UNIVERSITÀ DEGLI STUDI DI FERRARA
DIPARTIMENTO DI ECONOMIA ISTITUZIONI TERRITORIO
Via Voltapaletto, 11 – 44100 Ferrara

Quaderno n. 14/2011

October 2011

Role of external knowledge flows in cluster upgrading: an empirical analysis of the Mirandola biomedical district in Italy

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Abstract

The paper analyses the role of external knowledge flows in the upgrading of the biomedical district of Mirandola, Emilia-Romagna region, in Italy. The district produces two types of products, namely disposables and electromedical machines, and the paper considers this second production type. The Mirandola district has been able to maintain a relatively good competitive position. The paper shows that while all firms in this sector in this region tend to have fairly good performance in terms of size and revenue growth, a significant difference exists in terms of innovation performance. Firms in the Mirandola district produce more patents and more scientific publications. From a methodological point of view, negative binomial regressions are made on the determinants of patenting and publishing activity by firms. Two major factors seem to explain the superior performance in terms of innovation. First, the significant role of the leader firms in the district. Second, linkages external to the district, namely relationships with research centres (universities in particular) located not only in the region but also in the rest of the country and abroad. The importance of external relations and institutional diversity (in terms of variety of institutions collaborating in scientific publications), appear to grow over time.

Keywords: innovation, upgrading, industrial districts, biomedical sector.

JEL codes: O31, L60, R11

1. Introduction

The paper aims at analysing the role of external knowledge flows in the upgrading of the Mirandola district, operating in the biomedical instruments sector and located in the city of Mirandola in the Emilia-Romagna region, in Italy. The district has produced two types of products, namely disposables or plastic products to be used in medical surgery only once, as well as electromedical machines, to be used in medical diagnosis, dialysis, cardio surgery and blood transfusion. Although confronted to intense and increasing competition, like other districts do, the Mirandola district has been able to maintain a relatively good competitive position, being able to grow despite the crisis.

We use the term cluster upgrading as the capacity of the cluster to improve products and/or production process and adapt to structural changes in the market and therefore face changing competitive conditions. The concept of upgrading seems to have been used for the first time in the context of clusters in developing countries (Humphrey and Schmitz, 2000; 2002). Humphrey and Schmitz (2004) generalise their findings to the case of clusters in developed countries. These authors distinguish between four types of upgrading, namely process upgrading, whereby the production process is made more efficient, sometimes by the use of new technology; product upgrading, namely the improvement in the quality or knowledge content of the product; functional upgrading, namely the improvement in the functional operations of the firm, and inter-sectoral upgrading, namely the use of competencies or knowledge originating in other sectors to make improvements in own activities.

In this paper, I focus on product and process upgrading, namely the capacity to introduce new processes and new products, measured through innovative outputs. The measures I use are the number of patents and the number of scientific publications, that is, the publication of articles in scientific journals. Although publications in scientific journals tend to regard mostly basic research, the literature has looked at the behaviour of firms regarding publishing and has found that businesses in all sectors increasingly publish scientific papers. The main reasons for publishing seem to be linked to the growing collaboration between firms and universities, since most publications include co-authors from universities.

After a literature review of cluster upgrading in the various sectors, the paper examines the upgrading processes of the firms in the Mirandola district, focusing on one production activity, namely electro-medical machine production. Previous research focused on the evolution of the Mirandola district in the 1990s, stressing the role of large firms in the district (Biggiero, 2002), the patenting activity of firms in the late 1980s and early 1990s (Santarelli, 2004) and the role of social capital in innovative activities (Cainelli et al., 2007, regarding innovation in the period 2000 to 2002). These studies are primarily concerned with the production of disposable products, which is not the focus of this paper.

For this purpose, I build a database of the firms in the electro-medical production sector of the whole region, in order to distinguish firms belonging to the district to firms realising the same activity but not located in the district. I collect and match data on firms' structure, investments and growth, together with firms' performance in terms of size and revenue, data on patents and on scientific publications (respectively from the databanks AIDA, the European Patent office and ISI Web of Sciences).

The paper shows that while all firms tend to have fairly good performance in terms of size and revenue growth, a significant difference exists in terms of innovation performance. Firms in the Mirandola district produce more patents and more scientific publications. From a methodological point of view, negative binomial regressions are made on the determinants of patenting and publishing activity by firms.

More precisely, I examine the determinants of the number of patents and find that being member of the district significantly and positively contributes to increasing the number of patents. I then look at the determinants of research quality measured by the impact of scientific publications, namely papers' citations. While patenting firms are found both within and outside the district, most publishing firms are located within the district. Publishing firms are mainly the larger firms of the district, which seem to have the resources to set-up research collaboration with universities, research centres, hospitals and other firms that end up in scientific publications. Regarding citation impact, I find that external relations represent a key factor of quality, especially collaborations with universities or with various types of institutions. Institutional diversity of collaborators seem to positively affect the quality of research. The geographical extent of collaborative networks seem to have a positive impact too, but to a lesser extent than the type of institutions. In particular, collaborating with regional institutions does not significantly improves the impact of research, indicating a limited effect of the regional innovation system, but only regarding the impact of research. This can be interpreted as evidence of the importance of the capacity of the regional innovation systems to build relationships not only within the system but also outside the system. In other words, building 'global pipelines' (Bathelt et al., 2004) is key.

Although generalisations from particular cases should be made with caution, the paper concludes by highlighting the particular attention policy-makers wishing to support cluster upgrading may put on leading firms in clusters.

The paper is structured as follows. Section 2 reviews the literature on cluster and district upgrading, while section 3 examines the characteristics of the Mirandola district. Section 4 presents the data and methodology used in this paper, while section 5 presents the results of the empirical study. Section 6 concludes.

2. Literature review: upgrading and districts

We are interested in the upgrading of firms and districts in the context of changing competitive conditions. The major structural change facing industry nowadays is globalisation, namely the intensification of world trade and FDI, implying increasing competition in markets. The rising competitiveness of emerging countries in all sectors is also a source of rising competition, but also of rising extent of the market, since markets in emerging countries expand and offer new possibilities.

Clusters in all sectors are therefore faced with increasing competition. The main reaction is to increase the knowledge content of products, raising quality and product innovation and renewal. Globalisation implies that clusters relate more tightly to global networks of knowledge creation, production and commercialisation (Bathelt et al., 2004; Audretsch and Lehman, 2006; De Propris et al., 2008; Hervàs-Oliver and Albors-Garrigos, 2008; Bellandi, 2009). The literature on global value chains (Gereffi, 1994; Sturgeon, 2008) or global production networks (Dickens, 2001; Coe et al., 2004) highlights the rising geographic fragmentation of production processes currently arising in all industrial sectors. Different studies have examined the effects of productive internationalisation on regional clusters (Christopherson and Clark, 2007; Phelps, 2008; Sammarra, Belussi, 2010). Some clusters concentrate on the production phases which are more intensive in intangible assets, namely pre and post manufacturing phases such as research and development, design and subsequently marketing and commercialisation, and delocalise the other production phases. The firms in the cluster that specialised in the delocalised phases find themselves in difficulties and tend to exit markets, implying a reduction in the number of firms in the cluster and a concentration on SMEs that control the most strategic phases.

