Explaining firms' growth through the interaction between internal capabilities and external relationships: An empirical analysis in Life Sciences industry

Abstract

This research is one of the first attempts to integrate the relationship among several key features into a single model: internal capabilities and resources (managerial capabilities, relational skills, technology orientation, investments in R&D and human resources), external relationships (divided into local or distant relationships, focused on innovation or operations), innovation capacity and the economic growth of firms. Two econometric models are developed based on a composite dataset of 151 firms in the life sciences sector. The first, a count data model, evaluates the impact of internal capabilities and inter-organizational architecture on the innovation capacity, measured as the number of patents. Subsequently, an OLS regression model is used to evaluate how internal capabilities, innovation capacity and external relationships influence the growth of companies, measured in terms of variation in sales. The results demonstrate that internal technological orientation and access to distant knowledge have a positive effect on innovation capacity. Economic growth is instead positively influenced by local operational relationships, innovation capacity and managerial capabilities.

Key words: *Internal capabilities, Resources, Networks, Inter-organizational architecture, Distant knowledge, Growth, Life Sciences*

Introduction

The growth of firms has been broadly explored in economic literature since the 1950s and early 1960s (Penrose, 1959; Chandler, 1962), becoming a classic theme of strategic management research. The fundamental principle in all the research is that a firm seeks growth and so pursues the strategic choices which it considers most likely to reach this end (Child, 1972; Miles and Snow, 1978). According to this strategic perspective, the mainstream theory of firm growth has traditionally presumed the existence of two dominant models: internal growth associated with the generic strategy of *expansion*, and external growth carried out through the strategy of *acquisitions* (Yip, 1982). In the first case, from the seminal work of Penrose (1959) and with greater emphasis from the mid-1980s with works that create the bases for the resource-based view, the firm begins to be viewed as a collection of resources (Wernerfelt, 1984) and of organizational routines (Nelson and Winter, 1982) which influence growth. In the second case, in agreement with the theory of transaction costs (Williamson, 1975), the firm seeks growth through a strategy of expansion of its own limits, generally through fusions and acquisitions (Haspeslagh and Jemison, 1991), with the aim of fully exploiting its underutilized resources (Teece, 1982). Alongside these two dominant models, network strategy (Powell, 1990) has begun to establish itself as a possible third strategic choice. According to this approach, growth is the result of strategic choices that aim not only to reinforce the internal structures of companies, but also to gather the opportunities that the external environment may offer (Pfeffer and Salancik, 1978) through network forms of organizations (Powell, 1990) generated by inter-organizational relationships in many different forms: strategic alliances, joint ventures, partnerships, etc. (Jarillo, 1988; Ring and Van de Ven, 1994; Gudergan *et al*., 2012; Albers *et al*., 2013). These are intermediate forms of governance between market and hierarchy (Hennart, 1993; Powell, 1990; Williamson, 1991) which reflect the inability of the isolated firm to effectively pursue either of the two traditional strategies, generic expansion or acquisitions (Peng and Heath, 1996).

Coherent with this third strategic approach to firm growth, this research aims to evaluate how the relationships between internal capabilities and the structure of inter-organizational architecture influence the growth of the firm. To respond to this query, we rely on two main theoretical approaches to the study of the firm, the resource-based view of the firm (RBV) and the theory of social capital. The first emphasizes the role of the internal resources controlled by the firms (Wernerfelt, 1984; Rumelt, 1984; Barney, 1991) and of the competences and routines developed (Nelson and Winter, 1982; Teece *et al*., 1997). According to this approach, the competitive advantage of firms, and so their growth, can be explained by their possessing unique resources that are only partially negotiable and difficult to imitate (Wernerfelt, 1984; Barney, 1991). The second approach, linked to the theory of social capital (Leenders and Gabbay, 1999), instead suggests that the network of external relationships among firms provides a determining contribution to their growth (Uzzi, 1997; Nahapiet and Ghoshal, 1998; Stam and Elfring, 2008) through an embedded logic of exchange which favors economic results by sharing resources, cooperating and adapting (Uzzi, 1996, p. 675). From this viewpoint, firms interact with clients, suppliers and other partners to reach external resources (Pfeffer and Salancik, 1978) that are complementary to and interdependent on those owned internally. These *network resources*, as they are termed (Gulati, 1999), are outside individual firms and embedded in a network of alliances within routines and processes shared among many different organizations (Dyer and Singh, 1998). The firms operate within a structure of

economic and social relationships (Granovetter, 1985) that depend both on the technological characteristics of a given sector but also on the social norms and institutional elements regulating them (Kogut, 2000).

Studies on the internal resources and capabilities of firms on the one hand and the contribution of external relationships on the other represent two great thematic areas in the managerial literature of the last thirty years. All the same, there are not many contributions which attempt to study and integrate, especially empirically, these two thematic areas. If we consider the growth of the company as a multidimensional construct that "*primarily involves expansion of organizational size measured by assets and employees; increase in volume of sales, profit levels, or activities; as well as generation of new economic functions or more lines of products and services*" (Peng and Heath, 1996, p. 495), it is possible to distinguish research which has explored how the interaction between internal capabilities and external relationships contributes to reinforce the innovative capability of the firm (Caloghirou *et al.*, 2004; Su *et al.*, 2009; Belussi *et al*., 2010). Other studies have integrated the two approaches and studied the firms' boundary choices (Yang *et al.*, 2010). Still others have evaluated how the interaction between internal capabilities and networking influences the performance of the firm (Lee *et al*, 2001; Zaheer and Bell, 2005). All the same, some aspects requiring further study remain. In particular, the works analyzed do not agree on a single set of internal capabilities to place inside the models. Lee *et al*. (2001) use technological capability, entrepreneurial orientation and the financial resources of the firm; Caloghirou *et al*. (2004) R&D investments (both financial and HR) and the capability of taking advantage of knowledge transfer pathways; Su *et al*. (2009) functional capabilities in the areas of R&D, marketing and production; Yang *et al*. (2010) *knowledge specialization*; Zaheer and Bell (2005) innovation capacity; Belussi *et al*. (2010) R&D investments. Furthermore, studies which evaluate the simultaneous influence on growth of internal capabilities and external relationships divided into local and distant factors are rare, and these few are contributions which specifically study the dimension of the growth connected to the development of innovations. Research on this has shown how the access to distant knowledge has different effects on the capability of extracting value from innovation compared to local relationships (Bell, 2005; Stuart and Podolny, 1996). Lastly, we note that with the sole exception of the work of Lee *et al*. (2001), no study has evaluated empirically the influence on growth of the interaction between the two predictors.

To respond to our research question and fill the gaps which are now clear, we propose a model which integrates internal capabilities and inter-organizational architecture. In an initial stage the impact of both these features and of their interactions on the innovation capacity of firms is evaluated. We are here interested in understanding how the relationship between internal capabilities and external relationships determines that particular dimension of growth connected to innovation development (cf. Peng and Heath, 1996, p. 495). In a second stage, we evaluate instead how internal capabilities, innovation capacity and external relationships (and their interactions) influence the growth of firms, this time measured in terms of economic performance.

The research field chosen to test the model is the Tuscan life sciences cluster. The biotech sector and life sciences in general represent ideal laboratories where research hypotheses can be tested since they are considered representative of high-technology-intensive sectors where the R&D performance is of great importance (De Luca and Verona and Vicari, 2010, p. 301). Furthermore, the cluster, "*a geographically proximate group of interconnected companies and associated institutions in a particular field, including product producers, service providers, suppliers, universities, and trade associations*" (Porter, 1998, p. 197), represents a research unit of particular usefulness when considering research questions. The proximity of the firms within a given region (Audretsch, 2001; Bell, 2005) and of the shared institutional framework (Cooke, 2001) are important factors in facilitating the spread of innovations (Jaffe *et al*., 1993), the promotion of forms of exchange of knowledge (Gomes-Casseres *et al*., 2006) and furnishing better access to information (Porter, 1990).

The research is structured as follows: the following section contains the literature review of the relationship between the internal capabilities of the companies, external relationships and growth, demonstrating how this study fits into the body of existing research. The conceptual model and the research hypotheses are then presented, followed by the section outlining the research method. Lastly, the results of the study are presented and discussed and the study concludes with some suggestions for future research.

