The Eleventh Annual
High Technology Small Firms Conference
Manchester, 12-13 June 2003

HTSFs in Peripheral, Knowledge Intensive Areas: an In-Depth Analysis in Pisa[1]

Alberto Di Minin§ (adiminin@uclink.berkeley.edu)
Michela Lazzeroni° (lazze@sssup.it)
Andrea Piccaluga^ (a.piccaluga@economia.unile.it)

° University of Pisa and In-Sat Lab, Scuola Superiore Sant'Anna (Italy)
§ University of California, Berkeley (USA) and In-Sat Lab, Scuola Superiore Sant'Anna (Italy)
^ University of Lecce and In-Sat Lab, Scuola Superiore Sant'Anna (Italy)

Abstract

The case of Pisa, in Italy, emerges as an effective representation of the difficulties and opportunities of HTSFs in peripheral regions, as well as of the challenges and phases that a knowledge-based local economic policy might face. The paper summarizes the results of a three year empirical analysis of the local HT sector. Over 200 firms, with an impressive average growth rate, have been identified and analysed in the province of Pisa, where a traditional manufacturing sector is slowly but constantly declining and coexists with an outstanding public research system, which attracts and retain in the city important human resources, generates high-tech start-ups and attracts external companies in the area. Four different categories of firms are identified and analyzed: (1) *established innovators*, (2) *technology integrators*, (3) *technology labs* and (4) *emerging innovators*. Furthermore, three phases of development of Pisa high-tech sectors are described: (1) *birth and innovative growth*, (2) *consolidation and stability* and (3) *clustering and restart*.
It seems that the knowledge-based potentialities of the area will represent a strong asset for its future development; nonetheless, the relative weakness of networking initiatives, the lack of a clear public and private leadership in the sector, and the inadequacy of the local financial market are identified as the main bottlenecks for the further growth of an already promising HT cluster.

[1] A previous version of this paper has been presented at the RSA conference on *Reinventing Regions in the Global Economy*, Pisa, 12-15 April 2003. We acknowledge useful comments from Phil Shapira and Nicola Bellini. We also thank Chiara Cavallo, Alessandra Patrono and Federica Vannelli for useful collaboration during the research. Most of the empirical data about HTSFs in Pisa have been collected within the Observatory on High-Tech companies in the Province of Pisa (http://osservatorio.sssup.it/), managed by In-Sat Lab and the Provincial Government of Pisa. The present work is the result of a common research effort; nonetheless, par. 1 can be attributed to Andrea Piccaluga, par. 2.1, 2.2 and 2.3 to Michela Lazzeroni and par. 2.4 and 2.5 to Alberto Di Minin.

Introduction

In this study we seek to describe a particular growth model for high-tech (HT) businesses in a local, peripheral economy, characterised by the presence of a traditional manufacturing sector and important higher education and scientific research public structures. The model takes into account the clear distinctions which exist between traditional and HT sector and, within the HT sector, between the main subsectors and players in the HT arena. We argue that some of the characteristics of this model, such as the interactions between companies and with local institutions, the knowledge and technology transfer process, and localization advantages, are only partially mapped by a purely quantitative approach. A more in depth study is needed to understand strengths and weaknesses, factors of competitiveness and reasons of expansion and decline of such a HT cluster. The object of analysis is the HT cluster present in the province of Pisa, in central Italy, which well explains the contradictions, problems and opportunities of a traditional economy which evolves towards an increasingly HT- and knowledge-based development model.

This paper is divided into three parts. In the first one, the model is presented and described in relation with other models discussed in the literature, in particular those dealing with a local HT led growth process. Different approaches to the study of local technological transfer and concentration of knowledge intensive activities are also introduced and discussed. The second part deals with the analysis and interpretation of the HT sector in Pisa. Four different types of HT firms are identified and discussed in relation to three distinct stages of development of the local economy. The third part of the paper tries to identify general characters of the Pisa case with regard to both its strengths and weaknesses, and the application of a similar approach for the study of potential HT led growth areas.

1. High-Tech Development in Italian Peripheral Regions

HT led growth has been among the most studied topics by regionalists and economists. The result is an impressive amount of models, methods of analysis and cases, with the objective of capturing the phenomenon and its crucial components. Political authorities in both developed and emerging economies have clearly identified the HT sector as one of the most strategic ones to monitor and promote. The role and importance of HT for local economies has been vastly discussed. Previous studies, such as Storey and Tether (1998), empirically supported the claim that high-tech sectors in advanced economies are likely to experience fastest employment and income growth rates. Also, dynamic small high-tech based firms might play an important role by linking the sources of knowledge creation such as universities, and the industry, in a way not feasible for big corporations (Autio and Yli-Renko, 1998). In some cases, such as in biotech, this is explained by the nature and complexity of the technology and the research (Jones, 1992). In these cases, big companies integrate, in their strategic behavior, the presence of small companies, in the early phases of commercialization (Arora and Gambardella, 1990). The nature and evolution of the HT sector governance structure therefore becomes an important element of analysis (Delapierre et al., 1998).

Empirical findings, such as Carlino (2001), showed that HT firms are likely to concentrate in metropolitan areas, or in the proximities of public and private R&D centers (Bade and Nerlinger, 2000). However these studies of agglomeration are not likely to fully explain the reasons behind this phenomenon. As in the traditional “low tech” sectors, agglomeration is often a precondition for positive clustering dynamics. This study tries to contribute to that part of the economic literature

which has identified similarities and differences between the HT concentrations/clusters and industrial districts as known in the Italian experience, or clusters of firms in traditional sectors.

