adopted this concept since the 1990s and have translated it into concrete public policies from the national to the local scale (Hobson et al. 2018). In France, for example, the creation of the *Institut de l'Economie Circulaire* (Institute of the Circular Economy) in 2013 was the culmination of the introduction of the concept into public policies. It has led to its very rapid spread among firms and territories. It is also widely promoted by ADEME (*Agence De l'Environnement et de la Maîtrise de l'Energie*), the national public agency in charge of environmental and energy transitions, which has launched several experimentations in various territories in order to develop the circular economy in French regions.

In this article, we are interested in one of the operational strategies of the circular economy: industrial and territorial ecology (ITE). ITE aims to optimize the management of material and energy flows between the various economic players in a territory by drawing inspiration from the cyclical nature of natural ecosystems (Cerceau et al. 2018). In other words, the waste of some becomes a resource for others; the practices related to this are called flow closures or industrial ecology synergies (Erhenfeld 1997). These ITE approaches are above all based on collective action, which requires stakeholders' intentional collaboration toward a common and shared objective: economic development and environmental impact reduction (Gertler 1995).

First, mainly considered from a technical and engineering point of view, as defined by Allenby (1999), the territorial dimension is at the heart of ITE, which is, in terms of its construction, spatialized. Indeed, beyond the individual interests of actors, these clustering flows, located in a given area and taking place between local actors, could make an important contribution to territorial development processes, in particular, by enabling the recycling and recovery of local inputs, while promoting a more sustainable and autonomous mode of growth. Furthermore, the

characteristics and resources of the territory will influence the way in which ITE is implemented (Kasmi 2020; Torre and Dermine-Brullot 2021). The current craze with regard to the circular economy tends to encourage the deployment of these initiatives, which are largely financed by public authorities. Indeed, ITE becomes a policy of economic development and the reduction of the environmental impact of industrial activity.

However, these initiatives are not always easy to implement. Beyond the economic, technical, and regulatory aspects that condition the feasibility of flow exchanges, organizational elements, specifically the forms of coordination and cooperation between actors, appear to be central and are often problematic (Mirata 2005; Boons and Baas 1997). This is why methodological devices have been developed (often thanks to public funds) and are promoted by public actors (ADEME in France) in order to facilitate the implementation of ITE projects that are generally driven by public actors, as opposed to self-organized approaches for which the issues of coordination and collaboration do not constitute problems (Chertow and Erhenfeld 2012). These planned initiatives require coordination by an intermediary actor called a facilitator. The methodological device includes operational tools, sometimes IT tools, and is based on a set of actions to be implemented by the facilitator in order to support the process of collaboration between firms in a sustainable way.

So far, no studies have been conducted on these devices and their capacity to fundamentally transform the nature of relations between actors and to densify the network of actors, in order to generate conditions conducive to the emergence of lasting inter-firm cooperation that is favorable to the development of ITE (Jambou 2016). The work presented here aims to determine their validity through three French case studies, which illustrate the French government's desire to develop an ambitious policy in terms of ITE and, more globally, the circular economy. The three case studies are based on comparable territorial and institutional situations but are distinguished by the use of different methodological devices (tools and methods), particularly in the creation of inter-firm relations. We try to answer the following questions: Are these devices effective? Do they make it possible to promote the establishment of processes of sustainable territorial development and the circular economy at the territorial level? In order to analyze their deployment and the results produced, we carry out an analysis in terms of social networks, which allows us to characterize inter-firm relationships and monitor their evolution over time.

In this paper, we first examine the need to consider the spatial dimension of ITE approaches in greater depth to understand the conditions for the emergence of inter-firm cooperation, before proceeding to the three case studies. For each ITE project, we present the device used and identify all the inter-firm relations. We then study their evolution over time using social network analysis before analyzing the causes of the contrasting evolutions that we observe. We conclude with a discussion on the effectiveness of the methodological devices studied, the intermediary role played by the facilitators, and the difficulty of perpetuating relationships beyond the face-to-face meetings organized by the facilitator.

2 Territorial approach of industrial ecology processes

Among the various circular economy strategies, ITE is the only one that integrates a proven spatial dimension (Torre and Dermine-Brullot 2021). First, from an economic and environmental perspective, it only makes sense if the firms that exchange material and energy flows are geographically close. Second, the inclusion of the approach within a territory consists in considering the latter's specific characteristics (Korhonen 2001), both in terms of the problems to be solved and what it offers regarding the resources that can be mobilized to solve these problems.

2.1 Context-dependent conditions of emergence through cooperative and trust relations

To analyze the inter-firm cooperation processes in ITE approaches, it is essential to look back on the numerous studies that have sought to explore the conditions for the emergence and development of this behavior. Following industrial economics or game theory approaches, cooperative relationships may be informal or based on agreement, symmetrical or asymmetrical, or based on trust or mistrust. But, they are always distinguished by a voluntary commitment from both parties, which leads them to reveal their intentions and some information in the hope of obtaining mutual benefits from the pooling of their interests and a part of their resources (Axelrod 1984; Contractor and Lorange 1988).

The cooperation between firms can take various dimensions, from informal relations to formal agreements or joint ventures. Regarding production systems or innovation behaviors, many agree on the need for geographical proximity between actors, be it permanent (Boschma 2005) or temporary (Gallaud and Torre 2004). It is assumed that it can reduce transaction costs and the environmental impact associated with the management of the flows concerned (Ehrenfeld and Gertler 1997), and foster the social and cognitive links that are essential for cooperation (Baas and Huisingh 2008). However, short distances are not enough. Mirata and Emtairah (2005) also highlight the importance of collective learning in cooperative processes to bring out a set of common interests that go beyond individual interests.

Several scholars argue that trust is omnipresent in the processes (through empirical approaches), without necessarily seeking to describe its mechanisms (Gibbs 2003; Hewes and Lyons 2008; Ashton 2008). The role of intermediary actors in facilitating exchanges and cooperation is also highlighted (Paquin and Howard-Grenville 2012). Exchanges of flows are linked to inter-firm relations, which are often organized within networks of actors that should be analyzed regarding social capital and territorial anchoring. Indeed, according to Boons and Howard-Grenville (2009), ITE approaches rely on economic and organizational activities, which are at the heart of social arrangements. These processes will contribute to creating trust, facilitating the collective learning process, or providing the necessary ingredients for cooperation. Thus, the analysis of the conditions for the emergence and development of inter-firm cooperation in ITE approaches leads us to believe that they highly depend on the context of the territory in which the process takes place.

Numerous studies show that inter-firm cooperation is more easily deployed when the ITE approach takes the social and institutional characteristics of the territory into account (Kasmi 2020; Cerceau 2013; Jacobsen and Anderberg 2009). Economic activities are linked to the structural organization of social relations (Granovetter 1973). This explains the fact that actors rely on their own networks (professional, friendship, family, etc.) to develop ITE cooperation. However, these actors also belong to companies that are themselves embedded in legal, regulatory, and political regimes of their own. These characteristics can thus create opportunities and constraints.

2.2 The development of territorial methodological devices

Inter-firm cooperation relationships are never easy to build and often need to be assisted by public authorities or local governance systems (Radicic et al. 2020). This is even truer in the case of ITE processes, characterized by their novelty and risk-taking nature, which makes enterprises reluctant to embark on this type of approach. That is why mechanisms have been created to help companies collaborate on environmental approaches. Methodological devices are a set of actions, means, and measures deployed to implement an ITE approach at the local level. Their aim is to identify priority needs or issues for stakeholders, whether firms or public actors, and to focus the search on synergies between them. The objective is to generate dynamics, exchanges, and results very quickly. By focusing on the needs of firms, which are also involved at a very early stage in the process, these devices consider firms' sustained mobilization and motivation. Methodological devices help to build an inter-firm network, create and maintain new relationships, identify opportunities for synergies, assist with their implementation and evaluation, and ensure the ITE approach's sustainability.