2. Theoretical background

2.1 Internal resources and capabilities

Wernerfelt's article "A resource-based view of the firm" (1984) has been cited nearly 15,000 times in academic work (source: Google Scholar). The idea of considering the firm as a broad collection of resources has its roots in the seminal work of Penrose (1959) as well as in Ricardo's theory of returns and in Schumpeter's theory of economic development, and Wernerfelt's study still remains an important reference point for all studies facing the theme of competitive advantage and the growth of firms. Beginning with Wernerfelt (1984) and the researchers immediately after him (Rumelt, 1984; Dierickx and Cool, 1989; Barney, 1991), the growth differentials of firms begin to be explained no longer based solely on an *industry structure view* (Porter, 1980) but also on the basis of their heterogeneity, or rather on the difference generated by the possession of unique resources, only partially negotiable and difficult to imitate (Wernerfelt, 1984; Barney, 1991). Barney (1991) defines resources as "*all assets, capabilities, organizational processes, firm attributes, information, knowledge etc. controlled by a firm*" (Barney, 1991, p. 101). Amit and Schoemaker (1993, p. 35) then develop the concept of capability as a further and distinct source of competitive

advantage: "*Capabilities, in contrast, refer to a firm's capacity to deploy resources, usually in combination, using organizational processes, to effect a desired end*". A capability, unlike resources, is thus embedded in the organization and in its processes and for this reason it is difficult to transfer. Moreover, the principal aim of a capability is to strengthen the productivity of the other resources owned by the firm (Makadok, 2001, p. 389). The definition of capability in Amit and Schoemaker (1993) draws from the works of Prahalad and Hamel (1990) and Nelson and Winter (1982). The first define what they call core competences, expressed in the knowledge a firm has about how to coordinate the various productive and technological skills embedded in the organizational processes and activities in which resources are utilized. The second set of researchers refer to the concept of organizational routines, that is, all those patterns of actions (regular and predictable behavior) and tacit knowledge (the authors compare it to the *genes* of biology) which permeate the entire organization and permit it to preserve itself. The concept of capability is further developed by Teece *et al*., (1997) who define *dynamic capabilities* (ibid, 1997, p. 516) as "*the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions (Leonard-Barton, 1992)*".

In the mid-1990s knowledge is increasingly considered to be important among the critical resources of a firm; the immaterial components of the *chain of value* (Porter, 1985) are ever more determinative in defining the competitive positioning of firms. In the era of knowledge, knowledge itself becomes the principal productive factor and at the same time the result of the production process (Nonaka and Takeuchi, 1995). Grant (1996), while creating the bases for his knowledge-based theory of the firm, highlights some characteristics pertinent to how knowledge is used within the firm to create value. These characteristics include *transferability* (connected to the mechanisms of transfer between individuals, space and time), *capacity for aggregation* (in terms of capability to transmit from one part and receive on the other through common communication), *appropriability* (the ability to create value by the ownership of a tacit or explicit knowledge), *specialization in knowledge acquisition* (in terms of the human resources specifically dedicated to that activity) and the *knowledge requirements of production* (in the sense that any productive process which transforms input in output is necessarily based on knowledge). In particular the concept of *capacity for aggregation* expressed by Grant (1996) is based, from the point of view of the receiving object, on the concept of absorptive capacity already expressed by Cohen and Levinthal (1990). Both on the individual and organizational level, then, the ability to recognize, assimilate and apply new information coming from outside the firm to commercial purposes represents a fundamental driver of success in the innovative processes (Cohen and Levinthal, 1990; Lane *et al.*, 2006) and in the creation of adequate innovation capacity in the firm.

2.2 Networks of inter-organizational relationships

In the literature, the last twenty years has seen an extraordinary growth in both theoretical and empirical research about the concept of strategic alliances and around the more general theme of the network of relationships (Oliver, 2001, p. 467). This is evident also in the numerous special issues dedicated to this theme which have appeared in international journals from the 1990s to today. Here are just a few examples: *Academy of Management Journal* (eds.: Osborn and Hagedoorn, 1997), *Organization Science* (eds.: Koza and Lewin, 1998), *Organization Studies* (ed.: Grandori, 1998), *Industrial Marketing Management* (eds.: Moller and Halinen, 1999), *Journal of Marketing* (eds.: Achrol and Kotler, 1999), *Strategic Management Journal* (eds.: Gulati *et al*., 2000), *Long Range Planning* (eds.: Gibbert and Välikangas, 2004), *Academy of Management Review* (eds.: Parkhe *et al*., 2006). The various specialist areas of the journals (managerial, organizational, marketing, etc.) also demonstrate how the theme has crossed through different areas of research and involves all corporate functional roles in a systematic way. The various disciplines have contributed to the study of the networks with differing approaches and viewpoints. Thus management studies have focused in particular on the effects of inter-organizational relationships on the innovativeness of a firm or on its economic performance. Organizational studies have concentrated on the analysis of extra-organizational networks and how these influence intra-organizational networks. Sociologists have studied the impact of the networks on society and the economy, and geographers have analyzed the spatial dimension of the networks. The very wealth of the approaches makes a systematic overview of the research on networks difficult to achieve.

In management studies, there are three seminal works at the basis of all network research. The first, from which the other two then derive, is that of Granovetter in 1973, where the author conceptualizes the difference between strong ties and weak ties within a network and demonstrates how these latter allow an easier access to certain information to which an organization could not arrive only through tighter and closer relationships. The second study is that of Coleman in 1988, which demonstrates that operating from within a dense network with reliable connections can be a source of competitive advantage for firms due to the reinforcement of coordination mechanisms. The third, instead, is that of Burt, 1992, in which the concept of structural holes is formalized; Burt demonstrates that the competitive advantage of firms depends on their ability to fill the structural holes which are created among cohesive groups of firms within a network.

Oliver (1990) indicated six principal factors which explain the reasons why relationships form among firms: 1) the necessity to satisfy legal or regulatory requisites, 2) asymmetry in the potential of one organization to exercise power or control on another organization (vertical links), 3) reciprocity in collaborations and cooperation (horizontal links), 4) efficiency in the efforts of a firm to increase its own internal input-output, 5) stability as an adaptation to uncertainty in

local conditions, 6) legitimization in developing reputation, image and prestige. Hagedoorn (1993) explains alliances among firms considering the complex and multidisciplinary knowledge at the basis of a sector or market: the higher the complexity, the more easily firms tend to collaborate externally. Gulati and Singh (1998) concentrate instead on coordination and appropriation costs: in sectors with weak appropriability regimes (typically those with a high component of technology) and high coordination costs, the network structures which form will be of greater hierarchical control. Lastly Arora and Gambardella (1990), in their biotech sector study, demonstrate how alliances take place with greater frequency between large firms which offer access to new markets and small firms which bring their own contribution of science and technology.

With reference to the reasons firms tend to form alliances, a specific line of study has concentrated on the theme of organizational learning (Berghman *et al*., 2012) and on the relationship between innovation and networks. Even if historically firms have managed innovation internally through their own R&D laboratories (Mowery, 1983), today innovative activity is greatly fragmented in terms of both place and task (Bell, 2005; Sobrero and Roberts, 2002). According to Von Hippel, studying the sources of innovation means "*categorizing firms and individuals in terms of the functional relationship through which they derive benefit from a given product, process, or service innovation*" (Von Hippel, 1988, p. 3). As mentioned above, collaboration among firms has intensified in recent years, and the pharmaceutical and biotechnological sectors represents emblematic cases, since innovation no longer comes from a single firm but from a network of firms (Belussi *et al.*, 2010). Firms thus do not form alliances only to have access to new resources, but also to learn and be able to take advantage of new knowledge to develop innovation (Dyer and Singh, 1998). According to Powell *et al.*, (1996), when the knowledge at the basis of a sector is complex and the competences are broadly dispersed and fragmented, the source of innovation must be found in a learning network rather than in a single firm. Through an empirical analysis of the biotech sector, the authors demonstrate in particular how when in a firm there is an increase in the number of alliances focused on R&D, in the experience of managing both the R&D relationships and other types of cooperation and in the diversity of links created outside, the firm progressively takes on a more centralized position within a network. This more centralized firm then manages to create ever greater relationships aimed at the development (or not) of innovation. Considering the distinction between exploration and exploitation (March, 1991), organizational learning is at the same time a function both of the access to new knowledge and of the capability to use this knowledge to develop innovation (Powell *et al.*, 1996, p. 118).

3. Conceptual model and hypotheses development

The analysis of the literature above allows us to construct the conceptual model represented in Figure 1.We assume that at a first stage the innovation capacity of firms depends on internal capabilities and resources, on the relationships which form its inter-organizational architecture and on their interaction. At a second stage we assume instead that the internal capabilities and resources together with the very same innovation capacity and with external relationships (and their interactions) influence the growth of the firms measured in terms of economic performance. The innovation capacity is thus a capacity which the organization possesses in virtue of the interaction of its own internal resources and capabilities with the external network of relationships and it is determinative for the economic growth of firms.

As already mentioned in the introduction, the studies analyzed do not converge on a single set of capabilities and internal resources within the models proposed. We hypothesize three principal internal capabilities to consider: managerial capabilities, relational skills and technology orientation. *Managerial capabilities* represent the ability of the firm to manage its own financial and human resources as well as the operational activity of the firm (Hooley *et al*., 2005). *Relational skills* represent the capability of the firm to manage its partnerships (Walter *et al.*, 2006); thus it does not consider the ability of creating new and different relationships but rather that of managing relationships already formed. Lastly, *technology orientation* represents the degree to which the company is able to utilize and manage new technologies and scientific discovers within its own organization and its own products (Zhou and Li, 2010). Alongside these three capabilities we also consider two principal resources: R&D expenditure (Belussi *et al*., 2010; Lee *et al.*, 2001) and human resources (Caloghirou *et al*., 2004).

