The strategic and technological determinants of the structural forms of Hi-tech Clusters[1]

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Abstract: The goal of this theoretical contribution is to explain how knowledge can orient a Hi-tech Cluster (HC) towards a certain type of structural organisation. The theoretical model here proposed suggests that, at firm level, the main condition affecting the structural form of a HC is the extent to which market and technological knowledge of some lead organisations influence knowledge of the other organisational members of that network (dependency of minor cluster firms on lead companies). At industry level, technological complexity is the other critical condition orienting a HC towards a certain structural form

Keywords: Hi-Tech Clusters; dependency; knowledge; technological complexity; inter-firm relationships.

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1 Introduction

The survival and growth of every firm depend on its capability of finding in its external environment valuable and differentiated resources, as knowledge (Pfeffer and Salancik, 1978). This dependency of firms on their environment is critical in those relational contexts as social networks where learning, entrepreneurship and innovation are used to occur mainly thanks to the frequent inter-organisational relationships between the nodes there 'embedded' (Granovetter, 1985; Burt, 1992).

These propositions find wide confirmation by observing the behaviour of firms in Industrial Clusters (henceforth: ICs), which often benefit from local spill-over of knowledge. These networks are built on relational systems linking together a variety of different actors of a region. Becattini (2004) and Perry (2005) suggest that the

'cognitive strength' of regional clusters is to provide a free and available bundle of common knowledge for all their members. Large and small firms, in fact, are used to integrate such knowledge coming from their local partners and their specialised competencies in order to produce new ideas, strategies and products.

Scholars have always focused on how small local companies interact, exchange and create new knowledge within the cluster boundaries (e.g., Marshall, 1892). But the contribution of lead companies within ICs for their knowledge 'richness' is well known in management literature as well. Indeed they commonly play the role of:

- technological gatekeepers (Malipiero et al. 2005)
- network 'feeders' (Lazerson and Lorenzoni, 1999)
- entrepreneurial sources (Schiavone, 2008).

All these views clearly suggest that under given conditions the knowledge of main cluster companies can both orient the network evolution and affect the knowledge of their minor local partners and/or subcontractors. In other words, the strategy of a large company does not affect only its own structure (as argued by Chandler, 1962) but it is likely to influence also the structural form of its local network of suppliers.

Theory and practice suggest it occurs in Hi-tech Clusters (henceforth: HCs) as well. According to Saxenian (1998) a HC is

> "a regional network-based industrial system that promotes collective learning and flexible adjustment to changed conditions among specialist producers of complex, related technologies."

In this field, recent studies stress the critical relevance of knowledge and governance of inter-firm relationships in HCs in order to define their organisational structure and explain their internal dynamics, as learning (e.g., Parrilli and Sacchetti, 2008).

This paper attempts to develop new theory about HCs management and organisation providing a specific knowledge-based and multilevel categorisation of their structural forms. Indeed, this theoretical contribution (Rindova, 2008)[2] wills to explicate how knowledge (at firm level) and technological complexity (at industry level) can affect the structural organisation of these networks. According to a widely accepted framework in order to build theoretical contributions (Whetten, 1989), in this study it is argued that there are four main factors explaining the structural form of a HC:

1 the extent to which the market knowledge of the leading organisations affects the market knowledge of minor companies
2 the extent to which the technological knowledge of the leading organisations of the HC affects the technological knowledge of minor companies
3 the level of hierarchy of inter-firm relationships among lead and minor firms
4 the level of technological complexity of the products assembled in the cluster.

The contribution proposes the first two factors determine the third. The assumption of this framework, in fact, is that the dependency of minor firms' knowledge on leading companies' knowledge affects the level of hierarchy characterising inter-firm relationships within an HC. The level of hierarchy (or flatness) in an HC and the technological complexity of cluster products are the factors orienting that HC towards a certain type of structural organisation. The structural form of an HC tends to be

'pyramidal' if hierarchy and technological complexity are high. Otherwise, HCs tend to achieve a 'flat' form. All this argumentation and its assumptions stem from observing how inter-organisational relationships among leading and minor firms orient the structural form of industrial clusters in traditional industries.

The paper is organised as follows: Section 2 describes the concepts of industrial cluster and analyses the main structural forms that these clusters can hold. Section 3 explains the concept of HCs and its main features. Section 4 analyses the various structural forms of HCs and how a HC can change its structure during the course of the time. Finally, Section 5 suggests some policy and managerial implications, limitations and further developments of the study.

