University of Bergamo

University of Brescia

University Carlo Cattaneo - LIUC

Polythecnic of Turin

DISSERTATION THESIS

Innovation systems and technological complexity: essays on evaluation and management from the aerospace industry

Dario Moncalvo

PhD program in Economics and Management of Technology

University of Bergamo

University of Brescia

University Carlo Cattaneo - LIUC

Polythecnic of Turin

DISSERTATION THESIS

Innovation systems and technological complexity: essays on evaluation and management from the aerospace industry

Dario Moncalvo

PhD program in Economics and Management of Technology

SESSION XX

Head of PhD program: prof. Gianmaria Martini, University of Bergamo

Supervisor: prof. Mario Calderini, Polytechnic of Turin

Index

Introduction 8
1. Technological innovation beyond the single firm boundaries...................................... 9
Abstract.. 9
1.0 Introduction 9
1.1 Complexity and complementarities in technological innovation: determinants to going beyond the firm boundaries 11
Knowledge sourcing 12
Development interdependence 16
Exploitation opportunities 18
Wrapping up: open innovation ? 19
1.2 Technological innovation systems: paradigms and experiences 21
Industrial clusters.. 21
Localised knowledge spillovers... 23
Regional Innovation systems... 25
Limits and research questions 26
1.3 Technology platform: toward a new model ?.. 27
1.4 Conclusions 30
Reference 31
2. Technological knowledge base and R&D cooperation potential: a patent based evaluation exercise from the EU aerospace sector 38
Abstract.. 38
2.1 Introduction 38
2.2 The aerospace sector at a glance... 39
2.3 The innovation process in aerospace sector 42
2.4 Knowledge base of aerospace sector as driver for joint R&D platform development?.. 44
2. 5 The evaluation of the knowledge base of a firm 45
2.6 A methodology to estimate and represent technological proximity 49

2.7 Technological proximity in the aerospace sector: a methodological exercise 54
2.8 Knowledge base and R&D cooperation potential 60
2.9 Conclusions 64
References 79
3. Aerospace clusters and innovation management: a platform approach 83
Abstract.. 83
3.1 Introduction 83
3.2 Aerospace cluster academic review.. 90
3.3 Research questions and methodology 91
3.4 Aerospace clustering paths 95
Aerospace Valley (France) 95
Midlands Aerospace Alliance... 97
Hegan.. 98
BavAIRia 100
3.4 Organizational forms and operations in aerospace clusters................................ 102
3.5 Conclusions 106
References 108

Index of figures

Figure 1 - Determinants to overcome firm-centric approach to technological innovation 14

Figure 2 - Firm and external agents involved in innovation process........ 17

Figure 3 - Open innovation funnel (from Chesbrough, 2003)........ 19

Figure 4 - Transformation of Knowledge to Invention and Innovation from Ibrahim and Fallah (2005) 24

Figure 5 - RIS elements (De Laurentis, 2006) 26

Figure 6 - ETPs implementation stages........ 28

Figure 7 - ACARE participants categories........ 29

Figure 8 - ACARE Research challenges 30

Figure 9 - Difference between EU and USA in R&D spending and nature of the industry 40

Figure 10 - the aerospace productive structure (Niosi and Zhegu, 2005) 41

Figure 11 - Aerospace firms identification methodology........ 55

Figure 12 - keyword in patent filter for large multi-industry companies in the Top 100 list 56

Figure 13 - Patents retrieval process 56

Figure 14 - Distribution of aerospace patents in the F classes 58

Figure 15 - Knoledge base analysis process........ 59

Figure 16 - R&D project retrieval 62

Figure 17 - Markusen (1996) industrial cluster taxonomy........ 85

Figure 18 – Porter's competition diamond of local industrial clustering (1998) 87

Figure 19 - Martin and Sunley (2003) collection of cluster definitions........ 88

Figure 20 - Taxonomy of cluster dimension (Swan, 2002) ... 89

Figure 21 - Aerospace cluster data gathering ... 92

Figure 22 - Aerospace cluster in EU and USA ... 93

Figure 23 - Aerospace cluster database structure ... 94

Figure 24 - Aerospace valley activities ... 96

Figure 25 - Midlands Aerospace Alliance – activities ... 98

Figure 26 - Hegan organisational scheme ... 99

Figure 27 - BavAIRia organisational scheme ... 100

Figure 28 - Taxonomy of cluster organizations ... 103

Figure 29 - Classification of cluster operations ... 104

Figure 30 - Cluster classes and operations ... 105

Figure 31 - Operations by number and class of aerospace cluster implementing them 106

Figure 32 - Elements enabled by the different organisational form in aerospace cluster organisations ... 107

