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Innovation Policy in a Complexity Perspective: Levels and Levers for Policy Intervention

by

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[1] This research was carried out in the context of the European project ISCOM (EU-IST-35505-2001), while the empirical analysis was performed as part of the ancillary activities of the RPIA-2002 Programme of the Tuscany Region. A version of this paper will appear as a chapter of the book "A New Perspective on Innovation and Social Change", edited by D.A. Lane, G. West, S.E. van der Leeuw, and D. Pumain, Dordrecht: Springer Methodos Series (in press). The book collects several articles that describe the results of the ISCOM project (www.iscom.unimore.it). We are especially grateful to David A. Lane for comments on previous versions of this draft.

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Abstract

We investigate to what extent and how the adoption of a complexity-based perspective to innovation (Lane and Maxfield, 1996, 1997, 2005; Lane et al., 2008; Read et al, 2008; Russo, 2000) can support policymakers in their quest to implement effective interventions, able to foster innovation processes and to create structures that sustain them over time. We argue that broad attempts at theorizing innovation processes do not lend themselves to a quick translation into simple 'policy recipes', because conceptualizing innovation as a complex multi-level process implies that it is not possible to devise context-independent ways to support it: improved theoretical understanding of innovation processes should not aim to provide policymakers with simple encompassing solutions, but it should help them formulate and address questions that are appropriate to the particular context within which they operate. In line with this approach, we present our analysis of a specific policy experiment, the 'Technological Innovation in Tuscany' programme (henceforth RPIA-ITT). In this context - drawing upon a dynamic interactionist theory of innovation whose main building blocks are the concepts of generative relationships, competence networks, scaffolding structures and the role of narrative in driving action in situations characterized by ontological uncertainty (Lane, Malerba, Maxfield and Orsenigo, 1996; Lane and Maxfield, 1997, 2005, 2008; Russo, 2000, 2005) – we have been able to identify methodological and analytical tools that can be applied to policy design, implementation, monitoring and evaluation activities. We conclude with some broader implications for innovation policy as well as an agenda for future research.

JEL classification: O25 - Industrial Policy, O31 - Innovation and Invention: Processes and Incentives, O32 - Management of Technological Innovation and R&D, R58 - Regional Development Policy

0. Introduction

In this paper, we discuss the policy implications that can be derived from the adoption of a complexity-based perspective to innovation (Lane and Maxfield, 1996, 1997, 2005; Lane et al., 2008; Read et al, 2008; Russo, 2000): we investigate to what extent and how this theoretical approach can support policymakers in their quest to implement effective interventions, able to foster innovation processes and to create structures that sustain them over time. To address this issue, we first discuss the problematic relationship between innovation theory, on the one hand, and innovation policy – its objectives and its implementation - on the other; in section 1, we focus on the example of current European innovation policy in order to illustrate the problems arising in this context. In section 2, we explore the rationale for innovation policy according to our complexity-based, dynamic interactionist approach, and we briefly introduce its main features. We claim that policy analysis should mainly be concerned with the processes through which policy problems and solutions can be identified, rather than with the direct formulation of general policy recommendations. To substantiate this claim, in section 3, we present a specific example of policy analysis based upon our approach and its associated tools. In section 4, drawing from this exercise, we present some methodological remarks as well as an agenda for future research.

1. Theory and implementation in innovation policy: the European scenario

When designing, implementing and evaluating policies, awareness of the theoretical framework that inspires them is crucial in order to ensure consistency between policy measures and the tools available for their monitoring and evaluation. Policy analysis should not only investigate what are the most effective instruments for policy intervention, it should also clarify their theoretical underpinnings, which may carry very different implications. In addition, it must be remembered that policy measures are implemented within specific institutional and administrative contexts that guide them in practice, not necessarily in the same direction as the stated objectives.

In Europe, institutional decisions concerning innovation policy in the last ten years have been driven by a theoretical framework that has been made public through numerous 'guidance' documents issued by Community institutions, the European Commission and the European Council in particular[2]. Support for innovation was first acknowledged as a public policy goal

[2] This issue was explored in detail in a previous paper (Rossi, 2007) where we attempted to reconstruct the

in the Green Paper on Innovation (1995), followed by the First Action Plan for Innovation in Europe (1996), which included numerous policy suggestions. Since then, and particularly after the Lisbon European Council (2000), innovation has gained increasing importance in the context of European development policies, whose objective is to improve and consolidate the competitiveness of the economic system, and which often pay special attention to small firms (European Commission, 2004; European Council, 2000, 2005). The connections among innovation, competition and development and the role of innovation in the knowledge economy are the keystones of these policies, which are explicitly inspired by a 'market approach' (European Commission, 2000, 2003). This term is used both to emphasize the need for private intervention alongside public incentives, as well as, quite often, to portray a view of innovation in terms of 'demand' and 'supply': in this case, innovation is seen as a sequence of individual actions so that it is possible to identify certain actors that 'demand' and others that 'supply' innovations (basically, the former are firms producing goods and services, while the latter are universities and research institutions).

The theoretical framework shaping European innovation policy has, of course, been influenced by the academic discourse on the topic of innovation. Over the last twenty years economic and sociological theories of innovation have changed markedly, abandoning the traditional linear view of innovation in favour of systemic approaches. The linear view of innovation conceptualizes the innovation process as a sequence of well defined, temporally and conceptually distinct, stages. Although rarely codified in the economic literature, the linear model is widely shared, often implicitly, in the academic discourse[3]. The model postulates that innovation starts with the basic research activities performed by an individual inventor or, more often, by a research group, which lead to an invention - that is, a new idea or a new entity that is not yet ready for commercial exploitation. Subsequently, applied research and development activities, usually performed within industrial research laboratories or university spinoffs, lead to the embedding of the invention into an artifact or process that can be commercially exploited. The resulting innovations are sold in the marketplace, adopted by users, imitated by other companies. Individual adoption choices lead to a process of diffusion of such innovations.