The cluster may become part of global value chain managed by a firm external to the cluster, in which case the cluster lose autonomy and becomes vulnerable to the will of the leader. Only the capacity to maintain distinctive competencies and create new competencies and knowledge can reduce this vulnerability (Christopherson and Clark, 2007; Phelps, 2008). In other words, only by upgrading can vulnerability reduce.

The term 'upgrading' seem to have been used for the first time in the context of clusters by Humphrey and Schmitz (2000, 2002), in the study of clusters' production processes in developing countries. Humphrey and Schmitz (2004) subsequently generalise results to clusters and production unbundling also in the case of developed countries. They distinguish different types of upgrading according the type of production organisation. They distinguish four types of value chains, according to the degree of control of the firms over their productive activities, from market relations to hierarchy. The different types of production processes in turn determine the type of upgrading which is possible:

1) process upgrading: improvement in the production process, making it more efficient with or without new technology;

2) product upgrading: the product improves by gaining better technical characteristics or a higher product sophistication;

3) functional upgrading: firms change functions and improve the functional aspects of their activity;

4) inter-sectoral upgrading: the firm uses the competencies and knowledge acquired in some activities to move to different sectors.

Overall, two major evolutionary processes seem to arise from the empirical literature on clusters. On the one hand, the cluster develops autonomous capacity in that one or some firms of the cluster adopt or develop new technologies or new products that allow process or product upgrading. The leaders are not necessarily larger than other cluster firm, but they are more dynamic. When they are few they often act in team or in groups (Cainelli and Iacobucci, 2005). On the other hand, the cluster create relationships with external leaders in order to create new product lines or improve productive technology, thereby accessing a global production network.

In the first case, the firms of the cluster can remain independent and often manage a global production network. The cluster will be less vulnerable when the leader remain embedded locally. However, some cases exist whereby leaders move, transferring headquarters in other cities or regions, especially when they grow and get quoted on the stock exchange. This is the case for example of the maritime cluster in the Midwest in Norvegia (Lillebrygfjeld Halse e Bjarnar, 2011) or the case of the ceramic district of North Straffordshire in the UK (Sacchetti and Tomlinson, 2009; Day et al., 2000), where the leaders have moved headquarters to London and consequently became more and more external to the district. The very subsistence of the district was put into question by the leaders' decisions to move many productive phases away from the district to other countries.

In the second case the firms become dependent upon external leaders. As stressed by Bellandi (2001), in this case the effects of the relationship between the cluster and external leaders are determined by not only the cluster's characteristics, but also the degree of embeddedness of the external leaders in the local community. These effects will depend on the type of localization of the external leader, namely on whether the external leader creates a local subsidiary or not; the type of activity created locally (production, R&D, marketing or all of them) and the objectives of the leaders in the creation of relationships with the local firms (acquire products or acquire competencies); the characteristics of the external leader (proprietary assets, organization, production system, and so on); the characteristics of the local cluster (capabilities, local factors that create external economies); the characteristics of transactions (frequency, trust and assets specificity). All these factors combine in different ways and imply different possible effects of the relationship of the cluster with an external leader.

The literature often considers industrial districts as a particular type of cluster, where firms divide a production process locally embedded. Some scholars consider districts as different from clusters, defining them as local societies that can be linked to particular clusters (Bellandi, 2009).

However, the evolution of industrial districts following the changing competitive pressure outlined above is similar to that of clusters in general (Becattini, 2004; Becattini et al., 2009; Carabelli et al., 2007). The first evolutionary process is characterized by the coherent evolution of the district, on the basis of autonomous capacities. The knowledge and competencies necessary to upgrading are found within the district itself, building on the knowledge base accumulated through time (for instance in Italy, the leather-producing Santa Croce district in Tuscany; the Montebelluna district in Veneto or the district which is analysed in more details in this paper, namely Mirandola in Emilia-Romagna). In this case the role of leaders in the district is generally important, guiding transformations, taking the initiative to search new technologies, new markets and new design for products (Corò and Grandinetti, 1999), besides offering the advantage of scale economies and risk sharing through a pooling of resources (Bellandi et al., 2010). The district's leaders serve as 'bridges' between the district firms (De Propris, 2008).

The second evolutionary process is characterized by the creation of relationships with leaders external to the district in order to access new markets, new technologies and new design, as in the case of the high-quality leather goods production district of Scandicci in Tuscany (Bacci et al., 2010).

Chiarvesio et al. (2007) survey 41 Italian districts and find that leaders play a primary role in the ability of districts to access world markets and in their insertion into world production networks. They identify a best performing model that they call 'open networks' where the district, guided by leaders, become an active node in global production networks.

Districts are therefore experiencing deep transformations, due to the changes in the extent of the markets. The most simple production phases are often delocalised in territories where labour costs are lower. The product generally becomes more sophisticated, incorporating more knowledge and know-how and the firms able to realise this upgrading remain in the district. This evolutionary process requires both a continuous improvement in the capacities of the district firms' teams and a systematic exploration and exploitation process, discovery and application of new ideas, possibly with the help of specialised research centres and universities.

The local milieu is thus key to the effectiveness of upgrading. As stressed by Bellandi (2009, p. 13), upgrading requires a regional milieu comprising dynamic cities and districts and a coherent development of collaboration between firms, research centres, knowledge services, infrastructure dedicated to international trade and high quality and pro-active policy-makers. The Emilia Romagna region in Italy has been shown in the literature (Cooke, 2001; Asheim et al., 2011) to have become a regional innovation system, thanks to long-term industrial development strategies designed by the regional authorities (Bianchi and Labory, 2011). The development of the regional system of innovation may have two opposite effects on the gains from district membership: on the one hand, it may reinforce the benefits from district membership, by making district relations more dense; on the hand, it may reduce the district effect by making relationships with regional institutions located outside the district easier, thereby making the relevant milieu of regional rather than merely local size.

This paper will therefore check whether firms in the Mirandola district are more innovative than firms in the same sector in the rest of the region. In other words, I will check whether there exist a positive district effect in terms of innovation. Besides this, I will check whether research networks differ between firms and impact on the quality of research. Research networks might differ in terms of density (depth of relations), of extent (number of institutions included in the network), and of effectiveness (patents or scientific publications jointly produced). Evidence on the effect of the regional milieu will also be provided.

3) The Mirandola district

The 2001 industrial census indicates that the biomedical sector in Italy comprises, in 2001, 1400 firms and almost 17000 employees. The sector is geographically concentrated in the Centre and North of the country and two regions in particular which together account for about 60% of the total employment in this sector in the country. The most important region is Emilia-Romagna, which accounts for 32% of employment in the sector, followed by Lombardia (27%). The other regions are Tuscany, Veneto, Piemonte and Lazio. In Emilia-Romagna, the Modena province accounts for about 63% of the employees in the biomedical sector in the region.

The biomedical district of Mirandola in the Emilia-Romagna region, Italy, is particular in that it is relatively recent, created in 1963, and in that it is specialized in a high-tech sector, contrary to most Italian industrial districts.