Introduction

In the contemporary economic debate innovation has acquired a prominent role both in the academy and business communities. Globalisation pressures advocate investments in innovation as a prescription to allow developed country play a leading role in the fast changing competitive scenario were differential in talent pools, manpower and raw materials costs can be seized shifting the traditional industrial equilibrium.
The innovation strategies played by firms are been adapted to the new challenges by involving even more stakeholder to share risks and gain new worldwide opportunities.
In this context to look at innovation as a system outcome is mandatory to fully understand and handle the changing industrial practises. In this line of reasoning the present work is structured in three papers analysing the innovation system from different perspective that share in the technological knowledge a common pivot element. Moreover the aerospace industry has been chosen to circumscribe the perimeter of the analysis with both an interesting focus characterised by an high-technology profile and practical reference. In the first work "Technological innovation beyond the single firm boundaries" a survey of the main determinants leading to the adoption of a system perspective is presented as a general theoretical framework to manage the topic. The second part namely "Technological knowledge base and R&D cooperation potential: a patent based evaluation exercise from the EU aerospace sector", focusing on an empirical methodology to analyse knowledge base of firms by their patent portfolio, is strongly influenced by the attention to the aerospace sector.
This industry, that synthesizes a variety of technological disciplines, offers the possibility of working on detectable research projects thus leading to the possibility of studying the linkage between technological complexity, knowledge bases and inter-firm cooperation potential. Finally, with "Organised clusters in the aerospace sector: supporting local innovation systems for global competitiveness" the innovation system perspective is seized by a policy making point of view. Starting from the aerospace cluster literature, the paper analyses organisational forms and operations that the aerospace industry support is used to develop and underlines the linkages between governance and support actions.

1. Technological innovation beyond the single firm boundaries

Abstract

The contemporary literature in economics and management of technology locates the rise of systems and networks of multiple classes of agents at the top of the list in the ranking of the most important factors explaining successful technological innovation. After a general introduction to the topic, in Chapter 1.1 the main literature streams giving insight about the determinants leading managers to look beyond the boundaries of their own enterprise in order to develop technological innovation are surveyed.

The chapter is not aiming at providing the reader with a comprehensive literature review but at supplying a general framework to understand the roots of the phenomena with an international (ISI standard) and contemporary (2000-2007) reference to the involved issues. With the same attentions, in Chapter 1.2 the main models and conceptual frameworks grown around innovation as a system's outcome are presented. Chapter 1.3 is dedicated to an emerging model, the technology platform, meaningful both as an analysis unit and a policy tool. The conclusions are focused on the future development and the research agenda coming from the presented research and literature scenario.

1.0 Introduction

Structured innovation efforts have entered into a new organisational era. After the first stage of the single innovator/entrepreneur and the long season of the lab-centric knowledge accumulation and exploitation, a new tenet has appeared in the R&D management practices and policies: the knowledge networks leverage. Growing technological complexity and rising competitive pressure due to globalisation effects, coupled with the scarcity of resources, have increased innovation risks far beyond traditional levels. This trend, combined with emerging multiplicity in innovation opportunities outside traditional developing schemes, is forcing the firms to redefine the innovation processes. In particular, the recent idea of “Open Innovation” as a new exploitation model stresses the importance of innovation systems as the place where assets and human resources can find the right complementarities to deliver to the market the results of complex innovation inputs.

From a managerial and policy perspective, such situation requires the development of new conceptual and empirical tools to deal with innovation systems in terms of potential knowledge complementarities among the private and institutional players, overcoming the isolated firm as the only relevant unit of analysis. To better understand the changes in progress, it is worth analyzing the underlying reasons behind those changes. Those determinants have been identified and seized by different literature streams, even not belonging to the innovation studies field. Far from looking at providing a comprehensive bibliography on each bit of this literature puzzle that includes many classics of the economic thought, in the following a framework including the principal contribution is presented and justified. The selected articles that will be cited were collected with a twofold concern. Firstly, they come from an international standard bibliography, namely the ISI Web of Knowledge, that is worldwide acknowledged as the benchmark in scientific literature quality. Secondly, the mentioned contributions are only from contemporary literature (belonging to the period 2000-2007) in order to keep the focus on what is relevant to the topic of innovation beyond the single firm boundaries, privileging a streamlined, simple but modern analysis and avoiding any philological/historical approach.

The same criterion is applied in the subsequent introduction to the main models and conceptual frameworks already developed to identify and deal with innovation as the result of a complex system. Moreover in this section the examined contributions show a focus oriented toward evaluation and measurement rather than classical theoretical analysis, giving, by that characteristic, an operational approach to a field that involve a variety of academics, policy makers and practitioners. The liveliness of the topic is witnessed by the recent introduction of the policy concept of Technology Platform (2005) within the European Union Framework Programmes and from the thick research agenda arising from the multiplicity of investigation paths starting from the delineated issue.