The works of Piore and Sabel (1984) and Sabel (1993), among others, showed to the international research community the particular nature of Italian industrial districts, the "studied trust" present in non market transactions, which is relevant to explain possibilities of success and failure for industrial agglomerations. The analogy with the HT sector, empirically tested that local cooperation was, also for technology based firms, an element which was facilitating competitiveness and innovativeness (Shan, 1990). Social capital of the region was also found to be positively correlated with faster technical knowledge growth and competitiveness, for HT companies (Yli-Renko and Autio, 2001). By shifting the focus of the analysis from agglomerations to networks, researchers were able to show that the knowledge/awareness of resources available in the network became itself an important resource, to be coupled with internal capabilities, for the HT firm (Lee et al., 2001). A more qualitative approach is therefore necessary to suggest important interactions between the firm and its environment. In particular, an analysis of the level of the agglomeration cannot clarify why some groups of firms or entire regions have an easier access to markets and technologies (Heydebreck and Klofsten, 2000). Examples of these types of approaches focus on the advantages that spring off the agglomeration/clustering of activities in a particular sector, within the borders of a regional economy, such as biotech in Cambridge (Cooke 2002, 146) or Silicon Valley (Saxenian, 1994). This emphasis on knowledge flows leads to labeling all sorts of clusters as "HT concentrations", since it is misleading to talk about "low technology" (Porter, 1998), given that all technology is high, complex and critical to monitor, even in sectors dominated by the most traditional productions.

Nevertheless, in an economy often characterized by the dominance/monoculture of a successful "traditional" industry, the transition, so much desired, to a new HT based excellence, is all but obvious. The emphasis of the literature shows that the attention of the researchers has to be focused on the appropriate combination of entrepreneurial culture, and the capacity to attract or to endogenously create new technological competences. Some of the areas in transition are very peripheral, with respect to the traditional hubs of innovation and economic power. This represents both the incentive to consider new technologies as a gateway for a new centrality and growth, but it is also an obstacle that policy makers need to consider in order to secure the efficacy of their efforts[2]. Italy, despite its traditional inclusion among the most important players in the world economy, is a country which traditionally lags behind in R&D investments, mainly because of the large numbers of small and very small firms, and overall lacks large R&D-based companies[3]. Also, the public research system has good scientifc performance in terms of number and quality of publications, but is not generating much needed intense technological transfer processes, which on the other hand seems to be experienced elsewhere in both Northern Europe and Us.

With the objective of contributing to the already vast literature on this topic (Lawton-Smith 2000) we propose four categories HT-based development in peripheral regions in Italy.

1. *Non metropolitan areas, often medium-sized university cities, where the public sector has heavily invested in scientific research*. In this contexts HT firms are likely to be set up, often as spin-off of public research centres; also, established firms are attracted in the area by the abundance of qualified human resources, often in the same sectors of specialization of public laboratories. The case of **Pisa** falls into this first category.

[2] The CyberGeorgia project http://www.cherry.gatech.edu/cyberga/ is an example of such an effort to promote technological adoption and networking in peripheral and mid-sized cities.
[3] See for example the Technology Achievement Index, developed by the UN in 2001. Italy is excluded from the group of 18 *innovation leaders*, and ranked among the second group of *potential leaders*.

2. *Areas where a significant private investment, usually by one or a few large technology-intensive companies, has promoted a more effective exploitation of existing excellence areas in local public scientific research*. The most typical case in Italy is **Catania** where, according to Schillaci et al. (2000), investments by Stm exploited and further strengthened significant positive externalities from the local public research effort in physics (University of Catania and the National Institute of Physics).

3. *Areas which are not historically characterized by relevant entrepreneurial or industrial tradition, and where previous public investment in research seems to have had some relations with a more recent private investment, which determined the development of an HT cluster*. The relative importance of private and public investments in these cases is debatable, as for example is the development of the **Cagliari** ICT cluster. In this case a public investment in the CRS4 project might have had some influence in the successive investment by Video on Line and the Tiscali phenomenon (Ferrucci and Porcheddu, 2002).

4. *Areas where the concentration of firms in a new specific technology-based industrial sector has reached a critical mass without relevant contributions from public research and thanks to the action of a sort of schumpeterian innovator and the involvement of larger firms from external areas and abroad*. In these cases, high or mid-tech activities established in areas which were relatively poor in terms of scientific and technological know-how, but with a strong and established entrepreneurial culture. Examples are the bio-tech clusters in **Mirandola** (Lipparini e Lomi 1999) and the packaging district around **Bologna**. In the first case, the entrepreneurial initiative of Mauro Veronesi in the Sixties initiated a process which today led to the creation of something like 100 firms. In the second case, critical is the leadership role of the firm Acma.

These typologies and cases show that HT-based development can be pursed in different ways in peripheral areas. For example, some peripheral locations offer advantages (or overcome disadvantages) that more traditional centers are not able to offer. At the same time, the dimensions of the local market, the business community and the scarcity of some of the factors of production (such as qualified labor or capital) might represent bottlenecks for the development of an HT economy.