As regards the inter-organizational architecture, instead, we assume that the network of relationships which firms create externally has two principal dimensions: the spatial dimension that distinguishes local from distant relationships, and the functional dimension of the relationships, which distinguishes relationships focused on operational matters from those concerned with innovation. With reference in particular to the spatial dimension, several empirical research studies have demonstrated that face-to-face contacts and geographic proximity are important factors in facilitating the spread of innovation (Jaffe *et al*., 1993), promoting forms of transfer of knowledge (Gomes-Casseres *et al*., 2006) and furnishing improved access to information (Porter, 1990). More recent studies have all the same raised doubts that mere spatial proximity is sufficient to improve learning networks. Boschma (2005) demonstrates that institutional and organizational proximity are as important as geographic, Boschma and Ter Wal (2007) claim that not only local but also global connections increase innovative performance, and other contributions show how global connections are complementary to local ones (Bathelt *et al*., 2004; Doloreux, 2004).

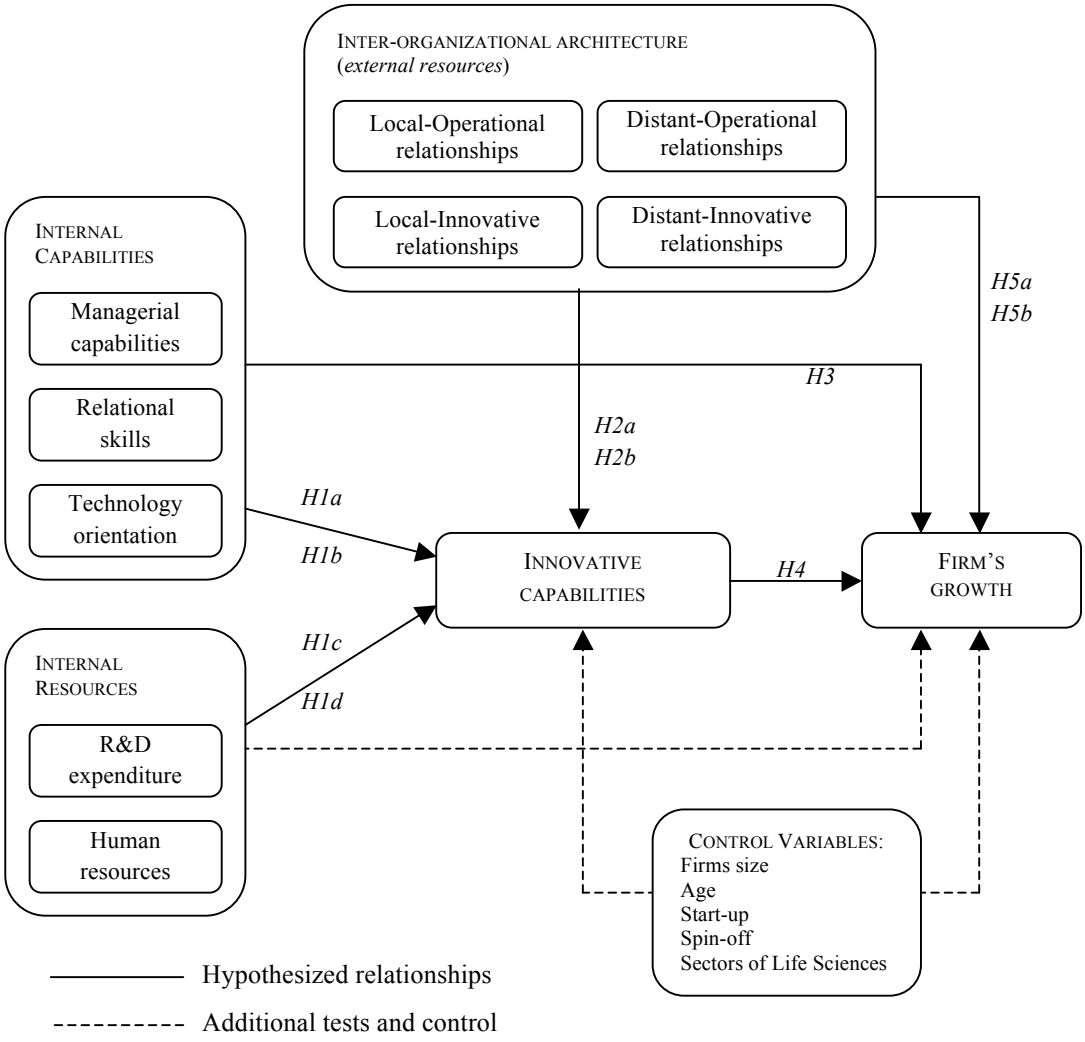


Figure 1. The conceptual model

The literature on which the proposed conceptual model is based allows us to formulate of the following research hypotheses.

The ability to accumulate technological and scientific knowledge, the rapid acquisition of new discoveries and research results as well as the capacity to remain informed about cutting-edge technologies all represent competences which allow firms not only to take advantage of existing knowledge to improve and differentiate already-developed products (Gatignon and Xuereb, 1997) but also to recognize and anticipate emerging or potential technological trends as well as to reallocate and reconfigure internal resources to take advantage of new opportunities (Wilden *et al., 2012;* Zhou *et al.*, 2005). Technology orientation – the degree to which a firm is able to use and manage new technologies – is thus a determining factor in the development of innovation capacity in firms (Zhou and Li, 2010). Our first research hypothesis is thus as follows:

H1a: the degree of technology orientation is positively associated with the innovation capacity of a firm.

As indicated in the introduction, the literature has shown how today innovation is a highly fragmented process, both spatially and functionally (Von Hippel, 1988; Sobrero and Roberts, 2002, p. 160). Several studies have also suggested that the relational skills of the components of an organization are determinative in effectively connecting its resources with those of other companies through partnerships (Walter *et al*., 2006). This is a sort of social competence (Baron and Markman, 2003) which includes aspects such as communication skills, the propensity to cooperate, the ability to manage conflict, flexibility, etc. (Marshall *et al*., 2003). Knowing how to manage collaborative efforts, in particular those targeted at development and innovation, is thus crucial for the success of innovative processes. Our next research hypothesis is thus:

H1b: the level of relational skills is positively associated with the innovation capacity of a firm.

It is by now generally accepted in the literature that the innovation capacity of firms is associated with certain critical resources, in particular R&D expenditure (Belussi *et al*., 2010; Lee *et al.*, 2001) and the human capital within an organization (Caloghirou *et al*., 2004). Our next research hypotheses are thus as follows:

H1c: the level of R&D expenditure of an organization is positively associated with the innovation capacity of firms.

H1d: the human capital of an organization is positively associated with the innovation capacity of firms.

In recent years the literature about networks and about industrial clusters in particular has emphasized their capacity to generate and spread new knowledge (Giuliani and Bell, 2005, p. 47). Bell (2005) demonstrated that Canadian companies located in an industrial cluster and centrally in a network increase their innovation capacity. Aharanson *et al.* (2004) in their study of the biotech sector claim that clustered firms are more innovative than those which are geographically spread out. Sonn and Storper (2003) and Almeida and Kogut (1999) arrive to analogous conclusions. As has already been mentioned, recent studies have shown that spatial proximity is not sufficient to guarantee an increase in innovation capacity in a firm (Boschma and Ter Wal, 2007; Bathelt *et al*., 2004; Doloreux, 2004). Our next research hypotheses are therefore:

H2a: relationships with local partners for innovation development are positively associated with the innovation capacity of firms.

H2b: relationships with distant partners for innovation development are positively associated with the innovation capacity of firms.

Managerial capabilities were identified by Day in 1994. These may be usefully categorized along the traditional lines of corporate functions: human resources, operations and finance. The first two have to do with the development of individual human potential within an organization in line with its strategic objectives; operations also include the activities of production and commercialization of goods and services of value to the client. Finance involves the administration of the financial resources of a firm (Hooley *et al*., 2005, p. 20). The literature indicates how these capabilities are positively associated to the performance growth of firms (Day, 1994; Hooley *et al*., 2005), so our next research hypothesis is:

H3: the level of managerial capability is positively associated with the economic growth of a firm.

Various contributions in the literature have shown that the innovation capacity of firms is positively associated with their growth, in particular if measured in terms of economic performance (Stuart, 2000; Zaheer and Bell, 2005; Lew and Sinkovics, 2012); our next hypothesis is thus:

H4: the level of innovation capacity is positively associated with the economic growth of a firm.

