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Innovation, generative relationships and scaffolding structures. Implications of a complexity perspective to innovation for public and private interventions

Abstract

The linear model of innovation has been superseded by a variety of theoretical models that view the innovation process as systemic, complex, multi-level, multi-temporal, involving a plurality of heterogeneous economic agents. Accordingly, the emphasis of the policy discourse has changed over time. The focus has shifted from the direct public funding of basic research as an engine of innovation, to the creation of markets for knowledge goods, to, eventually, the acknowledgement that knowledge transfer very often requires direct interactions among innovating actors. In most cases, policy interventions attempt to facilitate the match between “demand” and “supply” of the knowledge needed to innovate. A complexity perspective calls for a different framing, one focused on the fostering of processes characterized by multiple agency levels, multiple temporal scales, ontological uncertainty and emergent outcomes. This contribution explores what it means to design interventions in support of innovation processes inspired by a complex systems perspective. It does so by analyzing two examples of coordinated interventions: a public policy funding innovating networks (with SMEs, research centers and university), and a private initiative, promoted by a network of medium-sized mechanical engineering firms, that supports innovation by means of technology brokerage. Relying on two unique datasets recording the

interactions of the organizations involved in these interventions, social network analysis and qualitative research are combined in order to investigate network dynamics and the roles of specific actors in fostering innovation processes. Then, some general implications for the design of coordinated interventions supporting innovation in a complexity perspective are drawn.

Keywords

Innovation policy, complex systems, innovation networks, technology brokering, social network analysis

Introduction

An increased emphasis on the role of innovation as a primary driver of economic growth in contemporary knowledge-based economies has put the politics of innovation processes on the front burner. But just what exactly one thinks should be done depends crucially on the theory of innovation that is adopted. In this contribution, we explore how a view of innovation inspired by complexity theory can help us to understand whether we need coordinated interventions to support innovation and, if so, to understand how these can be designed.

Complexity theory is a developing area of research characterized by a wide – and increasing – range of interdisciplinary applications. As a result, the meaning and implications of this approach even within the relatively narrow field of innovation studies are still being negotiated, and different, sometimes conflicting, positions coexist. Therefore, in the next section, we describe what we mean by a complexity perspective to innovation, contrasting our approach and its policy implications both with the traditional “linear” model of innovation and with more recent and broader “systemic” approaches. Then, having broadly outlined the theoretical framework on which the analysis is based, we explore its implications for coordinated interventions in support of innovation, with reference to two case studies. Finally, we draw some concluding remarks for policy design.

A complexity perspective to innovation

Economic and organizational theories have progressively moved beyond the traditional linear view¹ of innovation - which conceptualizes innovation as a sequence of well defined, temporally and conceptually distinct, stages - in favour of systemic approaches that interpret innovation as a complex process. In this latter approach, the analyst must pay attention to a multiplicity of actors, to the relationships between those actors, and to the social and economic context in which they are embedded. The influential literature on national systems of innovation, which emerged at the beginning of the 1990s (Freeman, 1988; Lundvall, 1992; Nelson, 1993), has highlighted the interplay of a wide range of factors, organizations and policies influencing the capabilities of a nation’s firms to innovate. At the same time, the focus on the cognitive aspects of innovation has fostered interest in interactions

¹ For an overview of the historical development of the linear model, see Godin, 2006.

among agents as sources of new knowledge. Direct interactions among people are considered the main modes of transmission and creation of tacit knowledge (Hagerstrand, 1970; Polanyi, 1969), which is thought to be a key source of innovation. Researchers have begun to study various forms of cooperation between firms directed at developing innovations, including user-producer interactions (Von Hippel, 1978; Lundvall, 1985; Rosenberg, 1963; Russo, 1985). The role of proximity – cognitive, technological, social or geographic – in fostering innovation processes has also been explored theoretically and empirically (Audretsch and Feldman, 1996; Jaffe, 1986; Nooteboom, 1999; Lundvall, 1992).

Paralleling the evolution of the academic discourse, policymakers' theoretical understanding of innovation processes has also evolved, particularly in Europe (Mytelka and Smith, 2002). In line with a systemic approach to innovation, it has been acknowledged that innovation policies must be implemented through interventions that involve not only the activities of basic scientific research, development and commercialization of research outcomes, but also the productive activities of firms and the social and institutional contexts in which they operate. Interest in social interactions as a locus for innovation has led policymakers to assign particular importance to supporting the activities of “clusters”, intended as aggregations of organizations, as well as networks of cooperation among heterogeneous actors (Audretsch, 2002).