According to the consortium of firms of the district, the district comprises 292 firms in 2009 in the core businesses of the area, namely the production of disposable products to be used in surgery, and the production of electro-medical equipment for diagnosis. The first product type accounts for about 84% of the district production and the second, about 16%; however, the share of electro-medical equipment has been growing over time.

The district is dynamic and growing, despite the financial crisis: the number of firms in the district increased by 15% over the period 2007-2009 and export grew +1.2% between 2008 and 2009.

Table 1. Firms and employees 2009.

	% of firms	Nber of employees
1-9 employees	80.4	511
10-49 employees	14.3	854
50-249 employees	4.0	989
250-499 employees	0,5	452
500 and more	0,8	2145
Total	100	4951

Source: Consobiomed ASRL and Osservatorio distretti italiani (http://www.osservatoriodistretti.org/node/274/distretto-biomedicale-di-mirandola).

The empirical identification of the manufacturing firms belonging to the districts was based on two dimensions: the productive specialisation and the localisation. Regarding productive specialisation, the district firms produce both disposables and electro-medical equipment. The first type of products belong the 2007 sectoral classification of the Italian central statistical office (ATECO) 32.5, while the second type correspond to the 26.6 class, namely manufacturing of instruments for radiation, electro-medical and electro-therapeutic equipment. Given that the production of disposables is important but firms have been shown to increasingly diversify into electro-medical machines beyond disposables (Ballarini, 2003), we focus here on the second type. Disposable medical products are produced world-wide by very large firms, with different production centres including delocalisation to developing countries, such as in Pakistan (Nadvi, 1999). The electro-medical equipment sector is the sector with highest profit margins and highest product differentiation, hence innovation.

The Mirandola district specialises in three health areas. First, renal healthcare area, which is also the main source of demand for electro-medical equipment produced in the district. The major competitors in the global market are Gambro (Sweden), Fresenius (Germany) and Baxter (USA). Baxter used to produce disposable products in the district but left in 2004 and shifted activities in Malta, where labour costs for this rather standardised product type are lower. The second and third areas are the cardiovascular and the transfusion areas.

Overall, the activity of the district is led by 5 large multinational groups, operating in the three health areas of the district. The five groups are:

1. Gambro: Swedish firm, leader in renal products and renal healthcare, founded in 1964 and with 7500 employees worldwide, with production centres in 9 countries. It has 350 employees in R&D activities, which is performed in Sweden (Lund), France (Meyzieu), Italy (Medolla) and Germany (Hechingen). The subsidiary in Mirandola is Gambro Dasco SpA, which has announced this year a restructuring plan to focus on electro-medical equipment and terminate the production of bloodline disposable products in Medolla.

2. B.Braun: German group with more than 40,000 employees over the world. The subsidiary in mirandola is B.Braun Avitum Italy which specialises in extracorporeal treatments.

3. Mallinckrodt (now USA): leader in the imaging for diagnosis and pharmaceutical products, in Mirandola the Mallinckrodt Dar has about 331 employees. Mallinckrodt was purchased in

2001 by Tyco Healthcare; in 2007, the healthcare business unit was spunoff under the name Covidien.

4. Fresenius: global German group with 337552 employees in 2009 (2010 Annual Report). World leader in dialysis care and dialysis products (70% of total group activity), infusion and transfusion products (Fresenius Kabi) (20%) and Fresenius Proserve (10% of activity) dealing with engineering. The group has been in the biomedical valley since 1993, when it bought Biofil. The Italian company in Mirandola (Fresenius Hemocare Italia) is specialised in the production of filters for blood transfusion.

5. Sorin group (previously Sorin Snia but the two groups separated in 2003), world leader in the treatment of cardiovascular diseases, manufactures medical technologies for cardiac surgery and for the treatment of cardiac rhythm disorders. It is an Italian company with headquarters located in Milan. The group has about 3600 employees of which 14% are in R&D activities. R&D is performed in different location, including Mirandola specialising in cardiopulmonary diseases. The Mirandola subsidiary (Dideco and Bellco) has more than 400 employees.

4) Data and methodology

In this paper, I focus on product and process upgrading, through an analysis of innovation processes of firms in the Mirandola district. I use both patents and scientific publications in order to measure the firms' innovation activity. Patents is a classic indicator used in many studies. Scientific publications is a rather recently used indicator, measuring the number of articles published in scientific journals. Studies show that firms in all sectors are increasingly publishing in scientific journals (Zitt and Bassecoulard, 2004; Gittleman, 2005; Kumaramangalam, 2005). Bibliometric data are generally taken from the Thompson ISI Web of Knowledge database, an American database collecting information on most journals. Information includes the title, abstract and other details of the content of the article, together with the number and addresses of authors, the impact factor and number of citations. The information on authors and their affiliations allows to study research collaboration networks, while the information regarding impact factor or citations is used to measure the quality or impact of research. In general, the literature finds a positive effect of collaboration on the quality of research (Persson et al, 2003; Gittelman, 2005) and the importance of the presence of international partners (Zucker et al., 1998; Glänzel, 2001; Glänzel and De Lange, 2002; Kumaramangalam, 2005; Frenken, Hölzl and de Vor, 2005).

Although all sectors are affected by the rising publication behaviour of firms, some sectors are more concerned than others, especially sectors where the frontier between applied and basic knowledge is blurring (such as biotechnology, see Iorio et al., 2011). The biomedical sector is one of these, because it is a science-based sector and because testing makes collaboration with public organisations such as hospitals in particular useful.

From a theoretical perspective, a few scholars analysed firms' publishing behaviour. According to Nelson (1990), firms have five main incentives to publish: attracting customers; establishing legal rights; attracting capital; informing suppliers; and gaining reputation. Pénin (2007) reviews the extent and the reasons for firms' knowledge disclosure. He finds overall seven main reasons for knowledge disclosure: 1) defensive behaviour, preventing other firms from patenting the innovation; 2) triggering feedback from the users in downstream sectors; 3) expanding production in downstream sectors; 4) benefiting from network effects, since

disclosing may make the adoption of the technology as a standard more likely; 5) achieving compatibility of interdependent products (especially in software); 6) building a reputation for innovation; and 7) increase the motivation of researchers in the firm, since publishing papers raise their reputation in the scientific community.
Collaboration on scientific publications allows firms to access the knowledge base of universities, since the direct collaboration of firm members with university scientists allows both more innovation and a higher transfer of knowledge (Gittelman, 2005; Calvert and Patel, 2003; Hicks, 1995). In particular, tacit knowledge is more easily exchanged via direct collaboration (Rosenberg, 1990). Firms have also been shown to publish in order to increase their absorptive capacity (Cohen and Levinthal, 1990; Cockburn and Henderson, 1998), through two effects: collaboration with university scientists might allow firms to draw a direct and an indirect benefit. The direct benefit is that firms get access to the latest created knowledge and to the university's knowledge base. The indirect gain is that firms' members might learn from the collaboration with university scientists and allow them to better understand the new knowledge, thereby raising their absorptive capacity.

The dataset is made of all firms in the sector of electro-medical equipment located in the ER region. The data source is AIDA, which limit is to contain only firms of more than 20 employees. However, AIDA provides balance sheet data, of which I used revenue to compute dimensional classes. I further collected data on patents from the open site of the European patent office (Espacenet), as well as data on firms' publication in scientific journals, from ISI Web of Sciences.