We have seen how the network of external relationships, if managed well (Hoffman, 2005; Holmberg and Cummings, 2009), can furnish a determining contribution to their growth (Uzzi, 1997; Nahapiet and Ghoshal, 1998; Stam and Elfring, 2008). The creation of inter-organizational links may favor the economic results (Uzzi, 1996, p. 675) of firms that have access to external resources complementary to their internal ones as they interact with their own clients, supplier and other partners (Pfeffer and Salancik, 1978). Our final hypotheses are therefore:

H5a: operational relationships with local partners are positively associated with the economic growth of a firm.

H5b: operational relationships with distant partners are positively associated with the economic growth of a firm.

4. Data and methods

4.1 Data collection and sample description

Research in this study was carried out in the life sciences sector and in particular in the Tuscan regional cluster. Activity in the life sciences sector is composed of two fundamental and distinct elements. In the first place the scientific knowledge it develops is directed at understanding why a certain therapy influences humans in a given way, and secondly, the curative or preventative therapies the sector develops are directly connected to improving the quality of life of people (Stremersch and Van Dick, 2009, p. 5). The main industries included in the life sciences sector are therefore pharmaceuticals, biotechnology and medical devices. Alongside these there is a third and emerging segment of firms specialized in the production of cosmetics (cosmeceuticals) and food products with therapeutic characteristics (nutraceuticals). Lastly, there is a fourth segment of firms specialized in delivering services to support these industries;

this segment includes laboratories for analysis and clinical tests, diagnostic services, laboratories of bioinformatics and bioelectronics, and contract research organizations (CRO).

As has already been indicated, the life sciences cluster represents an appropriate context to respond to the research questions for four main reasons. First of all, the biotech sector and the life sciences in general tend to cluster geographically, which means this study is coherent with earlier empirical works based on these groups of firms (Casper, 2007; Moodysson *et al*., 2008). Then, the Tuscan cluster is third in Italy for its concentration of pharmaceutical and biotechnological industries, only preceded by the regions of Lombardy and Piedmont (Farmindustria, 2011; AssoBiotech, 2012). Thirdly, the cluster has evolved from the local level, as a first grouping of firms around a scientific park, to the regional level and is preparing for the next level of evolution to the national and international level. Lastly, the geographic proximity between the research team and the empirical setting has simplified control of the consistency and quality of the research data.

Initially, all 317 firms which operate in the field of life sciences in the Tuscan cluster were taken into consideration. The list was drawn up based on national censuses of professional associations respectively for the biotech sector (AssoBiotech, 2012), pharmaceuticals (Farmindustria, 2011) and medical devices (AssoBiomedica, 2012) subsequently integrated with data from the Chamber of Commerce. This list is updated to December 2012 and includes only those firms which satisfy four specific criteria: 1) they include the characteristics indicated above for firms belonging to the life sciences sector, 2) they are for-profit, 3) they are not only commercial, 4) they have operational units in Tuscany.

This group of firms employs a total of 19,419 people and had an overall turnover of approximately 7 billion euro in 2011.

The questionnaire was tested with founders and managers of five of the firms respectively representing the five segments of the life sciences sector, with two managers of the Tuscan Life Sciences Foundation[1] and with two members of the Steering Committee of the Tuscan Regional Life Sciences District[2]. The data was gathered through email surveys from March-May 2012. All 317 firms were contacted through a presentation letter in which the research objectives were outlined and the privacy of the data collected guaranteed. Subsequently, the information obtained through the questionnaire was verified and when necessary integrated through follow-up telephone interviews with the spokesperson who had completed the questionnaire in each firm (entrepreneurs, owners or CEOs). Questionnaire data concerning the number of employees, the sales of the firm and the number of patents registered were verified through secondary sources, namely the Chamber of Commerce for the structural data of the firms and the number of patents in the Qpat database.

A total of 151 completed questionnaires were returned for a response rate of 47.63% and an excellent statistical representation of the sample (Table 1).

Table 1. Sectoral classification of life sciences firms: universe and sample of firms (year 2011)

Firms of the Tuscan life sciences sector	**Population**				**Sampled firms**			
	Firms		**Employees**		**Firms**		**Employees**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Biotechnology	36	11.36	673	3.47	24	15.89	487	3.56
Pharmaceuticals	47	14.83	11919	61.37	25	16.56	8297	60.58
Medical devices	116	36.59	3399	17.5	48	31.79	2541	18.55
Cosmeceuticals and Nutraceuticals	28	8.83	817	4.21	9	5.96	691	5.04
Others	90	28.39	2611	13.45	45	29.8	1681	12.27
Total	317	100.00	19419	100.00	151	100.00	13697	100.00

Redemption: 47.63% (151/317). Our elaboration of Chamber of Commerce data, website and interviews with sector experts

4.2 Measures

Dependent variables

There are two dependent variables in our study: the innovation capacity that we measure through patent activity (Belussi *et al*., 2010) and the growth of the firm that we measure through the variations in sales (Dunne and Hughes, 1996; McCann, 1991; Merz and Sauber, 1995; Miller, 1987; Delmar *et al*., 2003; Lee *et al*., 2001). Specifically the PATENTS variable measures the number of patents registered by a firm in the preceding four years (2008-2011). The

[1] "The Tuscan Life Sciences (TLS) Foundation is a non-profit organization that has been active in the regional panorama since 2005 with the objective of supporting research activities in the life sciences and, in particular, of sustaining the development of projects from basic research to industrial application. The founding partners of TLS are the Region of Tuscany, the Monte dei Paschi di Siena Foundation and Bank, the Province of Siena, the Universities of Siena, Pisa, and Florence, the Sant'Anna and Pisa Normale Schools for Advanced Studies and the IMT Institute for Advanced Studies of Lucca, the University Hospital of Siena, and the City and Chamber of Commerce of Siena." (*http://www.toscanalifesciences.info/en/the-foundation*).

[2] The Tuscan Regional Life Sciences District - whose president is Rino Rappuoli, worldwide head of Research for Novartis Vaccines & Diagnostics – was established with resolution no. 603/2010 of the Tuscan Regional Council. The Steering Committee is composed of representatives from the world of industry and research and provides strategic direction for the District.

SALES_GROW variable measures sales carried out by the company in the years 2011 and 2010 subtracting sales from 2009 and 2008.

Internal capabilities and resources

The first group of independent variables refers to the internal capabilities and resources of the firms. To measure capabilities we used three multi-item constructs already validated in the literature (Table 2).

The managerial capability construct, MANAG_CAP (α = 0.89), developed by Hooley *et al*. (2005), is measured by three items that evaluate the competences of the firm in managing its financial and human resources as well as its operational activities. The technology orientation construct, TECH_OR (α = 0.89), developed by Zhou and Li (2010), is measured by four items which evaluate the degree with which the firm is able to use and manage new technologies and scientific discoveries within its own organization and in its products. The relational skills construct, REL_SKILL (α = 0.91), developed by Walter *et al*. (2006), is measured by five items which evaluate the capability of the firm to manage its partnerships; therefore it does not evaluate the ability of the firms to create new and different relationships but rather their skill in managing a relationship once created (Draulans *et al*., 2003).

As can be noted in Table 2, all constructs have a Cronbach's α higher than 0.80, indicating a high level of reliability. Furthermore, total correlations vary from 0.53 to 0.80, thus all above the threshold of 0.45 suggested in the literature (Parker *et* al., 1997). To ensure an acceptable rapport between observations and items, an exploratory factorial analysis was carried out. The items were factorized using maximum-likelihood estimation and promax rotation. The factor loadings were superior to 0.77 and without significant cross-loadings, thus assuring convergent validity (that is, the degree of agreement among two or more measurements within the same construct). To test the discriminant validity, that is, the extent to which the measurements of conceptually distinct constructs differ among themselves, a confirmatory factorial analysis was conducted. The average variance extracted (AVE) from this varies from 0.65 to 0.71, all above the threshold of 0.50 suggested in the literature (Hair *et al*., 2009). The evidence furnished by the validity and reliability measurements allows us to use the average scores of the items of each construct in the analysis which follows.

The internal resources are measured by the number of specialized (Master or PhD) (SPEC) employees in the firm (cf. Caloghirou *et al*., 2004) and by the logarithm of the expenditures in R&D (RD_EXP) allocated on average by the firm in the 2006-2011 period, if available (cf. Belussi *et al*., 2010; Lee *et al*., 2001). The choice of using the mean R&D expenditures over the last 6 years was made in order to allow a temporal lag of at least two years from the investment in R&D to the period of patent activity (cf. Lee *et al*., 2001).