2 Structural forms of industrial clusters

Industrial clusters received broad attention from social scientists. Indeed, several regionalists (Markusen, 1996; Scott and Storper, 1989; Saxenian, 1998), economists (Marshall, 1892; Pyke et al., 1990; Becattini, 2004) and sociologists (Bagnasco, 1977; Trigilia, 2001) have provided detailed descriptions of the main assumptions and working mechanisms of these regional models of production using an interdisciplinary approach. Within management studies, Porter (1998, 2000) has stressed the role of spatial agglomeration of firms in order to achieve regional economic development. In particular, he has defined an industrial cluster as

> "a geographic concentration of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions… in a particular field that compete but also cooperate." (Porter, 2000)

Clusters positively affect regional competitiveness for three main reasons:

- they increase productivity of local companies
- they drive the direction of innovation
- they stimulate the star-up of new local ventures.

The organisations members of an IC frequently interact in collaborative and/or competitive ways. It allows these actors to utilise and 'mix' the various types of knowledge present in the clusters in order to reach their purposes and implement their activities (Groen, 2005; Schiavone, 2008; Brown et al., 2008):

- *Firm-specific knowledge*. This is the core activity, the specialisation of the company. Such type of knowledge depends on the internal capabilities of the firm, its history and previous experiences, skills and education of its entrepreneur and employees. This knowledge defines the firm's core competencies and competitive advantage.
- *Partner-specific knowledge*. It is not internal but it comes from the knowledge of which the firm benefits thanks to its formal and/or informal cooperation with another organisation. This type of knowledge is specific and bundled within a single bilateral inter-firm relationship and therefore it does not have direct impact on the other actors of the cluster and the general structure of the network.

- *Network-specific knowledge*. This is a type of information that is obtained by the local company through its working ties within the district and the social ties between its members and members of other firms. This type of knowledge is not specific and bundled within a single inter-firm relationship but under given conditions it is 'open' to all the local actors.

Referring to the functions of knowledge, it is useful to distinguish between market and technological knowledge. The former refers to the set of practices, information and know-how used by firms to interact with distribution channels and final markets (e.g., trends and data about final costumers or worldwide distribution chains) (Guercini and Ranfagni, 2007).[3] According to an extended notion, technological knowledge is instead the set of specialisation, techniques and expertise of firms in specific technological activities directly related to the production process (e.g., operations or R&D). This definition of technological knowledge does not focus solely on the divergences between science and technology (Herschbach, 1997)[4] but also stresses its link with specific and pragmatic activities.

Referring to the structural organisation of industrial clusters, a well-known paper by Markusen (1996) suggests that these networks can assume four different types of structural forms. The first type is the 'marshallian' cluster, which is expressly related to the concept of industrial district (Becattini, 2004).[5] In this type of cluster a complete value-chain is concentrated in one region. A production process is not performed by a single firm but it is 'fragmented' among several local firms each specialised in one of these activities. As commonly occurs in this kind of clusters, all the firms co-operate in order to realise 'jointly' the final product. This variant of cluster is the one recognised by Alfred Marshall in his analyses about the British districts of Lancashire and Sheffield. The main points of strengths of firms in Marshallian districts are commonly: strong specialisation in their tasks, strong social connections with various types of economic and institutional actors, in depth knowledge and competencies concerning production processes and the creativity of their entrepreneurs (Becattini, 2004). Relationships between firms are usually both competitive and co-operative.

Hub and spoke clusters are typical of many American industrial systems (such as Seattle or central New Jersey), where in a geographical region one or more large corporations play the role of attractive poles (hubs) for creating other SMEs (spokes). These usually are aimed at supplying the larger companies of the cluster as sub-contractors or partners. It implies therefore that the success and activities of local SMEs greatly depend on the corporate strategies their hub. For instance, it has been analysed how the Italian cluster of the eyewear in Agordo has always been dominated by a large company (Luxottica) that has utilised its strong connections with final markets since the 1960 in order to orient the local population of SMEs (e.g., frames suppliers). During the last 20 years, the 'hub' also started to integrate its production process vertically by buying some of its former local partners in order to increase its profits. This strategic change of Luxottica has been very problematic for the survival of the entire cluster which in that period was already in trouble for the increasing competition of the Asian eyewear companies (Camuffo, 2003).

A state-anchored cluster grows up thanks to the presence of a public or a non-profit organisation (as an university, a military base and so on) that increases the creation of new local businesses in one region, aimed to interact and to supply this public organisation. This type of IC therefore is a public variant of the former hub and spoke

model. Finally, a satellite platform cluster is a congregation of branch facilities of externally based multiplant firms. Its main feature is that the financial and technical resources allowing its development are not endogenous; in fact they are usually external, for instance through actions and programmes of national or provincial governments aimed to encourage foreign investments within underdeveloped areas. The cooperation between firms of these clusters is almost absent. It implies that companies in this type of cluster "must be able to more or less stand alone" (Markusen, 1996, p.304). For instance, a similar type of cluster rose in Manaus (Brasil) where a spatial concentration of large import and export companies has grown during the last few years.