However, despite the widespread attention dedicated to these issues, designing interventions that are consistent with a systemic approach to innovation often proves a challenge (Russo and Rossi, 2009). Indeed, the European Commission (2003) has explicitly admitted that many interventions claimed to be consistent with a “systemic” approach to innovation in fact owe much to the linear model. We argue that the solution lies in a conceptualization of innovation as a complex process. This entails, however, recognizing also that it is not possible to devise context-independent ways to support it. Two of us have argued elsewhere (Russo and Rossi, 2008) that innovation theories should not be used to derive general “policy recipes” but rather they should support policymakers in formulating and addressing questions that are appropriate to their particular socioeconomic and institutional contexts. Taking this step, however, requires an improved theoretical and empirical understanding of innovation processes, of the economic actors that drive them and of the channels

through which communication processes take place and lead to the development and consolidation of innovations.

To help fill the gap between theoretical understanding and policy implementation, we elucidate the policy implications of a “complexity theory” understanding of innovation processes, drawing in particular on the “dynamic interactionist” perspective outlined by Lane and Maxfield (1997, 2005; Lane, this volume).

According to this perspective, processes of innovation are guided by (formal or informal) “scaffolding structures” that shape the rules guiding the operation of the market systems in which such innovations will be embedded, and that create the “competence networks” that sustain and reproduce necessary systemic functionalities. Scaffolding structures include organizations such as trade or professional associations, but also regular events such as exhibitions and trade fairs, as well as various kinds of publicly funded interventions. Such structures are essential if agents are to effectively manage uncertainty by jointly shaping the direction in which market systems develop (for example, by agreeing on technological standards) and often provide interaction spaces where agents can develop “generative relationships” that give rise to further innovations. Relationships have high potential to generate innovations when the agents share a common focus on the same artifact or process (aligned directedness) but differ in terms of expertise, attributions or access to particular agents or artifacts (heterogeneity). They also have high potential when they have the chance to work together on a common activity (opportunities for joint action), as well as when agents are able to carry out discursive interactions outside conventional exchanges confined to requests, orders, declarations, and such (right permissions). Agents must also seek to develop recurrent pattern of interactions from which a relationship can emerge (mutual directedness).

In the next section, we show what it means, in practice, to construct scaffolding structures as a means to support diffuse innovation processes. We present two cases, using microdata on inter-organizational interactions studied through network analysis. Although not by itself explanatory, network analysis can help highlight certain features of inter-organizational interactions whose meaning and purpose can then be interpreted through the prism of our theory of innovation. The analysis has then been complemented by qualitative interviews.

Empirical analysis

The case studies discussed here concern two very different coordinated interventions in support of innovation, both of which have been implemented in Italian regions whose economic structure is characterized by the presence of clusters of firms organized in industrial districts. These are presented to illustrate what it means to devise interventions that take into account the complex nature of innovation processes.

3.1. A public policy intervention supporting heterogeneous innovation networks

The “Innovazione Tecnologica in Toscana” programme, funded within the ERDF Innovative Actions framework (henceforth, RPIA-ITT), was implemented by Tuscany’s regional administration in the period 2001-2004; the programme was conceived as a pilot test for the use of further structural funds in the region.

RPIA-ITT intended to promote development in the regional economy through the creation of networks of organizations tasked with carrying out innovative projects. Project proposals were solicited within four action lines. The programme required heterogeneous networks (the call for tender requested each cooperation network to comprise at least four firms, one university or public research centre, and one public, private or mixed company having among its statutory aims the provision of services to firms) and encouraged participation by SMEs, which in fact constituted a large share of the actors taking part in the programme. Table 1 summarizes the main data on the programme.

[insert Table 1 about here]

For our present purposes, the relevant question is whether this intervention in fact fostered the creation of innovation networks that produced good quality project proposals and exploited them in ways that could give rise to further “cascades of innovation”. A few organizations played key roles in the policy programme. We set out to investigate these roles by studying the relationships between organizations involved in different projects. To do so, we constructed the two-mode network describing the participation of the 409 organizations involved in the programme to the 36 (funded and non-funded) project proposals. From this large network we extracted the one-mode network of relationships between the 36 projects (participation of the same organization to more than one project indicated a connection between these

projects) as well as the one-mode network of relationships between the 409 organizations (participation of the same two organizations to the same proposal indicated a connection between these organizations).

Here we present a brief summary of our findings². Apart from two isolated projects whose participants were not present in other networks (and which failed to secure funding), most projects were connected through one or more organizations in common. We focused in particular on the 58 organizations that were present in more than one project: these featured 177 times as project partners, out of a total of 528 participations (33.5%).