Table 2. Internal capabilities: measurement items and validity assessment (N = 151)

Measure	Item description [a]	Total correlat.	Factor Loading*
Relational skills α = .91 AVE = .67 (Our adaptation from Walter *et al*., 2006)	*To what extent do the following statements apply to your organization?* 1. We have the ability to build good personal relationships with business partners 2. We can put ourselves in our partners' position 3. We can deal flexibly with our partners 4. We almost always solve problems constructively with our partners 5. We analyze what we would like and desire to achieve with which partner	.53 - .80	.77 - .84
Technology orientation α = .89 AVE = .65 (Zhou and Li, 2010)	*With reference to your technology orientation, to what degree do you agree with the following statements:* 1. We use sophisticated technologies in our new product development 2. Our new products are always at the state of the art of the technology 3. Technological innovation, based on research results, is readily accepted in our organization 4. Technological innovation is readily accepted in our program/project management	.55 - .76	.78 - .85
Managerial capabilities α = .89 AVE = .71 (Hooley *et al*., 2005)	*To what extent do the following statements apply to your organization?* 1. Strong financial management capabilities 2. Effective human resource management 3. Good operations management expertise	.72 - .74	.83 - .85

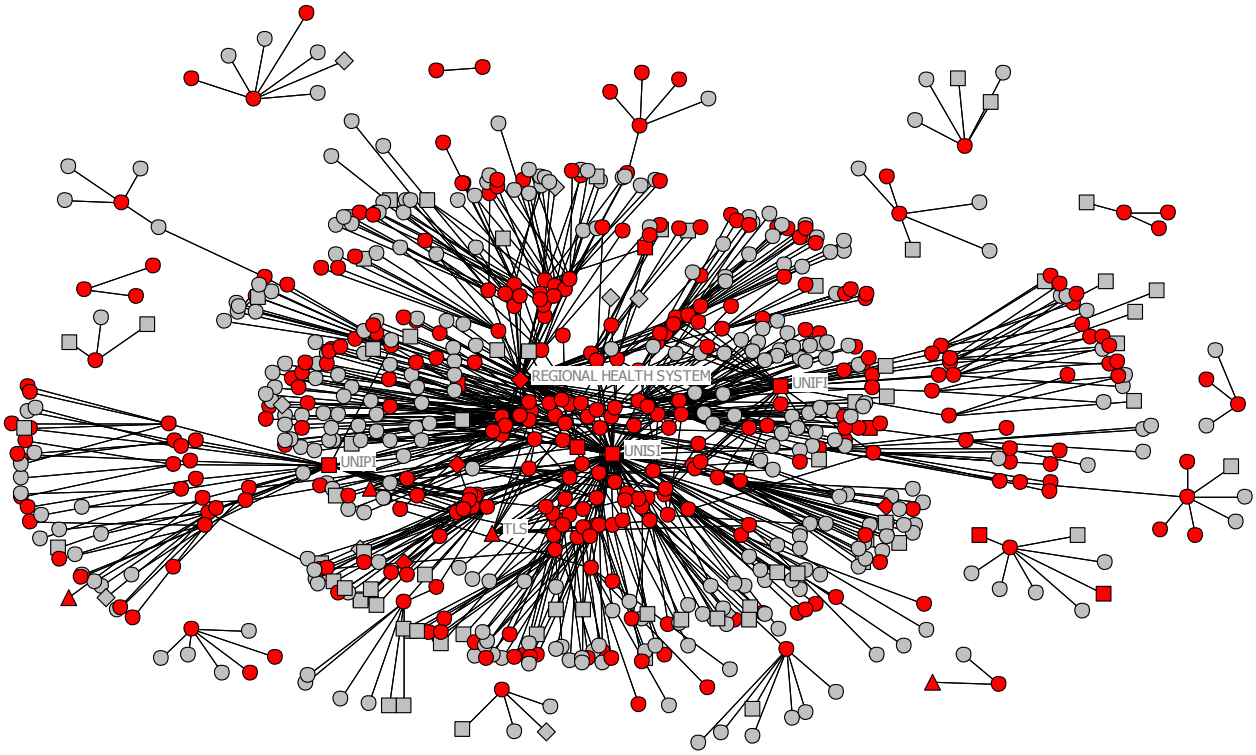
[a] Seven-point scale anchored at 1 = *not at all* and 7 = *to an extreme extent*.

* Promax rotation.

Inter-organizational architecture

To construct the measurements relative to the inter-organizational architecture for each firm, the questionnaire asked for the name and location of those partners considered strategically relevant to each firm's activity. For each partner the type of activity was requested as well, that is, if it was another firm/private entity, a public research organization (PRO), a public institution (not research) or a scientific park/incubator. Lastly, firms were asked to specify the reason for the relationship, if it was for operational reasons (supply, distribution, sales) or rather for reasons related to R&D and improvement of innovation. The data collected allowed us to create the relational map in Figure 2.

As can be noted, some institutions seem pivotal within the network; in particular the three public universities of Florence (UNIFI), Pisa (UNIPI) and Siena (UNISI) and the Regional Health System[3] are the nodes with the greatest number of links (network degree).



Node key:

Red circles are intra-cluster firms, gray circles are extra-cluster firms, red boxes are intra-cluster PROs, gray boxes are extra-cluster PROs, red diamonds are intra-cluster Public Institutions, gray diamonds are extra-cluster Public Institutions and red triangles are Scientific Parks/Incubators.

Figure 2. The network within and across the cluster boundaries

In Table 3 the general characteristics of the total network and its connected component are reported.

[3] The Regional Health System node represents the breakdown of all the relationships which firms have with one or more of the 12 Local Health Units, that is, the public firms into which the regional health system is articulated.

Table 3. General characteristics of the total network and of the connected component

Index	Total Network	Connected component
Number of nodes	756	695
Number of ties	917	868
Density	0.0032	0.0036
Average degree	2.426	2.498
Network degree centralization	3.26%	3.54%
Network closeness centralization*	-	28.70%
Network betweenness centralization	38.33%	45.33%
Clustering coefficient	0.069	0.073
Average distance	4.350	4.352

* The centrality index is not calculated since the total network is not connected

Table 4 reports, instead, the spatial distribution of the mapped links for each type of relationship. The geographic distance of the relationship is measured by whether the unit belongs to the regional cluster or not. Therefore, local relationships are those which the firm has created with other regional units (intra-cluster) and distant relationships are those with entities outside the region (extra-cluster). Almost 62% of the relationships are firm-to-firm, nearly 20% is firm-to-PRO, 16% are relationships with public institutions (not research), while only 2% are relationships with scientific parks or incubators within the cluster.

Table 4. Types and spatial distribution of the overall relationships of the 151 sampled firms

Type of relation	N.	%	Mean
Firm-to-firm relationships			
Intra-cluster	232	25.30	1.54
Extra-cluster	336	36.64	2.23
Firm-to-PRO relationships			
Intra-cluster	106	11.56	0.70
Extra-cluster	74	8.07	0.49
Firm-to-Publ. Inst. relationships			
Intra-cluster	140	15.27	0.93
Extra-cluster	9	0.98	0.06
Firm-to-Sc. Park/Incub. relationships			
Intra-cluster	20	2.18	0.13
Extra-cluster	0	0.00	0.00
Total	917	100.00	6.07

Table 5 reports the inter-organizational architecture measurements which are used in the econometric analysis presented below. The number of operational relationships separated into local and distant (INTRA_OP and EXTRA_OP) and the number of innovation oriented relationships, likewise separated into local and distant (INTRA_INNOV and EXTRA_INNOV) are counted for each firm.

Table 5. Strategic domain and spatial distribution of the overall relationships of the 151 sampled firms (ego-network measures)

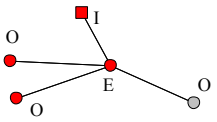
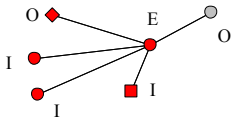
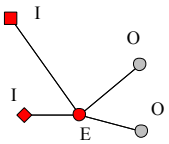
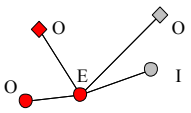
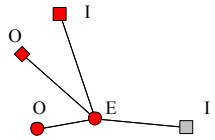
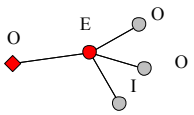
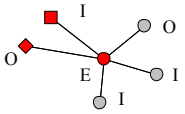
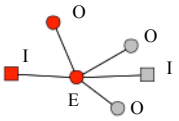
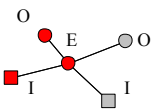
Strategic domain	N	Mean
Innovation-oriented		
Intra-cluster	190	1.26
Extra-cluster	242	1.60
Operational		
Intra-cluster	340	2.25
Extra-cluster	176	1.17
Total *	948	6.28

* 31 ties are among companies in the sample.

Lastly and for purely descriptive reasons, Table 6 reports on the different types of inter-organizational architecture according to the type and the localization of the prevalent relation. Even if the size of the sample did not allow this distinction to be considered in the econometric models subsequently used, it is interesting to note how many of the

firms (25.8%) have an inter-organizational architecture prevalently centered within the cluster. Nearly 58% of the firms all the same has prevalent or balanced (the same number of innovative relationships internal and external to the cluster) innovative extra-cluster relationships. This represents a first confirmation of what has been recently indicated in part of the literature, that non-local relationships are as important as local relationships for the development of innovative activity (Boscham and Ter Wal, 2007; Bathelt *et al*., 2004).