1.1 Complexity and complementarities in technological innovation: determinants to going beyond the firm boundaries

The theory of transaction costs, whose roots could be found in the seminal work of Coase (1937), may explain, on the basis of effectiveness and efficiency in transaction management, the dichotomy between economic activities organized and performed inside firms and the ones leaved to free bargaining in market regimes. In this line of reasoning, it could be concluded that a firm needs to encompass inside its boundaries all the assets required to create value and delivery it to its own customers. This can be readily applied to the cases in which the fundamental inputs of production could be identified into physical assets and raw materials.

However, if the investigation focus is directed to technological innovation, intangible assets become relevant, and among them, knowledge plays such a major role in innovation development and value creation that it could be considered the main raw material of any improvement process (David, 2005). The nature of knowledge as an economic good implies specific paradigms both for its conceptualization and management that, especially in technology intensive industry, can have dramatic impacts in reconfiguring the overall value chain. For this reason it becomes evident that, to fully understand technological innovation in a contemporary environment, the unit of the analysis should be enlarged beyond the single firm boundaries and adopt an innovation system approach. To set up the above mentioned framework, it is worth considering some recent literature contributions debating innovation schemes where the role of the enterprise as starting point for technological innovation studies is questioned.

With reference to this issue, Jacobides and Billinger (2006) discuss the classical choice of make, buy or ally, introducing innovation as a prevailing determinants in explaining both vertical business architecture and decisions about boundaries that can transform a firm's strategic and productive capabilities and prospects.

Lechner and Dowling (2003) explicitly mention firms' networks as sources for the growth and competitiveness of entrepreneurial firms and SMEs in developing both successful commercial and knowledge transactions.

The unit of analysis to be adopted in technological innovation studies should not be limited to the firm, but needs to include also the institutional setting, especially if complex product are to be considered. In this context institutions could facilitate, and even make possible, partnership between asymmetric classes of agents such as universities, research centers and firms of largely different sizes. Nooteboom (2000) underlines this coordination role played by institutions in innovation systems. Even if largely accepted, the introduction of a systemic focus in technological innovation management leaves on the ground a number of open questions arising, among the others, from the aspects of the traditional approach, focused on manufacturing and tangible assets that dominates the mainstream literature in the field.

The changes required to adopt a more effective viewpoint includes a profound revisiting of many concept already employed in the economics literature and new methodologies in the measurement and evaluation perspective of R&D (Arnold, 2004). In the following a survey of the determinants to be taken into account to realize why is necessary to operate at a level broader than firm centric one to develop technological innovation is presented with brief references to contemporary literature insight. **Figure 1** shows the essential structure on which this analysis is based. The topic of technological innovation beyond firm boundaries is broken down into a threefold MECE (mutually exclusive and collectively exhaustive) scheme of issues that covers the innovation process ranging from the quest for innovative knowledge to the appropriation of the technological innovation value.

Knowledge sourcing

From a management perspective, innovation, in particular the technological one, is based on the application of creativity and knowledge to change the firm's outcomes in order to improve value creation. In the quest for useful knowledge, many factors are to be taken into account in order to succeed in technology development. Even if innovation is always an intrinsically risky option so that its outcomes could not be described in deterministic terms, a structured and rational approach could be adopted to avoid a variety of errors, thus leading to a rising in the probability of positive outcomes. In the knowledge sourcing area a particular attention should be paid to balancing with a proper governance both internal and external sources of knowledge according to their characteristics and dynamics (Fey, 2005).

The process of technological knowledge accumulation that characterises the firms operating in technology intensive industries embeds the well known "**path dependence**" phenomenon (Nelson and Winter, 1982). Even if it could be considered as an unavoidable and even desirable characteristics affecting every structured R&D unit and leading to distinctive specialisation and competitive advantage, it should be emphasized that it tends to develop technological lock-in and may reduce the capacity to exploit new knowledge. This aspect clearly indicates the necessity for a contemporary R&D manager to systematically go beyond his firm boundaries in order to scan the relevant technology frontiers and integrate the most interesting opportunities.