According to a knowledge-based view, each type of IC can be 'shaped' by market knowledge and/or the technological specialisation prevailing in it. For instance, in marshallian clusters (that with hub and spoke clusters are the most relevant and frequent types of ICs) firm-specific knowledge of each SME has to be aligned with the technological specialisations of the other local companies in order to 'fit' properly within the general cluster organisation. Firms share their technological knowledge via market relationships (collaborative and/or competitive) and most of them have direct links with their industrial and final markets (mainly small profitable market niches). These conditions imply there is no dependency of some companies on the others and both market and technological knowledge of all the actors are equally relevant for the survival and competitiveness of the entire cluster.

In contrast, ihub and spoke clusters, the knowledge of the majority of companies has to be in line with the strategy and technological needs of few local lead actors (as in the case of Luxottica). Leading companies are able to decide the set of technological knowledge which is more relevant in their network (Malipiero et al., 2005). For instance, their development of certain new product lines rather than others obliges their subcontractors to hold some specific technical capabilities rather than others. Two critical conditions strengthen the dependency of cluster spokes on hubs:

- a stronger market knowledge (links with final markets and distribution channels), often reinforced by a well-known awareness of the hub brand and products
- a larger and richer organisational structure allowing the hubs to invest more financial resources than spokes in order to develop large scale production processes (and/or to undertake innovation).

The potential dependency of market and/or technological knowledge directly affects the level of hierarchy characterising local inter-firm relationships among IC companies. In marshallian clusters the level of hierarchy of inter-firm relationships between local firms is therefore quite low. On the other hand, in hub and spoke clusters, the market and technological dependency of lead firms on minor ones is higher and thus the level of hierarchy as well. Between these two ideal-types,[6] several studies on both traditional ICs (Nadvi, 1999) and HCs (Parrilli and Sacchetti, 2008) show that inter-firm collaboration within these clusters are based on hybrid mechanisms of control and governance, between market and hierarchy.

The proposed relationship between knowledge dependency and IC hierarchy is a reasonable argumentation (at firm level) for why ICs tend to reach different structural forms. At industry level, the technological complexity of ICs products is another critical variable in order to orient them towards a certain structural form. A technology is complex if it (Singh, 1997):

- *is systemic*: this means that "a complex good or technology comprises elemental units or components, usually organised in hierarchies of subsystems"
- *has multiple interactions*: this means that a product performs its functions thanks to the "multiple interactions and feedback between (its) components within subsystems, between components across subsystems, and between subsystems at various hierarchical levels (that) create a complicated network of non simple relationships"
- *is not decomposable*: this means that a product "cannot be separated into its components without seriously degrading its capabilities or performance".

This definition of technological complexity does not imply that, on the one hand, all science-based industries are complex and, on the other hand, all traditional industries produce 'easy' goods. Referring to the latter, two brief examples of traditional ICs assembling products of different technological complexity can enforce this assertion.

On the one hand, the Italian marshallian district of Prato has always been composed of hundreds of SMEs specialised in all the different production phases of the textile industry (Becattini, 2004). A wide geographical division of labour links local companies. This is not centralised by some lead actors but it is based on both competitive and collaborative relationships arranged directly by all small local firms in order to work 'together' utilising different processes (drapery, weaving) and raw materials (cotton, wool, synthetic fibre) and sell their products in different market segments (both mass and niches). On the other hand, the Murgia cluster in Italy has its hub in 'Natuzzi Salotti', a leading international company of the couch industry. Natuzzi usually assembles its products internally after buying the couches components from its local suppliers (e.g., structure, upholstery, skeleton) and sells them to profitable international market segments.

Despite these examples, a causal relationship is not always sustainable between the level of technological complexity of ICs products and the clusters structural form. The case of Luxottica also shows how clusters specialised in not very complex products (glasses) can assume a hierarchical structure during the course of time. Nevertheless, it is possible to argue (although if not normatively) that marshallian clusters are likely to occur in those industries in which the products complexity is low (e.g., textile). On the other hand, hub and spoke clusters are likely to realise technologically more complex final products even if with a low content of technological innovation (e.g., furniture). The main reason is that ICs specialised in technologically complex outputs need more coordination due to the several technological subsystems and components that are assembled into those products. This coordination can be ensured just by some leading hub companies 'driving' the other cluster organisations.