Table 6. Types of inter-organizational architecture

Type of innovative tie prevailing	Type of operational tie prevailing	N.	%	Example*
Intra-cluster	Intra-cluster	39	25.8	
Intra-cluster	Balanced	9	6.0	
Intra-cluster	Extra-cluster	16	10.6	
Extra-cluster	Intra-cluster	38	25.2	
Balanced	Intra-cluster	17	11.3	
Extra-cluster	Extra-cluster	12	7.9	
Extra-cluster	Balanced	8	5.3	
Balanced	Extra-cluster	5	3.3	
Balanced	Balanced	7	4.6	

* Example of a minimal inter-organizational architecture containing at least three types of relationships.
Legend:
E: Ego; I: innovation partner; O: operational partner.
Red circles are intra-cluster firms, gray circles are extra-cluster firms, red boxes are intra-cluster PROs, gray boxes are extra-cluster PROs, red diamonds are intra-cluster Public Institutions and gray diamond are extra-cluster Public Institutions. Lines are direct relationships.

able 7. Measures, correlations and descriptive statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Sales_grow	1000																
2. Patents	0.566**	1.000															
3. RD_exp (log)	0.291**	0.272**	1.000														
4. Spec	0.473**	0.397**	0.419**	1.000													
5. Rel_skill	-0.049	0.068	0.155^	0.054	1.000												
6. Tech_or	0.193*	0.231**	0.373**	0.152^	0.404**	1.000											
7. Manag_cap	0.375**	0.307**	0.202*	0.487**	0.082	0.122	1.000										
8. Intra_innov	0.144	0.150^	-0.011	0.098	0.021	0.006	0.101	1.000									
9. Extra_innov	0.530**	0.779**	0.402**	0.419**	0.087	0.345**	0.283**	0.136^	1.000								
10. Intra_op	0.502**	0.435**	0.306**	0.473**	-0.041	0.086	0.446**	0.320**	0.432**	1.000							
11. Extra_op	0.163^	0.183*	0.171*	0.199*	0.159^	0.137	0.016	0.250**	0.251**	0.142^	1.000						
12. Size (log)	0.522**	0.467**	0.609**	0.786**	0.111	0.258**	0.525**	0.114	0.592**	0.533**	0.215**	1.000					
13. Start_up	-	-0.089	-0.234**	-0.146^	-0.085	-0.049	-0.120	0.001	-0.106	-0.028	-0.121	-0.204*	1.000				
14. Age	0.216*	0.125	0.390**	0.500**	0.076	0.091	0.304**	-0.067	0.253**	0.168*	0.096	0.628**	-0.368**	1.000			
15. Spin_off	-0.087	-0.079	-0.152^	-0.172*	-0.049	0.029	-0.144	0.179*	-0.138^	-0.030	-0.036	-0.283**	0.117	-0.245**	1.000		
16. Pharma	0.318**	0.235**	0.117	0.290**	0.075	0.011	0.163*	-0.043	0.239**	0.150	-0.092	0.305**	-0.040	0.338**	-0.062	1.000	
17. Biotech	-0.072	-0.049	-0.033	-0.131	0.071	0.123	-0.104	0.193*	0.053	0.019	0.031	-0.099	0.169*	-0.223**	0.108	-0.194*	1.000
N	128	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Mean	5.511	5.808	9.671	9.046	5.460	5.033	4.446	1.258	1.603	2.252	1.166	2.419	0.152	17.742	0.126	0.166	0.159
Std. Dev.	21.576	23.582	4.858	16.751	1.124	1.139	1.225	1.016	2.236	1.870	1.197	1.806	0.361	18.136	0.333	0.373	0.367
Min	-3.741	0.000	0.000	0.000	1.600	1.000	2.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
Max	201.767	191.000	18.642	89.000	7.000	7.000	7.000	4.000	14.000	9.000	6.000	7.869	1.000	107.000	1.000	1.000	1.000

^ $p < .10$; * $p < .05$; ** $p < .01$; Sales growth is in mln of euros. Sales growth is calculated only for firms older than 3 years. Log of RD_exp is conventionally set to 0 for R&D expenditure equal to zero.

Control variables

As early as the 1960s the literature indicated how the growth of a firm could be influenced by its age, dimensions and industry affiliation (Penrose, 1959; Stinchcombe, 1965). Therefore, during the tests conducted to verify the relationships hypothesized, some control variables were introduced which could have an influence on the innovative capacity and on the economic growth of the firms. The dimensions of firms (SIZE) were measured as logarithms of the number of employees. The age (AGE) of the firm was measured by the number of years passed since the firm was

founded. The origin of the firm was controlled introducing two dummy variables, one for the firms of academic origins (SPIN_OFF) (1 = *spin-off*, 0 = non *spin-off*) and one for the firms in a start-up phase (START_UP) (1 = 3 years or less of existence, 0 = more than 3 years of existence). The segment a firm belonged to was controlled by introducing two dummy variables for the pharmaceutical (PHARMA) and biotechnological (BIOTECH) segments.

Table 7 furnishes the descriptive statistics and the correlations among all the variables used in the study. We point out that the number of observations considered for the economic growth of the firms is 128 because 23 firms were less than three years old and obviously it would not be possible to measure the SALES_GROW variable as it was constructed in these cases.

4.3. Analytical approach

In order to investigate the relation between patent activity, internal resources and capabilities and inter-organizational architecture, we have chosen to use a count data econometric model based on the likelihood approach: the zero-inflated negative binomial (ZINB) model. The choice was motivated both by the discrete nature of the response variable (number of patents) and by the high proportion of zeros within this which would render the use of other econometric models inappropriate. In particular, the excess of zeros may originate from two distinct processes. In the first case, the value "0" is listed for those firms which have never registered patents. In the second case, the "0" may originate from the fact that the firms sampled did not carry out any patent activity in the window of time under consideration.

To specify the ZINB model let:

- $f(y_i, \delta|X_i)$ be the function of probability of the negative binomial with expected value $\mu=exp(X_i\beta)$, parameter of overdispersion α, $\delta=(\beta'\alpha)'$ and y_i the count;
- X_i be a vector of explicative variables;
- π be the probability to count "0" in the model of presence/absence estimated by a logit function that depends on an observed vector of covariate W_i: $\pi_i=exp(W_i\vartheta)/[1+exp(W_i\vartheta)]$; π is therefore the parameter which inflates the proportion of the zeroes;

thus:

$$Pr(y_i) = \begin{cases} \pi_i + (1-\pi_i)f(y_i = 0, \delta|X_i), & for\ y_i = 0 \\ (1-\pi_i)f(y_i, \delta|X_i), & for\ y_i = 1,2,\dots \end{cases}$$

Table 8 reports the VIF scores and the tolerances of the explanatory variables for the ZINB model. These values (compared as well to the correlation values of Table 7) do not indicate significant issues of multicollinearity among variables.

Table 8. VIF scores and tolerances (explanatory variables for ZINB model)

Variables	VIF scores	Tolerance
RD_exp (log)	1.47	0.68
Spec	1.72	0.58
Rel_skill	1.24	0.81
Tech_or	1.45	0.69
Manag_cap	1.47	0.68
Intra_op	1.72	0.58
Extra_op	1.19	0.84
Intra_innov	1.20	0.83
Extra_innov	1.56	0.64

Mean VIF: 1.45. Condition number: 21.730

Table 9. VIF scores and tolerances (explanatory variables for OLS model)

Variables	VIF scores	Tolerance
Patents	1.38	0.73
Spec	1.57	0.64
Rel_skill	1.23	0.81
Tech_or	1.26	0.79
Manag_cap	1.46	0.68
Intra_op	1.54	0.65
Extra_op	1.10	0.91

Mean VIF: 1.37. Condition number: 18.781

To investigate instead the relationships among patent activities, resources and internal capabilities, inter-organizational architecture and growth of the firms (variation of sales), we employed ordinary least squares (OLS) regression. In Table 9 the VIF scores and the tolerances of the explanatory variables inserted into the regression model are reported. Also in this case the values (compared as well to the correlation values of Table 7) do not indicate significant issues of multicollinearity among the variables.

5. Results

5.1 ZINB model

Table 10 reports the results of the count data regression for the study of the effect of the explicative variables on the innovation capacity of the firms measured as the number of patents registered.

The control variables were inserted at the first stage (Model 1); the capabilities and internal resources were inserted in stage two (Model 2), while at the third stage the measurements relative to the inter-organizational architecture were added (Model 3).