We first noticed that many of them had already collaborated, before and outside the RPIA-ITT programme, on other projects funded by the European Commission, by the regional administration, and by national government agencies. Furthermore, many had also been involved in a set of talks set up by the regional administration before the launch of the RPIA-ITT programme. This suggests that the projects were activated by relatively few organizations that were already accustomed to working with each other and with the regional administration.

The network analysis performed on the network of 36 projects showed that there are several separate “k-cores”³, indicating groups of projects that have relatively high dense connections with each other and sparse connections with projects outside the core.

Two of these k-cores were composed of projects mainly submitted to action lines 1 and 2; the funded projects in this group were assigned 45% of the programme’s total budget. The organizations connecting these projects, both located in Pisa, are the most central in the main one-mode network⁴ described above: Scuola Superiore S.Anna (an influential postgraduate research institution) and CPR (a research consortium whose partners include several local administrations and the main provincial academic institutions, including S.Anna itself).

² A more detailed analysis is presented in Russo and Rossi (2009).

³ For the notion of “k-core” (groups of connected vertices which have at least k links with each other) see Moody and White (2003).

⁴ Different measures of centrality (degree, betweenness and closeness centrality indexes: see Degenne and Forsé, 1999, for definitions) relative to the same network led to similar results.

The third k-core was composed of 7 projects that were promoted by a network of research centres specialized in optoelectronics, a field characterized by technological convergence in a vast range of applications. The interviews confirmed the presence, in the region, of an established network of prestigious public research institutions in this field (CEO, INOA, CNR-IFAC) and of a company, El.En, worldwide leader in laser technology. This is complemented by a tight fabric of SMEs involved in the production of high-technology optic instruments and of related software applications. In order to set up a large number of projects, these organizations were able to rely on their previous experience of successfully bidding for public funds, since optoelectronics had already been a focus of regional policy during the 1990s.

Therefore, the network analysis highlighted the important role played by some research centres and large firms (already accustomed to collaborating with each other and with the regional administration, and to monitoring funding opportunities) in the coordination of most project proposals.

The analysis of individual projects' networks and the qualitative interviews showed that the requirement of heterogeneous competences within each project enabled many organizations to interact with partners with whom they might not have worked otherwise. However, the recruitment of certain organizations, specifically small companies and university departments, proved difficult since both, for different reasons, were unaccustomed to collaborative innovation and were often ill-equipped to deal with the complicated administration of EU-funded programmes. In these cases, their involvement had to be mediated by a set of service providers. Despite having different structural characteristics, different behaviours and different objectives, these service providers engaged in activities (training, certification, research and technology transfer) that allowed them to weave close relationships with both manufacturing firms and other local actors (trade associations, local administrations, universities). These organizations can be defined as "multivocal": they understand several "languages" – from academic research to the specific production technology – and they can interpret the needs of actors that might not even be able to express them. As such, they were essential in order to recruit actors with specific competences, and in many instances, they were also able to develop good quality project proposals and to effectively disseminate the projects' results.

3.2. A private technology broker sponsored by a group of large firms

Our second case study involves an organization – called Centro di Ricerca and Innovazione Tecnologica (CRIT) – that acts as a “technology broker” primarily but not exclusively for many leader firms in the Modenese and Emilian mechanical engineering industry. A cross between an association and a firm, CRIT was an indirect consequence of a 1999 law that offered funding and incentives for universities to connect with other research centers in the region of Emilia Romagna. One proposal involved linking a network of university research centers to a “Science technology park” (Sardo, 2009) that would be placed in Spilamberto, a town in an area densely packed with mechanical firms on the border between the provinces of Modena and Bologna. The project had the support of local governments (who saw a chance to rehabilitate a large swath of industrial land long in disuse), of the university, and of some of the larger mechanical firms in the region, fourteen of which established CRIT in 2000. They each committed to paying what was for such leader firms a relatively limited amount – 25,000 euros annually – to sustain the organization. The idea was that CRIT would have a small technical and administrative staff that could draw upon the expertise of its member-owners to analyze the demand for innovation in the region. Using that knowledge, it would then broker the demands for technology of the mechanical industry - especially of member firms - and sources of supply. The latter would mostly be located in the proposed technology park, which would host regional research centers and universities.

However, while efforts to establish the technology park have foundered amid political infighting, CRIT has not only survived, it has added eleven new members to its original fourteen founders. We argue that it has done so because it has been able to remake itself as an organization that aims more generally to stimulate “collaborative innovation,” working primarily but not exclusively with member firms that are not direct competitors, but that often share some overlapping technologies and perhaps suppliers.