As mentioned above, Cainelli et al. (2007) examined the role of social capital in favouring innovation in Mirandola based on the data from a survey realised in the district in 2003. They were able to distinguish product and process innovation, using a sample of 40 firms.

Santarelli (2004) analysed the advantage of being located in a district in terms of number of patents produced. He performed a panel estimation regressing the number of patents on a number of variables, including firm characteristics and location in a district. However, his dependent variable is a count data and a Poisson or negative binomial regression might be preferred (Hausman et al., 1984). In addition, his sample is made of only innovative firms, namely firms having at least one patent. He finds that being in a district does not significantly raise innovation, but his results in fact only show that the location in a district does not raise the number of patents obtained by the firms.

However, the location in the district may simply allow firms to obtain at least one patent. Given that firms have been found not to persistently innovate (Geroski et al., 1997, for a seminal paper), obtaining one patent is already a good innovative performance that distinguishes the firm from competitors. Hence the location in a district may favour firms innovation in the first place, namely obtaining at least one patent.

Therefore, in this paper I consider all firms in the biomedical sector (ATECO2007 26.6) located in the Emilia-Romagna region, and present in the AIDA database (only firms of more than 20 employees). The sample thus contains 105 firms, 21 of which are in the Mirandola district. I identified the firms in the Mirandola district not only according to their specialisation in the biomedical sector, but also according to their localisation: the district officially contains seven municipalities, namely Mirandola, Medolla, Concordia, Cavezzo, San Felice sul Panaro, San Possidonio e San Prospero, and our 21 firms all belong to these municipalities.

I am thus able to compare district firms from non-district firms. Table 2 shows the distribution of firms in the sample in terms of dimensional classes (measured by revenue because the data on the number of employees in AIDA are not reliable) and location in the district. Given that the database from which we extract the data excludes firms with less than 20 employees, our sample is biased towards largest firms. This is especially true regarding firms belonging to the Mirandola district, where polarisation of size appears to be higher than in the regional sector as a whole. Care will have to be taken in interpreting the data.

Table 2. Dimension of sample firms (%)

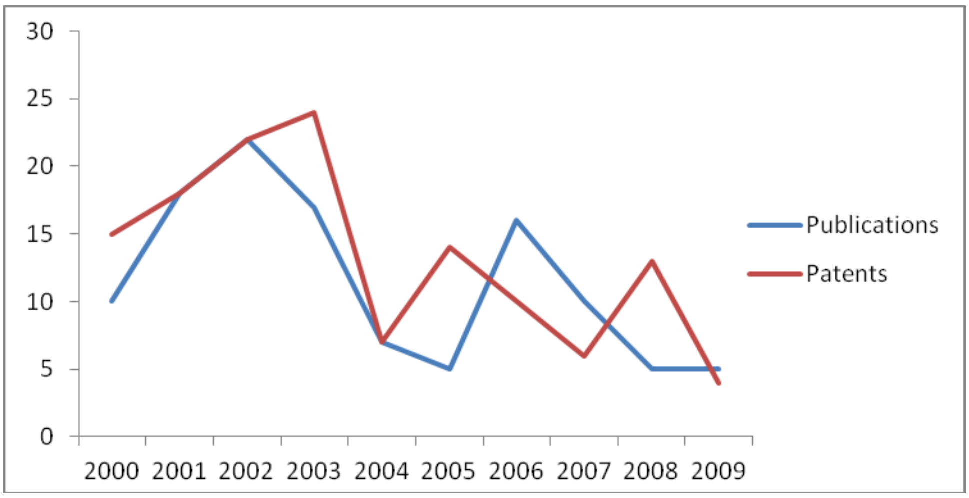
Location Dimension	All sample	Mirandola
0 – 249 thousands	23,9	14,4
250 – 499 thousands	22,9	19,0
500 – 4999 thousands	30,5	19,0
5 million and more	22,9	47,6
Total	100	100

As the dependent variable is a non-negative count variable, I estimate a negative binomial model, as it is usual in the studies concerning both patents and paper citations (Gittelman and Kogut, 2003; Frenken, Hölz and de Vor, 2005). Hausman et al. (1984) discuss the superiority of these models in the case of count data. In this model, the count variable is believed to be generated by a Poisson-like process, except that the variation is greater than that of true Poisson. This extra variation is referred to as overdispersion. The negative binomial model is superior to the Poisson one if the overdispersion parameter α results significantly different from zero. In case the observations contain many zero values, as in our case, a zero-inflated model may be used. I therefore also test this specification, using the Vuong test (see results below).

I obtained information on firms' patenting from the European patent office site, with the result that 27 out of the 105 firms obtained patents since 1999. The average number of patent per patenting firm in the period is 4, and the most patenting firm is Gambro Dasco Spa of the Mirandola district, with 26 patents.

Regarding evolution during the period under consideration, Figures 1 to 3 show the number of patents and the number of publications of the firms in the sample. Figure 1 shows that both indicators tend to reduce over the decade, due to a high innovation at the beginning of the period, in the years 2001 to 2003, followed by a return to normal innovation rates. There seems to be a relation between publishing and patenting behaviour, the peaks in publications preceding the peaks in patenting. One interpretation is that firms realise joint research with universities or research centres which outcome is a scientific publication, because university scientists are more interested in this type of knowledge diffusion, while the firm realises a specific application into a new product or process afterwards, which is patented.

Figure 1. Number of articles and number of patents, 2000 to 2009



Figures 2 and 3 show the contribution of the firms in the Mirandola district to the total number of patents and publications produced in the sector in the ER region over the period 2000 to 2009. While firms in the Mirandola district produce about half of the patents obtained in the sector, they contribute to almost whole scientific publications.

One interpretation of the very strong contribution of district firms to publications is that only larger firms are able to set up relationships with universities or other research centres. Such research collaborations require funding, so that public researchers and academics are motivated to collaborate. Larger firms are more likely to have such funding at their disposal. In addition, university – business relationships require time and dedicated person that contact liaison offices and academics, which larger firms are more likely to be able to do.

In any case the distinctive feature of firms belonging to the Mirandola district relative to other firms in the same sector but still located in the ER region is that the former seem to be more active in scientific publication, being motivated either by the willingness to get a reputation for scientific quality within the research community, or to establish more relationships with universities and other research organisations. It seems therefore interesting to analyse research collaborations as emerging from the data on publications in more details, which I do below by estimating the citation impact of publications.

Figure 2. Number of patents in the ER biomedical sector, 2000 to 2009, whole region versus Mirandola.