Recent approaches, instead, tend to conceptualize innovation in systemic terms, as a process that involves, in each moment, many actors – sometimes impossible to identify in advance –

theoretical view of innovation that underpins Community recommendations and we explored the kinds of innovation-supporting interventions that have been sponsored with EU funds.

[3] For a comprehensive reconstruction of the historical development of the linear model, see Godin, 2006.

their relationships and the social and economic context in which they are embedded. Kline and Rosenberg (1986) suggested that innovation should be represented by a chain-linked model in which the various aspects of economic and scientific activity, internal and external to the firm, are linked together by multiple relationships of causality and feedback. Economic issues, technical issues, the existence of a demand for innovation, are all interdependent elements of the process of innovation. This model has opened the way to numerous systemic conceptions of the innovation process, seen as the result of dynamic interactions among heterogeneous elements[4].

The most recent perspectives in economics see innovation as a process of creation of new, often tacit, knowledge. Increasing attention for the cognitive aspects of innovation has fostered a corresponding surge in interest for interactions among agents as sources of new knowledge: direct interactions among people are in fact the main modes of transmission and creation of tacit knowledge[5]. Researchers have begun to study various forms of cooperation between firms directed at developing innovations (Freeman, 1991; Mowery and Teece, 1996), including user-producer interactions (Von Hippel, 1978; Lundvall, 1985; Russo, 2000). Sociologists and organization theorists have underlined the importance of the cognitive distance among agents in stimulating innovation (Nooteboom, 1999; Lundvall, 1992), while other scholars have claimed that it is instead geographical proximity among firms - which often implies cognitive proximity - that fosters innovation.

The influential literature on national systems of innovation - which emerged at the beginning of the 1990s with the path-breaking contributions by Lundvall (1988; 1992), Freeman (1988) and Nelson (1988; 1993) - has highlighted the interplay of a wide range of factors, organizations and policies influencing the capabilities of a nation's firms to innovate (Nelson, 1993).

In the last ten years, such heterodox approaches to the analysis of innovation and technological change have influenced European institutions[6]. This theoretical redirection has even been acknowledged explicitly in some of the European Commission's documents[7].

[4] Among these, an approach that, in the late 1990s, found favour among academics and policymakers, is the so-called 'triple helix' (Etzkowitz and Leydesdorff, 2000). Developed within the 'evolutionary economics' framework, this approach suggests that the cycles of production, innovation and policymaking mutually evolve as in a triple helix, in which dynamic selection takes place both within each helix and between helixes, fostering interactive and recursive relationships.

[5] This issue was first raised in the literature by Hagerstrand (1965, 1970) and Polanyi (1969).

[6] Mytelka and Smith (2002) reconstruct the role that some heterodox economic theories have had in influencing the policymakers' thinking within institutions like the European Commission and OECD, but not within others, such as the World Bank.

A first consequence of the adoption of a more systemic approach to innovation has been the transition from framing innovation policy exclusively in the context of research and industrial policy to a more 'transversal' approach. In fact, some of the 'systemic' policy objectives outlined by the Commission - for instance, as stated in the First Action Plan for Innovation in Europe (1996), "fostering an innovation culture", "establishing a framework conducive to innovation" and "better articulating research and innovation" - can be attained only through a mixture of interventions in several policy fields, involving, among others, education, social, industrial, enterprise, development and research policies. The Commission recognizes that innovation policies must be implemented through interventions that involve not only the activities of basic scientific research, development and commercialization of research outcomes – according to the linear model described above – but also small and medium firms and the social and institutional contexts in which they operate[8]. In the same direction, another strand of policy analysis is linking innovation not only to the actions of isolated companies, but also to the activities of 'clusters' intended as aggregations of organizations[9].

Another related consequence is that, besides the usual 'top-down' interventions, 'bottom-up' interventions are emphasized, where the role of Community institutions is mainly to enable and coordinate policies rather than to dictate their contents (Triulzi, 1999).

However, despite the widespread attention dedicated to innovation issues from researchers and policymakers alike, and despite the quantity of funds that are being channelled into innovation-supporting activities[10], the relationship between innovation theory and implementation of innovation policy is problematic. There remains a large gap between the comprehensive approach to innovation advocated by the Commission and the range of interventions that are being funded in practice. The latter can be subsumed within a narrow list of topics: providing information services that facilitate interactions between different

[7] For example in COM(2003)112 and COM(2003)27.

[8] COM(2003)112 states that: "The evolution of the innovation concept - from the linear model having R&D as the starting point to the systemic model in which innovation arises from complex interactions between individuals, organizations and their operating environment - demonstrates that innovation policies must extend their focus beyond the link with research. Since it is through enterprises that the economic benefit of the successful exploitation of novelty is captured, the enterprise is at the heart of the innovation process. Innovation policy must have its ultimate effect on enterprises: their behaviour, capabilities, and operating environment". (European Commission, 2003, p.4)

[9] The Europe Innova Conference (held in Valencia in Novembre 2006), for example, was focused on the role of innovative clusters.

[10] According to our estimates, expenditure on innovation-related interventions in the EU (broadly intended to include Framework Programme interventions as well as innovation-supporting measures sponsored by the Structural Funds) increased from approximately 6,052 million euro per year in the period 1994-1997 to approximately 7,404 million euro per year in the period 2002-2005 (figures computed from data presented in Rossi, 2007).

kinds of institutional actors; simplifying and extending access to patent protection; increasing firms' private research expenditure; supporting small innovative firms and start-ups through interventions aimed at simplifying bureaucracy and granting access to innovation financing; supporting innovation through public procurement. Although the Commission explicitly recognizes the systemic nature of innovation phenomena, actual interventions are generally not consistent with these premises[11]. Therefore, even when policymakers engage in conscious efforts to develop a sophisticated theoretical framework on which to ground their innovation policies, implementation is far from easy or automatic.