The most innovative feature of CRIT is the combination of activities in which it engages. CRIT combines services to firms of two basic sorts that we conceptualize as either “switches” or “spaces”. Switching is classic brokerage, in which CRIT is approached with a demand for a service or for information, uses data in internal databases or conducts an external search, and either provides the service using internal engineers or connects the client to an organization that can provide the

desired service. Switching includes R&D projects, technology “scouting”, analyses of competitors’ patenting patterns. CRIT serves instead as a space of potential interactions when it creates opportunities for open dialogue. CRIT does this by hosting events such as “thematic working tables”, seminars, technology tours, group training events, and meetings of technical directors. These events are sometimes proposed by CRIT, but are often born of initiatives proposed by member firms. The key is that they take place in a setting in which participants can openly share ideas, but are structured enough that the conversation will be limited to particular topics of “technological” relevance.

In the period 2000-2008, there were 187 “space” events, against 295 “switches”. 169 organizations participated in just spaces events, 94 in just switches, while 60 took part in both sorts.

In order to understand the nature and dynamics of the interaction space enabled by CRIT – without which such interactions would have not occurred - we analyzed the pattern of co-participation of different organizations to the events. We created a two-mode network involving all CRIT events and all participants in the period 2000-2008. From this we extracted several sub-networks on the basis of temporal intervals (different years) and/or of types of events (switch or space, or particular types of switch or space events). These sub-networks have also been transformed in one-mode networks. Here we present a brief summary of our findings⁵.

First, we observe that the network generated by serviced offered by CRIT grew around a nucleus of more active and “central” actors. Mechanical firms have the highest centrality⁶ in space events; among these, member firms are even more central. The most central group is a nucleus of seven that are especially active: GD, IMA, Tetrakpak, Gruppo Fabbri, Selcom, System, and CMS. These are slightly more central than another also quite central group that includes Sacmi, Italtractor, Rossi Motoriduttori, CNH, and Datalogic. These are also, notably, the same firms that generally have a high centrality in switch events. But for switch events, we see high centrality also for nonmembers, including especially research centers and universities:

⁵ A more detailed analysis is presented in Russo and Whitford (2009).

⁶ Most analyses were performed using betweenness centrality indexes, but consistent results were found when degree centrality was used instead.

the fact that they have very particular competencies explains their occasional involvement in a seminar, or in a particular technical meeting.

Second, the analysis of “islands”⁷ within each one-mode network of participants over time shows that, even among central actors, there is a nucleus that is even more central and that tends to interact a great deal (and that has become even more stable since 2005, the year that CRIT became fully independent of the technology park). It is a nucleus whose activities are highly varied (by type of event, and therefore by the potentiality of interactions with other participants).

Third, there have been changes in the services asked over time. Initially, many firms asked for R&D projects and for technological “scouting”. Over time, the importance of “space” events has increased considerably, as if member firms “learned” how to best use CRIT over time. CRIT too learned from experience, by introducing new services some of which, if not important quantitatively, show that CRIT experiments in response to needs signalled by firms.

Conclusion: supporting collaborative innovation in a complexity perspective

Both case studies concern coordinated interventions that have been successful in promoting innovation in their specific contexts. As such, their interpretation in light of some concepts of complexity theory can help us derive some indications for policy design.

First of all, both interventions were inspired by fairly conventional views of innovation, but they ended up unfolding along unconventional lines.

In the case of RPIA-ITT, the setup of heterogeneous innovation networks was underpinned by a fairly rigid view of what would be an appropriate “division of innovation labour” within the networks: according to the policymakers, the projects should have consisted in exercises of technology transfer from universities and research centres – which would have developed relevant innovations – to firms that would implement them in particular applications; small firms would generally act as mere testers of innovations developed elsewhere.

But, the small firms’ involvement went beyond the testing of new technological applications. Thanks to the mediation of service providers, the program became a

⁷ The computation of the “line islands” was done with Pajek (min=3, max=32).

learning experience and firms became more likely to participate to collaborative innovation in the future. In addition, the university departments acquired a better knowledge of SMEs competences and needs. The projects (even the planning of those that were not funded), provided a temporary space which allowed unusual interactions. The requirement of heterogeneity, which in the eyes of the policymakers should have simply allowed knowledge transmission from universities and research centres to firms, in fact served also to provide opportunities for further innovation.