The organization of inter-firm workshops is recommended to bring about new cooperative relationships. The time available for data collection and the identification of synergies is short (collecting data on incoming and outgoing flows from companies or by consolidating databases). It may include computer tools dedicated to the search for synergies. The devices also rely on a facilitator's presence as a third-party actor. They facilitate the adhesion of firms and their networking and aim to create a relational context favorable to exchanges. As the synergy identification phase is very short, they claim to dedicate more time to the support and follow-up of synergy projects to encourage the sustainability of the inter-firm cooperation process.

3 Methodology

Our approach is based on the comparison of three French case studies (see the map in the appendix), each one corresponding to the implementation of a methodological device for setting up synergies between firms. Each of the cases is subject to an in-depth examination based on participant survey questionnaires, followed by an

analysis of social networks. The analysis is carried out over the period 2015–2017, and the longitudinal aspect is important since the phenomenon studied, namely the emergence of inter-firm relations, evolves over time.

3.1 The three case studies

The particularity of the selected case studies is that they are based on the organization of workshops that aim to connect firms. Inter-firm workshops allow new cooperative relationships to be formed and data to be collected (inputs and outputs of firms that could be exchanged thanks to what is called a synergy). They improve communication in terms of offering economic opportunities to convince firms to participate. A software tool is used to capitalize resources (inputs and outputs) and identify synergies, with more or less advanced options, such as synergy management or the provision of a collaborative platform. Experienced over periods of two years or less, their common feature is the desire to generate inter-firm dynamics, exchanges, and synergies rapidly. A synergy is considered to be created when an inter-firm exchange enables a (material or immaterial) resource to be substituted or pooled to reduce the environmental impact.¹

Three methodological devices were chosen for different reasons. First, INEX Circular and ACTIF were the only two IT tools that were easily accessible to practitioners and therefore widely used in France. ACTIF is the official tool of the national Chambers of Commerce and Industry (CCI) network, which is very often in charge of the monitoring of ITE initiatives in France. It could be widely used in future. INEX is a more recent occurrence and was developed by a private French consulting firm. It is particularly interesting because it claims to solve the problem of coordination and the linking of actors over the long-term, which is one of the main difficulties faced by ITE initiatives. It presents itself as a trusted third-party. Finally, the NISP was chosen by ADEME and the Institute of the Circular Economy (*Institut de l'Économie Circulaire*) to be tested in four French regions. It too promised to create strong links between actors thanks to the originality of its workshops and its relative efficiency in collecting data (Fig. 1).

The methodological device inspired by the National Industrial Symbiosis Program (NISP) (Mirata 2005), in the *Nord Isère territory*, was developed by the English consultancy *International Synergie*. The experimentation is coordinated by the Institute of the Circular Economy and co-funded by the candidate regions and ADEME. In the *AURA region* (Auvergne-Rhône-Alpes), the experimentation is led by the CCI of Nord Isère and Grenoble. This methodological device relies on inter-firm workshops, in which firms formulate their needs (resources they are looking for or waste products they want to discard) on cards that circulate from table to table. All the actors have the opportunity to present themselves and thus identify potential synergies. All resources are capitalized in an IT tool named SYNERGie, which allows inter-firm connections to be deduced. This tool is used by the facilitator and

¹ Examples of synergies noted in our surveys may have concerned the pooling of IT equipment or the recovery of wooden drums, white and printed paper, cardboard and plastic film, or IT equipment.

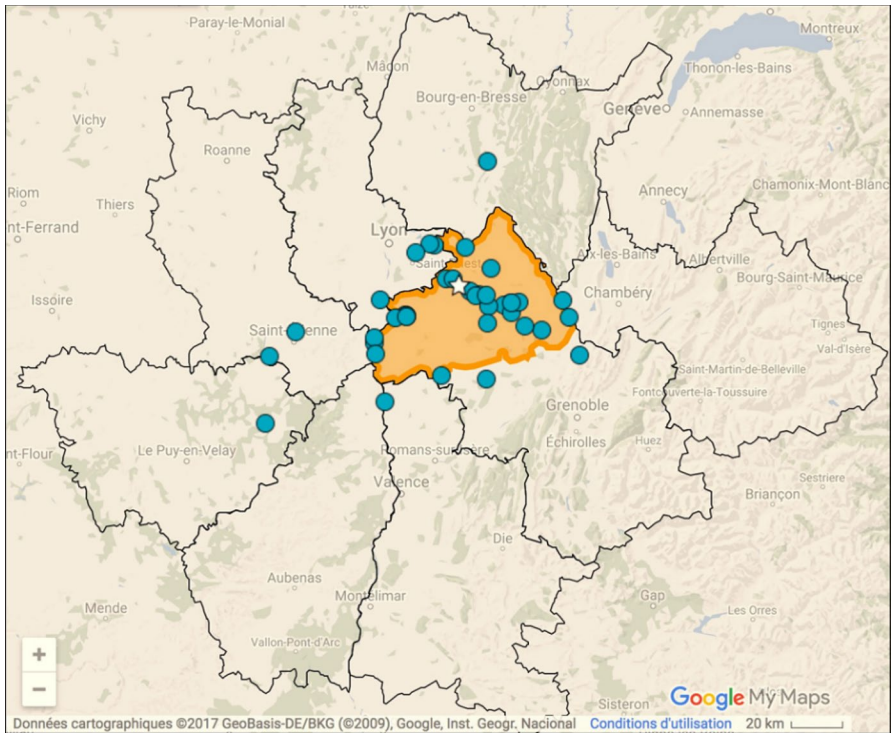


Fig. 1 Localization of the firms using the NISP device in Nord Isère

offers the particularity of analyzing the environmental impact of synergies and monitoring them over time. The device has brought together 39 firms from the Nord Isère territory and neighboring areas. The Nord Isère territory, which comprises two sub-prefectures (*Vienne* and *La Tour du Pin*), covers 2,708 km² and includes 232 municipalities grouped into 17 inter-municipalities (*Communautés de Communes*)²: its economy is dominated by the tertiary sector (transport-warehousing, health), but the manufacturing industry is also well-established, despite a decline in the number of employees over the last decade (Fig. 2).

The *INEX*³ methodological device in the *Drôme-Ardèche* territory (or *Communauté de Communes Porte de Drôme-Ardèche*) is based on an IT tool named *INEX Circular*. The device enables the pre-identification of potential synergies from open data and provides a collaborative platform to facilitate inter-firm exchanges and communication. This initiative is part of a global project developing ITE activities in the *Rhône-Alpes* sub-region. It aims to support companies in their search for the optimization of energy and waste treatment costs in order to increase their competitiveness and improve territorial development. It is based on the organization of

² Geographical data from the official website of the Chambers of Commerce and Industry of Nord Isère (2016).

³ For *Ingénierie Technique et Environnementale* (Technical and Environmental Engineering).

