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Fuzzy front end of systemic innovations: A conceptual framework based on a systematic literature review

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ABSTRACT

This study aims to analyze the fuzzy front end stage (FFE) of systemic innovations, which are characterised by interdependence with other innovations and actors of the business ecosystem. The methodological approach selected is a systematic literature review based on bibliometric, social network analysis and content analysis. The analysis of the literature reveals that systemic innovations are addressed in a limited manner in specialised articles on FFE. The main frameworks on FFE were analysed in-depth and a conceptual framework for the fuzzy front-end stage of systemic innovations was proposed, encompassing the following elements: (i) ecosystem mapping and identification of the organisation positioning within the ecosystem during the analysis of the influence factors; (ii) use of mechanisms of coordination, collaboration, self-regulation and adaptation as innovation drivers; (iii) conception of new business models, value networks or strategic positioning as a result of the definition of concepts; and (iv) strategic planning or corporate venture capital as stages subsequent to the FFE, instead of the formal process of new product development.

1. Introduction

Systemic innovation (SI) corresponds to the type of innovation that only generates value if accompanied by complementary innovations. It opposes autonomous innovation, which can be developed independently of other innovations (Chesbrough and Teece, 2002). For Taylor and Levitt (Taylor and Levitt, 2004), systemic innovation changes business processes and requires companies to change their practices. Moreover, it requires significant adjustments of the other parts of the business system involved (Maula et al., 2005).

On the one hand, there is an increasing importance of understanding the innovation dynamics in complex systems to ensure the competitive advantage of companies (Iansiti and Levien, 2004). As the SI processes expand beyond the company boundaries, they generally involve the coordination of different parts of the value network. According to Taylor and Levitt (2004)), SI typically increases general long-term productivity but can create switching or initiation costs for some participants and reduce or eliminate the role of others, making SI initiation and diffusion more complex.

On the other hand, the fuzzy front end (FFE) appears as the stage that requires the most investigation while having the greatest potential to increase the success probability of the innovation process (Khurana and Rosenthal, 1997; Koen et al., 2001; Kim and Wilemon, 2002). FFE is defined as the initial stage, and generally chaotic, that starts by identifying opportunities and by generating ideas, and finishes by approving new concepts for a more structured phase of the innovation process (Koen et al., 2001; Smith and Reinertsen, 1992). This stage is usually part of a Stage Gate® (Cooper, 1990) type model, which is performed by new product development teams.

Thus, the FFE concept arises in a context of new product development within a single organisation. Just a few studies expand beyond the organisation boundaries, addressing only a single additional actor in the business ecosystem, such as the supplier (Wagner, 2012) and the users/customers (Magnusson, 2009; Dahl and Moreau, 2002). Studies of collaboration between functions (cross-functional collaboration) appear to be limited to areas within the same organisation (Moenaert et al., 1995; Brettel et al., 2011).

Wagner (2012), Brettel et al. (2011), Brentani and Reid (2012), Fixson et al. (2012), Verworn et al. (2008), and Rice et al. (2001)) show that there is a lack of FFE studies that take into account more variables and external stakeholders to the organisation (environmental factors) to understand this initial stage of the innovation process.

Analysing the SI literature, several authors (Adner and Kapoor, 2010; Afuah, 2000; Jacobides et al., 2006; Prieto, 2013) indicate the need to coordinate the actors of the value chain or business ecosystem that are external to the organisation frontiers for SI, considering the type of connection (e.g., vertical integration, contract, partnerships, and alliances), the choice of the governance structure, the degree of trust/uncertainty among the actors and the mechanisms of knowledge transfer

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among firms. As aforementioned, the relation between FFE activities and issues associated with external actors has not yet been sufficiently explored.

Another issue related to the FFE stage in SI is the need to conceive new business models or new ecosystem architectures, because the value, in this case, is generated and distributed by complex interrelationships among the various actors (Adner and Kapoor, 2010; Jacobides et al., 2006; Moore, 1993). Because the FFE literature focuses on generating concepts for new products instead of new businesses, one question is whether there are theories that support the conception of new business models as one of the activities for the FFE stage of a SI.

This paper aims to prepare the ground to identify the theoretical contours of this emerging field, building on the insight into the potential research gap between FFE and SI. The following research question was defined: how should the FFE of systemic innovations be?

An extensive body of knowledge on FFE and SI is available; however very little work has been reported with respect to the FFE stage of a SI. In the background of FFE and on SI, we find the stepping-stones to link both fields. For this, a systematic literature review (SLR) approach was selected combining bibliometric, network and content analysis. The first phase was the bibliometric approach to identify the most relevant literature on both — FFE and on SI, going through the network analysis for the key points at which these two fields intersect. Keyword network analysis was performed with the software Sitkis, Ucinet, and Netdraw, based on the keywords used by the studies surveyed. This approach was selected in order to rapidly grasp an overview of the relationships between constructs for conceptual modelling, based on the current literature. The second phase, content analysis, was performed by identifying the core FFE models in the literature, which were used as a code tree for the content analysis. In addition, in the SI scholar literature, the key aspects related to the FFE stage were identified and coded. From this background, in the third phase synthesis, we position the conceptual model on FFE and SI, in which the insights from the current literature were reorganised in a new format while pointing out possible new directions.

This paper is structured into five sections. Section 2 presents the summary of the literature review in context for FFE of SI. Section 3 presents the methodological approach and research methods. Section 4 presents the results. Section 5 presents a discussion of the findings and the conceptual framework proposed, and Section 6 presents the conclusions and contributions of the research.

2. A context for FFE of SI

First, let us clarify the definition of FFE and SI adopted in the research. Then, let us turn to the relevance of the research question of how to pursue SI at the FFE stage.

The FFE stage has three characteristics shared by all the authors in the sample studied:

- It is the first stage of innovation development;
- It precedes the formal and structured innovation development;
- The termination of the phase is characterized by a formal approval or rejection of the project for the next stage.

The definition of systemic innovation is far more incipient compared to FFE and deserves further discussion along with the content analysis performed herein. In short, Teece, as the main early author on the subject highlighted three aspects:

- Innovation that requires complementary innovations to generate value;
- Innovation that requires significant changes in other sub-systems;
- Innovation in which coordination and cooperation are necessary.

SI has attracted increasing attention due to recent successful business cases and also due to pressing demands for great infrastructure transitions to achieve a more sustainable economy (Boons et al., 2013; Boons and Lüdeke-Freund, 2013). A typical successful business case of SI is Apple's iPhone and its ecosystem. The way in which Apple delivered a whole pack of innovations surrounding iPod and iPhone is an inspiring case, involving the iTunes, in a partnership with major record labels for online legal music distribution, and App Store as a new way of crowd developing and distributing useful applications for consumers, revolutionalised the mobile communication industry. In terms of major transitions towards a sustainable economy, one example is the Smart Grid, which requires orchestrated moves from utility companies, technology suppliers, telecom operators, regulators and changes in consumer habits to fully generate its expected value to society.