3 Hi-tech Clusters: main features

This section aims to describe the main features of HCs. In several countries, nowadays, the theoretical and political debate about regional development has greatly shifted from clusters in traditional industries towards science-based clusters. Several cases (as Dubai in United Arab Emirates, Dublin in Ireland or Bangalore in India) indeed showed that it was possible to quickly and successfully create 'ex nihilo' HCs. During the last 20 years the problems of developing, organising and managing HCs became some of the main

interests for an increasing number of economists, geographers, entrepreneurs and policy-makers due to the quick rise all around the world of these knowledge intensive networks (Saxenian, 1998; Bresnahan and Gambardella, 2004).

The main core businesses of their companies are R&D, the production of technological knowledge and outputs. It depends, according to Pavitt's (1984) taxonomy, on the assumption that science-based industries are sectors in which research and innovation are the main factors influencing the industrial dynamics and competitiveness of firms. Knowledge therefore a crucial factor is for these regional networks in order to orient local relations, probably also much more than in other types of industrial clusters. Main critical conditions for the rise and development in one region of such local systems of 'manufacturers' of technological knowledge are (Bresnahan et al., 2001):

- a large labour force with technical and scientific knowledge that is not fully exploited
- the presence of individuals with strong and valuable managerial capabilities
- a good link with final demand, often established by nascent district firms exploiting innovative niches still unexplored within their technological markets.

Large hi-tech firms 'dominating' HCs often play a critical role in spreading technological knowledge and enhancing entrepreneurship in their surroundings as well. For instance, Giarratana et al. (2004) have shown that the presence of US multinational corporations (such as Motorola, HP, Intel, Microsoft) was one of the most important conditions for the diffusion of technological knowledge within the Irish ICT cluster of Dublin, mainly through personnel mobility and spin-offs.

The 'Triple Helix' model summarises all these considerations and evidence. According to this framework, the rise and development of a HC within a region (Etzkowitz and Leydesdorff, 1997) is explained by the interaction of the actors indicated in Figure 1. The model assumes that there are three key actors in order to stimulate technological entrepreneurship in one territory: public institutions (government), no-profit and private research centres (university), and local hi-tech firms (industry).

Knowledge covers a key role since its production and exchange are the final common goals of all these actors. Indeed, their role is to establish a wide and rich network of knowledge-based relationships in order to start a three-step process of economic development and change through the creation within the region of a:

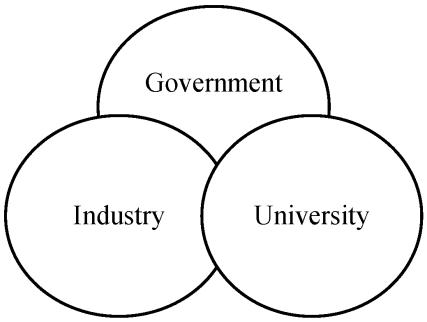
- 'knowledge space'
- 'consensus space'
- 'innovation space' (Etzkowitz, 2002).

HCs therefore can be seen as regional innovation systems, which are commonly defined as the set of relationships linking together public and private actors working in the same region and aimed at developing its economy trough technological knowledge (Cooke, 2001).

Silicon Valley in California is commonly considered the oldest and most famous hi-tech district of the world. It rose in the area of Palo Alto (near San Francisco) during the 1940s, when in the region increased both the number of specialised labour force (primarily engineers graduated at the near Stanford University, as the HP co-founders William Hewlett and David Packard) and amount of investments of the US army.

This latter condition, along with the scientific support of the Stanford Research Park, pushed several local companies towards innovative and profitable niches of hi-tech markets, such as military technologies and defence systems.

Figure 1 The triple helix model



Source: Etzkowitz and Leydesdorff (1997)

Other examples of this type of regional network are Cambridge (UK), Silicon Wadi (Israel), Sophia Antipolis (France), Hsinchu (Taiwan) and Twente (Holland). All these clusters have the characteristics of 'learning regions' (Lundvall and Johnson, 1994), involving the capability to learn and innovate thanks to frequent knowledge exchanges and local interactions between:

- hi-tech large, medium and small firms
- banks and other financial brokers
- universities and research centres
- consulting and services companies
- final users/consumers of the technology
- local and national public institutions governing the region.

In order to organise an HC properly, on the one hand, it is crucial to understand how to set up and manage the set of local relations linking together harmonically and 'systematically' public and private organisations. On the other hand, it is important as well to consider the flows of knowledge that are exchanged by all these network nodes.