Today, Italy is in a particular international competitive position. On the one hand, the country faces the competition of advanced economies which are investing heavily in R&D (both by public and private actors), and are able to impose their technological leadership on international markets. On the other hand, emerging economies are becoming good quality manufacturers themselves and also represent alternative locations for qualified private investments, due to the presence of a skilled and cheap labor force and political environments which open up to foreign direct investment (and technologies). Betting on the HT development of Italian peripheral areas might indeed seem an interesting albeit risky alternative. The role that the public sector needs to play should overcome the disadvantages of a peripheral position, which might be an obstacle for private investors. The description of the case of Pisa shows problems and opportunities that an economy based on traditional and small firms faces in the transition towards an HT based economy, and the creation of new linkages between research and territorial development.

2. In Search of an HT Identity: the case of Pisa

2.1 Public Research and Advanced Education in Pisa

Pisa is a midsized "university city", characterized by a strong public research system, with an outstanding public research base and a well-developed education and training system. The city has three universities, including two schools of advanced studies. The University of Pisa is the largest, enrolling 7,000 students a year and employing about 1,500 researchers. The two superior schools - the Scuola Normale Superiore and the Scuola Superiore Sant'Anna - specialize in pure and applied sciences respectively, employing overall about 260 researchers.

Among the most significant presences:

- the National Research Council (CNR) specializing in computer science, physics, mathematics, geology, chemistry and natural sciences (800 researchers),
- the National Institute for Nuclear Physics (INFN), which employs 250 researchers in particles dynamics and fundamental and theoretical physics,
- a laboratory of the National Institute for Energy and Environment (ENEA),
- the Research Center for Experiences and Studies for Military Applications,
- a laboratory of the former electric power monopoly company ENEL (150 people).

The University of Pisa is the birthplace of IT in Italy. Here, in 1955, a team of professors built the first Italian computer, called CEP (Pisa Electronic Calculator). The machine, entirely assembled in Italy, was one of the most advanced computers of the time. After this project, the importance of the IT sector in the city became furrther increased: Cnuce, a university national institute for IT, and the first computer science faculty in Italy have been set up respectively in 1964 and 1968.

The Pisa university system also has a remarkable capacity of attracting students. The number of students, for a city with less than 100,000 inhabitants is impressive. Altogether 42,500[4] people were enrolled in the academic year 2000-1. These students are an important source of qualified labor, and this potentially represents an important advantage that the city has, when compared to other peripheral areas, for the attraction of HT investments. Almost half of the students graduate from scientific or engineering departments, with an average far above the national one.

Table 1: Composition of the University Population in Pisa compared to Tuscany and the rest of Italy

	Students (2000)	*Students per 1, 000 inhabitants*	*Graduated (2000)*	*Graduated in scientific-technology studie*	*% graduated in scientific-technology studies*	*% of graduated in engineering*
Pisa	42,466	109.6	3,657	1,710	46.8	17.1
Tuscany	114,260	32.2	10,674	3,375	31.6	10.4
Italy	1,560,342	27.0	139,108	41,794	30.0	11.6

Source: MIUR, www.miur.it

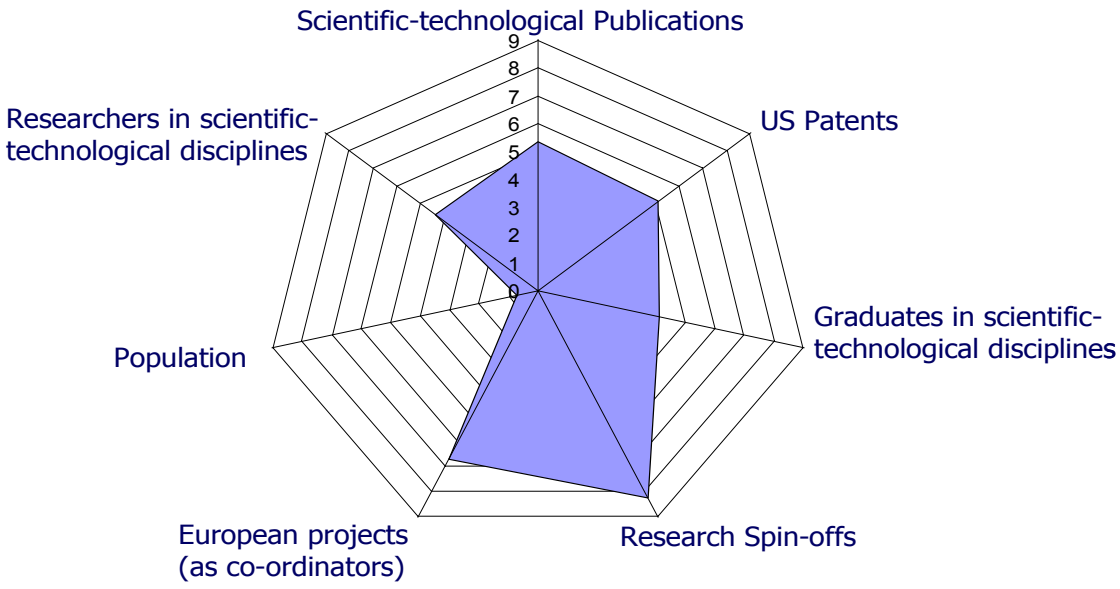
[4] Source www.miur.it.