However, different stages of SI require different ways of innovation. In addition, a substantial share of the literature on FFE tends to focus on individual product innovations and/or R&D project. This is the stage at which regulation, social acceptance, and technology are still malleable, open-ended and uncertain (Boon et al., 2011); therefore, the great challenge of managing cumulative risks between several parties must be addressed (Adner, 2006). The hope to shed light on these issues was the research team's motivation for this paper.

3. Research methods

Fuzzy front end (FFE) and systemic innovation (SI) have been addressed by various studies, but the intersection between these two fields is still scarce. To bridge both fields, a systematic literature review (SLR) approach was selected to explore the body of knowledge available.

A multi-method combination for SLR is applied, mixing bibliometric, keyword network analysis and content analysis. These methods are complementary (Carvalho et al., 2013), and used in order to get the most from the current literature before a more costly field research. Whereas bibliometrics and network analysis aid in understanding the publication patterns in the main databases, content analysis focuses on the surveyed articles and help to develop the conceptual framework.

The first phase was the bibliometric approach to identify the most relevant contributions of both — FFE and SI, by surveying the existing literature on key scientific databases. Keyword network analysis was performed, going through the network analysis for the key points at which these two fields intersect. This approach was selected in order to rapidly have an overview of relationships between constructs for conceptual modelling, based on the current literature. The second phase, the content analysis, was performed by identifying the core concepts for FFE and SI. From this background, in the third phase synthesis, we position the conceptual model on FFE and SI.

3.1. Articles sample and bibliometrics

To obtain the first sample, articles published in indexed journals, having their impact factor calculated by the JCR (Journal Citation Report) from the ISI Web of Knowledge (Web of Science) database were selected. This database was chosen because it includes articles from other databases, such as Scopus, ProQuest, and Wiley. Moreover, this database provides metadata crucial for the bibliometric analysis, including summaries, references, the number of citations, the list of authors and keywords. All the articles recorded in the database until September 2013 were considered in the initial search.

The search words used in step 1 were ["*fuzzy front end*" *or* "*fuzzy-front end*" *or* "*fuzzy-front-end*"], leading to 105 articles, from which 3 were excluded as they only dealt with the "*fuzzy logic*" method. To select the most relevant articles, the impact factor of each article (I) was calculated based on the number of citations (C) and the impact factor of the journal in which it was published, obtained by the Journal Citation

Report (JCR), according to Eq. (1), as suggested by Carvalho et al. (2013)).

$$I = C * (JCR + 1) \quad (1)$$

The articles were listed by decreasing order of impact factor, and a Pareto analysis was performed. As we prioritized quality over quantity, we narrowed the sample by impact factor. Then, the first 27 articles (27% of total), representing 90% of the total impact of the sample calculated according to Eq. (1), were chosen for the content analysis. To also include recent articles not cited because they were relatively new rather than because they were irrelevant, another 23 articles published from 2009 to date in journals with a JCR higher than 2 were selected, resulting in a total sample of 50 articles.

For step 2, the keywords ["*systemic innovation*"] were used. However, the first search led to a sample of 29 articles. Ten of those were excluded from the abstract analysis because they focused mainly on geographic (regional or national) innovation systems, not systemic innovation as defined in this research. To improve the quantity and the quality of the sample, the snowball sampling technique (Fink, 1995) was employed to identify the references that cited or were cited by the articles identified as being within the research scope, using the function "article to reference" provided by the Sitkis software (Schildt, 2002). This process was repeated with the resulting sample until we reached 133 articles. These articles were listed in decreasing order of impact factor, and 24 articles representing 90% of the total impact factor of the sample and 39 articles published in the last 5 years in journals with a JCR higher than 2 were chosen. Additionally, a book chapter was included, leading to a total sample of 62 texts.

Using this sample of articles, a network analysis of the keywords was performed for each topic, computer-aided by Sitkis (Schildt, 2002), Ucinet 6 and Netdraw (Borgatti et al., 2002). The network analysis is the graphical analysis developed in the bibliometric study context to understand the relation (intensity and centrality) between keywords, authors, and references. The topics were clustered using the Affinity Diagram technique (or KJ method, after its Japanese designer Kawakita Jiro) (Carvalho, 2005), by organising the keywords under common themes defined by the authors. A bibliometric analysis of the frequency of publications per year and per journal of the sample was also performed.

3.2. Content analysis and framing

The research plan consists of three steps: (1) review of FFE, emphasising conceptual models and the relationship between management practices and superior performance, (2) review of SI and (3) conceptual framework development.

A content analysis was performed in the surveyed literature in order to identify and to select the most comprehensive conceptual FFE model, which, in turn, was used to build a code tree for the content analysis of the SI literature and to calculate the frequencies of occurrence.

A survey of the methodological approaches and units of analysis were conducted. Afterwards, the content analysis was performed to identify the definitions and conceptual models of FFE. These models were compared, and those that were most comprehensive and coherent with the dynamic and complex nature of systemic innovations were chosen to organise the content analysis. The content analysis allows analytical flexibility, as suggested by Duriau et al. (2007); thus, the content analysis was based on core concepts instead of on authors, as suggested by Webster and Watson (2002).

According to Duriau et al. (2007), the content analysis involves the manifest content of the text (number of text statistics) and the latent content and deeper meaning embodied in the text. For the content analysis, a table compiling all the relationships between variables identified by the authors of the SI sample (those proved by either the statistical analysis or by means of theoretical articulation, case studies or literature review) was produced. The SI relationships were evaluated separately and classified according to the conceptual FFE model adopted. An integrated critical synthesis and analysis of the groups identified for each of the topics were subsequently performed. Finally, a conceptual framework for FFE specific for SI was proposed based on the critical literature analysis.

4. Results

4.1. Bibliometric and network analysis of the FFE sample

The first article of the sample regarding FFE was published in 1992 by Smith and Reinertsen (1992) and was one of the main studies responsible for disseminating this term. Three years later, an important article was published by Moenaert et al. (1995), showing the first quantitative analysis specifically for the FFE stage. A large number of relevant articles were published in 2002, such as Koen et al. (2001) and Kim and Wilemon (2002)). Since 2009, the number of yearly relevant publications on this topic has increased. These results are presented in Table 1.

More than 50% of the articles were published by two journals, "*Journal of Product Innovation Management*" and "*R&D Management*", both targeting researchers and managers of new product development (NPD) and research and development communities.

For the initial analysis of the main concepts and variables involved in the FFE research, the keyword network of this sample was analysed. In this network (see Fig. 1), the lines indicate that the keywords were cited together in the same article, and the line thicknesses correspond to the intensity of this relationship (how many times the keywords were cited together in the sample). The results were divided into affinity groups for an initial preview of the possible conceptual framework variables and relations.

The top cluster of the FFE keyword network shows that the most widely used units of analysis in the sample are companies (*firms*, *organisation*) and projects, as shown in Fig. 1. On the right side of this network, the objective cluster, or dependent variable cluster, is composed of the following keywords: innovation, success, impact and project performance. The FFE keyword is intensively related to the dependent variable cluster, which suggests a positive impact of FFE on innovation and on performance, according to the sample surveyed. The environment and strategy cluster identified links between the FFE with market-oriented strategy and decision-making processes of the organisations in an environment of uncertainties.