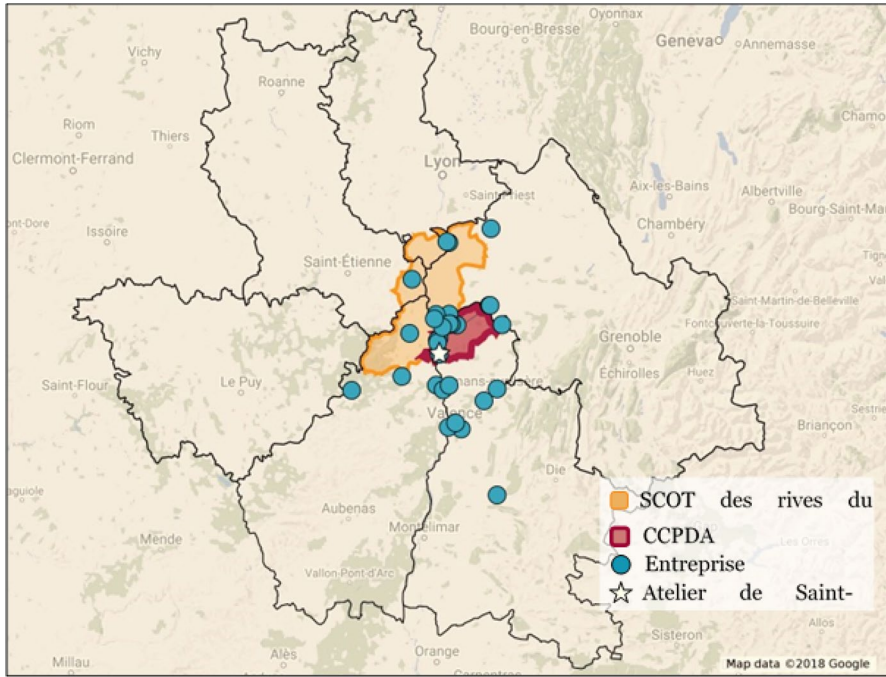


Fig. 2 Localization of the firms using the INEX device in Drôme-Ardèche

workshops, in which firms are grouped together around themes that have been pre-identified as priorities. They highlight their needs and are offered the opportunity to continue the discussions on a collaborative platform. The project supported by the local government has brought together 32 firms from a variety of sectors. The territory covers an area of 1,479 km² and partly five French *Départements* (Isère, Drôme, Rhône, Loire, and Ardèche).⁴ The economic activity is mainly focusing on the tertiary sector, but the industrial sector is very present, especially the chemical industry (Fig. 3).

The methodological device developed by the *Quimper Cornouaille Chambers of Commerce and Industry (CCI QC)* uses the *ACTIF* tool, dedicated to the search for synergies, based on flow data (the inputs and outputs of firms). The Quimper Cornouaille CCI are pioneers in the deployment of ITE in the *Brittany region*, in particular with regard to issues related to the circular economy. The data collection method is inspired by the approach developed by the NISP. It is based on business-to-business workshops, in which firms exchange their needs (in terms of resources and waste products) based on an auction system to reduce data collection time while enabling direct contact. This device was tested in an ITE initiative launched in June

⁴ *Schéma de Cohérence Territoriale des Rives du Rhône* (2012). An urbanism document about regional planification.

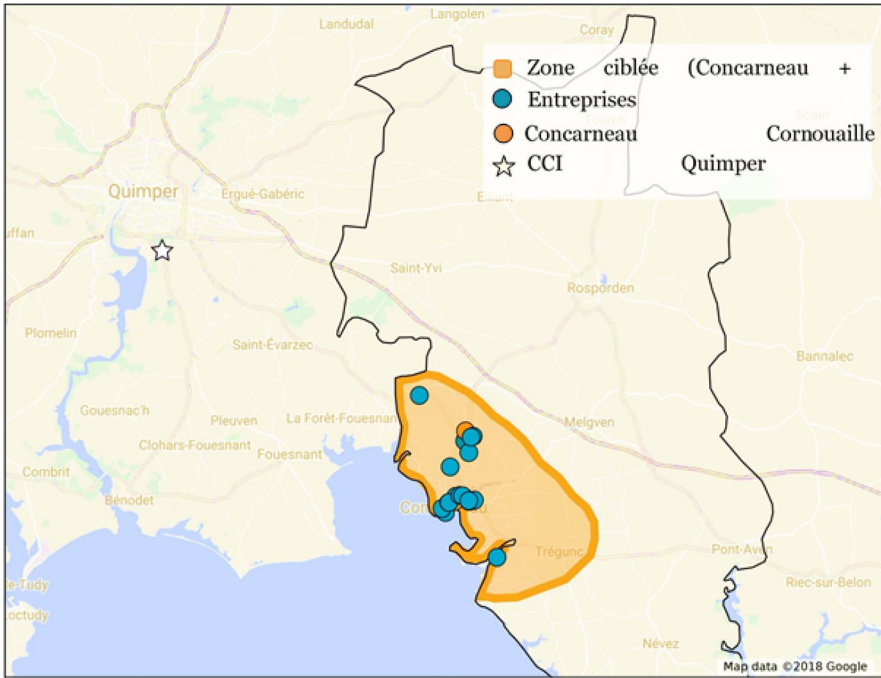


Fig. 3 Localization of the firms using the ACTIF tool in Quimper Cornouaille

2016, which brought together 18 firms from various activity sectors, half of which came from the maritime and fishing industries. The firms were all located within the local government, in south-western Brittany in the Finistère *Département*, covering an area of 2,484 km².⁵ A significant share of its economic activity is made up of services and trade, but the part occupied by the food-processing industry remains essential.

The characteristics of the three case studies are summarized in Table 1.

Despite their similarities, these three methodological devices have very distinct features. The NISP device needs considerable human and financial resources compared to the other two devices, and has a sophisticated monitoring system to follow the implementation of the synergies. The INEX methodology is the only one with a pre-identification system to identify synergies before the workshop, and it is also the only one that provides a collaborative platform to facilitate inter-firm exchanges. Finally, ACTIF is a more basic tool compared to the others and differs in terms of its auction device.

⁵ *Panorama économique de Cornouaille*, Chambers of Commerce and Industry of CCI Quimper Cornouaille (2015). Official report on local economic activities.

Table 1 Summary of the three case studies

	Nord Isère	Drôme-Ardèche	Quimper Cornouaille
Territory concerned	Nord Isère	Scot des Rives du Rhône	Concarneau
Surface area	2,708 km ²	1,479 km ²	41 km ²
Beginning	September 2015	June 2015	April 2016
Duration	2 years	18 months	6 months (or longer if successful)
Actors involved	CCI Nord Isère (2016); ITEC; Regional agency of ADEME	INEX; local and regional governments	CCI QC; local government; Regional agency of ADEME
Number of firms	38	32	18
Human resources	1 part-time advisor (CCI Nord Isère 2016)	1 consultant and 1 trainee (INEX)	2 advisors (part-time) and 1 trainee (CCI QC)
Methodological framework	NISP	INEX	QC CCI methodology
Method	Inter-firm workshop (<i>Business card exchange</i>)	Inter-firm workshop (<i>Thematic discussion</i>)	Inter-firm workshop (<i>Auction device</i>)
Tool used	SYNERGie	INEX	ACTIF

3.2 Social network analysis

Network analysis premises go back to Simmel's (1917) work, which laid the foundations for the science of the structures of social relations. Research in sociometry and, more broadly, in social psychology (Moreno 1934), anthropology (Levi-Strauss 1969), and applied mathematics (graph theory and linear algebra) (Harary et al. 1965; White et al. 1976) also contributed to the evolution of the concept. A network is defined as a set of nodes (individuals or organizations) linked by one or more types of relations (Wasserman and Faust 1994). Its analysis focuses on a description of the interdependencies between actors (the presence or absence of links) and allows a simplified representation. A social network exists if it is possible to define a set of actors (organizations or individuals) and particular types of observable, existing, and non-existent relations between these actors (Lazega and Snijders 2015).