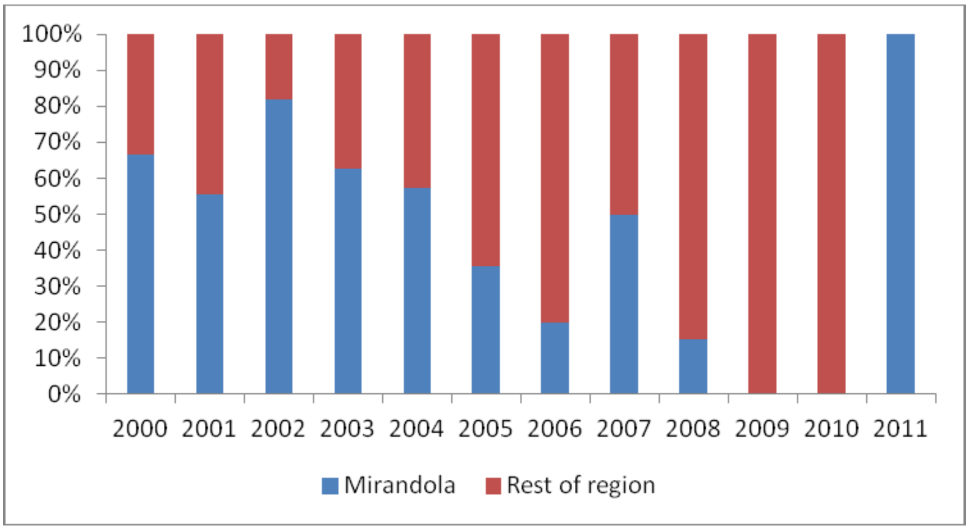
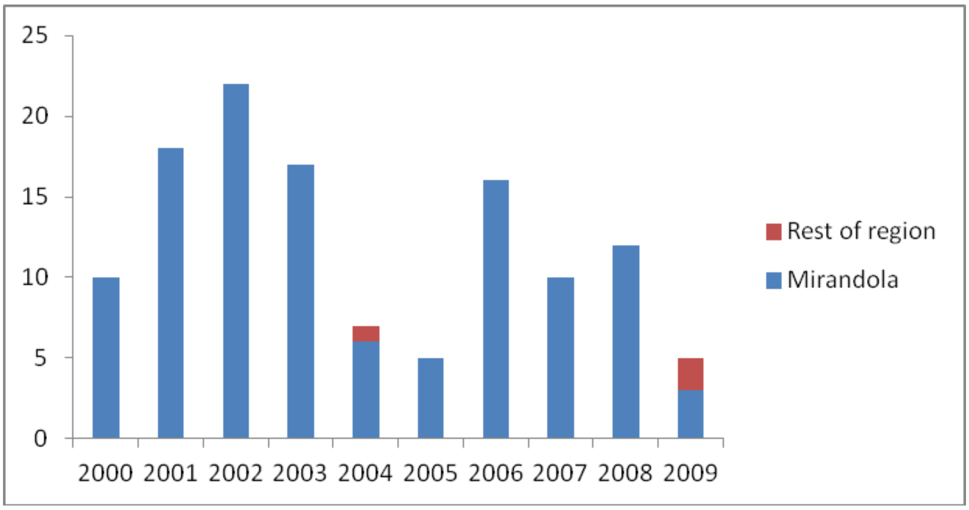


Figure 3. Number of scientific publications in the ER biomedical sector, 2000 to 2009, whole region versus Mirandola.



The following table shows the percentage of publications which include a collaboration with a specific type of institution located in the region, in the rest of the country or abroad. The types of institutions considered are universities, public research centres, hospitals or other firms (private research centres were included in the firm category). Notice that very often the collaboration with another firm is in fact a collaboration with another subsidiary of the same group.

Table 3. Collaboration on scientific publications. Percentage of collaborations including the specific institution.

Italian extra-regional hospital	36.0
University in the rest of Italy	14.8
Foreign university	9.9
Regional hospital	9.0
Foreign hospital	7.0
Regional university	6.4
Foreign firm	3.8
Foreign research centre	3.5
Italian extra-regional research centre	2.9
Regional firm	2.3
Regional research centre	1.5
Italian extra-regional firm	1.5
% of publications not including collaboration with any institutions	8.6

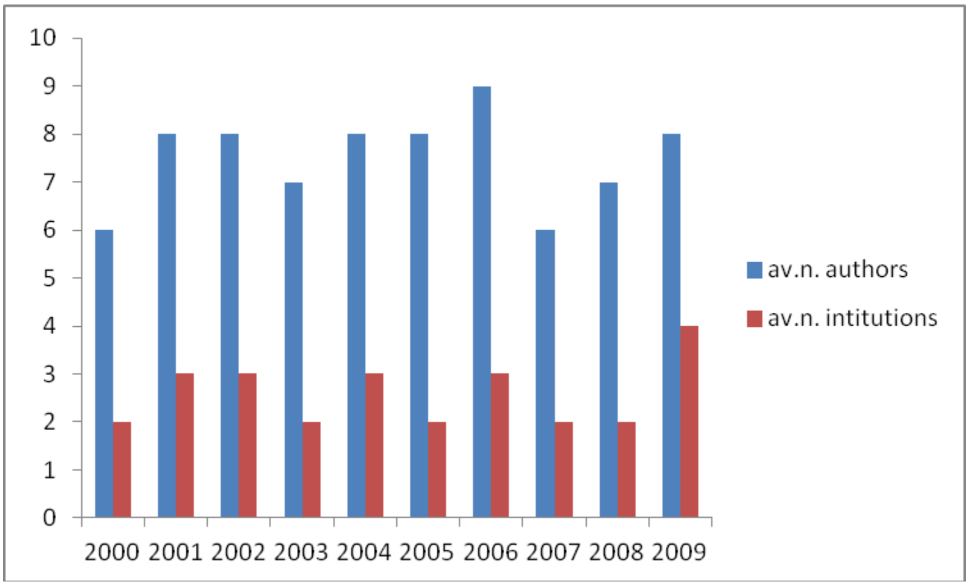
The aim of firms' publications appear to be related to collaboration: only 9% of firms publish in scientific journals without collaborating with other institutions. Most publications are done in collaboration, and it is likely that the choice to publish is related to the motivation of researchers in collaborating institutions. For instance, as mentioned above, academic scientists signal their quality and improve their careers prospects by publishing scientific papers. A firm collaborating with an academic scientist is therefore likely to accept scientific publication in order to provide incentives for collaboration.

Most collaborations (52%) include hospitals, especially Italian hospitals located outside the region (36%). Very often a paper include a large number of collaborating hospitals, one or two of which are in the region and other are in other Italian regions. The machines produced in the district are used in dialysis or blood transfusion and are developed directly collaborating with the users. The second most important collaboration is university, since 31% of collaborations concern this type of institutions. University – firm relationships are geographically extended, since the percentage of publications with collaboration including regional universities is 6.4%, a bit less than foreign universities (9.9%) and less than universities located in other Italian regions (14.8%). Collaboration with public research centres and with other firms is less frequent, but still tends to primarily regard extra-regional locations.

Many reasons can be ascribed to the lower collaboration with regional institutions relative to Italian extra-regional and foreign institutions. The disciplines and specialisations of regional universities and research centres may not be that adequate; alternatively, the firms may use other collaboration channels with regional institutions, such as research projects financed by regional funds, hiring neo-laureates or doctorates from the local universities.

Finally, figure 4 shows the evolution of the extent of collaboration through time, in that it shows the average number of authors and the average number of institutions per paper per year. Both indicators tend to slightly increase over the considered time period, thereby indicating a growing importance of collaboration and institutional diversity.