Several internal factors are grouped in a cluster at the bottom of keyword networks. The most widely studied internal success factors are new product development processes, research and development, communication, technology, management practices, absorptive capacity, communication, information and experience of the organisation. Keywords related to techniques of *Quality Function Deployment* and modelling emerged. The generation of ideas and design are particularly important activities, supported by creativity, which is strongly related to innovation (see Fig. 1).

Analysing the research approach in Table 2, a balance between qualitative and quantitative approaches is found in the surveyed articles. Among the qualitative research methods, the most widely adopted are the case study, and among the quantitative methods, the survey. Just 3 articles are literature review.

Regarding the unit of analysis, Table 3 confirms what was observed in Fig. 1. There is a predominance of studies at the firm level, involving management strategies, processes and organisational structures for FFE, and of studies at the project level, discussing the impact of the specific conditions of a project (such as the degree of technological novelty) and the application of techniques, tools and practices to the performance of new product development. It is worth noting that not a single work addressing the unit of analysis of the business ecosystem was identified, as mentioned in the introduction.

Table 1
Number of publications per journal per year (FFE).

Journal — FFE Sample	Yearly Publications																								Total
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Journal of Product Innovation Management							1			1		1				1	1		2	2	4	5	1	2	21
Research-Technology Management		1					1		2		1	1	1					1		1		1	1	2	13
R & D Management										1	1	1		1		1	1	2		1	2				11
International Journal of Technology Management												1	2			1			2	1	2	1			10
IEEE Transactions on Engineering Management					1					1						1			1	1	1				6
Others				1			1			2		2			2	2	3	4	3	4	6	9	1	7	57
$Total_{ISI}$		1		1	1		3		2	5	2	6	3	1	2	6	5	7	8	10	15	16	3	11	109
Content analysis sample		1			1		2		1	4	2	5	1	1	1	3	2	1	3	5	7	10	1	8	59

Note: Journals listed in decreasing order of publications.

4.2. Bibliometric and network analysis of SI sample

The first article of the SI sample was also published in the early nineties (1991), as observed with the FFE sample. However, the longitudinal analysis revealed that the number of publications began increasing in 2010, with a peak in 2013. One-third of the sample was published in 2013, indicating that the development of this topic is recent and has been gaining interest in the literature.

More than 70% of the SI samples are published in journals that specialise in innovation policy, technology, strategy and sustainability such as *Research Policy* and *Technological Forecasting and Social Change* (which represent 40% of the sample). This finding suggests that the level of SI analysis is greater than the FFE one: whereas SI is discussed in the public management sphere or at the company senior management, FFE is mainly concerned with the research and development areas. The presence of publications in the *Journal of Cleaner Production* is emphasised, suggesting the existence of a relationship between sustainable development and systemic innovation. These results are presented in Table 4.

When the FFE (see Fig. 1) and SI keywords (see Fig. 2) are compared, the similarities in the internal factors and objectives (dependent variables) clusters can be verified. Both fields of research stem from the resource-based view (RBV) to search for explanations for value creation conditions through innovation, which leads to superior performance or competitive advantage. However, the internal factor cluster presents a distinctive keyword - dynamic capacity, which appears just in the SI sample. It refers to the firm's ability to modify or to create internal and external competences to rapidly address changing environments, which seems to be the contextual background of systemic innovations.

Elements that differentiate systemic innovation from product innovation are the larger level of complexity and dynamism caused by evolving society movements and broad technological changes, whereas, in the case of product development, the improvements are oriented by trends in the consumer market. Another evidence of this difference is the employed techniques cluster: the FFE management is based on an understanding of the current customer voice using techniques such as QFD, whereas the SI management seeks to build future visions (*foresight*) and new business model development. The units of analysis identified in the SI keyword network vary from company/organisation to the group of living beings and environment (ecology), going through industries/markets and business ecosystems/value networks. This evidence reinforces the previous statement that the level of SI analysis is more advanced than that of FFE.

Finally, the key activities in SI and in FFE are distinct, despite being eventually complementary. In the key activity cluster of the FFE network, idea generation and creativity are highlighted, whereas, in the SI network, coordination of the business ecosystem is crucial as well as the delineation of boundaries of the organisation in the value network. The coordination mechanisms vary from the vertical integration, which supposes that the environment is completely competitive, to open innovation, which implies that the complementary entities collaborate.

Analysing the approaches and research methods in Table 5, there are more than twice the number of qualitative studies as there are quantitative studies, indicating that this field is at a more exploratory stage than FFE, although both appeared in the literature in the same period. According to Hobday et al. (2000)), complex products and systems create issues extremely difficult to measure for both academic and practical purposes, since each product and project tends to be different. These differences hinder the application of traditional performance benchmark techniques, which can at least partly explain this discrepancy.

Similarly to the FFE sample, there is a predominance of case studies in the qualitative approach, with an emphasis on the theoretical and conceptual discussions articulated from the existing knowledge in the

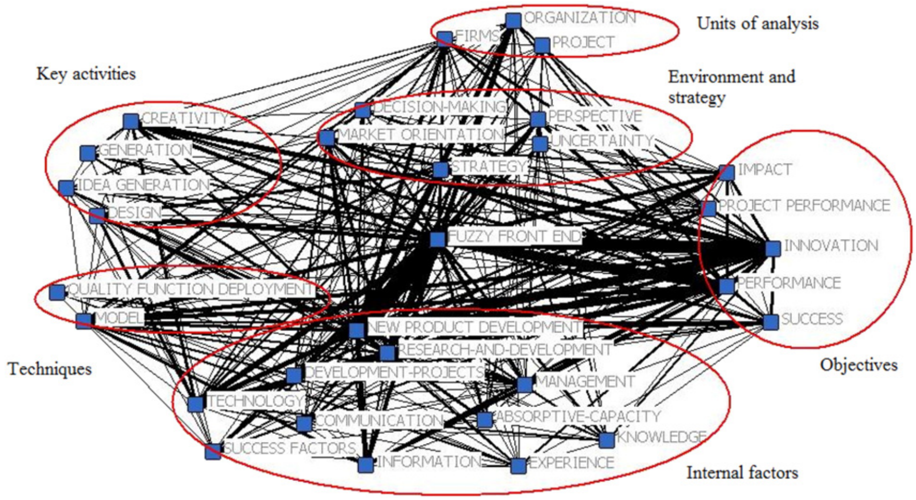

Fig. 1. FFE keyword network. Note: Output Software Ucinet and Sitkis.

light of new phenomena, such as the success of some companies in building business ecosystems (e.g., Microsoft, Cisco, and WalMart). Few studies go beyond the qualitative research and try to mathematically formalise and empirically validate the models proposed.