Since we are interested in the set of inter-firm interactions that are present or absent in ITE approaches, we have chosen to build a network describing the organization of relations between local actors. It allows the identification of the overall structure of the studied group and sub-groups and their interconnections and the positions of central and intermediate actors. The network structure characteristics are measured by indicators that allow the connections to be described based on matrices recording the relations between actors. The most global indicator is density (i.e., the ratio between the number of existing links and the number of links that could exist): a high density reveals strong group cohesion, a particular social control, and a sense of belonging. The minimum distance between two actors makes it possible to reveal the 'openness' or 'disconnection' of a network: if two actors cannot join (even through a large number of intermediaries), the network will be described as 'disconnected,' whereas if it is open, it is possible to determine how far each actor is from any other. The absence of links, or structural holes, allows to identify non-redundant contacts (with the same relational structure).

Different indicators can be used to identify cohesive groups, such as a 'clique,' a subset of actors within a network where each one is linked to all the others, or the 'n-click' (or 'quasi-click'), where each one is linked to all the others by one path of length 'n' or less (Borgatti 2002). Structural equivalence classes are subsets of actors who have the same set of links and the same relational profile but are not related to each other (Lorrain and White 1971). Identifying bridges (or rare links) between cliques is another interesting indicator in the characterization of the structure of a network. Indeed, without bridges between cliques, the network becomes disconnected, so locally connected networks (with a density close to one) can be disconnected on the global scale.

Centrality indices make it possible to qualify the positions and the importance of the actors in the network structure. The centrality degree is measured by the number of links corresponding to an actor: the more central it is, the more 'active' it is and the more it can 'capture' what is happening in the network (Freeman 1979). Closeness centrality is the number of individuals an actor has to pass through to contact the other actors in the system: the more central the actor is, the more easily it interacts with the other members of the network (Beauchamp 1965). The centrality of intermediarity (betweenness) is measured by the number of times a node is on the

geodesic paths of all the other pairs of nodes (Newman 2003). Intermediarity is a link, a bridge, and makes it possible to identify 'relay individuals' (Brandes 2001). Finally, eigenvector centrality is defined by the nodes to which an actor is directly connected and considers both the node's position and the structure of the entire network (Bonacich 1972).

3.3 Data collection and analysis

Our objective was to reconstitute the networks of actors and their evolution by noting the inter-firm relations. To collect the information related to the exchanges and necessary for the analysis of social networks, we carried out a series of 67 executive interviews⁶ consisting of sociometric questions with a choice of predefined answers, conducted with the firms and structures playing a significant role in the process (facilitator, funder, coordinator) and carried out between 10 and 15 months after the inter-firm workshops. We questioned each firm about its relations with all the other participating firms; when the choice of response required additional information, we asked the interviewee to expand on his or her remarks. This questionnaire was followed by three open-ended questions regarding the company's motivation to participate in the process, its satisfaction with regard to the expectations it had, and its overall opinion (including successes, shortcomings, and possible improvements). We also carried out seven semi-directive interviews to refine the answers and gather additional information.

For each case, we were able to interview almost two-thirds of the firms that participated in the ITE workshop (22 out of 39 for Nord Isère, 19 out of 32 for Porte de Drôme-Ardèche, and 14 out of 20 for Cornouaille). The questionnaires enabled us to reconstitute the network of relations before and after their participation. The term 'relation' here implies a bilateral communication exchange (whether it is verbal, electronic, direct, indirect, formal, or informal) that can take place across several frameworks (professional, commercial, friendly, leisure, personal, etc.), which involves giving one thing and getting another in return. If one person communicates with another without getting anything in return, we do not consider this to be a relation. Concerning the relations between the firms with which we were unable to talk, we have reconstructed the type of relations based on the network facilitator's knowledge. When no information was available, we arbitrarily considered that there was no relation between the firms concerned. Thus, the network was not constructed completely (Wasserman and Faust 1994), and we assume a part of the network is missing.

A diachronic analysis of the network was carried out for each case study. The population studied corresponds to the firms that participated in the workshops, from which additional qualitative information was requested. The questions, inspired by

⁶ Initially, we had planned to carry out two periods of interviews per case study, a first occurring three to four months after the workshop and a second twelve months after it. However, we were not allowed to speak with the firms in the first few months. Therefore, we made the choice to favor the second interview period by slightly readjusting the questions to bring out the diachronic aspect of the relationships.

Torre et al. (2019) and Ashton and Bain (2012), consist of evaluating the relations maintained with the other firms in the network. Answers were coded according to the following criteria:

- Existence of a relationship between companies, coded as 0 (no) or 1 (yes).
- Origin of the relationship to determine whether it is related to the ITE workshop, coded as 0 (before the process) or 1 (through the workshop).
- Was there a previous knowledge, coded as 0 (no) or 1 (yes).
- Frequentation of networks, clubs, and associations outside the ITE process, coded as 0 (no) or 1 (yes).
- Existence of a collaboration outside the ITE workshop, coded as 0 (no) or 1 (yes).
- Evolution of the intensity of the relationship since the ITE workshop, (0=no evolution; 1=yes, but only in the following 3–6 months; 2=yes, we continue to maintain the relationship).
- Perception of the geographical distance that separates the actors, coded from 0 to 2 (0=near; 1=far; 2=neither).
- Establishment of synergy, coded from 0 to 2 (0=no; 1=yes, under discussion; 2=yes, completed).

From this questionnaire, we elaborated a picture of the networks, before, during and after the workshops. The data collected were grouped together in matrices, with one matrix per question type. As we were unable to interview all the firms, these matrices were not complete. We assumed that the firms that were not interviewed were not connected with any other firms in the network (except if one of the interviewed firms affirmed having a relationship with them). In fact, in our three case studies, according to the interviews with facilitators, most of the firms that could not be interviewed were not very connected before the workshops and did not maintain any contact after the workshops. However, this strategy, which follows the recommendation about the missing relational data from the reconstruction of the history of interactions (Grossetti et al. 2011), can be considered to be a limitation of our study.

To exploit the results, we used the social network analysis software, *Ucinet* and *Netdraw*. The *Ucinet* software made it possible to measure the global structure of the network (density, number of relations) and the actors' centrality according to their position in the network and thus to apprehend their 'importance' in the network. The *Netdraw* software contributed to the visualization of the general structure of the network; in other words, it made it possible to visualize some of the results obtained with *Ucinet*. The diachronic comparison between the indicators of density, centrality, and subsets (n-clicques) corresponding to the periods before and after the approach enabled us to identify the evolution of the network's structure, the subsets, and the most central actors.

4 Results

For each case, we will now analyze the structure of the inter-firm relations network (its density, the number of relations, and the presence of sub-groups), the actors' positions (the centralities), and the type of relations maintained within it. We identify a business-to-business connection when at least one communicative exchange (a verbal, electronic, direct, indirect, formal, or informal one) has been made between two representatives about topics related to ITE. The nature of this exchange is above all professional (commercial, business network, etc.). Still, representatives may also maintain exchanges of a personal nature (friendly, leisure, family, etc.), which are also reported later on.

4.1 The NISP device in Nord Isère: difficulty in maintaining the relationships created during the workshop

The software for managing inter-firm synergies in Nord Isère makes it possible to capitalize on all the flows of the various actors and to find connections between them, and then to assess the environmental impact of a synergy and to monitor it over time; in other words, it enables its state of progress to be assessed. Following the workshop, the facilitator is expected to get back in touch with each of the firms within three months. To assess the effectiveness of the NISP methodological device and to judge its capacity to build relations and support the economic actors of the local approaches in terms of ITE, we have analyzed, for three periods (before, during, and after the workshop), the inter-firm network formed by the participants in the initiative.