2.2 Changes in the Economic Structure of Pisa

Apart from the historical presence of the pharmaceutical and chemical sector, the economy of the city was based on traditional industries, such as furniture, footwear, leather and textiles and the transport industry, with the presence of the Piaggio company (the manufacturer of world famous Vespa). These sectors still remain important for the local economy, in terms of employment and revenues, but have entered in a stage of consolidation and hard restructuring. The furniture sector is declining, and the transport industry (mainly Piaggio and its network of sub-suppliers) is on the edge of a serious crisis. Tourism continues to be a crucial resource for the local economy, as about 10 million people visit the city every year to see the world famous Leaning Tower. It is however mostly a one-day tourism, which has only a partial impact on the local economy. Overall the economic situation of the province is in between the restructuring of some of the big companies, and the slow but significant growth of some of the small firms.

As a matter of fact, it is in the area of knowledge-based indicators that the city of Pisa shows performance indicators which are clearly above national and European average (Figure 1).

Figure 1: The relative weight of the province of Pisa, compared to the rest of Italy (Lazzeroni, 2004)



In fact, despite its small population, Pisa has more than 4% of total Italian researchers, more than 5% of total scientific-technological publications, more than 5% of Italian patents in the Us, about 4% of graduates in scientific-technological disciplines, more than 8% of total research spin-off firms and more than 6% of European projects where an Italian organization is project coordinator.

For esample, Pisa counts on some examples of technological spin-off activities from the public research to private industry. Scuola Sant'Anna began a technology incubator-like initiative in 1990 which has resulted in twelve spin-off firms headed by professors and/or students in robotics,

mechatronics and It. The Scuola Sant'Anna, the Piaggio company, and the provincial and city local administrations also promoted the launch of a new company, Pont-Tech, to encourage technology venture development in the area. A technology incubator in the town of Navacchio is located in a former factory renovated with local and EU funds. Initiatives such as the Pisa Research Consortium, seek to provide support for technology transfer projects to existing firms, or to promote quality management practices, as in the case of Qualital, established in 1988. Nonetheless, despite this presence, previous quantitative research (Counts and Di Minin, 2003) and political authorities agree on the fact that the quality and volume of the local public research effort is not fully exploited, and in particular the city lacks the links between research and factors that can lead to more robust territorial development.

The area is characterized by the presence of more than 200 high-tech companies, with a turnover of 1.4 billion Euros, for an employment of approximately 6,500 people. These firms operate in a diverse variety of sectors, even if IT clearly dominates in terms of number of establishments.

2.3 The Evolution of the HT Sector in Pisa

Looking back at the economic development in the area of Pisa, it is possible to identify at least three distinct evolutionary phases.

Birth and Innovative Growth (1955 – 1980). In this phase Pisa was in the favorable position to exploit the extraordinary investment in IT by the public research system. Large companies, such as Olivetti and IBM, decided to invest in Pisa in order to have privileged access to the results of the public research system. However, these investments, as well as the setting up of smaller IT companies, remained a rather isolated phenomena, not linked to the rest of local manufacturing activities which at that time were far more important in terms of employment.

Consolidation and Stability (1980 – 1995). This phase is characterised both by a consolidation of competencies in the IT field and by a diversification of research and private industrial actors in other scientific and technological fields, such as mechatronics and life sciences. Attention on technology transfer activities greatly increases, despite the fact that various initiatives are launched without a single, widely accepted plan for the area. Tertiary activities are increasingly considered as possible complement or even substitutes, for more consolidated and declining manufacturing sectors. Spin off companies, and small HT start-ups replicate the "dual system" of a few big firms and a large group of small companies already present in other traditional sectors in Pisa.

Clustering and Restart (1995 – 2003). In this phase the area of Pisa is widely recognised as an important high-tech cluster, and valorization of research results becomes a priority for local public research organizations. Awarness of the importance of knowledge-based development increases at both regional and local administrative levels. The HT community diversifies and opens up to sectors such as the medical-pharmaceutical, electronic, micro-electronic, and telecommunication. Growth rates show rapid increase in bot the number and the turnover of high-tech businesses. The funding of technology parks and incubators in the province of Pisa, leads to a spatial diffusion of what was before a mainly urban phenomenon. Nontheless, the economic and socio-political weight of the HT community should further increase if the mission of a knowledge-based area is really accepted.

At present (Table 2) more than half of HT firms in Pisa operate in the IT sector. The following table shows the composition of the industry.

Table 2: Distribution of HT Firms in Pisa

Industry	*Number of firms*	*% of total firms*
IT Services	62	29.7%
IT R&D	46	22.0%
Innovation Management	27	12.9%
Mechanics & Electronics	22	10.5%
Energy & Environment	9	4.3%
Telecommunication services	6	2.9%
Microelectronics	9	4.3%
Pharmaceutical	7	3.4%
Telecommunication R&D	6	2.9%
Biomedical	3	1.4%
IT Diffusion	2	1.0%
Other	10	4.8%
Total	209	100%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003

According to the Observatory, the HT sector produces a turnover of 1.4 billion Euros, employing about 6,500 people, most of whom highly qualified. The so-called "IT Diffusion" and the pharmaceutical sectors are the largest in terms of turnover, being responsible for respectively 63% and 17% of the total revenues. Also, within the HT sector, it is therefore possible to observe the mentioned dualism between small firms and big companies. In fact, 70% of the HT companies in Pisa employ less than 30 people. The IT sector is dominated by firms which employ an average of 12 people per company, while the average in the pharmaceutical sector is 297 employees per firm.