4 Structural forms of Hi-tech Clusters

This section wills to describe the various structural forms that HCs can assume. As for ICs, theory and practice about HCs suggest various modes by which these networks can be shaped by market and technological knowledge.

The prior discussion about ICs suggests the hierarchy through which leading IC companies impose their (market and technological) knowledge to the other local organisations and the technological complexity of cluster products affect the structural form of the entire network. These two conditions are important to define HCs structural

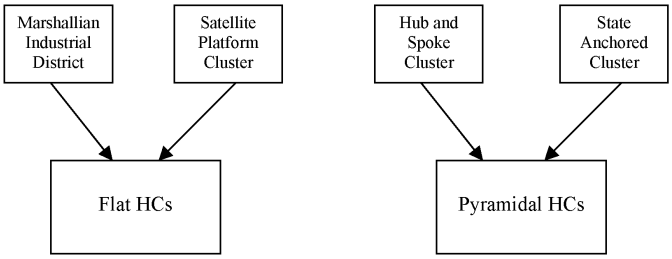
forms as well but some specific HCs features do not allow adopting completely the Markusen classification of ICs.

First, a common characteristic of HCs is the central role played by local universities and public research organisations in order to produce and widespread scientific knowledge in the region. It implies that each HC is also genetically a state-anchored cluster, whatever the influences of market and technological knowledge of lead firms on minor organisations are. For instance, in Milan the "European Institute of Oncology" (IEO) is one of the main 'hubs' of a rising metropolitan cluster of hospital utilities suppliers and research-based biotech companies. Thus, this category (as proposed by Markusen) if applied to HCs is weak and cannot be considered very useful in order to perform a new taxonomy.

Second, in HCs networking and local cooperation are crucial in order to widespread technological knowledge. It brings about that the satellite platform type, being a kind of cluster with very low rates of cooperation and competition between local firms. It is a structural form scarcely interesting for the present analysis since it cannot stress knowledge interdependencies between HCs firms.

These considerations bring about that just the marshallian cluster and the hub and spoke clusters are structural forms valuable for HCs as well. Accepting that the degree of hierarchy within a HC can explain its structural form as well, on the one hand marshallian clusters can be merged with satellite platform clusters into one single category characterised by low hierarchy and flatness. On the other hand, hub and spoke and state-anchored clusters can be merged into another category of HC since both of them assume a hierarchical control of one or few local actors (lead companies and/or universities) on the others. Figure 2 summarises the proposal of revision of Markusen typology in order to classify HCs.

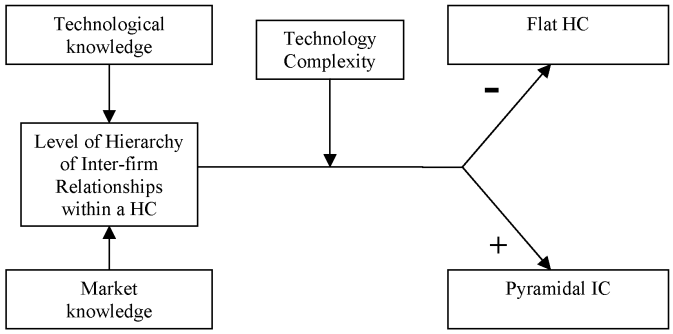
Figure 2 A new typology of structural forms of HCs



HCs can assume a 'pyramidal' structure or a 'flat' one. On the one hand, knowledge (expressed by market links and technological specialisations) of leading firms greatly affects knowledge needed by the rest of the HC. In this case, the dependency of minor firms on knowledge of lead firms is high and technology complexity is likely to be high as well (final products are composed by several different types of technologies). These conditions orient the HC towards a pyramidal form. On the other hand, the HC holds a flat form if the specificities of the technological and market knowledge of leading companies do not affect corporate strategies and technological developments of the other clusters actors. In this case, the dependency of minor firms on knowledge of lead firms is low. Technological complexity is likely to be low as well (final products are not composed of several different types of technologies).

These four variables (technological knowledge, market knowledge, hierarchy of inter-firm relationships within the HC, technological complexity) derive from the analysis of ICs structural forms and are used also to explain how HCs achieve their structural forms. Figure 3 summarises the theoretical model of the study.