Finally, the unit of analysis of the research studies confirms previous suggestions regarding the more advanced level of SI relatively to FFE: almost half of the sample is performed at the business ecosystem level (also known as the value network), 9 studies are undertaken at the even more macro-level of ecology (society and environment) and 5 at the industry level (value chain). The unit of analysis 'firm' is relevant in both FFE and SI, enabling the confrontation or complementation of theoretical propositions. Three other studies address intermediary organisations that mediate the innovation processes without directly participating in the value network, and one tackles dyadic relationships between organisations (manufacturer–distributor), as shown in Table 6.

4.3. Results of content analysis: FFE sample

Based on the content analysis of the FFE sample, FFE can be defined as the first stage of the new product development, which occurs before the formal and structured development process and finishes with the go/no-go decision. The activities included in FFE are more thoroughly presented in the conceptual FFE models, which are summarised in Table 7.

Most models present a linear vision of this step, except forKoen et al. (2001), whose model is recursive. Table 8 summarizes the steps in FFE.

Table 2
Approaches and research methods in the FFE sample.

FFE	#	%
Qualitative	31	48%
Case study	20	28%
Conceptual–theoretical	7	12%
Literature review	3	6%
Action research	2	2%
Quantitative	27	52%
Survey	19	36%
Modelling	3	6%
Experiment	2	4%
Statistical sampling	1	2%
Simulation	1	2%
Quasi-experiment	1	2%
Total	59	100%

According to McCarthy et al. (2006), innovation processes can vary from linear to chaotic depending on the degree of unpredictability. Kim and Wilemon (2002) and Zien and Buckler (1997) emphasise that the FFE is different from the formal product development due to its low degree of formalisation and a high degree of experimentalism with an uncertain character. These characteristics make this stage closer to a non-linear model.

In addition to being non-linear, the model of Koen et al. (2001) is the most comprehensive as it can include the other models. The nomenclature is not consolidated; thus, the diagram of affinities was used here to generate the groups presented in Table 8. In some cases, such as idea generation and idea creation, the terms used by the authors are very similar. Others, more complex were analysed and grouped, such as (1) governance (Khurana and Rosenthal, 1997) and (2) concept evaluation (Smith and Reinertsen, 1992; Cooper, 1988; Montoya-Weiss and O'driscoll, 2000). The first item was considered in the element 'engine' as proposed by Koen et al. (2001), and the second was grouped at the concept definition stage.

4.4. Results of content analysis: SI sample

The SI definitions are presented in four articles of the sample (see Table 9), but all cite some work by Teece (1986) or subsequent research by the same author.

The definition of the term still lacks conceptual specification. For example, where is the limit between innovation in one component and complementary innovations? How can a significant readjustment be identified? Do the subsystems affected need to expand beyond the organisational boundaries to be considered a systemic innovation? The same question regarding boundaries can be posed with regard to coordination and cooperation, which are indicated as necessary by Mlecnik (2013). Multidisciplinarity is a feature of any product development process (Moenaert et al., 1995), considering that SI is different because it demands adjustments besides the coordination and collaboration of external agents to the organisation.

Table 3
Units of analysis in the FFE sample.

FFE sample	#	%
Firm	28	48%
Project	20	36%
Portfolio	5	8%
Group	4	6%
Individual	2	2%
Total	59	100%

Table 4
Number of publications per journal per year (SI).

Journal — SI sample	Yearly Publications																								
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Research Policy	2				1		1			1						1			1	1	1		4	1	14
Technological Forecasting and Social Change						1													1	4		1	5		12
Journal of Cleaner Production																					1	1	6		8
Technovation																			1	1	2	1	1		6
Strategic Management Journal										1									1	1			2		5
Manage Science													1				1								2
Harvard Business Review			1											1											2
Others						1				2	1	1				1				2	1	2	3		14
Content analysis sample	2		1		1	2	1			4	1	1	1	1		2	1		4	9	5	5	21	1	63

Given that the SI and FFE are built with a resource-based view of firm strategy, the "significant readjustment" can be concluded to refer to changes in the capabilities demanded by the co-ompetitors, such as suppliers, complementors, customers and regulators (Afuah, 2000).

Comprehensive conceptual models of the development of SI were not found in the sample. However, other innovation typologies commonly associated with SI are identified and summarised in Table 10.

Another important term of this research topic that needs to be defined is business ecosystem (also called value network). This term was mentioned by 7 authors of the sample, all referencing (Moore, 1993), who defined this term as a fluidly interconnected network of companies and other entities whose abilities co-evolve around a shared set of technologies, knowledge and competencies and that work cooperatively or competitively to develop new products and services. In a business ecosystem, the organisations interact among themselves in complex ways, and the health and performance of each depend on the health and performance of the whole (Iansiti and Levien, 2004). The three main characteristics of business ecosystems are symbiosis, platform of development and co-evolution (Li, 2009).

5. Discussion

Based on the content analysis results, understanding the influential factors is evidently a key point for managing FFE of SI because the (current or desired) positioning of the organisation within the ecosystem affects the potential of other FFE activities. For example, a central company is able to stimulate the cooperation of other complementary organisations through various mechanisms of coordination and collaboration, which are not feasible for niche companies or companies with low capital investment. A niche company might not be free to select ideas due to the effects of technological lock-in imposed by key players in the ecosystem, which should, in turn, measure the impact of the idea not only inside but outside its boundaries.

Influence factors can be understood from the mapping and monitoring of the business ecosystems techniques based on social networking theory and strategic foresight. The application of such techniques is also useful for identifying and for evaluating innovation opportunities.

During the idea generation and concept development in SI, new business models, instead of new products or service designs, should be proposed. The innovative firm must choose in which value network it will compete and also define with which strategic positioning it will enter this business ecosystem. This choice can fundamentally change the FFE customers in the organisation: the next steps after FFE should be taken by the senior management, areas of new businesses development or corporate venture capital activities rather than by product development teams or R&D departments. This means that the key output of FFE in SI is a new business model instead of a product concept definition (see Fig. 3).

In the FFE of a SI, experimentation has a role in reducing not only the uncertainties about the future performance of products or of the final consumer acceptance but also the uncertainties related to the reactions of the other players in the ecosystem given the new business model, which intends to benefit everyone involved in value creation. Therefore, experimentation can also be observed as a coordination mechanism, reducing possible barriers to innovation within the ecosystem. The co-creation and open innovation mechanisms can also be valuable for understanding how to capture value not only for the company itself but also for other entities within the ecosystem that contribute to value creation. The FFE literature appears to be complementary to the SI literature, especially regarding the methods used to stimulate creativity and to generate ideas, which is hardly addressed in the SI literature.