This happens for several reasons. First, while the theoretical framework and the interventions performed are continually evolving, they are not perfectly synchronized; the relationship among these actions is mediated by numerous institutional levels and by processes that take place on different time and social scales so that the actors that are responsible for developing a broad theoretical framework to guide policy are generally different from those that devise concrete policy measures.

Secondly, as we have previously remarked, some objectives of innovation policy would require the implementation of coordinated interventions involving multiple policy fields, from education to social inclusion, from research to entrepreneurship. In this respect, European innovation policy appears to suffer from several constraints: the current policy framework, characterized by vertically separated policy fields, the organizational structure of the Commission, the funds' rules and scope for intervention, all place limitations on the kinds of policies that can be designed in order to support a complex process like innovation. Functional separation among policy areas at the Commission level is often mirrored by similar administrative boundaries at the regional level, so that integrated interventions - at any territorial level - are rarely implemented. Although European documents increasingly stress this issue, present rules in the deployment and use of EU funds (concerning administrative procedures, evaluation criteria, and monitoring tools) are still hampering the realization of coordinated interventions.

Third, policy programmes, once established, tend to consolidate, continue and expand over time, with the risk that interventions may overlap and that self-referential communities of actors accessing most of the funding may be created, further hampering the policies' effectiveness.

[11] See Communication COM(2003)226 "Investing in research: an action plan for Europe".

Finally, the problem with policy implementation is not simply procedural, but also conceptual. Broad attempts at theorizing innovation processes do not lend themselves to a quick translation into simple 'policy recipes', precisely because conceptualizing innovation in systemic terms - or, as we argue, as a complex, multi-level process - means that it is not possible to devise context-independent ways to support it.

For these reasons, improved theoretical understanding of innovation processes should not aim to provide policymakers with simple encompassing solutions, but it should help them formulate and address questions that are appropriate to the particular context within which they operate. In this sense, innovation policies should have a 'local' dimension, that is, they should be always "rooted in localities identified by sets of relations within specific communities of people, firms and institutions", as Bellandi and Di Tommaso (2006) remarked with reference to industrial policy.

2. Rethinking innovation

2.1. Changing rationales for innovation policy: from market failure to process building

Mainstream economics still views the innovation process as fundamentally linear, and is mostly concerned with the problem of inducing economic agents to produce enough scientific and technological knowledge to be fed into this process. Once the 'optimal' amount of knowledge is produced, firms just have to 'use' it to develop new products, and 'the market'– characterized by a pure or, more frequently, monopolistic competition framework - will clear supply and demand of the new goods through the usual price mechanism.

In this context, market failures associated with knowledge production provide a powerful rationale to justify public intervention. According to some well-known arguments, in fact, because the outcomes of basic and even applied research activities are characterized by uncertainty (with respect both to the timing and to the quality of results achieved), low appropriability and non-rivalry, market mechanisms would lead to an underproduction of the knowledge necessary for innovation (Arrow, 1962). Hence, public funding of science - either through direct state intervention (creation of public research institutions) or through public spending (funding of the university system and the research system) - is needed in order to ensure that the socially optimal amount of scientific knowledge is produced (Nelson, 1959). Other institutional mechanisms – in particular the patent system and legal devices such as trade secrecy - are designed in order to induce profit-seeking firms to fund private R&D expenditure, by increasing knowledge appropriability and imposing limitations to its rival use.

Aside from the mechanisms devised to foster knowledge production, also knowledge use (and related markets for knowledge) are subject to market failures due to information asymmetries (Akerlof, 1970, Arrow, 1971) which justify the existence and public support of other appropriate institutional mechanisms designed to curb those failures: various contractual forms, the promotion of standards and public regulations, copyright protection, and so forth.

When innovation is viewed as a complex rather than a linear process, instead, the rationale for public intervention changes. If we think of policy as having a 'local dimension', in the sense outlined above, policymakers can intervene not only in order to promote the correction of market failures, but also to achieve specific strategic objectives or to reach meta-economic ones – for example, promoting access to knowledge, education, health, fostering social or environmental sustainability, attaining a specific distribution of wealth or a status of development (Bellandi and Di Tommaso, 2006). Innovation promotion is a key element when implementing strategies in order to attain local development, and this in turn provides grounds to justify public intervention.

2.2. A complexity perspective to innovation

The dynamic interactionist perspective adopts an 'organization thinking' rather than a 'population thinking' approach (Lane, Maxfield, Read and van der Leeuw, 2008). Supra-individual social structures are not seen simply as aggregates of component entities, deprived of agency, useful only to "monitor changes in frequency distributions of their component's properties" (Lane, Maxfield, Read and van der Leeuw, 2008), as species are in biology; rather, in order to understand human sociocultural change, it must be taken into account that both individuals and organizations, belonging to 'tangled hierarchies' (Lane, 2005), are endowed with agency. They can generate changes in the structure of agent-artifact space, and, in turn, their structure and the functionalities that they support can be modified by the actions of entities positioned at other levels in the social hierarchy. In this analytical framework, there is no ex-ante selection of a level of analysis in order to understand innovation processes, and social processes in general. The focus shifts from proving causal relationships between variables to understanding how different structures of relationships carry different functionalities over time, and therefore support different kinds of processes.