Figure 4. Average number of authors and institutions per paper and per year, 2000-2009



5. Empirical results

I first analyse the determinants of the number of patents obtained by the firms, using the available data, in order to check whether the location in the Mirandola district produces a positive effect on the productivity of research and on innovation.

For this purpose I test two models. First, I estimate the probability of obtaining at least one patent in the whole period under consideration, using a probit regression. Second, I estimate the number of patents obtained in the period using a negative binomial regression, after checking whether alternative models (the Poisson model and the zero-inflated regression) are better. The determinants considered are dimensional class (four classes as indicated in Table 2), the age of the firm, number of publications, number of co-authors in the publication and the presence in the district (dummy equal to 1 if the firm is located in the district).

Both estimation strategies indicate a positive district effect on innovation in the biomedical sector. This positive effect is probably driven by the presence of a large proportion of multinational leaders in the Mirandola district.

As mentioned in the methodological discussion, count variables have to be estimated with specific models. The Poisson regression is often used, although it has the very strong assumption that conditional variance is equal to the conditional mean. The negative binomial model might therefore be preferred. However, I try the Poisson model which may happen to fit. Using Stata, we estimate the Poisson model with robust estimations, as recommended by Cameron and Trivedi (2009). The estimation is satisfactory, with desired sign on the dummy of the location in our district. The negative binomial model is also satisfactory, and the alpha test shows that this model is preferred to Poisson.

Table 4. Estimates of patenting

	Probit estimation on patenting dummy (1 if at least one patent obtained)	Poisson regression on number of patents	Negative binomial on number of patents
Dimensional class	.467 (0.003)*	0.715 (0.000)*	0.755 (0.014)*
Location in Mirandola district	.322 (0.354)*	1.409 (0.003)*	0.564 (0.483)*
Age	0.0005 (0.966)		
Number of publications		0.012 (0.111)*	0.067 (0.454)*
Number of observations	104	105	105
LR Chi2(3)	14.27	30.01 (Wald Chi2)	18.78
Pseudo R2	0.1220	0.3175	0.0777
Alpha			4.321°
Vuong test			1.37 (0.0855)

P-values (P>|z|) in brackets.
*Significant at 5 percent level;
° Likelihood-ratio test of alpha=0: chibar2(01)=151.00; Prob>=chibar2=0.000

The estimations would require other variables to get more explanatory power. However, both the probit and the negative binomial models are quite significant. Since the observations contain many zero values, I also tried the zero-inflated negative binomial model, with age predicting the zeros. The Vuong test is not extremely significant so an ordinary negative binomial model seems appropriate.

To conclude, the estimation confirm that being a member of the Mirandola district carries positive effects for a firm in terms of innovation, measured by the number of patents. Firms in the Mirandola district tend to obtain more patents than firms located outside the district, but still in the Emilia-Romagna region, considering only the biomedical sector. The estimation shows that being in the district raises the probability of patenting by 12%.

In addition, given that scientific publications almost exclusively regard firms located in the district, I analyse the quality of research measured by the impact of scientific publications, as done in the literature (Gittleman, 2005; Frenzen et al., 2005). The ISI Web of Sciences database also provides information on the number of citations of articles, which I use to measure the quality of research: the more an article is cited, the higher its impact on the scientific community and on the scientific knowledge base, hence its quality.

Following the literature analysing the determinants of the impact of research in different sectors, periods and countries (for instance in biotechnology Frencken et al., 2005, cover the period 1988-2002; Kumaramgalam, 2005 restricts attention to UK data in the period 1988-2001; Iorio et al., 2010 analyse Italian data over the period 1999 to 2008), I make a number of assumptions regarding the determinants of citations' impact. First, citations increase with the number of authors associated with the paper. I therefore include a variable indicating the number of authors in the estimation (AUT). However, the increase in the number and variety of co-authors and organizations also induces coordination costs to rise. Therefore, there will likely be decreasing returns to the number of collaborators, which I test including the square of the number of authors in the analysis (AUTSQ). A negative sign for this latter variable will be evidence of decreasing returns to the number of collaborators. I also include a number of dummies indicating whether there is collaboration with universities, other research centres, hospitals or other firms. I also check for learning effects, introducing year dummies. Lastly, I control for firm effects using firm dummies.

Other studies confirm the positive effect of collaboration on the quality of research (Persson et al, 2003; Gittelman, 2005) and the importance of the presence of international partners (Narin and Olivastro, 1992; Zucker et al., 1998; Glänzel, 2001; Glänzel and De Lange, 2002; Kumaramangalam, 2005; Frenken, Hölzl and de Vor, 2005).

Besides this, I consider whether mixed (from an institutional and or geographical point of view) network of co-authorship have an effect on the number of citations, using two dummies. One dummy is MIXINST and takes value 1 if the firm collaborates with at least two different types of institutions (the types being university, research centres, hospitals and firms). The other dummy is MIXGEO and takes value 1 if the firms collaborates with institutions located in at least two geographical zones (regional, Italian extra-regional and foreign). The importance of the diversity of institutions for knowledge creation outlined in the literature (Bonaccorsi and Thoma, 2007) will thus be taken into account.

The number of authors always significantly and positively affects the quality of publications. There is evidence of decreasing returns to the number of collaborators, since the variable AUTSQ has a negative sign. Hence raising the number of collaborators is beneficial up to a point where coordination costs become too high. Institutional diversity also produce positive effects on quality, since collaborating with at least two different institutions raises citations. Among the different institutions, models 1 and 2 shows that collaborating with universities always raises citations, while collaboration with other research centres and with other firms raises citations once control for years and firms are introduced. Collaboration with hospitals is not significant, probably because such collaboration is useful at later stages of the production process, at the commercialisation phases, or because collaborating with hospitals allows to better identify needs in terms of new product characteristics.

The results on the geographical locations of collaborators are the most striking. First, raising the geographical extent of collaboration raises citations but is not much significant. Second, collaborating with regional institutions alone does not raise research quality measured by citations' impact. However, collaboration with foreign institutions always raise citations' impact.

Model 3 distinguishes the type and the geographical location of institutions. Among regional institutions, only regional firms included in the collaboration raises the quality of research. There might be a bias however due to the fact that publications including certain types of institutions, such as foreign universities, especially those located in the USA, are in any case more cited than papers including only authors from the ER region. Alternatively, the effect of the regional innovation system is not felt in this case, and a policy implication would be to take measures to make the regional universities more internationalised and more included in international research networks, so that their work would be recognised by their peers. This is true also of research centres which, like universities, produce positive effects on citation only if located in other Italian regions or abroad. Collaboration with foreign institutions always raise citations, except for foreign firms, which is probably due to the fact that collaboration with foreign firms mainly regards foreign subsidiaries of the groups the firms are member of. Collaborating with foreign firms then means doing research within the same group, which may produce more new patents (secrecy) than open knowledge. The same might be true regarding firms located in other Italian regions.