4.1.1 Before the workshop: connections but a sparse inter-firm network

Before the workshop, the network brought together 39 firms from various backgrounds and only included 125 relations related to collaborations, attendance at other professional networks, or personal ties. It thus presented a low density (ratio between the number of ties observed and the number of possible relations), in the order of 0.145. The facilitator of the approach, an adviser to the CCI of Nord Isère (actor 29), already held a central position, which enabled him to control some of the network's interactions. The sociogram (Fig. 4), which graphically represents these relations, places the actors with the greatest number of relations in the center and those with the fewest relations on the periphery. On average, the companies knew eight organizations participating in the workshop and already had a relationship with six of them. Some of them, located on the periphery of the sociogram and mostly geographically distant (nodes 38 and 39), had no relations at all. In contrast, those that were the closest to the center had up to 14 relations (node 26) (Figs. 5 and 6).

We identified cohesive (strongly connected) sub-groups and the possible bridges (links) that connect them by measuring the number of n -cliques in the network to identify the most densely connected groups. The results revealed 27 n -cliques, with $n=2$, which shows that the network was not very cohesive. The weakness of these

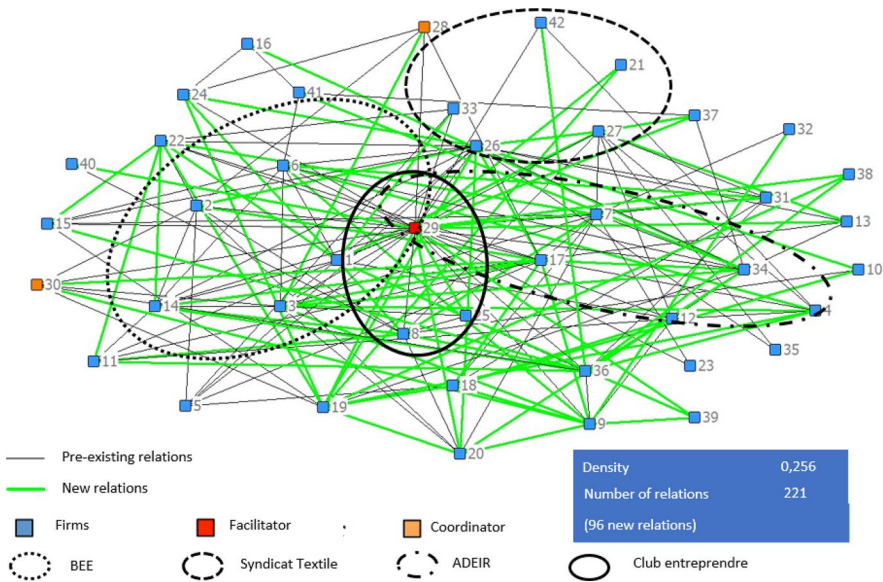


Fig. 4 The inter-firm network during the NISP workshop

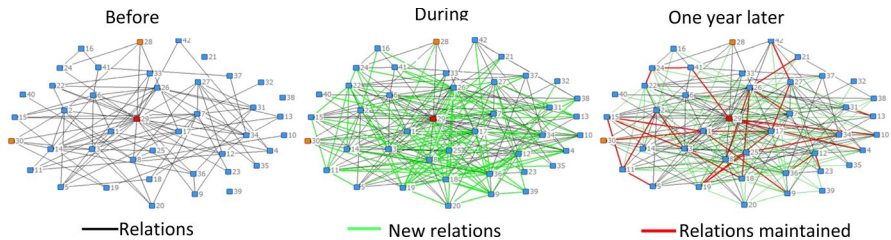


Fig. 5 The inter-firm network before, during, and after the NISP workshop

relations is also reflected in actors with a higher degree of intermediation than others, particularly those positioned in several n-cliques simultaneously, such as the facilitator of the approach and a dozen firms that were slightly more centralized than the others.

4.1.2 The network created at the business-to-business workshop

During the workshop, 96 new relations related to ITE were built, 11 of which involved the approach’s facilitator. The network grew denser (from 0.145 to 0.256), with the number of relations almost doubling to 221 (Fig. 4). The 96 new relations have led to a slight loss of centrality on the facilitator’s part. They have allowed a reduction in the average number of links that a company must mobilize to reach the other members of the network, which is positive for the creation of synergies.

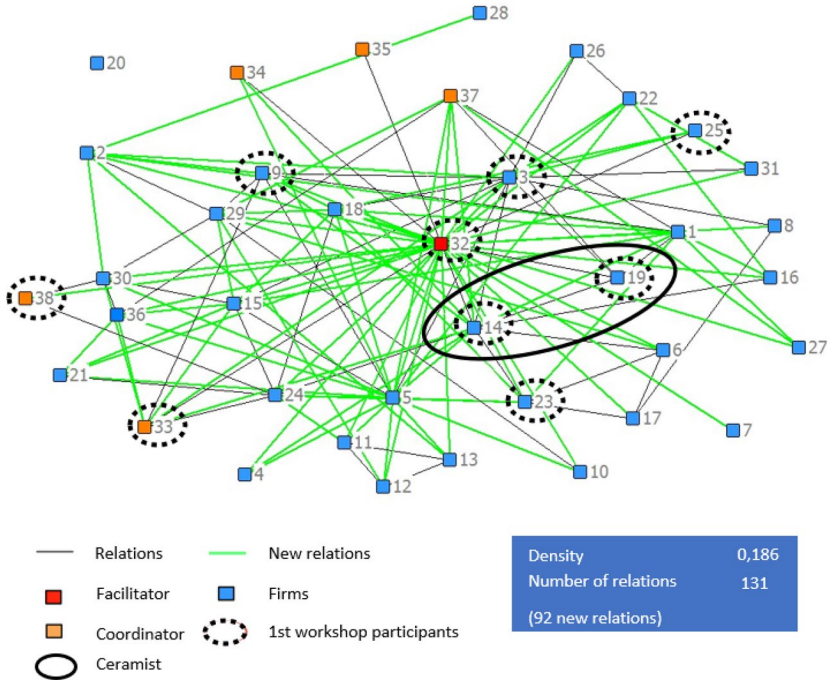


Fig. 6 The inter-firm network during the INEX workshop

This can be explained by the close geographical proximity created by the workshop, which allowed many face-to-face exchanges. The number of n -cliques, with $n = 2$, identified in the post-workshop network has decreased significantly compared to the initial situation, from 27 in the pre-workshop network to 4 in the post-workshop network. This result reveals that the network has become denser and more cohesive.

4.1.3 The disintegration of the network one year after the workshop

However, it turns out that these new relations have not been activated for the most part. One year after the workshop, only 31 relations (existing and new ones) out of 221 were activated during the year. By 'activated' we mean that, during this period, there was at least one bilateral exchange about the workshop (by email, by telephone, or face-to-face) between two actors during the post-workshop phase. The facilitator's late accompaniment explains this relatively low figure in the post-workshop phase, which led to a weakening of the dynamics due to the lack of contact and the weak maintenance of existing links. Regarding the structural analysis of the network and the actors' positions, there is no difference between the workshop's network and the one in place one year later. The number of relations, the network's density, and the actors' centrality remain the same (Fig. 5).