In the case of CRIT, the main function of the technology broker according to its founders should have been to favour the match between their “demand” for technology and information and the “supply” of that knowledge available elsewhere. However, CRIT and its founders learned over time that the classic brokering function was not the most interesting way to use the organization. Rather, CRIT could allow members the right “permissions” and opportunities to talk to other organizations, creating a kind of “public space” which according to Lester and Piore (2004) favours innovation since it provides “a venue in which new ideas and insights can emerge, without the risk that private appropriation will undermine or truncate the discussion”.

Therefore, both interventions were conceived as conventional technology transfer exercises, but much of their value added came from the creation of spaces for open-ended discussion, where the “interpretative ambiguity” (Fonseca, 2002; Lane and Maxfield, 1997) necessary for innovation could emerge.

This leads us to the second point: the importance of structuring interactions. In both cases, the space for interactions was designed (sometimes involuntarily) to provide the conditions that enhance generative potential. In the RPIA-ITT, the involvement of service providers allowed the recruitment of small firms and university departments that were relatively unaccustomed to dealing with each other, thus helping to achieve some degree of heterogeneity. In CRIT, heterogeneity is monitored by the members, which are careful to involve organizations that are not direct competitors. In both cases, opportunities for joint action and the right permissions for interaction were also present.

Within heterogeneous networks, an important role is played by mediating organizations capable of engaging in multivocality, as opposed to traditional brokering activities. Such mediators do not merely transmit information between

agents that do not know each other, bridging a “structural hole” in the network (Burt, 1992); they also facilitate direct exchanges among these agents. Service providers and the staff of CRIT are the agents able to perform this role in each case.

Third, both the RPIA-ITT programme and CRIT can be seen as scaffolding structures providing continuity in support of innovation processes that unfold in many cases over long temporal scales. Interventions supporting collaborative innovation generally need to last over a long period of time - the development of new technologies and the understanding of how to exploit them commercially are lengthy processes, after all. Especially in the case of radically new technologies that open up new market systems, scaffolding structures are important in order to foster the creation of the competences necessary to ensure that the technologies can be maintained and diffused. In the case of RPIA-ITT the short duration of the programme was perceived as a limiting factor, but not a critical impediment to innovation, since the main actors involved in the programme were able to exploit a wide range of policy instruments and managed to effectively use the regional policy infrastructure as a scaffold for their innovation activities. In the case of CRIT, it took its members several years to learn how to use the organization productively. This was made possible because firms had made a continuous commitment to participate in at least some sponsored activities.

Fourth, the comparison between these two cases highlights that there is no “one size fits all” approach to sustaining innovation through collaborative processes. The two interventions considered were inspired by a fairly conventional view of innovation, but they worked because their implementation was tailored to the actual features of the local innovation systems. For example, the RPIA-ITT explicitly involved service providers, which are key actors in Tuscany’s regional innovation system. The creation of CRIT probably would not have occurred without a critical mass of large local firms that are active in the same sector but are not in direct competition with each other. Despite these differences, one can still generalize to a conclusion: any successful coordinated intervention in support of innovation requires an effort to identify, ex ante, the key actors that are best able to construct networks of relationships that can support innovation processes by creating conditions that enhance the generative potential of key relationships.

Finally, improving the tools available for the analysis of collaboration networks can enhance our ability to monitor and support innovation processes. The analysis of

dynamic temporal networks and of multi-level networks involving both organizations and individuals should help in this sense, as should the development of agent-based models to construct scenarios relevant to innovation policies. Better integration of these quantitative techniques with ethnographic research should also enrich our set of tools for policy design and analysis.

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Table 1. A synthetic overview of the RPIA-ITT programme

| | applications | funded projects |
|--|---------------------|------------------------------|
| number of projects | 36 | 14 |
| number of partners | 528 | 264 |
| number of different organizations involved | 409 | 203 |
| number of SMEs featuring as partners | 295 | 129 |
| number of different SMEs involved | 262 | 118 |
| organizations involved in more than one project | 58 | 22 |
| budget (in euro) | 15.504.764* | 6.494.298** |
| * of these, 11.661.951 euro were to be financed by the Region | | |
| ** of these, 4.703.029 euro were financed by the Region | | |
| Action lines | | % available resources |
| 1. Promoting technology transfer and diffusion of innovation in Western Tuscany | | 29% |
| 2. Promoting technology transfer and diffusion of innovation in the fashion industry: textiles, clothing, shoes | | 27% |
| 3. Promoting technological development and industrial applications of optoelectronic technologies | | 21% |
| 4. Promoting technological development and industrial, agricultural, environmental applications of biotechnologies | | 23% |