Table 5 - Estimates of the quality of publications

Variables	Model1	Model2	Variables	Model3
AUT	.118* (.043)	.053 (.257)	AUT	.110 (.049)
AUTSQ	-.0009* (.053)	-.0004 (.234)	AUTSQ	-.0009 (.041)
UNIVERSITY	.429* (.264)	.55 (.110)*	Regional university	-.557 (.165)
RESEARCH CENTRE	-.465* (.236)	.197 (.598)	Italian extra-regional university	.286 (.263)
HOSPITAL	-.028 (.927)	-.038 (.900)	Foreign university	.208 (.239)
FIRMS	-.563* (.255)	.925 (.079)	Regional research centre	-.757 (.387)
REGIONAL INSTITUTIONS	-.629* (.062)		Italian extra-regional research centre	1.12 (.068)
ITALIAN EXTRA-REGIONAL	-.123* (.209)		Foreign research centre	.158 (.736)
FOREIGN	.105* (.257)		Regional hospital	-.275 (.200)
MIXINST	.752* (.116)	.328 (.445)	Italian extra-regional hospital	-.061 (.424)
MIXGEO	.355* (.372)	.158 (.648)	Foreign hospital	.376 (.129)
			Regional firms	.810 (.175)
			Italian extra-regional firms	-.602 (.509)
			Foreign firms	-.169 (.591)
FIRM DUMMIES	No	yes		Yes
YEAR DUMMIES	No	Yes		Yes
Nber of obs.	128	128		128
Pseudo R^2	.0462	.0873		.0980
Alpha	1.874°	1.355°°		1.270

Notes: Dependent variable = number of received citations**.**
P-values (P>|z|) in brackets.
*Significant at 5 percent level
° Likelihood-ratio test of alpha=0: chibar2(01)=1205.46; Prob>=chibar2=0.000
°° Likelihood-ratio test of alpha=0: chibar2(01)=598.01; Prob>=chibar2=0.000

6. Conclusions

This paper has analysed the role of external knowledge flows on the upgrading of a specific district, namely the biomedical district in Mirandola, Italy. For this purpose, data on the number of patents and the number of scientific publications of the firms in the regional sector are used. Unlike previous literature, the paper focuses on the most value-adding business activity of the district, namely the production of electro-medical equipment, which is the activity the district firms seem to have put increasing emphasis in the last years. The other activity is the production of disposables for surgeries and other medical operations which is more standardised and production appears to be shifted to lower-cost countries. Contrary to the literature, this paper also provides evidence over recent years, the while literature is focused on time periods up to the early years 2000.

I show that there is evidence of a district effect in terms of innovation. District firms produce more patents and more scientific publications. The number of patents obtained by firms is indeed significantly and positively affected by the fact of being located in the district. However, the district effect seems to be highest regarding scientific publications. Scientific publications of firms in the sector and in the region are obtained almost exclusively by district firms, especially – but not exclusively - the largest ones. These firms seem to benefit from their ability to set up collaborative research relationships with different institutions, including universities, research centres, hospitals and other firms, in different locations, in the region, in the rest of Italy or abroad. Collaboration is indeed a distinctive feature of scientific publications of these firms. Collaboration raises research quality as measured by the citations' impact of papers, especially collaboration with different institutions, with universities in general and with regional firms. Collaboration with regional universities does not seem to improve citations; this might be due to the fact that researchers citing papers tend to look at most famous universities; in any case, this means that regional universities must extend their internationalisation in order to get a worldwide reputation and be more cited. This would also raise the attractiveness of research collaborations with regional universities. Collaboration with other regional firms appears to improve the quality of research, which may be interpreted as an effect of the well-functioning regional innovation system. The regional government has indeed promoted research collaborations between actors of the regional innovation systems; it might be that such measures have worked well regarding collaborations between firms.

Collaboration with foreign universities, research centres or hospitals is always beneficial, providing evidence of the necessity to build global pipelines (Bathelt et al., 2004).

Overall, two major factors seem to explain the superior performance of firms in the Mirandola district in terms of innovation. First, the significant role of the leader firms in the district. Leaders are dynamic firms able to guide the whole district upgrading, looking for new markets and new products. They are not necessarily large. The role of this leaders in districts has been outlined in the literature (Labory, 2002; Bacci et al., 2010 in the case of the fashion sector in Italy; Chiarvesio et al., 2007 in a survey of Italian districts), but their role in the innovation processes of the districts have been less highlighted. In this paper, I find that leaders appear to have a key role in the setting up of research collaboration relationship with universities, research centres and hospitals located in the region and outside.

Second, linkages external to the district appear to be key in product and process upgrading: the district firms, especially leaders, create relationships with research centres (universities and hospitals in particular) located not only in the region but also in the rest of the country and abroad and these appear to be essential to the ability of the district to upgrade (also determining the number of patent obtained). The importance of external relations and institutional diversity (in terms of variety of institutions collaborating in scientific publications), appear to grow over time (the time period considered being 2000 to 2010).

Two main policy lesson regarding the Emilia-Romagna regional innovation system appears to be that after primarily aiming at making relations within the regional innovation system more dense, it might time now to focus on its external relationships, with for instance measures aiming at raising the innovation capacity and the reputation of regional universities and research centres in the rest of Italy and abroad.

Regarding industrial districts, this case shows that building relationships with external leaders can be a high road evolutionary pattern, conditional on the local system being able to maintain and develop specific knowledge and competencies.

References

Asheim B.T., Boschma R., Cooke P. (2011), "Constructing regional advantage: platform policies based on related variety and differentiated knowledge bases", *Regional Studies*, 45(7), 893-904.

Audretsch D.B., Lehmann E.H. (2006), "The role of clusters in knowledge creation and diffusion: an institutional perspective", in Asheim B. T., Cooke P., Martin R. (eds), *Clusters and Regional Development. Critical Reflections and Explorations*, Routledge, London.

Bacci L., Labory S., Lombardi M. (2010), "The evolution of external linkages and relational density in the Tuscan leather industry", in Belussi F., A. Sammarra (eds.), *Business networks in clusters and industrial districts. The governance of the global value chain*, Routledge, London, 146-171.

Bathelt H., Malmberg A., Maskell P. (2004), "Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation", *Progress in Human Geography*, 28(1), 31- .

Becattini G. (2004), *Industrial Districts: A New Approach to Industrial Change*, Cheltenham, Edward Elgar.

Becattini G., Bellandi M., De Propris L. (eds.) (2009), *Handbook of Industrial Districts*, Cheltenham, Edward Elgar.

Bellandi M. (2009), "Perspectives on Mature Marshallian Industrial Districts", Dipartimento di Scienze Economiche, Università degli Studi di Firenze, Working Paper n.15/2009.

Bellandi M., Caloffi A., Toccafondi D. (2010), "Riaggiustamento delle reti distrettuali e differenziazione dei percorsi di reazione alla crisi di mercato", in Zazzaro A. (a cura di), *Reti dìimpresa. Tra vincoli e nuove opportunità dopo la crisi*, Il Mulino, Bologna.

Bianchi P., Labory S (2011b), "Industrial Policy after the Crisis: the case of the Emilia-Romagna Region in Italy", *Policy Studies*, 32(4), 429-445.

Biggiero L. (2002), "The location of multinationals in industrial districts: knowledge transfer in biomedicals", *Journal of Technology Transfer*, 27, 111-122.