With this approach, not only do we obtain a better grasp of the processes constraining innovation, from macro scaling relationships constraining growth (West et al.; Pumain et al., 2008) to cognitive constraints limiting organizational size and dynamics (van der Leeuw et al., 2008), but we improve our understanding of the micro and meso-level processes

underpinning innovation, thanks to the development of a specific theory based on the agent-artifact space ontology (Lane and Maxfield, 1997). This ontology provides a language in which to describe innovation processes; it is a language whose syntax describes causal relationships between entities and processes and as such it is theoretical, not simply phenomenological (Lane and Maxfield, 2005).

The theory pays great attention to the role of uncertainty in innovation processes, although the concept of 'uncertainty' used here goes beyond its common characterization in terms of probabilistic knowledge. Instead, the theory claims that individuals involved in innovation processes act in situations characterized by 'ontological uncertainty', that is, situations where economic agents do not know what are the relevant entities that inhabit their world, which kinds of interactions these entities have among themselves, and how entities and interaction modalities change as a result of previous interactions. The impossibility to assess what entities will affect the results of the agents' own actions prevents any evaluation of future outcomes, even in probabilistic terms (for a discussion of the concept of ontological uncertainty and its relationship with the concept of 'probabilizable' uncertainty see Lane and Maxfield, 2005). In order to explain how innovation processes take place in conditions of ontological uncertainty, a three-level theoretical framework is presented: at the level of the individual agents (micro level), this approach describes how ontological uncertainty can be managed by agents in the short term through the adoption of a 'narrative theory of action'; at the level of agents interactions (meso level), it claims that innovation processes can result from particular kinds of relationships called 'generative relationships', and that a relationship's 'generative potential' can be monitored by paying attention to some of its features; at the level of market systems (macro level), it claims that agents take part in (formal or informal) organizations called 'scaffolding structures' in order to better manage ontological uncertainty and create 'competence networks' able to sustain and reproduce the functionalities needed for the market system to survive over time.

The main building blocks in this theory of innovation are, therefore, the concepts of generative relationships, competence networks, scaffolding structures and the role of narrative in driving action in situations characterized by ontological uncertainty (Lane, Malerba, Maxfield and Orsenigo, 1996; Lane and Maxfield, 1997, 2005, 2008; Russo, 2000, 2005).

3. Innovation theory and innovation policy: lessons from an empirical investigation

The complexity perspective adopted here enables us to identify analytical tools that can be applied to policy design, implementation, monitoring and evaluation activities. In this section, we illustrate these tools through our analysis of a specific policy experiment, the 'Technological Innovation in Tuscany' programme (henceforth RPIA-ITT).

This programme, implemented in the period 2001-2004[12] and funded in the context of the Regional Programme of Innovative Actions within the European Regional Development Fund, was intended to stimulate technological innovation processes in the Tuscan economy through the creation of cooperation networks among heterogeneous organizations - large and small firms, research centres, universities, local public institutions, business services providers, training agencies and finance institutions - with the purpose of integrating competences and testing new methodologies for promoting innovation. The decision to fund cooperation networks was relatively unusual, and complied with recent recommendations to promote systemic development in production structures composed of SMEs (Audretsch, 2002; European Commission, 2003; European Council, 2000).

This intervention was not only directed to supporting innovation processes, it was in its own right an experiment in innovative policy design. The Innovative Actions Programme, in fact, although assigned a relatively small budget, provides a framework for experimenting with new ways of community structural intervention[13].

The policy measure that we studied appears to be particularly close to the spirit of the theoretical approach proposed here. Through this programme, Tuscany's regional administration was trying to support innovation processes performed by competence networks characterized by heterogeneity, which could potentially foster generative relationships among local actors and thus trigger cascades of changes in agent-artifact space.

The main objectives of our analysis were: to assess whether the programme had succeeded in promoting the creation of well-functioning networks capable of integrating heterogeneous competences and of fostering systemic effects in the regional economy; to understand the extent to which the programme supported pre-existing networks of relationships or sparked the creation of new ones; to derive some suggestions that could be generalized to other

[12] We were not involved in policy design, but in the latter stages of policy analysis and assessment. The methodology and results obtained from this analysis are presented in detail in Russo and Rossi (2008).

[13] Several European regions, using available EU funds such as those assigned to the Ris, Ritts and Ris+ programmes, have promoted policies for supporting innovation in SME local production systems (surveyed in the papers by Nauwaelaers and Wintjes, 2003; Bachtler and Brown, 2004; Landabaso and Mouton, 2005; Rossi, 2007), but not many of them have explicitly focused on sustaining cooperation networks.

innovation-supporting interventions. In order to understand the structural characteristics of the networks of relationships underpinning the programme and to explore some of the systemic effects that resulted from it, we relied on complementary use of social network analysis and qualitative interviews with the actors involved.

Network analysis was performed on two levels. First, we reconstructed the networks of relationships *within* each funded project, using the participants' joint involvement in the various work modules of the project as proxy for the existence of a relationship between them. Secondly, we explored the network of relationships underpinning the programme as a whole. Here, we used the participation of the same organization in two project proposals as a proxy for the existence of a relationship between the projects. We used visualization techniques (Freeman, 2000), and we computed statistics relating to the network's cohesion and the nodes' centrality. The betweenness, closeness and degree centrality indexes (Degenne and Forsé, 1999; Wasserman and Faust, 1994; Freeman, 1979) highlighted the organizations most and those less actively involved in the programme, and therefore helped us select the organizations to be interviewed. While the study of the structure of relationships underpinning each funded project allowed us to better understand which agents were able to facilitate the generative relationships that support innovation, the study of the general network's cohesion[14] allowed us to assess if there were one or more cohesive subgroups of actors whose initiative was fundamental in recruiting a large number of organizations to the programme.

We present some of the 'lessons' that we have drawn from this case study as an example of how our theoretical approach can provide the appropriate lenses through which innovation policies can be designed, analyzed and monitored.