Figure 3 The theoretical model of the study



4.1 Pyramidal clusters

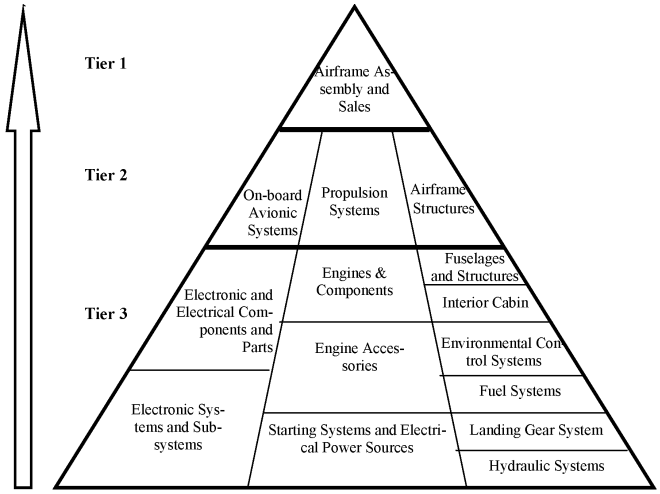
In the first case, we have one or few lead companies and a set of SMEs and research labs that are essentially suppliers of those companies.[7] This structural form originates from the traditional 'hub and spoke' model. The critical feature of this type of HC is that the specific knowledge and competencies of the leading company necessarily influence the variety and evolution of knowledge of the other organisations in the cluster. Such a dependency on leading firms does not come solely from their greater financial resources. It also derives from their strong connections with final markets and capability in co-ordinating several different types of technological subsystems.

For instance, in aerospace clusters, knowledge is commonly a key determinant of the shape and evolution of the entire network (Niosi and Zhegu, 2005). In these industries a pyramidal organisation of the network often rises and its shape is designed by the specialisations of the various firms located in the cluster according to a quite common scheme (Figure 4).

At the top of the pyramid there is one or a few large technological companies serving final markets and assembling the several types of components produced by their local subcontractors. These are placed in the middle or lower positions of the pyramid. Such a structure of regional industrial organisation implies that the firm 'commanding' the pyramid decides indirectly also what are the knowledge and competencies necessary for other local organisations in order to be enrolled successfully within the cluster. The entire cluster organisation, thus, is influenced by the competitive strategy and knowledge needs of the lead company (or companies) and the relationships with other companies and organisations are hierarchical.

The level of technological complexity of aircraft products is high. Single airplanes and projects are often produced and developed by different international networks of specialised companies. Indeed, aircraft manufacturing requires the combination of different types of aerospace parts and components (engines, wings, fuselage, aerodynamics, avionics) and diversified technologies (ICT, electronics, materials engineering) (Esposito and Raffa, 2007).

Figure 4 The aerospace producers' pyramid



Source: Niosi and Zhegu (2005)

An example from another industry comes from Italy where during the course of time the carmaker FIAT started up an automotive cluster in its region (Piedmont) by performing a large outsourcing strategy. Almost all the SMEs of the cluster are local subcontractors of FIAT. They produce components that afterwards the large Italian firm will assembly and therefore all their industrial and entrepreneurial activities greatly depend on the corporate strategies of their 'hub'. Also in this case, technological complexity restricts the access to final markets to FIAT subcontractors and hampers their attempts to reduce their dependency by the lead company strategies. Recently more innovative and democratic models of innovation emerged into the cluster (Consoli and Patrucco, 2009) but they are always controlled by FIAT.

Summarising, typical conditions of pyramidal HCs are:

- *knowledge*: the impact of market and technological knowledge of leading firms has a great impact on the technological and marketing strategies of the other firms
- *technology*: is quite complex and it requires the assembly of several components and different technologies (e.g., aerospace, automotive)
- *links with final markets*: leading companies almost totally hold them thanks to their strong brand reputation and stable relationships with distribution channels
- *inter-firm relationships*: these are based on hierarchical agreements.

4.2 Flat clusters

A second mode of organising through knowledge HCs is more 'democratic' and recalls the marshallian type of regional clustering. In fact, the HC does not gravitate around one or a few predominant companies, even if they have a strong brand reputation or a good knowledge of the final markets and distribution channels. In flat clusters, there is a minor technological and strategic influence of larger firms on smaller firms and research labs. It is possible since relationships between these different actors are not

only hierarchical but prevalently based on collaboration and/or competition. Smaller companies and research–based organisations can thus manage and plan their needs and advancement of technological knowledge more freely. A critical reason for this comes from their greater access to technological final markets.