Given this analysis, Fig. 3 presents the main references, a cross-referencing network and the main highlights found, in which the starting points are the FFE activities and the cross reference, as

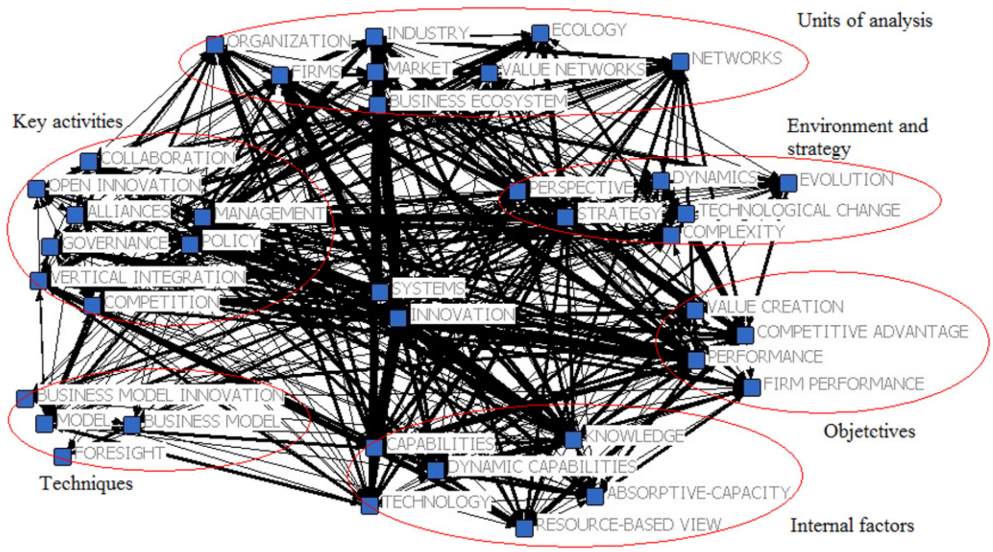

Fig. 2. SI keyword network. Note: Output Software Ucinet and Sitkis.

presented in Table 8, based on the most comprehensive FFE model selected (Koen et al., 2001). The distinctive aspects of FFE for SI highlighted in Fig. 3 were the core of the conceptual framework and will be discussed further in the following sections. These aspects affect three main activities of the conceptual model proposed by Koen et al. (2001): influence factors, engine and concept development. The names of these activities (engine, influence factors, and concept development) were kept from the original FFE recursive model (Koen et al., 2001) in order to provide a clear reference to FFE researchers.

Based on the systematic literature review summarized in Fig. 3, we propose the conceptual framework of the FFE management for SI, presented in Fig. 4. We found evidence in the literature to sustain that the FFE management practices for autonomous innovations are also necessary for SI, but yet insufficient. Coordination and collaboration mechanisms, ecosystems mapping and analysis as well as new business modelling/venturing/strategic positioning are fundamental practices to manage the FFE of SI.

Additionally, as previously noted, according to McCarthy et al. (2006), innovation processes can vary from linear to chaotic depending on the degree of unpredictability. Kim and Wilemon (2002) and Zien and Buckler (1997) emphasise that FFE is different from formal product development due to its low degree of formalisation and a high degree of experimentalism with an uncertain character and Adner (2006) observes that SI is even riskier and more uncertain than autonomous innovation. These characteristics make this stage closer to a nonlinear and recursive model, which was kept in the proposed framework.

To exemplify the non-linearity of the conceptual model, suppose that, during the ecosystems analysis, the team envisions a new opportunity with an actor from a totally different industry sector. This requires a new coordination and collaboration mechanisms to embrace the new actor, and the resulting innovation must include a way for this new player to generate and to share value. At the same time, a coordination mechanism might be proven ineffective with another key actor. This activates the ecosystem mapping and analysis in order to find other potential actors or other positions that the focus firm should explore.

The team may simultaneously conceive a new business model using the Canvas technique from the Business Model Generation (Osterwalder et al., 2010) and make room for new potential partners in the ecosystem, who, in turn, will have to be convinced to participate.

5.1. Ecosystems mapping and analysis

In this research, ecosystem mapping is related to business ecosystem literature and means identifying the player, the roles (such as leading firm, regulators, and contributors) and understanding the interdependencies among them. For instance, in the 1990s, Cisco sustained high growth by mapping and dominated key networking standards by mergers and acquisitions with key players in the ecosystem. It thus redesigned the business ecosystem, articulated by the Partner e-Learning Connection (PEC), which deals with the network engineers, hardware, and software developers that create complementary applications based on Cisco technologies and standards (Li, 2009).

The differences between network analysis and ecosystem mapping are that in ecosystem mapping the roles of each actor are clear (for example, core value proposition, complementary offers, supplying and enabling network), the direction and nature of transactions are explicit (whether it is flow of information, goods and services, money and credits, and from which party to which party). A pictorial illustrative example of ecosystem mapping is shown in Fig. 5.

Table 5
Approaches and research methods in the SI sample.

SI	#	%
Qualitative	44	70%
Case study	22	35%
Conceptual theoretical	10	16%
Literature review	7	11%
Longitudinal case study	5	8%
Quantitative	19	30%
Longitudinal study with statistical sampling	7	11%
Mathematical modelling	5	8%
Survey	4	6%
Social networks modelling	3	5%
Total	63	100%

Table 6
Units of analysis in the SI sample.

SI Sample	#	%
Business ecosystem/value network	31	49%
Company	14	22%
Ecology	9	15%
Industry	5	8%
Intermediary organisation	3	5%
Dyad	1	2%
Total	63	100%

Table 7
Conceptual models of FFE activities of the sample or mentioned in the sample.

Author	Description
Cooper (1988)	(1) Idea generation; (2) definition of product; (3) evaluation of product
Smith and Reinertsen (1992)	(1) Screening of ideas; (2) business plan; (3) detailed plan of project and product specification
Khurana and Rosenthal (1997)	Pre-phase 0: preliminary identification of opportunities, market and technological analysis; Phase 0: definition of the concept of product; Phase 1: definition of product and project planning. Foundation elements: Product strategy and portfolio; Organisational structure of project, roles, incentives and norms (governance)
Montoya-Weiss and O'driscoll (2000)	(1) Qualification of idea; (2) concept development; (3) concept assignment; (4) evaluation of concept
Koen et al. Koen et al. (2001)	Non-linear model. Considers influencing factors (external environment), engine (strategy, leadership and culture) and 5 activities: opportunity identification, opportunity analysis, idea generation, idea selection and concept definition
Langerak et al. (2004)	Pre-development activities in 4 stages: (1) strategic planning, (2) idea generation, (3) evaluation of ideas and (4) business analysis
Griffiths-Hemans and Grover (2006)	(1) Idea creation; (2) idea implementation; (3) commitment to the idea
Williams et al. (2007)	(1) Product strategy oriented to market; (2) Market and product opportunity research production; (3) business approval; (4) technical approval; (5) approval and product specification for a detailed project

Many studies on SI demonstrate the effects of interdependence among the actors of the business ecosystem in the innovation. Adner and Kapoor (2010)) show that greater technical challenges of innovation in supplier components increase the participation in the market of the focal company as it increases its domain over essential specialised assets, whereas greater challenges in complementary components reduce this advantage. Afuah (2000) demonstrates that the company's performance after a technology change decreases due to a more important obsolesce in the co-opetitors capacities. Cenamor et al. (2013) indicate that the availability and number of users of complementary products influence the adoption of the platform.