In short, the NISP methodological device's effectiveness in establishing relations and supporting businesses is somewhat mixed. The inter-firm workshop proved that it is a suitable means to generate a significant quantity of new inter-firm relations related to ITE resources and to maintain the existing ones. However, in the Nord Isère territory, once the workshop was over, the coaching could not occur as initially planned, and very few relations were activated. This directly impacted the implementation of synergies: among potential synergies identified during the workshop, only 45 were still identified one year later during our interviews, and very few of them were discussed during the post-workshop period. In the end, four synergies were achieved over the studied period, which brings us back to the initial objectives of the project and may seem very low. We must also consider the real likelihood of establishing so many relationships based on such a sensitive and not very obvious subject and of making them operational: there is no doubt that many firms would be interested in taking such steps and that they feel real potential, but at the same time that they do not really know how to achieve these expectations.

4.2 The INEX device in Drôme-Ardèche: the emergence of a network of good practices around ITE dimensions

The project implemented in Drôme-Ardèche is an experimentation that consists of supporting firms in their search for the optimization of costs related to energy and waste treatment to increase their competitiveness. The INEX design office was chosen to lead the approach and deploy its methodological device, which is supposed to facilitate inter-firm synergies related to ITE resources and experiments.

4.2.1 Before the workshop: a very poorly connected network

The process brought together 32 firms. Before the workshop, the inter-firm network was very sparse (0.065), with only 49 relations. It comprised 27 n -cliques, with $n=2$, which is representative of the lack of connections. The project leader did not occupy a central place in the network. Still, the number of relations maintained per firm, measured according to their centrality degree, informs us that three firms (nodes 3, 9, and 14) were slightly more interconnected than the others and, therefore, could play a potential role as intermediaries. It is worth noting the considerable number of firms (13 in total) that are located on the sociogram's periphery and that have only one relation or even none at all.

4.2.2 A workshop leading to a densification of the network

During the workshop, logically, the network became denser, with the number of relations almost tripling to 131, resulting in a density of 0.186. Eighty-two new relations related to ITE were built during the event, so that firms were almost three times more connected than before, even though the overall density of the

network remained relatively low (Fig. 6). The number of n -cliques increased to 2, with $n=2$, indicating a very high possibility of direct contact. The five firms that developed the most relations were initially positioned in the center of the sociogram (nodes 1, 5, 14, 15, and 18). Belonging to various activity sectors (agri-food, ceramics, wholesale trade, construction work), they do not have any marked similarities. Still, they are all located within the territory of the local government in charge of the project.

The workshop facilitated direct contact between firms by proposing a new reference framework focusing on the circular economy. The facilitator positioned himself as the central actor of the network: with 28 new relations, its intermediarity (betweenness) has greatly developed, allowing him to have control over the interactions or exchanges between other actors and thus to perform his role as a trusted third-party for many firms. The main type of relation developed during the workshop corresponds to economic cooperation based on synergies.

4.2.3 A structure activated one year after the workshop

Firm support was only carried out with a restricted core of firms, which continued their environment-related exchanges. One year after the workshop, the network structure had not evolved, just like the position of the actors, since the total number of relations, the density, and the centrality of the actors remained identical to those previously noted. Of the 131 relations, 29 were maintained, half of which involved the facilitator of the approach (Fig. 7). The sociogram shows that the centrality of the actors did not directly influence the maintenance of relations since the activated relations involved central firms (link 18–3), central and peripheral firms (link 22–3), and firms on the periphery among themselves (link 21–36). The structure of the network, as well as the results in terms of centrality, reveals that the position of the actors did not directly influence the emergence of potential synergies since the synergies discussed can be found both on the periphery (nodes 21 and 36) and in the center of the sociogram (nodes 18 and 3). In the end, the new relations were more activated than the pre-existing ones, which is encouraging in terms of the emergence of sustainable and virtuous local relations.

Thus, the INEX device has shown its effectiveness in creating new relations between the firms of the territory thanks to the organization of an inter-firm

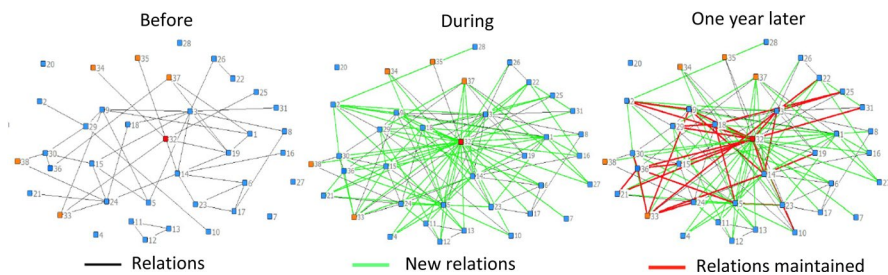


Fig. 7 The inter-firm network before, during, and after the INEX workshop

workshop. The maintenance of these relations remains mixed, but it is difficult to formally assess whether this is related to the methodological device, to the difficulty in terms of really building common resources linked to energy and waste treatment, or to the context in which the approach took place, since the support could not be carried out as initially planned. Of the 22 synergies that emerged during the workshop, 18 were discussed during the post-workshop period, 4 of which were concluded during the period studied. The synergies discussed and achieved emerged in greater numbers as a result of the new relations and are generally located in a geographical area considered by the firms as being 'close' (e.g., between 10 and 25 km away).

4.3 The CCI Quimper Cornouaille device: an approach that is ill-suited to promoting sustainable development?

The project implemented by the CCI QC was based on an innovative methodological device allowing the concretization of synergies and the formalization of the provision of ITE services to local governments.

4.3.1 Before the workshop: an already very dense network

Twenty firms, mainly from Concarneau, took part in the process, nearly two-thirds of which came from the fishing and boating sector. Before the approach, the network (the firms, the facilitator, and the carrier) of 108 relations was already very dense (0.468), which means that half of the possible interactions already existed. There were only 2 n -cliques, with $n=2$, which also reveals the actors' strong cohesion. Three actors (including the project leader) were somewhat more central than the others (the local government [node 10], the CCI QC [node 22], and firm 17 [node 17]) but appeared to be somewhat homogeneous in terms of centralities. The relations' content was based on numerous collaborations, the use of parallel networks, and some personal knowledge.

4.3.2 During the workshop: a slight densification

During the workshop, the network was further expanded (to 0.580), with the emergence of 26 new relations (Fig. 8).

On average, the workshop enabled two new relations related to ITE to emerge per company. The facilitator, the CCI QC, became the most intermediary actor, as shown by the eigenvector centrality analysis. The three structures that were initially the most central observed a slight loss in terms of their importance, while the less central firms upstream experienced the opposite trend. In the end, the homogeneity of the network in terms of centrality was reinforced, and overall, the workshop facilitated the gathering of actors around ecological-related synergies.