A key-characteristic of clusters which enables them to achieve this structural form seems their longevity. In fact, in networks with a long history, such as Silicon Valley or Cambridge, the centrality of the largest organisations tends to be reduced by the large amount of direct relationships among hi-tech SMEs. The organisational structure of the network depends on the knowledge shared and exchanged through these inter-firm relationships and the knowledge spillovers provided by its main technological firms. For instance, in the Israeli software cluster of Silicon Wadi there are hundreds of SMEs excelling in their hi-tech niches by implementing R&D partnerships, equity joint ventures and informal collaborations with both local and foreign firms (De Fontenay and Carmel, 2004). This open set of linkages denotes a dynamic and decentralised system of relations. Even if there are one or more leading firms, they tend to orient the nature of the specific knowledge of other firms without any direct and formalised form of hierarchy and/or government. Summarising, typical conditions of flat HCs are:

- *knowledge*: if compared with pyramidal HCs, in this case the market and technological knowledge of lead firms has a lower impact on the technological capabilities and marketing strategies of the other firms
- *technology*: it is quite simple and it does not require the assembly of several components and different technologies (e.g., software, ICT)
- *links with final markets*: leading companies do not monopolise them and hi-tech SMEs can establish direct contacts with their market niches and distribution channels
- *inter-firm relationships*: they are based on market agreements.

Table 1 summarises the various features above described of these two ideal-typical models of HCs.

Table 1 A comparison of Flat and Pyramidal HCs

	Flat HCs	*Pyramidal HCs*
Impact of the knowledge of the leading firms	Low	Strong
Technology	Simple	Complex
Relationships between large and small firms	Collaborative	Hierarchical
Links to final markets	Held by both large and small companies	Monopolised by larger firms
Technological knowledge of SMEs	Driven by their market needs and/or strategies	Driven by the technological strategy of Large Companies

Source: Our elaboration

4.3 Intermediate HCs structural forms

Of course, flat and pyramidal HCs are solely two theoretical 'ideal-types' but different intermediate structural forms (positioned between these two types) can be found in

practice. For instance, it is common to notice some pyramidal HCs sometimes can shift to a flatter form. A famous example of this evolution is the ICT cluster of Bangalore under (Saxenian, 2001; Basant, 2006). The Indian cluster was started thanks to the entry in that area of several large ICT Multinationals (as Texas Instruments, Intel, General Electrics, IBM, Oracle, HP, Sun Microsystems, Cisco, Motorola, Nortel, and Nokia). Between the end of the 1980s and the first half of the 1990s these companies established in Bangalore their own R&D centres and started to subcontract research small local Indian software firms. These actions brought about strong firm-specific knowledge spillovers in the region. In that period another two factors increased in the area the level of specialised ICT knowledge. One was the return to the region of valuable human resources formerly emigrated (as the hundreds of Indian engineers formerly employed in Silicon Valley). The other was the effectiveness of the local education system provided by Bangalore technical universities. In this way the Indian ICT network grew rapidly and its local firms became progressively independent of foreign large companies and, often, international market leaders as well. Presently there are over 1500 Indian IT firms in Bangalore (and many more in others hi-tech sectors), multinationals' subsidiaries and R&D labs, techno-parks and universities (as the IIIT-B) that together create and exchange their firm-specific knowledge in the cluster through strategic alliances and sell their products to final markets.

A similar example is the computer cluster of Large San Jose (Costa Rica), which shifted from a pyramidal 'multi-tier' organisation (dominated by lead companies as Intel, Microsoft and Phillips) towards a flatter structural form. This change was possible thanks to the rise in the region of several start-up companies during the last ten years, most of them controlled mainly by national capital and capable of acquiring leadership positions in their own market niches. These conditions allowed Costa Rican SMEs to reduce partially their knowledge dependency on lead multinational companies (Perrilli and Sacchetti, 2008).

Another interesting example is the Finnish ICT network of Oulu. Here Nokia has always been the leading company of the local industry, the hub around which all its local subcontractors gravitated. During the last ten years the Finnish corporation changed its strategy of 'utilising' knowledge of the Oulu SMEs (from subcontracting to strategic partnerships in manufacturing and R&D). It strengthened the capability of some local SMEs to face international markets and develop innovative product lines not related to their strategic partnership with Nokia. Indeed,

> "close cooperation with a big company has been very important because the cooperation has provided many small and medium-sized suppliers an indirect access to the global market." (Ali-Yrkkö, 2001)

Several other cases could be referred. Anyone of them suggests that, in general, a pyramidal HC starts to tend towards a flat form under the following conditions:

- the impact of market and technological knowledge of lead firms on the other firms' R&D and market strategies decreases
- the links with final technological markets are not established anymore just by lead companies but also by smaller ones, especially if these realise products for strategic niches not served by the former

- the technological complexity of final products is quite simple and, after an initial phase, it does not require large corporate efforts for co-ordinating and assembling their subsystems and components
- inter-firm relationships: they stop to be hierarchical and start being based on market agreements.