Bonaccorsi A., Thoma G. (2007), "Institutional complementarity and inventive performance in nanotechnology", *Research Policy*, 36(6), 251-283.

Cainelli G., Mancinelli S., Mazzanti M. (2007), "Social capital and innovation dynamics in disctrict-based local systems", *Journal of Socio-Economics*, 36, 932-948.

Calvert, J., Patel, P., 2003. University-Industry Research Collaborations in the UK: Bibliometric Trends, *Science and Public Policy*, 30(2), 85-96.

Cameron A.C., Trivedi P.K., (2009), "Econometric models based on count data. Comparisons and applications of some estimators and tests", *Journal of Applied Econometrics*, 1(1), 29-53.

Carabelli A., Hirsch G., Rabellotti R. (2007), "Italian SMEs and industrial districts on the move: where are they going?", in Haar J. and J. Meyer Stamer (eds.), *Small firms, global markets: competitive challenges in the new economy*, Macmillan, UK.

Chiarvesio M., Di Maria E., Micelli S. (2007), "Global value chains and open networks: the case of Italian industrial districts", *European Planning Studies*, 18(3), 333-350.

Christorpherson S., Clark J. (2007), "Power in firm networks: what it means for regional innovation systems", *Regional Studies*, 41(9), 1223 - .

Cockburn, I.M., Henderson, R.M., 1998. Absorptive capacity, co-authoring behaviour and the organisation of research in drug discovery, *The Journal of Industrial Economics*, 46(2), 157-82.

Coe N., Hess M., Yeung H W, Dicken P., Henderson J. (2004), " 'Globalising' regional development: a global production networks perspective", *Transactions of the Institute of British Geographers*, New Series, 29(4), 468-84.

Cohen, W., Levinthal, D., 1990, Absorptive Capacity: A New Perspective of Learning and Innovation, *Administrative Science Quarterly*, 35, 128-52.

Cohen, W., Nelson, R., Walsh, J.P., 2002. Links and Impact: the Influence of Public Research on Industrial R&D, Management Science, 48(1), 1-23.

Cooke P. (2001), "From Technopoles to Regional Innovation Systems: the evolution of localized technology development policy", *Canadian Journal of Regional Science*, XXIV(1), 21-40.

Corò G. e Grandinetti R. (1999)

Day M., Burnett J., Forrester P.L., Hassard J. (2000), “Britain’s last industrial district? A case study of ceramics production”, *International Journal of Production Economics*, 65, 5-15.

De Propris L., Menghinello S., Sugden R. (2008), “The internationalisation of production systems: embeddedness, openness and governance”, *Enterpreneurship and Regional Development*, 20(6), 493.

Dicken P. (2001), “Global Production Networks and te Analysis of Economic Development”, Working Paper, Manchester.

Frenken, K., Hölzl, W., de Vor, F., 2005. The citation impact of research collaborations: the case of European biotechnology and applied microbiology (1988–2002), *Journal of Engineering and Technology Management*, 22, 9-30

Gereffi G. (1994), « The organisation of buyer-driven global commodity chains : How U.S. retailers shape overseas production networks », in Gereffi G. and Korzeniewicz M. (eds.), *Commodity Chains and Global Capitalism*, Westport, CT : Praeger, pp. 95-122.

Geroski P., Van Reenen J., Walters C. (1997), “How persistently do firms innovate?”, *Research Policy*, 26, 33-48.

Gittelman, M., 2005. What makes research socially useful? Complementarities between in-house research and firm-university collaboration in biotechnology, *Revue d’Economie Industrielle*, 110(2), 57-73.

Glänzel, W., 2001. National Characteristics in International Scientific Co-authorships Relations, *Scientometrics*, 51(1), 69-115.

Glänzel, W., De Lange, C. 2002. A Distributional Approach to Multinationality Measures of International Scientific Collaborations, *Scientometrics*, 54(1), 75-89.

Hausman J., Brown B.H., Griliches Z. (1984), “Econometric models for count data with an application to the patents R&D relationship”, *Econometrica*, 52(4), 909-938.

Hervàs-Oliver J., Albors-Garrigòs J. (2008), “Local knowledge domains and the role of MNE affiliates in bridging and complementing a cluster’s knowledge”, *Enterpreneurship and Regional Development*, 20(6), 581.

Hicks, D. 1995. Published papers, tacit competencies and corporate management of the public/private character of knowledge, Industrial and Corporate Change, 4(2), 401-24.

Humphrey J. and Schmitz H. (2000), “Governance and upgrading: linking industrial clusters and global value chains”, IDS Working Paper 120, Brighton: Institute of Development Studies.

Humphrey J. and Schmitz H. (2002), “How does insertion in global value chains affect upgrading in industrial clusters?” *Regional Studies*, 36(9),

Humphrey J. and Schmitz H. (2004)

Kumaramangalam, K., 2005. Does collaborating with academia improve industry science? Evidence from the UK biotechnology sector, 1988-2001, Aslib Proceedings: New Information Perspectives, 57(3), 261-77.

Labory S. (2002), "Relazioni tra grandi imprese e PMI. Considerazioni generali con particolare riferimento al settore moda", in *Il sistema moda in Toscana*, a cura di S. Labory e L. Zanni, Collana IRPET, Firenze.

Lillebrygfjeld Halse L., Bjarnar O. (2011), “Cluster transformation from s supply chain perspective: theoretical models and the case of the maritime cluster in Mid-West Norway”, paper presentato alla conferenza annuale della *Regional Studies Association*, Newcastle, 17-20 aprile 2011.

Nadvi K. (1999), “Shifting Ties: Social Networks in the Surgical Instrument Cluster of Sialkot, Pakistan”, *Development and Change*, 30(1), 141-175.

Nelson, R., 1990. US Technological Leadership: Where did it come from and where did it go?, Research Policy, 19, 117-32.

Pénin, J., 2007. Open knowledge disclosure: an overview of the empirical evidence and the economic motivations, Journal of Economic Survey, 21, 326-48.

Persson, O., Glänzel, W., Danell, R. 2003. The decline of Swedish neuroscience: Decomposing a national science indicator, Scientometrics, 57(2), 197-213.

Phelps N. (2008), “Cluster or Capture? Manufacturing foreign direct investment, external economies and agglomeration”, Regional Studies, 42(4), 457 - .

Rosenberg, N., 1990. Why do Firms do Basic Research (with their own money)?, Research Policy, 19(2), 165-74.

Santarelli E. (2004), “Patents and the technological performance of district firms. Evidence for the Emilia-Romagna region in Italy”, Discussion papers on Entrepreneurship, Growth and Public Policy, Max Planck Institute of Economics, 29.

Sturgeon T.J. (2008), “From Commodity Chains to Value Chains: Interdisciplinary Theory Building in an Age of Globalization”, Working Paper, Sloan Industry Studies, WP-2008-2.

Zitt, M., Bassecoulard, E., 2004. Internationalisation in the Prism of Bibliometric Indicators, in Moed H.F., Glänzel W., Schmoch U. (eds.), Handbook of Qualitative Science and Technology Research, Kluwer Academic Publishers.