Lesson 1: The importance of developing innovative tools to monitor and assess the networks' generative potential. One of the implicit assumptions underlying the design of the RPIA-ITT programme is that innovation processes can be fostered by exploiting existing relationships and by supporting and consolidating generative relationships among organizations that are not accustomed to interacting with each other. Surprisingly, however, we found that the process of network creation and the networks' evolution over time were not carefully monitored by the policymaker, even in the context of a programme explicitly designed for policy experimentation, where great attention should have been paid to unanticipated effects.

In order to assess the projects' achievements, the regional administration used indicators relating only to the products realized by each network (patents, prototypes, software,

[14] See Moody and White (2003) for a critical survey on this notion.

publications, workshops, training courses). In our view, instead, it would have been more fitting to the programme's aims to focus on the interaction processes that enabled such products to be obtained, and to assess, among other things: how changes in network composition, in terms of partners involved and their competences, affected a network's success; which organizations proved to be more successful in recruiting partners and obtaining funding; what kinds of interactions were more conducive to successful innovation activities. We were able to answer these questions, at least in part, by integrating the information collected by the regional administration with the results emerging from our network analysis and from the qualitative interviews (Russo and Rossi, 2008; Agar, 1996, 2004; Spradley, 1979). Our approach allowed us to provide the regional administration with suggestions concerning the kind of monitoring tools (which information should be collected, in which form, how data should be organized and some suggestions for their interpretation), that they should have set up from the start in order to assess the success of this policy programme (Russo and Rossi, 2007).

Lesson 2: Timing of policies, projects, and innovation processes. It is widely recognized that the detailed development, and particularly the timing, of innovation processes cannot be foreseen, even with respect to innovations that have already been acknowledged as commercially viable (Rosenberg, 1996; Lane and Maxfield, 1997, 2005, 2008; Rossi, Bertossi, Gurisatti, Sovieni, 2008). Exploitation of results is itself a process that cannot always be implemented, and it is often not even clearly identified, in the limited time available for policy intervention, which in the RPIA-ITT was a scant 13 months. In this respect, the RPIA-ITT programme seemed to suffer from a problem that we had already observed while surveying EU innovation policies (Rossi, 2007): the lack of attention for what happens to products and services once they are brought to market and start competing with other products and services. Besides statements about the importance of understanding innovation as a system, even in the stage of the definition of general policy directions it appears that innovation continues to be conceived as a phenomenon that unfolds according to well defined stages and for which it is possible to identify a clear beginning and an end. The effects that new products and services, once marketed, have on the socioeconomic system, remain out of sight, just when they start producing (or not) those effects on growth in order to obtain which innovation policies are designed.

To avoid this shortcoming, the time span within which the effects of the policy programme are appraised should be reconsidered. By studying the effects that the programme has

produced over a longer time span, the policymaker should be able to assess the generative capacity of the relationships activated in the course of the programme and of the new relationships emerging thanks to the activities performed, as well as the actors' ability to initiate cascades of changes in agent-artifact space. In the RPIA-ITT case, the results described in the concluding reports should have been updated some time (at least twelve to eighteen months) after the conclusion of the programme. As it emerged from our interviews with some people in charge of funded projects, changes that took place after the projects were formally concluded were of utmost importance both for the networks and agents involved and for the impact of that project on the regional system of innovation. The assessment exercises describing the effects of each project should also consider to what extent the projects led to further projects or benefited from the simultaneous implementation of other projects.

*Lesson 3: The role of multivocal actor*s. Studying the structure of relationships underpinning the cooperation networks allowed us to better understand which agents are able to facilitate the generative relationships that support innovation. For example, we found that a number of business service providers were playing a special and important role in the RPIA-ITT networks. These service providers had different structural characteristics, different behaviours and different objectives. However, most of them were active in the fields of training, certification and technology transfer, a set of activities that allowed them to acquire a good knowledge of a wide range of companies' needs and potential (in terms of missing competences or idiosyncrasies), and to weave a close fabric of relationships with manufacturing firms and other local actors, such as trade associations and local governments. All this brought them close to many different contexts from which they learned several languages. Their 'multivocality' was important in order to identify local needs and sustain network creation. In particular, they were instrumental in bridging the world of applied research with small firms that had not previously been involved in collaborations with external organizations. The latter could be either 'follower' firms that were willing to participate in the projects once a core of participants had been established, or very small manufacturing firms whose activity was entirely focused on production, which were unlikely to establish dialogue with academia or with industrial research centres. In many instances, the service providers proved able to set up new projects starting from their experience accrued through participation to previous EU-funded projects. These experiences also equipped them with the ability to monitor funding opportunities and to manage the relevant administrative-accounting procedures. All these are crucial skills when it comes to organizing bottom-up policy interventions involving the participation of small firms.

Lesson 4: The role of central actors in generating networks. From the analysis of the RPIA-ITT programme we were able to study how the programme tapped into a pre-existing network of relationships and was in turn able to influence that network. We found that some actors were central in presenting projects and implementing funded proposals. Although ten per cent of the participants controlled almost half of the financial resources of the entire programme, they were also able, through multiple direct and indirect links, to involve a large number of other actors, many of whom had no previous experience of contact with research centres or universities. While the regional policymaker did not specifically target nor monitor these actors, the key roles that they played in the programme – from coordinating the project proposals to recruiting potential partners – became apparent both from our interviews and from our network analysis exercises. We also collected, though the interviews, some evidence that certain relationship formed in the context of the RPIA-ITT were likely to give rise to other joint collaborations and new applications for public funding – a typical 'emergent' effect of the policy programme which is generally ignored in the evaluation exercises.

Starting from this experimental programme, it may be possible to take advantage of this experience in the design of future programmes, exploiting the knowledge of how generative relationships can be created within the local system, and at the same time reducing the difficulties inherent in fostering joint action among different organizations.