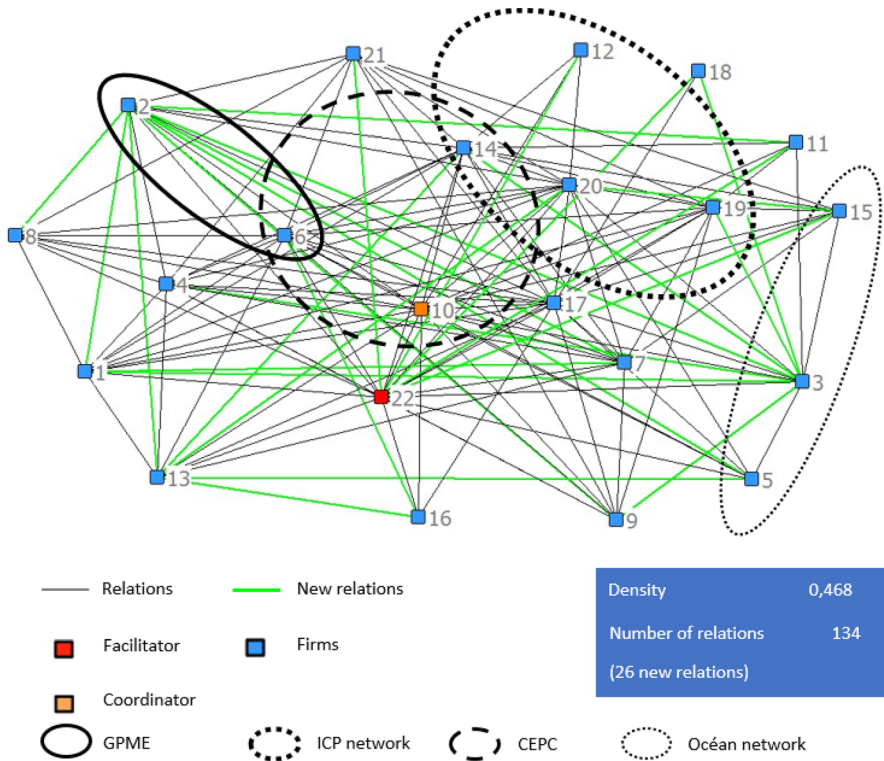


Fig. 8 The inter-firm network during the CCI workshop

4.3.3 One year after the workshop: few relations were activated

One year after the workshop, only 10 relations out of 134 were activated (2 from new relations and 8 from pre-existing ones), half of which involved the facilitator (Fig. 9). Compared to the other two approaches, the proportion of relations activated after the workshop is very low: 7% compared to 14% for the NISP project and 20% for the INEXe project. The lack of follow-up from the facilitator in the post-workshop phase partly explains this observation, which reveals that the firms do not get back in touch on their own once the synergy has been identified and that support is probably necessary. Moreover, the low number of relations activated after the workshop may mean that the methodological mechanism was insufficient in terms of facilitating the actors' coordination or that the relations' historicity plays a minor role in the emergence of synergies. To make pre-existing relations evolve, some collective, long-term learning that leads to a change in the mental frames of reference seems necessary. The methodological device clearly did not meet this expectation because the ecological framework appeared to be relatively undefined, especially since the obligation to build cooperation that could prove useful at the level of local

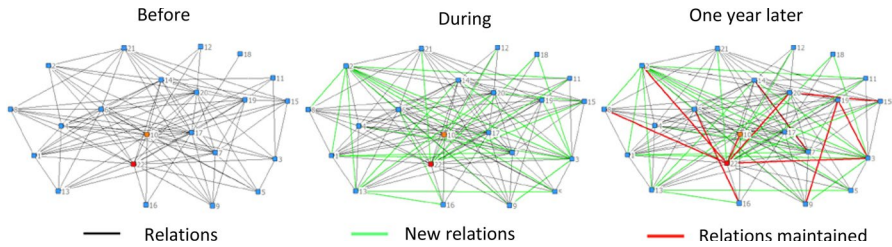


Fig. 9 The inter-firm network before, during, and after the CCI workshop

governments seemed distant for firms interested above all in processes with operational aims.

Finally, the CCI QC's methodological device does not seem to have been adapted to the types of relations encountered in the process (many pre-existing collaborations, with firms frequenting many networks). Indeed, the network's strong connectivity (i.e., many relations maintained, multiple collaborations) seems to increase expectations. Besides, the participants were working together in networks of expertise or economic development, looking for innovative environmental solutions (synergies) that they would not have been able to consider outside the approach's framework. Favoring an economic focus, the ACTIF approach did not sufficiently distinguish itself from other firms gatherings and ultimately led to a certain indifference.

5 Discussion

The schemes studied in our work proposed to bring together groups of local economic actors through workshops during which firms were invited to exchange and make contacts with regard to sharing resources related to ITE. The analysis showed that the results were generally positive during the workshop phase since many links between firms were built. However, the way the workshops was conducted led to the creation of different inter-firm relation categories depending on the cases studied and a variable, and often low, level of activation of these relations over time. These results question the possibility of setting up inter-firm cooperation processes concerning ITE procedures at the local level, and thus cast doubt on the creation of virtuous circuits of flows and products in favor of sustainable territorial development. They also conduct us to think about the implementation of these processes, as well as the actions or policies that support them.

5.1 Globally successful connections, but with structures of relations that vary from one device to another

As the workshops' context suggests, it was mainly business-opportunity-type relations that were forged during the meetings. Figure 10 provides a comparison of the three schemes in terms of business-to-business relations. We can see that the NISP

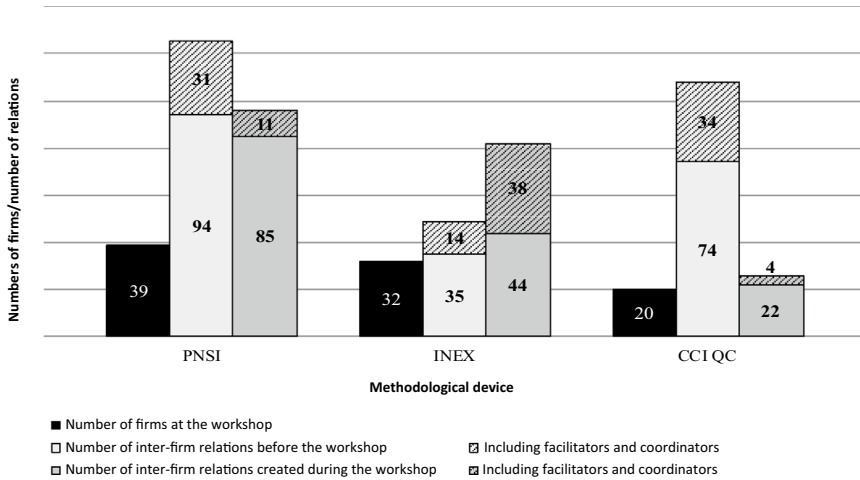


Fig. 10 Comparison of methodological arrangements in terms of inter-firm relations

workshop, where many relations pre-existed, was the one that generated the greatest number of new inter-firm ITE-based relations compared to the number of participants, ahead of the INEX and the CCI QC workshops (despite having a very close networking methodology to that of the NISP). It is assumed that the number of new relationships, in the latter case, is smaller due to, in particular, the large number of pre-existing relationships.

Firms were put in touch with one another in a targeted manner, according to the themes that were supposed to present common issues or interests, to identify solutions through ITE. The way the workshop was conducted seems to have impacted the content of the relations that were built as a result. The main objective of the workshops was to generate new economic cooperation based on synergies. Our interviews show that most of the exchanges indeed focused on the identification and discussion of synergies between firms. They led to the creation of cooperative relations related to this theme, but the informal moments of the workshops (warm-up, breaks, closing) also made it possible to build other types of relations (Table 2), namely commercial collaborations, networking relations, and personal or courtesy relations. However, according to the INEX workshop method, which is

Table 2 Type of business-to-business relations built in the workshops

Type of relations	NISP	INEX	CCI QC
Economic cooperation regarding the synergies	++	+++	+
Commercial relations	++	-	++
Collaborations (excl. synergies))			
Prospecting/Canvassing	++	-	+
Networking/Exchanging of good practice	+++	++	+
Personal relations	+	-	++
Courtesy	+++	++	++

more directive than the other two, the participants are sometimes less focused on the objective of the workshop and have time to develop new business or courtesy relations. Clearly, the general commitment shown here remains relatively weak and limited to a few relations, except in the NISP case; it is not sufficient for establishing lasting relationships and, even less so, for popularizing or seriously launching operations or procedures related to the circular economy at the territorial level.