Pierce (2009) shows how changes in the central companies in an ecosystem may be devastating for niche companies that do not possess dynamic capabilities. Hernández-Espallardo et al. (2011)show that learning to collaborate with distributors promotes continuous learning, which positively influences innovation and indirectly improves the general performance of the company. Each research covers a single industry, for instance: lithography (Adner and Kapoor, 2010), computers (Afuah, 2000), video games (Cooper, 2000), automobile (Li, 2009) and food and drinks (Osterwalder et al., 2010). It is possible to infer that the relevance of interdependence in the business ecosystem has a broader reach.

Table 9
SI definitions.

References	SI definition
Chesbrough and Teece (2002)	Innovation that only generates value when accompanied by complementary innovations.
Teece (1986), Kano (2000) and Maula et al. (2005)	Innovation that requires significant readjustments in other sub-systems (that are part of the business system in which the innovation is inserted).
Teece (1986) and Mlecnik (2013)	Innovation in which coordination and cooperation are needed in its development process.

Interdependency implies a need for ecosystem mapping and monitoring. Budde et al. (2012) shows how changes in the actors' strategies can be explained by changes in the expectations that are relatively volatile. Battistella et al. (2013) also highlights the ecosystem mutability, which requires a dynamic monitoring of events, weak signals, structures and flows, and proposes a methodology of business ecosystems network analysis (MOBENA). Binz et al. (2013)demonstrate that the ecosystem boundaries vary greatly over relatively short periods, suggesting that caution must be taken when defining the business ecosystem to be monitored. Dedehayir and Mäkinen (2011) created a model to measure the rate of development of a SI based on the rate of development of the subsystems that compose it. Other approaches for understanding the ecosystem by network analysis are proposed by Peppard and Rylander (2006), Snijders et al. (2010), and Hermans et al. (2013).

Casadesus-Masanell and Yoffie (2007)propose a mathematical modelling of profit optimisation to predict the complementary behaviours of companies and to orient the decision-making of investments and innovation pricing. Peppard and Rylander (2006) proposes a study of Bayesian networks to investigate the probability of events sequences in the value network. Cagnin et al. (2013) advocates the application of technological prospection methods grouped under the umbrella of the *future-oriented technology analysis* (FTA) term to anticipate systemic transformations.

5.2. Collaboration and coordination mechanisms

In the original text by Koen et al. (2001), this element addresses leadership, culture and roles only in the relationship between entities internal to the organisation. However, to start a new SI, the mechanisms of coordination, knowledge sharing and new role types that expand beyond the boundaries of the organisation are required. Strategic positioning becomes crucial, especially in terms of defining boundaries and external relationships.

Conflicting views exist regarding the definition of the ideal frontiers for a SI. Some authors argue that vertical integration is the best strategy (Chesbrough and Teece, 2002; Kapoor and Lee, 2013), as it allows better control over complementary assets. Nonetheless, Li and Tang (2010)

Table 8
FFE models summary.

	Cooper (1988)	Smith and Reinertsen (1992)	Kim and Wilemon, 2002	Khurana and Rosenthal (1997)	Montoya-Weiss and O'driscoll (2000)	Langerak et al. (2004)	Magnusson (2009)	Griffiths-Hemans and Grover (2006)	Williams et al. (2007)	Koen et al. (2001)	Total	%
OI_Opportunity identification				1			1		1	1	4	11%
OA_Opportunity analysis	1		1	1					1	1	5	14%
IGE_Idea generation and enrichment	1	1	1		1	1	1	1		1	8	22%
IS_Idea selection		1			1	1	1	1		1	6	17%
CD_Concept definition	1	1	1	1	1	1	1		1	1	9	25%
IF_Influence factors										1	1	3%
E_Engine				1		1				1	3	8%
Total	3	3	3	4	3	4	4	2	3	7	36	100%
%	8%	8%	8%	11%	8%	11%	11%	6%	8%	19%	100%	

Table 10
Innovation typologies compared with systemic innovation in the sample.

References	Typology of innovation	Description	Relation with SI
Henderson and Clark (1990) and Bonaccorsi et al. (1996)	Architectural innovation	Changes in the way components interrelate without changing the components themselves.	It is a subtype of systemic innovation.
Christensen (1997), Christensen et al. (2001), Klenner et al. (2013), and Christensen and Rosenbloom (1995)	Disruptive innovation	Cheaper, simpler, smaller or more convenient products than established operators. They invade the existing market over time and, with technological development, eventually dominate it.	Disruptive innovations imply the development of new value networks (business ecosystems), and it is also a specific subtype of SI.
European Commission apud Boons et al. (2013)	Eco-innovation	Production, assimilation or exploitation of novelties in products, processes, services or management and business methods that, throughout its life cycle, prevent or substantially reduce the environmental risk, pollution and other negative impacts of the use of resources, including energy.	According to the author, sustainable development requires SI.
Charter et al. apud Boons and Lüdeke-Freund (2013)	Sustainable innovation	Process in which the sustainability (environmental, social and financial) is integrated into the innovation systems of the company due to the generation of ideas until commercialisation. It applies to products, services, technologies, organisation and business models.	According to the author, sustainable development requires SI.
Cooper (2000) andMlecnik (2013)	Radical innovation	Variation that can only be measured by adding new dimensions to the product evaluation, redefining the market perception.	The authors indicate that radical innovations are generally systemic.

empirically demonstrates that the relationship between the degree of vertical integration and performance has an inverted U shape because, when in excess, it can create barriers to knowledge acquisition. Kapoor and Lee (2013)) demonstrate that alliances increase the probability of new technologies adoption somewhat superior to vertical integration. Debresson et al. (1991), Freeman (1991), and Herskovits et al. (2013) argue that innovation in networks is important for sharing risks and for value creation. Adner and Kapoor (2010)demonstrate that the positive relationship between the company's performance and vertical integration increases throughout the life cycle of technology as the level of uncertainty decreases. The diversity of network actors also contributes to its resilience (Boons et al., 2011).

Assuming the impossibility of vertical integration, the need for other mechanisms of coordination arises. Bonaccorsi et al. (1996)) recommend aggressive marketing projects to ensure the adoption by a critical mass; also recommended are the investment in research and