4. Implications and applications of a complexity perspective

As we have previously claimed, the strength of our approach is mainly related to its ability to solicit the right questions for policy. Starting from an improved understanding and description of innovation processes, policymakers can design more effective interventions, by exploring combinations between top-down and bottom-up measures, paying attention to meso-level structures, reflecting on who should be involved in policy design and planning, who should be the recipients of innovation policies, what kinds of processes should these policies attempt to influence, and in what ways.

Performing the analysis of a specific case study through these theoretical lenses has not only allowed us to derive some recommendations specific to that programme, but it has also suggested some methodological considerations that we present as concluding remarks.

We consider generative relationships as the privileged locus where shifts in attributions of identity and functionality take place. In order to foster innovation, policymakers should attempt to increase and monitor relationships with high 'generative potential' (Lane, Malerba,

Maxfield and Orsenigo, 1996; Lane and Maxfield, 1997). To do so, policymakers would first of all need to explore which kinds of interactions - among which kinds of organizations and concerning which kinds of activities - support innovation processes; what are the most likely interaction loci that promote the emergence of generative relationships; and how can interactions with high generative potential be identified, monitored and supported. Also, when interactions are not producing desirable results in terms of innovation, policymakers should explore innovative instruments in order to foster change; for example, they could seek to identify the main 'narrative structures' driving the actions of organizations in a certain area or industry, and understand whether these are hampering or promoting innovation.

At a higher level than bilateral relationships, Lane and Maxfield (2005) claim that innovation processes are sustained by specific cognitive and physical scaffolds and require the creation of competence networks. In order to sustain competence networks supporting production and innovation, policymakers should understand their structure and scope: they should identify whether local actors belong to local, regional, national, international competence networks, and which structures, if any, coordinate the competences required at the local or industry level with the training needs of individuals and organizations. They should explore how can such structures be monitored and supported, whether there are any 'missing links' in the competence networks at the local or national levels, whether coordination with other policy fields (education, social, industrial) is required in order to design appropriate interventions, and, finally, whether it is possible to design policies that foster the emergence of new competence networks - promoting interactions between organizations that are involved in producing, using, installing the same technology or similar technologies - in this way encouraging the development of new applications.

In order to implement effective interventions it is also crucial to identify the key agents and scaffolding structures that support local innovation processes, so that policies can be designed to work with them in promoting innovation. For example, in the RPIA-ITT case study we observed that the business service providers' multivocality is a key competence in order to select potential participants to a programme requiring network activities, and that some scaffolding structures, such as a network of research centres in optoelectronic, were important drivers of innovation processes. Both business services providers and research centres acted as important scaffolding structures for many of the innovative projects supported by the RPIA-ITT programme, although their roles were very different: the former played a crucial role in network formation and management, while the latter were instrumental in formulating

the project proposals and in ensuring access to regional funds (Russo and Rossi, 2008). Policymakers should understand how such scaffolds can be identified and monitored, and, if necessary, how can they be supported. On the basis of our empirical research, we would also like to formulate a more general claim. We argue that a public agent that intends to promote innovation processes should rely on the ability to mobilize resources, to engage them in creative interaction, to accept and drive change, and to foster non-routine activities and processes. We are thinking about a practice of the kind advocated by Hirschman (1967, 1995 rev.) with his 'hiding hand principle', which he claimed was most effective in the implementation of development projects: a practice which intends to relieve actors from the difficulties connected with confronting unexpected events, which are endemic in innovation processes, by concentrating resources on improving their ability to solve problems in creative ways. Such abilities will then increase their attitude to initiate further changes in the future, even after public incentives have finished.

Policymakers must also have the necessary tools to understand the wider range of effects that their policies engender. Policy interventions have implications at the micro-, the meso- and the macro-level. They directly influence microinteractions among individuals and organizations, whether such policies consist in distributing funds, tax relief or provision of information. They can also determine meso-level changes in the organization of relationships within a certain industry or territory. Finally they can impact macro variables such as imports and exports, investment, overall expenditure both in public and private R&D.

In a complexity-based approach, innovation policies should be evaluated with respect to the systemic effects that they produce. Policies change the space of interactions, whereby new actors are attracted to the innovation processes, recurrent patterns of interactions consolidate, and new organizational structures are created. Rather than assigning more resources to standard ways of monitoring these policies, new ways of monitoring and evaluating them should be sought: policymakers should devise new indicators, new evaluation procedures that take into account the different time scales that different innovation processes require in order to produce tangible results, new ways of assessing, in the course of the programme, the processes of interaction among the involved actors. Some potentially effective tools have been identified through our empirical analysis, where we have claimed that, apart from traditional firm-level indicators (number of patents, of new products, expenditure in R&D, expansion in the number of users, or potential users, of a technology, etc.), policy effects should be measured by new 'potentially generative' relationships activated, changes in the structure of

competence networks, new scaffolds created, changes in the patterns of use of artifacts, or systems of artifacts.

Complex system analysis provides other useful instruments in order to anticipate and assess potential impacts of policy programmes, such as tools from network analysis (see, for example, the work on multi-nets described by White, 2008) and agent-based models (Lane, Serra, Villani, Ansaloni, 2005), which policymakers recognize as potentially very important[15].

We believe that simulation models constitute a fruitful direction for further research into policy issues, allowing policymakers to explore alternative scenarios. Simulation models, applied to the analysis of specific policy programmes, can provide important insights with respect to the most effective ways in which public and private resources can be deployed to foster innovation. While these 'artificial laboratories' represent socioeconomic reality in a necessarily simplified way, they enable comparisons among the effects of different policy instruments, and in this way they provide an important theoretical support for policymakers in the choice of what specific set of measures to implement.