Table 10. Results of the zero-inflated negative binomial regression

	Mod. 1	Mod. 2	Mod. 3
Number of Patents			
RD_exp (log)		0.304*	0.063
		(2.49)	(0.72)
Spec		0.002	-0.008
		(0.07)	(-1.26)
Rel_skill		-0.176	-0.203
		(-0.87)	(-1.62)
Tech_or		0.936**	0.419**
		(4.38)	(3.52)
Manag_cap		-0.187	-0.103
		(-1.22)	(-1.10)
Intra_op			-0.107^
			(-1.68)
Extra_op			-0.041
			(-0.54)
Intra_innov			-0.036
			(-0.38)
Extra_innov			0.461**
			(8.83)
Size (log)	0.499**	0.154	0.004
	(4.24)	(0.95)	(0.04)
Start-up	-0.849**	-0.569*	-0.112
	(-2.83)	(-2.03)	(-0.39)
Spin-off	0.287	-0.015	0.032
	(0.68)	(-0.04)	(0.09)
Pharma	0.529	0.971*	1.11**
	(0.92)	(2.27)	(4.88)
Biotech	0.514	0.199	0.169
	(1.54)	(0.61)	(0.83)
Constant	0.012	-6.282**	-1.283
	(0.03)	(-2.93)	(-0.86)
Inflate			
Intra_innov	0.009	-0.557	-0.195
	(0.03)	(-0.61)	(-0.40)
Extra_innov	-1.914**	-2.362**	-1.738**
	(-4.62)	(-2.56)	(-4.45)
Spec	0.018	0.002	0.012
	(1.16)	(0.08)	(0.73)
RD_exp (log)	-0.583**	-0.176	-0.641**
	(-3.61)	(-0.76)	(-4.26)
Constant	8.098**	4.192^	8.611**
	(3.90)	(1.65)	(4.67)
Wald Chi2	78.61**	114.51**	717.59**
LOG pseudo-L	-227.327	-216.931	-179.169
α [a]	1.082**	0.888**	0.114*

^ p < .10; * p < .05; ** p < .01; N = 151; *z* in parentheses. [a] Significance expressed for LR test of $\alpha = 0$

Among the inflate variables chosen to measure the probability of not registering at least one patent[4] the only significant ones are R&D expenditures and the relationships oriented to extra-cluster innovation. As we might have expected, the tendency to pursue patent activity is positively associated to the firm's investments in R&D. Contrary, instead, to what we might have expected, intra-innovative relationships do not have a significant effect on the probability of registering a patent. As regards the count, the technology orientation is positive and significant in explaining the number of patents registered as are extra-innovative relationships. The intra-operational relationships instead associate negatively and significantly. With reference to the control variables the only significant in the full model (Mod. 3) is PHARMA. That highlights how the pharmaceutical industry have a greater capacity for innovation (number of patents) compared to other areas of the Life Sciences. Table 11 reports the regression models complete with the addition of the interaction terms. All the variables involved in the interaction terms relative to the multi-item constructs are centered on the average to reduce multicollinearity (Aiken and West, 1991). W e chose not to introduce all the interaction terms in a single model first to avoid problems of multicollinearity and secondly because the dimension of our sample was not enough to permit the operation (cf. Lee *et al*., 2001). Table 11 reports only the significant interaction terms: *Tech_or* x *Intra_op* (β = 0.104), *Extra_innov* x *Spec* (β = 0.004) and *Rel_skill* x *Extra_innov* (β = 0.091).

Table 11. Results of the zero-inflated negative binomial regression with interactions

	Mod. 4	**Mod. 5**	**Mod. 6**
Number of Patents			
RD_exp (log)	0.027	0.039	0.068
	(0.35)	(0.54)	(0.83)
Spec	-0.010	0.008	-0.012
	(-1.58)	(0.71)	(-1.63)
Rel_skill	-0.200^	-0.216^	0.114
	(-1.70)	(-1.68)	(0.58)
Tech_or	0.686**	0.353*	0.432**
	(3.68)	(2.56)	(3.58)
Manag_cap	-0.074	-0.101	-0.146
	(-0.86)	(-1.03)	(-1.49)
Intra_op	-0.038	-0.054	-0.068
	(-0.77)	(-0.85)	(-1.08)
Extra_op	-0.042	-0.056	-0.145^
	(-0.70)	(-0.79)	(-1.79)
Intra_innov	-0.036	-0.043	-0.022
	(-0.44)	(-0.35)	(-0.23)
Extra_innov	0.479**	0.661**	0.511**
	(9.31)	(4.73)	(10.82)
Tech_or x *Intra_op*	0.104*		
	(2.30)		
Extra_innov x *Spec*		0.004^	
		(1.79)	
Rel_skill x *Extra_innov*			0.091*
			(2.33)
Size (log)	0.027	-0.047	-0.031
	(0.28)	(-0.49)	(-0.31)
Start-up	-0.214	0.011	-0.196
	(-0.77)	(0.03)	(-0.74)
Spin-off	0.078	-0.087	-0.133
	(0.24)	(-0.25)	(-0.38)
Pharma	1.093**	1.025**	1.214**
	(4.97)	(4.34)	(5.22)
Biotech	0.075	0.055	0.114
	(0.34)	(0.24)	(0.53)
Constant	-2.552*	-1.090	-2.951^
	(-2.09)	(-0.76)	(-1.67)
Inflate			
Intra_innov	-0.139	-0.424	-0.124

[4] As mentioned above, the ZINB model provides a preliminary estimate of the probability that the count is zero in a logit function.

	(-0.31)	(-0.32)	(-0.23)
Extra_innov	-1.707**	-1.753**	-1.749**
	(-4.32)	(-4.81)	(-4.20)
Spec	0.012	0.024	0.009
	(0.72)	(0.74)	(0.52)
RD_exp (log)	-0.628**	-0.752*	-0.665**
	(-4.29)	(-2.40)	(-4.18)
Constant	8.398**	9.624**	8.643**
	(4.63)	(2.60)	(4.54)
Wald Chi2	1028.68**	757.08**	794.97**
LOG pseudo-L	-177.284	-177.064	-177.154
α [a]	0.082**	0.090**	0.102**

^ p < .10; * p < .05; ** p < .01; N = 151; *z* in parentheses. [a] Significance expressed for LR test of α = 0

5.2 OLS model

Table 12 reports the results of the analysis of the OLS regression of 124 observations; the 23 observations concerning firms in a start-up phase and four outliers have been eliminated[5]. The complete model explains the 80.2% of variance. In this last model, managerial capability (β = 0.596), the number of patents (β = 0.387) and the intra-operational relationships within the cluster (β = 1.417), have a positive and significant effect on the variation in sales.

Table 12. Results of OLS models: sales growth in 2011 and 2010 (N = 124)

Variables	**Mod. 7**	**Mod. 8**	**Mod. 9**
Size (log)	5.133**	1.080	0.339
	(1.561)	(0.833)	(0.695)
Spin-off	2.371^	0.939	0.212
	(1.377)	(0.617)	(0.715)
Age	-0.254*	-0.070	-0.038
	(0.119)	(0.073)	(0.058)
Pharma	6.039^	0.376	0.260
	(3.481)	(2.256)	(2.058)
Biotech	-1.335	-0.880	-1.321
	(1.700)	(0.781)	(0.958)
Rel_skill		-0.462	-0.371
		(0.309)	(0.346)
Tech_or		0.046	0.156
		(0.305)	(0.300)
Manag_cap		0.993**	0.596^
		(0.327)	(0.350)
Spec		0.118	0.105
		(0.091)	(0.077)
Patents		0.398**	0.387**
		(0.052)	(0.048)
Intra_op			1.417**
			(0.459)
Extra_op			0.285
			(0.552)
Constant	-5.398**	-3.159	-4.341^
	(1.698)	(2.049)	(2.338)
Adj. R^2	0.442	0.767	0.802
Incremental *F*-test	-	16.14**	6.23**

^ p < .10; * p < .05; ** p < .01 (two-tailed test). Standard errors are in parentheses

[5] Four multinationals where the sales variations are significantly different from those of the other observations.

Table 13 reports the regression models (Mod. 10 – Mod. 15) complete with the addition of interaction terms. In this case as well all the variables in the interaction terms relative to the multi-item constructs are centered on the average to reduce multicollinearity (Aiken and West, 1991). The significant interaction terms are: *Manag_cap* x *Patents* (β = 0.159), *Manag_cap* x *Spec* (β = 0.141), *Manag_cap* x *Intra_op* (β = 1.146), *Intra_op* x *Spec* (β = 0.104), *Patents* x *Intra_op* (β = 0.068) and *Patents* x *Spec* (β = 0.008).