Table 3: Pisa High-tech industries' invoice and employment

Industry	*Average turnover (valuation)*	*Average Number of employees (valuation)*	*Average employment growth rate (1998-2001)*
IT Services	5.7%	20.4	86.5%
IT R&D	7.7%	16.1	79.4%
Innovation Management	0%	5.2	5.6%
Mechanics & Electronics	4.2%	17.7	40.3%
Energy & Environment	12.5%	8.5	73.3%
Telecommunication services	5.0%	5	0%
Microelectronics	0%	5.1	35.8%
Pharmaceutical	2.2%	179.1	
Telecommunication R&D	12.0%	40.5	N/A
Biomedical	N/A	8.5	N/A
Other	14.1%	25	98.2%
Total	6.2%	28.0	62.3%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003

During the 1998-2001 period, the HT sector experienced a significant and steady growth of more than 62% in employment. The Information Technology sector (both IT Services and IT R&D) has been the fastest growing sector, in particular in terms of number of people employed (+87% in IT Services and +79% in IT R&D).

The number of HT companies has experienced a steady growth during the 90s. Almost half of the HT companies localized in Pisa have been set up after 1995 (41,5%). The youngest firms usually operate in the IT sector (51,4%), telecommunication, energy and environment.

Table 4: Foundation years of the high-tech companies in Pisa

Foundation year	*Number of sampled firms*	*% of total sampled firms*	*Number of IT Sampled firms*	*% of total IT sampled firms*
From 1910 to 1980	13	9.6%	4	5.6%
From 1981 to 1985	10	7.4%	7	9.7%
From 1986 to 1990	19	14.1%	8	11.1%
From 1991 to 1995	37	27.4%	16	22.2%
From 1996 to 2001	56	41.5%	37	51.4%
Total	135	100%	72	100%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003

This growth trend is confirmed by data from the Italian Central Bureau of Statistics (Istat), according to which in 1981 the HT sector in Pisa employed 3,859 people, while in 1991 this number increased by 35%. According to Istat data, in 1996 the HT sector in Pisa was employing 5,707 persons[5], with an average yearly growth of 3% over a 15 years period.

Also, important financial and governance restructuring happened within the HT industry. The three main typologies are (1) *merging and acquisitions of local companies by behalf of international corporations*, (2) *holding relationships with national companies*, and (3) *the rise of local industrial groups*.

The pharmaceutical sector has been by far the most dynamic. Five out of the seven companies based in the province got access to foreign capital anche changed radically their proprietary assets. In 1997, the Gentili Institute, one of the oldest chemistry firm in Pisa (set up in 1917), became a member of the Merck Sharp & Dhome Group. In the same year, the American Baxter acquired the Austrian Immuno, and the English financial group 3i took part to a family buyout operation for Farmigea in 2001; finally, two foreign companies recently invested in Pisa: the Spanish Grifols (1994) and US Abiogen Pharma (1997).

Beyond the pharmaceutical sector, other important foreign groups invested in Pisa. In the aerospace sector, Alenia Marconi System, the result of a joint venture between British Aerospace and the Italian Finmeccanica, has a small research centre. In mechanics and electronics, the Japanese multinational Mitsuba and German Siemens invested in Pisa, while in the IT sector Engisanità (previously part of Olivetti) was set up as a joint venture between the French group GFI Informatique, and the Italian Ingegneria Informatica; in 1997, ISL (a local IT company) was acquired by the French group Altran.

[5] According to estimates of the Observatory, this number is now beyond 6,500. The upcoming results of the official census will soon confirm this growth trend.

Italian corporations also invested in the area. This happened either by means of buying local companies (such as the Espresso Group acquiring Ksolutions in IT, or Laboratori Guidotti becoming part of the Menarini Group in pharma), or by establishing local branches in the area, such as Netikos, part of the Telecom Italia, which absorbed a pre-existing Italian It company. As a result, 28.3% of the sampled IT companies and 60% of the pharmaceutical ones are now part of larger business groups.

Table 5: Equity relationships in the high-tech sector

Industries	*% of companies held by an industrial group*	*Nature of the group*		
		Local group	*National group*	*Foreign group*
Pharmaceutical	60.0%	-	33.3%	66.7%
Information Technology	28.3%	52.9%	35.3%	11.8%
Total Industries	31.3%	48.4%	32.3%	19.4%
Industries	*% of companies which hold shares in other companies*	*Local group*	*National group*	*Foreign group*
Pharmaceutical	60.0%	-	-	100.0%
Information Technology	23.3%	78.6%	14.3%	7.1%
Total Industries	27.8%	63.0%	22.2%	14.8%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003

2.4 Strengths and Weaknesses of HT in Pisa

The following table summarizes the results of the study on Pisa HT sector. This section expands the discussion about the main findings.