Once again, our experience with the analysis of RPIA-ITT provides a useful reference. This exercise has allowed us to collect information on the features of an experimental policy programme directed at sponsoring innovation projects performed by networks of organizations. This information can prove useful in order to set up an artificial context which, although extremely simplified, would contain at least some elements of realism with respect to the relevant degree of agent heterogeneity, the number and types of organizations involved in the experiment, and the structure of the networks of relationships among them. After some of these realistic parameters have been entered in our artificial context, it would be possible to tweak them and visualize, thanks to the simulation, different scenarios in terms of the effects that the different policy parameters produce, and in this way compare the effectiveness of different interventions.

References

Agar, M., 1996. The Professional Stranger: An Informal Introduction to Ethnography, Academic Press, San Diego, 1-51.

[15] According to a recent report from a European Complex Systems Society workshop: "Complex systems science can help elucidate the systemic processes that embed decisions in case of crisis into a web of forces and interactions across biological, ecological, and societal dimensions. Relatively simple models inspired by complex systems science and its precursors in non-linear dynamical systems theory could have tremendous communication value in making clear what are otherwise non-intuitive ideas – for example, that we should expect small changes sometimes to lead to large consequences, or that perfect prediction is not always or even often an option". (Dum and Buchanan, 2007).

Agar, M., 2004. We Have Met the Other and We're All Nonlinear: Ethnography as a Nonlinear Dynamic System. Complexity. 10/2: 16-24.

Akerlof, George, 1970. The market for lemons: Qualitative uncertainty and the market mechanism. Quarterly Journal of Economics 84: 488-500.

Arrow, K. J., 1962. Economic welfare and the allocation of resources for invention. In Nelson, R. R. (ed.) The Rate and Direction of Inventive Activity: Economic and Social Factors. NBER (Princeton University Press, Princeton, NJ).

Arrow, Kenneth, 1971. Essays in the Theory of Risk-Bearing, Markham Press, Chicago.

Audretsch, D., 2002. Entrepreneurship: A Survey of the Literature. Prepared for the European Commission, Enterprise Directorate General.

Bachtler, J., Brown, R., 2004. Innovation and regional development: transition towards a knowledge-based economy. Report prepared for the Knowledge based regional development and innovation Conference, Florence, 25 and 26 November.

Bellandi M. and M. Russo, 2005. Soggetti destinatari vs. soggetti attivatori delle politiche per l'innovazione, paper prepared for the project "Politiche per l'innovazione e sistemi di PMI", Dipartimento delle Politiche di Sviluppo e Coesione, Ministero del Tesoro

Bellandi, M. and Di Tommaso, M., 2006. The Local Dimensions of Industrial Policy, in P. Bianchi, S. Labory (eds.), International Handbook On Industrial Policy. Cheltenham: Edward Elgar.

Degenne, A., Forsé, M., 1999. Introducing Social Networks, Sage, London.

Dum, R., Buchanan, M., 2006. Final report on the European Complex Systems Society Workshop "Science of complex systems: can science guide policies?", 19-20 December, Brussels.

European Commission, 1995. Green Paper on Innovation, COM(1995)688.

European Commission, 1996. First Action Plan for Innovation in Europe

European Commission, 2000. Towards a European Research Area. COM(2000)6

European Commission, 2003. Investing in Research: an Action Plan for Europe. COM(2003)226

European Commission, 2003. Green Paper on Entrepreneurship, COM(2003)27.

European Commission, 2003. Innovation Policy: updating the Union's approach in the context of the Lisbon strategy COM(2003)112

European Commission, 2004. Delivering Lisbon - Reforms for the enlarged union, COM(2004)29

European Council, 2000. Council Decision on a multiannual programme for enterprise and entrepreneurship, and in particular for small and medium enterprises.

European Council, 2005. Presidency conclusions of the Brussels European Council 22 and 23 March.

Etzkowitz, H. and Leydesdorff, L., 2000. The Dynamics of Innovation: from National Systems and "Mode 2" to a Triple Helix of University-Industry-Government Relations, Research Policy, vol. 29, pp. 109-123.

Freeman, L. C., 2000. Visualizing Social Networks. Carnegie Mellon: Journal of Social Structure.

Freeman, L.C., 1979. Centrality in Social Networks: I. Conceptual Clarification. Social Networks, 1, 215-239.

Freeman, C., 1991. Networks of Innovators: A Synthesis of Research Issues, Research Policy, 20: 499-515.

Freeman, C., 1988. Japan: A New National System of Innovation?, in G. Dosi et al. (eds) Technical Change and Economic Theory, London and Washington: Pinter.

Godin, B., 2006. The Linear Model of Innovation: The Historical Construction of an Analytical Framework. Science Technology Human Values, 31; 639.

Hagerstrand T., 1965. Quantitative Techniques for Analysis of the Speed of Information Technology, in C. A. Anderson e M. J. Bowman (eds.), Education and Economic Development, Chicago, Aldine Publ. Co., pp. 244-80

Hägerstrand, T., 1970. What about People in Regional Science?, Papers of the Regional Science Association, vol. 24, pp. 7-21

Hirschman, A.O., 1967, 1995 rev. Development Projects Observed, Brookings Institution, Washington, DC.

Kline, S., Rosenberg, N., 1986. An Overview of Innovation, in Landau et al (eds) The Positive Sum Strategy, Washington: National Academy Press.

Landabaso, M., Mouton, B., 2005. Towards a different regional innovation policy : eight years of European experience through the European Regional Development Fund innovative actions, in van Geenhuizen, M., Gibson, D.V. and Heitor, M.V. (eds.), Regional development and conditions for innovation in the network society. Purdue University Press.