5.2 Support that is underestimated and challenging to implement

This relative weakness is linked to the underestimation of the question of coordination (by the facilitator) and its role in the maintenance of local relations. In each situation, a variable number of relations was activated as a result of the workshop (Table 3). In the case of the INEX approach, slightly more than one in five relations were activated, half of which involved the facilitator of the approach. For the NISP approach, the proportion is slightly lower, with the activation of 31 of the 221 relations. For the CCI QC approach, very few relations were activated, only 10 out of 136 (i.e., less than one in ten). This observation highlights the lack of support for firms, which seems to be the three devices' weakest point. The lack of frameworks offered by the methodological devices makes the support process unclear and underdeveloped compared to the obstacles and difficulties met in terms of communication and collaboration.

The sharing of a common vision for the rest of the workshop and a precise timetable emerged as the missing elements in all the three study areas. Without this sharing, firms adopt a wait-and-see attitude or lose interest in the process and quickly return to their routines. This problem is linked to a certain lack of framing. Coaching proves difficult to translate into practice. Simple reminders by phone or email are limited in terms of maintaining a dynamic in the absence of physical meetings. The sending of a newsletter and the implementation of a collaborative platform are of interest to firms, but their consultation is not easy to estimate. The organization of new meetings is often favored by the participants, provided they are planned before or during the workshop and present the firms with deadlines and objectives. This element is seriously lacking in our three experiments.

Ultimately, the arrangements provided in their current form (i.e., based on remote contacts) reveal the difficulty in terms of providing support once the workshop has ended and of maintaining momentum without face-to-face interactions. As far as our case studies are concerned, the support was likely minimized while elaborating the

Table 3 Relations activated during the post-workshop phase

	NISP	INEX	CCI QC
Number of existing relations activated	18	23	2
Number of new relations activated	13	6	8
Total number of activated relations	31	29	10
% of activated relations regarding the total number of relations in the network	14%	22%	7%

procedures, rather than during the inter-firm workshops. The latter are quantifiable (number of participants, number of synergies identified) in terms of objectives and success indicators. In contrast, support is very random and subjective, often based on trial and error. Thus, it was severely reduced to weak monitoring at a distance. However, it seems that it is during this phase that an essential part of the cooperative process takes place and that cooperative relations can be built.

5.3 The facilitator: an indispensable third-party

The proportion of relations involving the facilitator of the inter-firm network approach is 20% for the NISP, 35% for the INEX, and 28% for the CCI QC. These figures indicate the facilitator's role as an intermediary; the more significant the proportion of relations involving this actor, the more the facilitator controls the network and positions itself as a relay actor. Our results confirm those of Paquin and Howard-Grenville (2012), showing that the facilitator can play an intermediary role and replace pre-existing social links by accelerating the development of a feeling of trust between firms that did not know each other before in the process of the creation of ITE relations. It also creates a link between firms from different sectors of activity, which makes the exchange of information more complex as they do not systematically have the same references, language, modes of reasoning, and capacity to absorb values and concepts of synergy. Therefore, a great deal of work is necessary to help them reach a mutual understanding that makes it possible to find a compromise between cognitive overlap and the diversity of knowledge (Nooteboom et al. 2005).

The intervention of the facilitator is therefore of decisive importance, whether it is during the phase of mobilizing the firms, by putting them in contact with one other, or in their follow-up and support (Patala et al. 2020). But, said importance is particularly crucial in terms of supporting firms, relaunching them, and helping them to implement their projects. As a recognized territorial institution, the facilitator's legitimacy is useful in the mobilization and networking phases, and his expertise is expected in terms of the follow-up. It clearly represents an essential link in the process of sustainable territorial development because it makes it possible to connect initiatives and local actors, and thus to initiate virtuous dynamics at the level of a territory. This issue has to be seriously considered to ensure the success of local governance operations or territorialized public policies in favor of the development of ITE.

6 Conclusion

The objective of this article was to assess under what conditions it is possible to implement voluntary ITE or local circular economy approaches, based on the fact that numerous works show that it is mainly a question of implementation flows and, even more so, of organizational issues and collaboration between local actors. Based on this observation, we focused our approach on the possibility of creating cooperation links at the territorial level concerning the sharing of resources to promote the implementation of ITE approaches. Our work was based on the study of three

methodological devices set up in three French territories, whose implementation and evolution in terms of the analysis of social networks was studied.

First, our results show that the methodological devices studied allow the creation of new relations between firms during the workshops. However, each situation is different according to the field and the particular methods used. Indeed, the relational and organizational context specific to each territory has to be considered. When there are many relationships between firms before the workshops (and therefore potentially a certain amount of trust and the sharing of common norms and values), it does not necessarily imply greater efficiency in the number of new relations created and, even less so, in the number of synergies implemented after the workshops. This even tends to complicate the whole process for several reasons: the actors know one other, and are more dissipated or will tend to exchange information on different subjects, and therefore be less focused on the objective of the workshop, which is to create industrial ecology synergies. It can also be assumed that if they know one other and are already aware of ITE, any potential synergies, if they are of interest to firms, will already have been implemented before the workshop.

Second, it turns out that while these mechanisms are effective at bringing actors together from their territories and especially firms, they are not very suitable for maintaining effective cooperation over time. Many ITE actors consider tools for identifying synergies, researchers, and practitioners alike as indispensable in ITE approaches (Grant et al. 2010). However, it must be noted that in the case of the approaches studied, the results remain limited in terms of the number of synergies implemented and, even more so, in terms of the creation of relations between firms. Indeed, like in other cases (Polge and Torre 2018), the support of an intermediary actor remains necessary to make the firms cooperate by helping to create a climate of trust between them, but also by supporting their cooperative relations and helping them to maintain them over time.

Third, we highlight the major role played by public actors in developing ITE. INEX, ACTIF, and the experimentation of the NISP program were developed within the framework of research projects partially financed by ADEME. ADEME is also promoting the constitution of a national network of practitioners called SYNAPSE, whose objective is to provide feedback and allow the sharing of good ITE practices, and more than 150 initiatives promoting ITE in the French territory are partly funded by a public actor. Public actors are involved in ITE initiatives all over the world, taking on different roles, such as operator, organizer, financier, supporter, policymaker, or regulator (Bourdin and Nadou 2020; Uusikartano et al. 2021), in order to make ITE a real strategy for the sustainable development of territories.

These results have important implications in terms of public policies and local public action in a period when the introduction of circular economy approaches seems to have become one of the new mantras of territorial development policies (Bourdin and Torre 2020). This is true at the European level and particularly in the French case, where ADEME is supporting them with a series of methodological tools that aim to facilitate interactions between voluntary enterprises. Our work shows that the implementation of these tools is not easy and that their success remains uncertain. Furthermore, it indicates that the provision of methodological devices promoting contacts and exchanges or the setting up of collaborative workshops is not sufficient. It is, above all, having people dedicated to this collaborative task that is essential because they can

carry out follow-ups that ensure the maintenance and sustainability of the relationships built. The cost of such interventions is quite different since it is not only a question of acquiring a turnkey method but also of financing the persons responsible for the intermediation functions at the local level. Of course, this choice implies a much heavier financial commitment and follow-up over time at the local level.

Appendix

Location of the three case studies.



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