Table6: Analysis of the main opportunities and obstacles for HT development in Pisa

Actors	*Pros*	*Cons*
University system	- an outstanding public research base and well-developed systems for education and training; - capacity of acting as catalyst to attract and retain students and potential entrepreneurs; - several technology transfer organizations have been established, and some technology poles are active in the area.	- networking activities within the area appears low and this hinders firms growth and transfer of knowledge from public science; - a main challenge for the area is how to encourage a more positive attitude towards risk-taking and adaptation to new trends in the educational sector.
High-tech firms	- fast and significant rise of new firms; - emerging new corporate governance; - steady growth trend of the sector: the number of high-tech companies	- lack of intense networking activities among firms; - weakness of HT led initiatives by local associations; - absence of a formally agreed strategy and lack of a clear leadership

	has risen constantly during the 90s, including foreign multinationals, local companies, start-ups and spin-off companies; - overall, good innovation capacity .	in the high-tech community; - low capacity to enter extra-regional markets and low marketing skills of the technical entrepreneurs.
Human resources	- highly qualified; - rather abundant; - less expensive than in the North of Italy and North of Europe.	- low possibility of labor mobility inside the area and risk of losing talents; - low attitude towards enterpreneurial risk.
The area of Pisa	- good quality of life; - presence of good transportation infrastructures (port, airport, highways, rail); - central geographical position in Italy; - presence of some high-tech incubators infrastructures.	- limited regional market; - low presence of innovative finance instruments; - lack of some knowledge business services; - need for better organisation of networking institutions and infrastructures.

R&D investment in the sector is quite relevant. Both the percentage of people employed in R&D activities and the expenditure in R&D over total revenues are quite high, by far above 10%, which is usually considered to be the minimum level for the HT sector. The level of people employed in R&D is 42% on average. These data might however overestimate the real importance of R&D in the sector, given the micro-dimensions of most of these firms, where it is quite common for R&D personnel to cover other roles in the organization. Nevertheless, the workforce is generally highly qualified, usually graduated from scientific and technical schools (72%), and 83% of the companies claim to have introduced technological innovations.

R&D is most of the time carried out in house, rather than acquired from outside (the make/buy ratio is 70/30), but there are significant differences among sectors. Outsourcing prevails in the telecommunication sector (with a make/buy ratio of 28/72), and the two channels have equal importance in the pharmaceutical sector (make/buy ratio of 51.5/58.5).

The use of patents is still quite limited. Only 23% of the interviewed companies own a patent or have applied for a US, European or Italian patent.

Table 7: Main R&D parameters

Industry	*% of R&D employees in 2001*	*% of R&D expenditures in 2001*	*R&D make/buy ratio*	*Number of patents*	*% of employees graduated in scientific-technical subject*	*% of firms that have introduced technological innovations*
IT Services	38.1%	21.9%	69/31	2	65.6%	92.9%
IT R&D	34.4%	26.2%	61/39	3	58.4%	77.3%
Mechanics & Electronics	36.1%	14.2%	90/10	6	68.2%	77.8%
Energy & Environment	56.7%	18.3%	87/13	4	94.5%	75.5%
Microelectronics	75%	38%	73/27	2	95%	100%
Pharmaceutical	12.3%	4.99%	52/48	2	38.17	100%
Telecommunication	36.2%	16.25	28/72	0	83.75%	66.7%
Innovation Management	12.5%	10.0%	N/A	1	52.75%	N/A
Biomedical	N/A	N/A	N/A	2	N/A	N/A
Other	44.4%	22.7%	68/32	2	74.5%	75%
Total	42%	20%	70/30	23	72%	83%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003 (Total sample: 73 companies)

It is important to consider the interactions that take place within the HT sector. The presence of a particularly strong public research investment should lead to significant networking between HT companies and the university system. However, even if the number of companies that have interactions with the university is quite high (76%), the frequency and extent of these relationships are quite limited.

The interactions between HT companies and university are often related to partnerships in research projects and internships for students, but they are not the most common source for new technologies. Generally, companies invest in in-house R&D, for the generation of new technologies, only rarely using collaborations with universities or with other HT firms.

Table 8: Sources used to develop new technologies

Ways to introduce new technologies	*Frequencies*			
	Never	sometimes	often	always
% of R&D inside of the company	4.0%	8.1%	52.5%	35.4%
% of collaboration with university	39.2%	34.0%	5.2%	21.7%
% of collaboration with companies	28.9%	46.4%	1.0%	23.7%
%of R&D bought by public research system	72.7%	20.2%	1.0%	6.1%
% of R&D bought by private research system	73.7%	20.2%	0.0%	6.1%
% of technology license purchase	62.2%	23.5%	2.0%	12.2%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003 (Total sample: 99 companies)

According to the survey, the interactions between the university system and HT firms are not based on systematically organized initiatives (like liaison offices or technology transfer partnership), but are often generated by personal contacts, and informally organized. The lamented difficulties to build up strong and lasting networking between university system and HT local companies have to do with different goals and time frames. Also, the different dimensions of the partners and the different desired scale of the projects, generate significant difficulties. In particular, it is hard to set up the right incentives to convince small companies to take part to university R&D projects. Usually, the small companies, which systematically interact with the university, have strong relationships with the academic environment even before the firm's start-up phase.

Generally, high-tech entrepreneurs recognize to the university system a crucial role. They demand local universities to be involved in basic research projects, to be internationally competitive, and to attract world class excellence. Local entrepreneurs feel that universities should also be able to produce transferable results, and should be more sensible to specific local needs.

Networking within the industrial HT community is also quite limited. What seems to be lacking is an agreed strategy to foster the development of the sector. There are no strong and active industrial associations. This is mostly due to the great variety of the high tech companies, which operate into several different sub-sectors. The full potential of the high-tech associations already present in Pisa is not fully understood and exploited.

Another important limitation of the HT community is the local dimension of the market which local companies are selling to. 35% of Pisa HT companies have the province or the region as their primary market, and only 11.3% are mostly active in an EU or world market.