Lane, D.A., 2005, Level hierarchies in agent-artifact space, in: Pumain D. (ed.), Hierarchies in Natural and Social Systems, Kluver.

Lane, D.A., Maxfield, R., 1997. Foresight Complexity and Strategy, in: Arthur WB, Durlauf, S., Lane, D.A. (Eds.), The economy as an evolving complex system II, Addison Wesley, Redwood City, CA.

Lane, D.A., Maxfield, R., 2005. Ontological Uncertainty and Innovation. Journal of Evolutionary Economics, 15.

Lane, D.A., Malerba, F., Maxfield, R. and L. Orsenigo, 1996. Choice and Action, Journal of Evolutionary Economics, 6:43-76.

Lane, D.A., Maxfield, R., Read, D., van der Leeuw, S.E., 2008. From population thinking to organization thinking. In: Lane, West, van der Leeuw, and Pumain, eds. A New Perspective on Innovation and Social Change. Dordrecht: Springer Methodos Series. (In press)

Lane, D.A., Serra, R., Villani, M., Ansaloni, L., 2005. A theory-based dynamical model of innovation processes, ComplexUs vol. 2 p. 177-194

Lundvall, B-A., 1985. Product Innovation and User-producer interaction. Aalborg: Aalborg University Press.

Lundvall, B-A., 1988. 'Innovation as an Interactive Process: from User-Producer Interaction to the National System of Innovation', in Dosi et al. (eds) Technical Change and Economic Theory, London and Washington: Pinter.

Lundvall, B-A., ed, 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London and Washington: Pinter.

Lundvall, B-A., 2006. National innovation system: Analytical focusing device and Policy learning tool, Aalborg University, Department of Business Studies, mimeo.

Moody, J., White, D.R., 2003. Structural Cohesion and Embeddedness: A Hierarchical Concept of Social Groups. American Sociological Review, 68/1: 103-127.

Mowery D., Teece, D., 1996. Strategic Alliances and Industrial Research, in Rosenbloom et al (eds) Engines of Innovation, Boston, Mass: Harvard Business School Press.

Mytelka, L., Smith, K., 2002. Policy learning and innovation theory: an interactive and co-evolving process. Research Policy, 31: 1467-79

Nauwelaers, C., Wintjes, R., 2003. Towards a new paradigm for innovation policies?, in Asheim, B., Isaksen, A., Nauwelaers, C. and F. Tötdling (Eds.), Regional innovation policy for small-medium enterprises, Edward Elgar, Cheltenham, UK and Lyme, US.

Nelson, R.R., 1959. The simple economics of basic scientific research, The Journal of Political Economy, 67/3: 297-306.

Nelson, R.R., 1988. 'Institutions Supporting Technical Change in the United States', in Dosi et al.(eds) Technical Change and Economic Theory, London and Washington: Pinter.

Nelson, R.R., ed., 1993. National Innovation Systems. A Comparative Analysis, Oxford: Oxford University Press.

Nooteboom, B., 1999. Innovation, Learning and Industrial Organisation, Cambridge Journal of Economics, vol. 23, pp. 127-150

Polanyi, M., 1969. Knowing and Being, (edited by M. Grene), Routledge and Kegan Paul, London

Powell, W. W., 1996. Inter-Organizational Collaboration in the Biotechnology Industry. Journal of Institutional and Theoretical Economics 120(1):197-215

Read, D., Lane, D.A., van der Leeuw, S.E, 2008. The innovation innovation. In: Lane, West, van der Leeuw, and Pumain, eds. A New Perspective on Innovation and Social Change. Dordrecht: Springer Methodos Series. (In press)

Rosenberg, N., 1982. Inside the Black Box, Cambridge: University Press.

Rosenberg, N., 1994. Exploring the Black Box, Cambridge: University Press.

Rossi, F., 2007. Innovation policy in the European Union: instruments and objectives, MPRA Paper n. 2009.

Rossi, F., Bertossi, P., Gurisatti, P., Sovieni, L., 2008. Incorporating a new technology into agent-artifact space: case studies from Europe. In: Lane, West, van der Leeuw, and Pumain, eds. A New Perspective on Innovation and Social Change. Dordrecht: Springer Methodos Series. (In press)

Russo, M., 2000. Complementary innovations and generative relationships: an Ethnographic Study. Economics of Innovation and New Technology, 9: 517-57.

Russo, M., 2005, “Innovation processes and competition: China challenges Sassuolo. How do innovation processes in industrial districts are affected by competition from new market systems”, in Proceedings of the conference in honour of Professor Sebastiano Brusco “Clusters, Industrial Districts and Firms: The Challenge of Globalization”, September 12th-13th . http://www.economia.unimore.it/convegni_seminari/CG_sept03/naviga.html

Russo M. and F. Rossi, 2007. Politiche per l’innovazione: dalla valutazione alla progettazione, Dipartimento di Economia Politica dell’Università di Modena e Reggio Emilia, Materiali di Discussione n.565/07.

Russo M. and F. Rossi, 2008. Cooperation partnerships and innovation. A complex system perspective to the design, management and evaluation of a EU regional innovation policy programme. Evaluation, 14/3.

Spradley, J. P., 1979, The Ethnographic Interview, Harcourt Brace Jovanovich College, New York.

Triulzi, U., 1999. Dal mercato comune alla moneta unica, SEAM, Roma.

Von Hippel, 1978. Users as Innovators, Technology Review, 81: 1131-1139

Wasserman, S., Faust, K., 1994. Social Network Analysis. Methods and Applications, Cambridge University Press, Cambridge, Mass.

White, D.R., 2008. Networks, Hierarchy and Cohesion. In: Lane, West, van der Leeuw, and Pumain, eds. A New Perspective on Innovation and Social Change. Dordrecht: Springer Methodos Series. (In press)