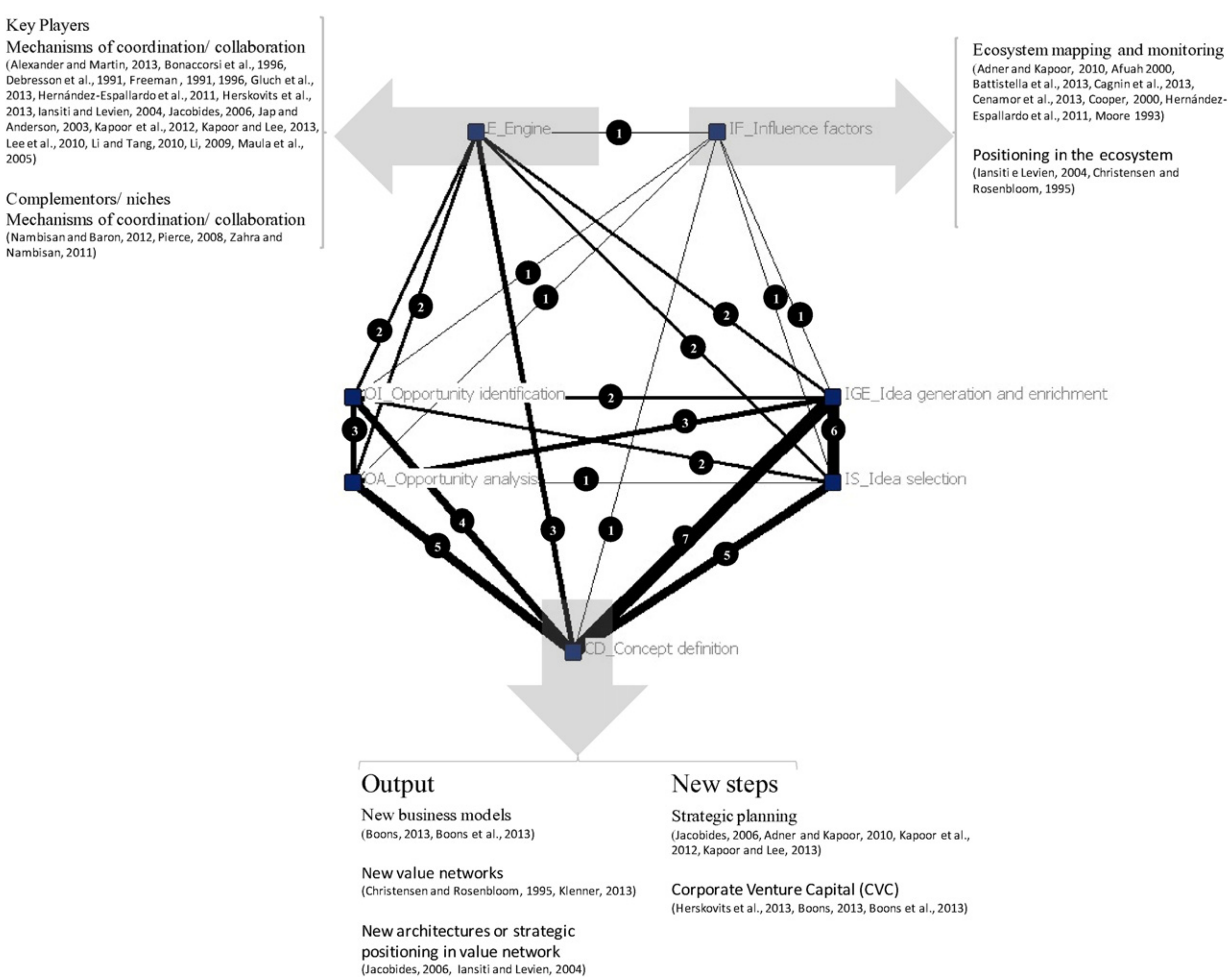

Fig. 3. References supporting the conceptual framework for the fuzzy front end of systemic innovation. Legend (n) Co-citation count [$Stage_i$, $Stage_j$] (see Table 8).

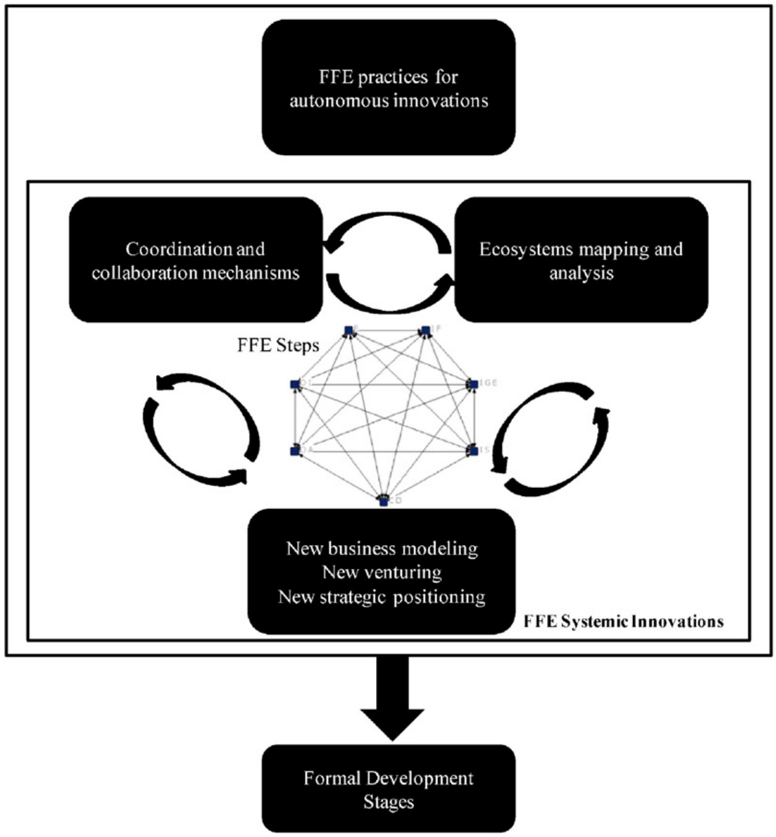

Fig. 4. Conceptual Framework for the fuzzy front end of systemic innovation.

development in all ranges of technologies involved in innovation, from basic science to industrial production, as powerful levers for control, and establishing a dominant design. Establishing standards in the ecosystem is also a coordination strategy indicated by Maula et al. (2005), Jacobides et al. (2006), Hobday et al. (2000), and Kano, 2000). These standards can be influenced by financial incentives, investments, sharing proprietary resources and information and participation in the standardisation processes of industry associations or normative organisations (Maula et al., 2005).

These mechanisms are valid, especially for key players – central organisations in the business ecosystem (Maula et al., 2005) – with high investment potential, including public authorities. For niche and entrant companies that opt to co-evolve within a business ecosystem, self-regulation (Nambisan and Baron, 2012), high absorptive capacity (Zahra and Nambisan, 2011) and dynamic capabilities (Pierce, 2009) are suggested.