5 Conclusions and implications

This paper is a contribution to the study of structural forms of HCs. This work is a progression of prior literature about the structural organisation of clusters since it readapts a traditional typology of traditional ICs (Markusen, 1996) to HCs. These are based on different features and working mechanisms and thus do not allow a total utilisation of previous taxonomies. The paper readapted Markusen categories according to more useful viewpoints (knowledge, inter-firm relationships and technology complexity) for management and organisation scholars.

Two main conclusions can be derived from the former discussion. First, two main structural forms of HCs can be found, and between these two ideal-types several intermediate forms can occur. Of course, there are many external variables and contingencies (e.g., market size, technology breakthroughs, entry barriers and so on) that do not permit us to say that one organisational form is, in practice, better than the other in fostering the efficiency and value creation of a cluster. Anyway, policy-makers should prefer the flat form to the pyramidal form for organising the relational structure of an HC for various reasons:

- it is less dependent on the strategies of the large firms
- it widely spreads technological knowledge within the regional cluster
- it maximises the collective learning and the diffusion of innovation in the cluster.

The second conclusion is theoretical. The research about HCs should enlarge the point of view by which it observes their organisational structure. In fact, it is not only important to coordinate and link together public and private actors producing and sharing knowledge within these clusters. It is also critical to select the most suitable governance mechanisms to manage knowledge and inter-firm relationships between small, medium and large companies and research centres in order to orient their HC towards a proper structural form. Researchers, thus, have to develop innovative methodological tools mainly aimed at identifying the best frameworks for achieving these goals.

All this brings about two main implications. First, managers should consider two critical variables in order to design the corporate and technological strategy of their organisation. One is to understand the organisational shape of their HC and evaluate if their firm (or research organisation) 'fits' properly or not within it. The other is to understand how to fill their eventual gaps in terms of market and/or technological knowledge. For instance, they should decide to arrange new strategic alliances within and/or outside their regional cluster. In this light, a continuous benchmark activity along the lines of technological research developed by the other organisations (both hubs and spokes) in the HC should be very fruitful in order to identify the best strategic partners and align, if necessary, the firm knowledge to cluster standards. In pyramidal clusters the

reduction of the technological gaps of local SMEs is useful to prevent the risk of a too large strategic dependency by the 'hub' of the HC. In flat clusters, it is a key determinant in order to increase the competitiveness of firm products on final markets.

Policy makers interested in developing science-based industries in a region should initially choose an organisational form for their future HC. This decision should consider all those market and technological conditions that are most appropriated for the development of a cluster shaped more by a pyramidal structure or by a flat structure. Afterwards, they should plan how to reach in the shortest and most effective way the most suitable set of local inter-firms relations (hierarchical and/or collaborative) according to the chosen organisational shape.

Our study has two main limitations. One is the lack of a more detailed field research (e.g., a longitudinal case study) describing with data and information how the organisational form of a HC reaches a certain status or evolves during time. The other is that this conceptual interpretation indirectly proposes a view of HCs as 'closed' and self-organising phenomena. For instance, partnerships and collaborations with firms and/or research institutions external (not located within the HC) are not considered. Instead these relationships are critical to reduce the hierarchy of a HC.

Further interesting developments of the present study may lead, therefore, to the analysis of how sources of knowledge external to an HC affect its organisational form. Finally, it might be interesting to extend the categorisation formalising other intermediate types of structural forms fitting better with those HCs that evolve during the course of the time (as Bangalore, San Jose and Oulu).

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Notes

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[2]A theoretical contribution is "a well-ordered whole, with a clear logic and explicated casual mechanisms" (Rindova, 2008).

[3]Market knowledge can be defined as "an objective representation of the market or as a mental reconstruction of the market itself" (Guercini and Ranfagni, 2007).

[4]"Technological knowledge arises from, and is embedded in, human activity, in contrast to scientific knowledge, for example, which is an expression of the physical world and its phenomena" (Herschbach, 1997).

[5]It is "the result of the relation between various factors: social and cultural traits of a community, historical and natural features of a geographic area and some technical features of the productive process. At the same time, an industrial district is the outcome of a dynamic integration process among division of labour in the district and the market enlargement of its products" (Becattini, 2004).

[6]Markusen (1996) too argues that there are clusters (labelled 'sticky places') that do not find a perfect match within none type of her taxonomy.

[7]It is important to remark that in HC also R&D labs and public research centres can be considered as members of the supply-chain of lead firms. Indeed, the core business of these research-based organisations is the production of new scientific and/or technological knowledge often financed by the HC larger companies.