Table 13. Results of OLS models with interactions: sales growth in 2011 and 2010 (N = 124)

Variables	Mod. 10	Mod. 11	Mod. 12	Mod. 13	Mod. 14	Mod. 15
Size (log)	0.727	0.979	0.402	0.635	0.869	0.783
	(0.718)	(0.665)	(0.640)	(0.579)	(0.708)	(0.697)
Spin-off	0.070	0.355	1.103	0.671	0.077	0.080
	(0.683)	(0.738)	(0.856)	(0.496)	(0.608)	(0.660)
Age	-0.024	-0.045	-0.019	-0.000	-0.032	-0.025
	(0.055))	(0.049)	(0.042)	(0.032)	(0.048)	(0.057)
Pharma	0.478	-0.695	0.010	-1.442	0.986	0.735
	(1.896)	(1.660)	(1.544)	(1.215)	(1.769)	(1.903)
Biotech	-0.316	-0.943	0.126	-0.680	-0.400	-0.384
	(1.167)	(0.880)	(0.963)	(0.890)	(1.053)	(1.150)
Rel_skill	-0.302	-0.107	-0.308	-0.174	-0.415	-0.327
	(0.339)	(0.357)	(0.288)	(0.229)	(0.329)	(0.347)
Tech_or	0.537*	-0.144	-0.0132	-0.100	0.585*	0.531^
	(0.270)	(0.328)	(0.318)	(0.207)	(0.250)	(0.288)
Manag_cap	0.224	-0.280	-2.398*	0.435	0.515	0.462
	(0.384)	(0.378)	(1.030)	(0.299)	(0.345)	(0.372)
Spec	0.080	-0.076	0.088	-0.240^	0.077	0.064
	(0.076)	(0.095)	(0.068)	(0.145)	(0.075)	(0.077)
Patents	0.022	0.345**	0.337**	0.303**	-0.099	-0.010
	(0.155)	(0.054)	(0.047)	(0.042)	(0.108)	(0.165)
Intra_op	1.282**	1.148**	0.820**	0.045	1.038**	1.266**
	(0.430)	(0.339)	(0.276)	(0.190)	(0.351)	(0.443)
Extra_op	0.191	0.515	-0.092	0.212	0.104	0.176
	(0.536)	(0.546)	(0.430)	(0.310)	(0.473)	(0.549)
Manag_cap x *Patents*	0.159**					
	(0.061)					
Manag_cap x *Spec*		0.141*				
		(0.062)				
Manag_cap x *Intra_op*			1.146**			
			(0.411)			
Intra_op x *Spec*				0.104**		
				(0.028)		
Patents x *Intra_op*					0.068**	
					(0.015)	
Patents x *Spec*						0.008**
						(0.003)
Constant	-4.993*	-0.920	9.746^	-1.592	-5.501**	-5.925**
	(2.195)	(2.249)	(4.965)	(1.593)	(2.054)	(2.210)
Adj. R^2	0.828	0.832	0.848	0.906	0.856	0.822
Incremental *F*-test	6.90**	5.12*	7.78**	13.93**	20.42**	7.46**

^ p < .10; * p < .05; ** p < .01 (two-tailed test). Standard errors are in parentheses

6. Discussion and conclusions

This study proposed evaluating how internal capabilities, inter-organizational architecture and their interaction contribute to the development of innovation capacity of firms and their growth, measured in variation in sales. In table 14 we summarize the results with reference to the assumptions made.

Table 14. Hypotheses confirmation

Hp. n.	Variables	Innovative cap.		Growth	
		Confirmed without interaction	*Confirmed with interaction with*	*Confirmed without interaction*	*Confirmed with interaction with*
H1a	*Technology orientation*	Yes	Yes with: *Local operat. relat.*		
H1b	*Relational skills*	No	Yes with: *Distant operat. relat.*		
H1c	*R&D expenditure*	No*	-		
H1d	*Human resources*	No	Yes with: *Distant operat. relat.*		
H2a	*Local innovative relat.*	No	-		
H2b	*Distant innovative relat.*	Yes	-		
H3	*Managerial capabilities*			Yes	Yes with: *Innovative capabilities*; *Human resources*; *Local operat. relat.*
H4	*Innovative capabilities*			Yes	Yes with: *Managerial capabilities*; *Local operat. relat.*; *Human resources*.
H5a	*Local operat. relat.*			Yes	Yes with: *Human resources*; *Managerial capabilities*; *Innovative capabilities*.
H5b	*Distant operat. relat.*			No	-

Notes: * The variable *R&D expenditure* is significant in explaining the *propensity* of a firm to undertake patent activity but not the amount of such activity.

As in previous studies (Belussi *et al*., 2010), the results indicate (and only partially confirm research hypothesis H1c) that investments in R&D are determinative in the tendency of a firm to undertake patent activity. Different from those earlier findings, however, the amount of such activity does not associate significantly with an increase in R&D expenditures. This indicates the existence of a threshold effect beyond which further R&D expenditures do not have a significant impact on the number of patents registered. Positive effects on patent activity can be had instead by increasing the number of distant innovation relationships (cf. Bathelt *et al.*, 2004; Doloreux, 2004), confirming hypothesis H2b, and by increasing a firm's technology orientation (confirming hypothesis H1a), whereby the firm is able to use and manage new technologies and scientific discoveries (cf. Zhou and Yim and Tse, 2005; Zhou and Li, 2010). Technology orientation is also useful in utilizing local operational relationships effectively (and innovatively), and here, too, the results are coherent with the literature reviewed. A firm that is constantly up-to-date about cutting-edge technology in its own sphere of activity can more efficaciously use its learning skills, even in strictly operational relationships (supply, distribution, etc.). The firm is in this case more predisposed to recognize and absorb (Cohen and Levinthal, 1990; Beghman *et al*., 2012) any information potentially relevant to its own innovation activity even in the case of relationships not directly connected with the development of new products. Relational skills are likewise positively associated with innovation capacity if they interact with innovation-oriented distant relationships. These capabilities can thus enhance external relationships, partially confirming research hypothesis H1b (cf. Ling-Yee and Ogunmokun, 2001; Hooley *et al*., 2005). There has been no confirmation, instead, of what was claimed in the literature about industrial clusters generating and spreading new knowledge (Aharanson *et al.*, 2004; Giuliani and Bell, 2005; Bell, 2005). Innovation-oriented local relationships are not positively associated with the number of patents registered by the firms in this sample (thus not confirming H2a). This may be explained in part by the fact that not all innovation-oriented relationships lead to a patent, and this explanation is further confirmed by the fact that Italian companies have historically been little inclined to register patents (Malerba, 1993). Global relationships may instead facilitate the transformation of innovation activity into patents (Boschma and Ter Wal, 2007). Lastly, human capital is significant only if considered within the interaction of innovation-oriented distant relationships, once again partially confirming hypothesis H1d.

Turning now to the effect on the economic growth of firms, the three features of managerial capability, number of patents and local operational activity associate positively with a positive variation in sales. As regards managerial capability and the level of innovation capacity, the results find a confirmation in the literature (Day, 1994; Hooley *et al*., 2005; Stuart, 2000; Zaheer and Bell, 2005; Lew and Sinkovics, 2012) and confirm our research hypotheses H3) and H4). As regards instead local operational relationships, only our hypothesis H5a) is confirmed, not H5b). An increase in local ties and embeddedness increases the knowledge and trust among subjects within a cluster who thus feel they belong to a common institutional and social framework (Kogut, 2000). This may help improve the economic performance of those firms whose inter-organizational architecture is made of operational ties prevalently centered within the cluster (Uzzi, 1996).

7. Implications, limitations and directions for future research

Several managerial and industrial policy implications emerge from this research. First of all, the results indicate that in R&D-intense sectors scientific and technological competences are not in themselves sufficient to guarantee the best strategic performance and thus the growth of the firm; the managerial component of the business activity appears to be just as significant in reaching greater strategic results. Secondly, public policies on innovation which limit support to merely reinforcing the R&D resources of firms run the risk of having little effect if further complementary actions are not taken. In particular, at first glance it would seem to be equally important to support the managerial growth of high-tech firms as well as to encourage cooperation – among firms and between firms and the world of research – directed at increasing the innovation potential of the regional system. Third industrial policies which want to support economic growth mainly reinforcing proximate connections between local partners seems non effective if they are not able to balance a mix of internal and external resources. Economic performance seems in fact positively associated to different strategies which are able to create at the same time: i) dynamic capabilities through the combination of distant external innovative connections associated with internal qualified human resources (from both universities and firms) and ii) efficiency based on qualified local operational relationships combined with effective internal management capabilities.

The research study also has some limits. The first is connected to the usual problem of survey research: although the controls did not indicate significant problems of common method variance, its potential influence cannot be completely excluded in a self-report research study (Podsakoff *et al*., 2003; Podsakoff and Organ, 1986) as regards the constructs for the capabilities within the firms. Moreover, the research design based on individual responses may represent a limitation. Secondly, the cross-sectional nature of the research could be a potential source of criticism, and future studies could employ a longitudinal research design to examine the dynamics and timing of the examined relationships. Lastly, the work is entirely based on the evidence from a particular regional cluster. If on the one hand the Tuscan cluster represents the third-largest life sciences cluster in Italy, on the other the specific characteristics of its context might limit the generalizability of the results obtained. A national or international comparison among clusters at the same developmental level would help to further validate the results.

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