The coordination of these actors faces various challenges resulting from a misalignment of objectives, investment schedules, prices,

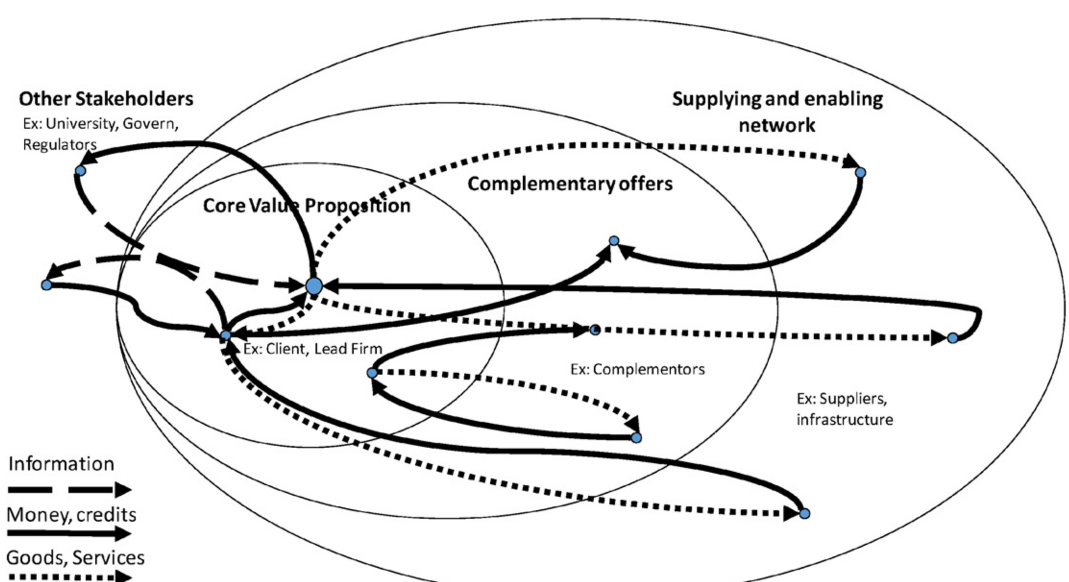

Fig. 5. Business ecosystem pictorial example.

strategies, and power, as well as an incompatibility of assets and opportunism (Debresson et al., 1991). Jap and Anderson (2003)demonstrate that in opportunistic situations, the congruence of objectives becomes a larger protection than interpersonal trust. However, bilateral investments (with shared risks for both parts) are relevant in all situations, independently of the presence of opportunistic behaviour.

The difficulty in coordination among actors originates intermediary organisations of the third or public sector that contribute to ensuring understanding among the stakeholders with conflicting interests (Hamann and April, 2013), promoting social learning (Van Mierlo et al., 2010), representing user demands (Boon et al., 2011), performing pilot projects (Gluch et al., 2013) or anticipating future changes (Cagnin et al., 2013).

In addition to coordination mechanisms, the literature highlights mechanisms of collaboration mainly for knowledge exchanges or transfers. According to Alexander and Martin (2013)), these mechanisms can be transactional (i.e., established in purchase and sale contracts) or relational (Table 11).

Regarding strategic positioning, Iansiti and Levien (2004)suggest that three types of position exist in a business ecosystem: (1) the dominant, which seeks to take all the value of itself, eliminating or incorporating other companies; (2) the key actor (*keystone*), which reduces entry barriers so that other actors can create value, strengthening the entire ecosystem; and (3) niche companies, which effectively create value. Jacobides et al. (2006) advocates that companies should seek an “architectural” advantage (similar to “keystone”), positioning themselves as holders of bottleneck resources, guarantors of quality or creators of conditions for other actors to capture value in the ecosystem.

5.3. From Concept development to new business modelling

In SI, the FFE end result is not only a new product concept but also a new business model (Adner and Kapoor, 2010; Boons et al., 2013), determining how the value created by a complex network of actors will be captured and distributed.

The specification of a new general business model, according to Boons et al. (2013), should consist of the following: (1) value proposition, describing the value embedded in the product or in the service offered by the company; (2) supply chain, describing how relationships with suppliers will be established and managed; (3) customer interface, describing how relationships with distributors or end customers will be established and managed; and (4) financial model, describing the costs and benefits of items 1, 2 and 3 and their distribution among the business model stakeholders. By expanding the model in the light of the findings of the present study, the forms of relationships with companies that have complementary products and services should also be determined.

Considering sustainable business models, in particular, the requirements for defining the concept are the following: value proposition with ecological and/or social benefits along with the economic benefits, responsible for supply chain and customer interface. This stimulates responsible consumption and a financial model with an appropriate distribution of costs and benefits.

Table 11
Mechanisms of collaboration for knowledge transfer.

Classification	Mechanisms
Transitional	Contracted research or development of product, consultancy, sharing of physical spacing, patents, licensing, purchase or sale of products and services, spin outs, joint ventures.
Relational	Joint or collaborative research, publication of articles in journals, training, joint supervision, joint conferences, transfer of people, networking, informal discussions, transfer of documents, collective development of roadmaps and scenarios.

In the specific case of SI, the definition of concepts appears to overlap the definition of strategic positioning itself, and competitive advantage stems not only from the products and services with superior performance but also from their strategic position in the ecosystem architecture (Jacobides et al., 2006). Another important issue for defining the SI concept is selecting the value network in which competition occurs (Klenner et al., 2013; Christensen and Rosenbloom, 1995). The phase that follows FFE in a SI is thus most likely not the development of new products but rather the review of the company's strategic plan, the development of new business units or corporate venture capital activities (Herskovits et al., 2013).

6. Conclusions

This study aimed to narrow the gap in the literature at the intersection between fuzzy front end and systemic innovations literature. The articles surveyed were systematically analysed using a multi-method approach (bibliometric, network analysis and content analysis). The key journals and the top cited articles are presented and analyzed in-depth. The analysis of the literature reveals that systemic innovations are addressed in a limited manner in specialized articles on FFE.

The keyword networks show different patterns concerning the FFE and the SI samples. The main differences are related to the units of analysis cluster, in which business ecology just emerges in the SI network. Moreover, in the internal factor cluster, dynamic capacity only appears in the SI sample and is neglected in the FFE sample. Finally, in the key activity cluster, the coordination of the business ecosystem is critical only to the SI network.

The present study proposes a conceptual framework for FFE of SI. The starting point was the content analysis of FFE traditional conceptual models, identifying the stages and their relation. Next, the key distinctive aspects of the SI sample were investigated and inserted into the FFE of the SI framework (see Fig. 3).

Despite the growing research into FFE and SI, this field was observed to still be in its exploratory phase with regard to the formal definition of constructs and the validation of theories, paving the way for future research, namely (1) empirical verification of specific features that define the systemic innovation typology, since the conceptual definition of the term still needs to be further refined to allow differentiation from other types of innovation, (2) empirical validation of the relationships presented in the proposed conceptual model, (3) contingency analysis for selecting coordination mechanisms as well as transactional and relational types of collaborations for the FFE of SI and (4) for investigating the creativity and idea generation techniques from the FFE literature that can be adapted to generate SI.

As implications for the industry based on results, we highlight the importance of recognising the innovation project as systemic, mapping the ecosystem (understanding the players and relationships among them) even in the initial phases of the systemic innovation, and to involve the company leadership, since the FFE will most likely result in the concept of a new strategic positioning or innovative business models, other than a single new product for development as usual in R&D/marketing departments. Intentionally building collaboration and coordination techniques even when innovation is not yet fully conceptualized seems to play an important role to successfully implement SI.

This research has some limitations related to the use of search engines and to the content availability of the ISI Web of Science. The extent to which this limitation compromises the results is reduced due to the high reputation of these databases in the scientific community. The content analysis was performed by a single researcher without triangulation with other sources of information in addition to the literature, which can generate an interpretation bias. In an attempt to minimise this bias, a review based on concepts rather than on authors was performed (Webster and Watson, 2002).

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