Table 9: Geographic location of the markets and of the main competitor

Geographic area	*Most important market*	*Second market*	*Location of the main competitor*
Province	12.5%	5.3%	12.5%
Tuscany	22.5%	31.6%	12.5%
Italy	53.8%	28.9%	43.8%
Europe	10.0%	10.5%	15.6%
Rest of the world	1.3%	23.7%	15.6%

Source: Observatory on High-Tech companies in the Province of Pisa, 2003

The data which have been collected as well as the in-depth interviews which have been conducted throughout 2002, have led to the identification of four main type of companies.

1. **Established Innovators**. These are large firms which spend a significant amount of resources in R&D. They also developed effective commercial strategies, and seek or do operate on large and even global markets. Collaborations with public R&D and with the national HT industrial community is considered very important. However, these firms argue they have to face severe obstacles in order to obtain an effective interaction with the local entrepreneurial community, and the local public research system.

2. **Technology Integrators**. These firms specialize in the adaptation and integration of technologies - which are already present on the market - for local or national customers. These firms usually do not invest significantly in human resources or in R&D projects, and

do not collaborate intensively with the public research system. Obviously, for these firms the interaction with other companies, both suppliers and potential customers is critical, for the definition of the market and for the organization of the process. Learning by doing and technical consultancy with clients represent the most strategic activities.

3. **Technology Labs**. These firms invest heavily in R&D, but they have not fully developed a coherent market strategy or at least they were not able to identify their markets. Most of the clients are local, even if the interaction with the local business and research communities is not fully exploited. However, this category experienced a significant turnover growth in the last years. Also, these firms are increasing the number of people employed, and most of all, they absorb a growing number of graduates from the local universities.

4. **Emerging Innovators** and **Research Spin-Offs**. These firms are still mostly focused on R&D activities, but they operate on a national market. The first group of companies in this category frequently interacts with the local HT community, whereas the spin-offs lament significant difficulties in finding the appropriate partners. These initiatives are quite likely the most interesting ones, and they deserve particular attention to overcome the difficulties typical of the start-up phase.

Apart from the first category, the three other ones fall within the definition of "technological artisans", because of their small size, regional markets and one-to-one relationship with customers and clients. The core business for some of these firms is technical consultancy. In the IT sector in particular, companies assist their clients in the adoption of new technologies or software. For these and other technological artisans, one of the main deficiencies is the lack of adequate marketing skills. Technological competence is not always coupled with the capacity to identify the most appropriate markets or clients.

Even if the level of internationalization of Pisa HT firms is not high, these companies need to face international competition on the local and national market. Only a few companies in the survey state that their local market is beyond the threat of international competitors. These are companies which adapt foreign technologies for the specific needs of local adopters. Their knowledge of clients' needs offer them some protection from an immediate threat of the producers of the technologies, even if this particular niche of market does not offer them the possibility to secure and expand their technological leadership, nor it represents a stable and lasting market.

Even if Pisa HT sector offers examples of impressive innovative and R&D activities, which are successfully exported abroad by internationally oriented companies (such as Baxter, Abiogen Pharma, Netikos, Siemens, Ids), overall the firms' small size, the exclusively local (and not particularly sophisticated) market, and the lack of intense networking represent the main limitations.

Another major problem for the technological development of the area is an endemic one among peripheral Italian HT communities. Growth is sometimes limited by the lack of specialized capital, in particular venture capital. With no surprise, the survey showed that most of the local companies in Pisa have been set up with personal funds belonging to the entrepreneur themselves. The lack of a specialized VC community has many negative consequences. Besides the most obvious ones, the lack of a pre-screening on behalf of a specialized financial expertise increases the mortality of firms, and even when personal funds are available, the lack of resources for an expansion lead to choices that might be too conservative and not competitive. Firms without the appropriate support of outside capital might never get out of the start-up phase. Also, the active presence of a VC leads to an important networking effect among assisted firms, which can only be beneficial for the local competitiveness. The already mentioned redefinition of the proprietary structure might offer a way

out of this dilemma, but might open up new problems in terms of the relative weight of the local area within foreign corporate strategies.

2.5 The Public Research System and its Importance for Human Resources and Entrepreneurship

Even if the public research system has not been able to enact a lasting technology transfer mechanism, the survey shows the role of the university system as a *factory of entrepreneurs.* The largest majority of HT entrepreneurs graduated from the local universities, but the most striking data is that 66.7% of them were not born in Pisa, and moved to the city during their university studies. Only 25.6% moved from other cities in Tuscany, while 41% moved to Pisa from other regions. The undergraduate programs of the university are therefore able to attract and, to some extent, retain in the area HT entrepreneurs.

The significant presence in the area of public research activities leads to a relatively large *local market for qualified labor*, which clearly distinguishes Pisa from other peripheral areas in Italy. This is among the most important elements that local entrepreneurs have indicated as reasons for locating in Pisa. Potentially, public labs represent also important *research partners* in particular for the largest companies. Marconi, Ericsson and Telecom, Austriamicrosystem International in the microelectronics industry, Komo Machine Inc. in the mechanics and electronics one, and Ital Tbs in the biomedical have set up research facilities in the city, to exploit the proximity with a big (but provincial) university.

Conclusion: HTSF in Peripheral Areas

This study tried to show how the case of Pisa might be useful to understand limits and opportunities that an HT-led growth strategy might face in peripheral regions. The complexity of the research question called for both a quantitative and an in depth qualitative empirical study of the economic and technological potentials of the area. The steady growth trends of the HT sector led to increasing political attention of local administrators, which envisioned in the "HT Mecca" the way out of the crisis for the traditional sectors (furniture and transportation in particular). The development of the HT sector in the area seems an important opportunity not to be missed, highly compatible with the local endowments research and knowledge intensity, qualified human resources and entrepreneurship. However the lack of innovative financial instruments, networking activities and technology transfer initiative seem to represent black clouds overcasting the HT sky over the city. Three main recommendations for policy makers in midsized cities and researchers involved in similar studies emerge from this study.

First of all, it is crucial to fully comprehend the extent of local resources endogenously available. In particular, the triangulation of different approaches should define what is not yet fully exploited, and which resources need further monitoring. In the case of Pisa, a world class university system and research community needs to be coupled with adequate linkings with the industry.

Secondly, the Pisa case shows the importance of institutionalized partnerships and lobbying groups, to contribute to the definition and, if necessarily, redirect HT policies, according to the particular needs of the industrial community. Similarly, the lack of leadership, both in the private sector and within the public research community might cause shortermism in technology policies, and both industrial and market strategies.

Finally, a main challenge for the area is to replicate the intense networking typical of the Italian industrial districts, within the HT sector. Agglomeration of firms in the same sector does not automatically lead to the benefits of clustering. Local firms need to increase their reciprocal knowledge, and the right incentives for this should be in place. The facilitation of personal contacts among entrepreneurs, technological partnerships and labor mobility are all ways to go in this direction and facilitate the local transfer of tacit knowledge.

References

Arora, A. and A. Gambardella (1990). “Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology”. The Journal of Industrial Economics. **38**(4): 361-379.

Autio, E. and H. Yli-Renko (1998). “New, technology-based firms in small open economies-An analysis based on the Finnish experience”. Research Policy. **26**: 973-987.

Bade, F. B. and E. A. Nerlinger (2000). “The spatial distribution of new technology-based firms: Empirical results for West-Germany”. Papers in Regional Science. **79**: 155-176.

Carlino, G. A. (2001). “Knowledge Spillovers: Cities' Role in the New Economy"”. Business Review. **Q4**.

Chiesa, V. and Piccaluga A. “Exploitation and diffusion of public research: the general framework and the case of academic spin-off companies”. Economic Innovation and New Technologies. **8**: 197-223.

Cooke. P. (2002), Knowledge Economies. Clusters, learning and cooperative advantage, London and New Yor, Routledge.

Delapierre, M., B. Madeuf, et al. (1998). “NTBFs-the French case”. Research Policy. **26**: 989-1003.

Ferrucci, L. and D. Porcheddu (2002). Start up and evolution of an ICT district: the Cagliari case. Software in Emerging Regions, Scuola Superiore Sant'Anna, Pisa, Italy.

Heydebreck, P., M. Klofsten, et al. (2000). “Innovation support for new technology-based firms: the Swedish Teknopol approach”. R&D management. **30**(1).

Jaffe, A. (1998). "Patents, patent citations and the dynamics of technological change", NBER. 2002.

Jones, S. (1992). The Biotechnologists. London, The Macmillan Press.

Lawton Smith, H. (2000), “Innovation Systems and ‘Local Difficulties’: the Oxfordshire Experience”, in Acs, Z.J. (ed.), Regional Innovation, Knowledge and Global Change, London and New York, Pinter.

Lee, C., K. Lee, et al. (2001). “Internal capabilities, external networks, and performance: a study on technology-based ventures”. Strategic Management Journal. **22**: 615-640.

Lazzeroni, M. (2004), Geo*grafia della conoscenza e dell’innovazione tecnologica*, Milano, FrancoAngeli.

Lipparini A. and A. lomi (1999), “Interorganizational Relations in the Modena Biomedical Industry: A Case Study in Local Economic Development”, in Grandori A. (ed.), Interfirm Networks: Organization and Industrial Competitiveness, London, Routledge.

Mowery, D. C. (1995). "The Boundaries of the US Firm in R&D". Coordination and Information. Lamoreaux and Raff. Chicago, NBER.

Piore, M. and C. Sabel (1984). The Second Industrial Divide. New York, Basic Books.

Porter, M. (1998). “Clusters and the new Economics of competition”. Harvard Business Review(Nov/Dec): 77-90.

Sabel, C. (1993). "Studied Trust: Building New Forms of Cooperation in a Volatile Community". Explorations in Economic Sociology. R. Swedberg. New York, Russell Sage.

Saxenian, A. (1994). Regional Advantage. Harvard University Press, Cambridge, Massachusetts & London, England.

Schillaci, C., C. Di Gesù, et al. (2000). “Microelettronica e Imprenditorialità: verso lo sviluppo di un polo Hi-Tech nell'area Catanese”. Economia e Management. **1**: 75-90.

Shan, W. (1990). “An empirical analysis of organizational strategies by entrepreneurial high-technology firms”. Strategic Management Journal. **11**: 129-139.

Storey, D. J. and B. S. Tether (1998). “New technology-based firms in the European Union: an introduction”. Research policy. **26**: 933-46.

Yli-Renko, H., E. Autio, et al. (2001). “Social capital, knowledge acquisition and knowledge exploitation in young technology-based firms”. Strategic Management Journal. **22**: 587-613.