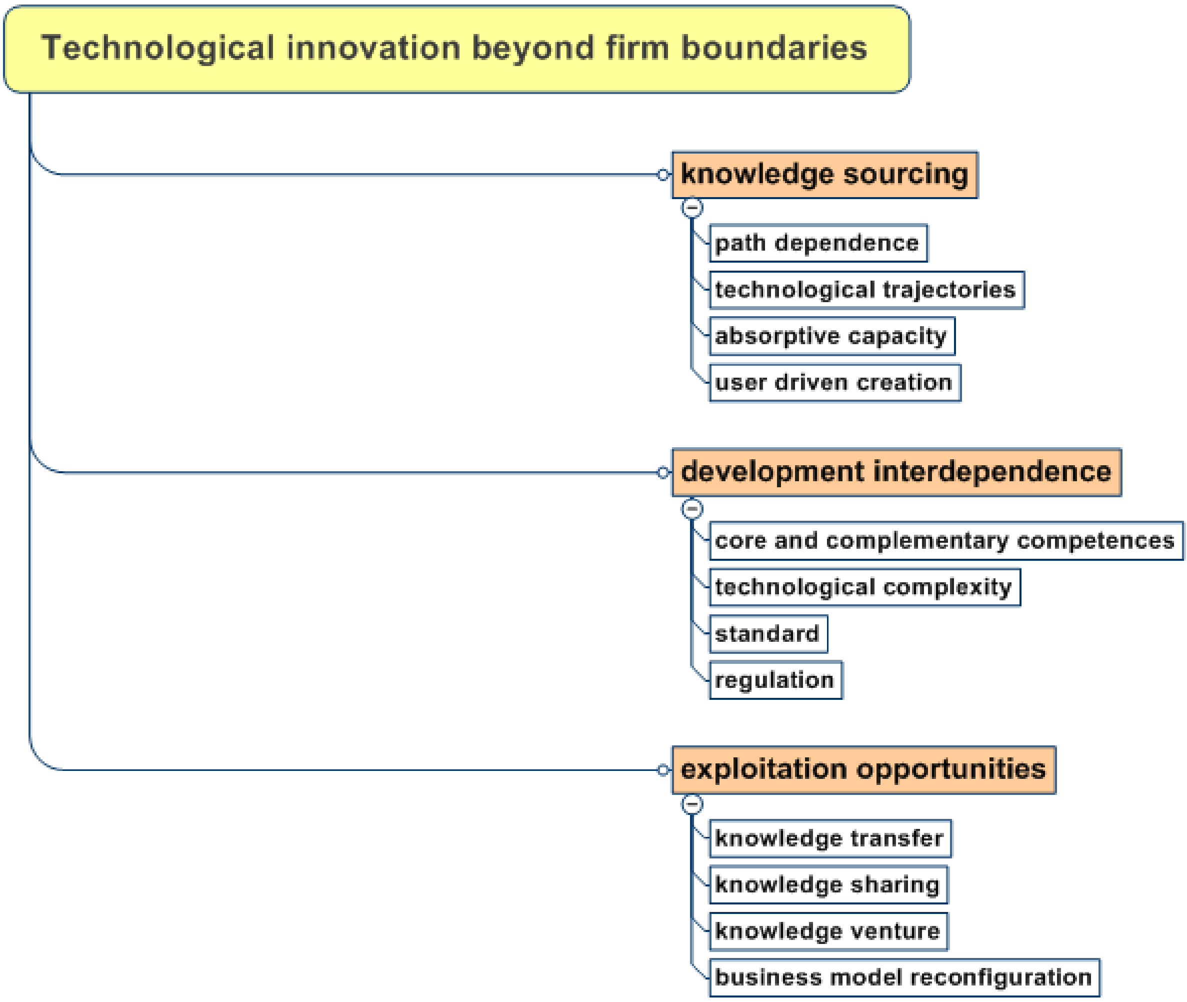

Figure 1 - Determinants to overcome firm-centric approach to technological innovation

With reference to this issue Rycroft and Kash (2002) point out that the path dependence is particularly relevant in the innovation of complex technologies and should be managed by the proper attention to networking and learning processes. Nerkar and Paruchuri (2005) recognize that path dependence could play a positive role in creating necessary scaffolds to further develop technological advances as well as raise serious limitations to the evolution of technological capabilities depending on the myopia of individual R&D leaders.

Closely connected with the knowledge accumulation processes leading to technological path dependence and lock-in effects, the issue of exploring new **technological trajectories** in order to enhance or challenge **technology paradigm** (Dosi, 1982) is another firm-centrifugal concern to be included in the rationales behind the adoption of a system approach to innovation. In the above mentioned evolutionary perspective, the distinctive technological knowledge of a firm is called to face both the intrinsic shock implied in the creation of new technological solutions and the competitors' moves on the same development track.

According to Cesaroni et al. (2005), the general research environment and the related technological trajectories in which a firm is committed to compete should be analyzed to choose proper internal R&D strategies. About the same topic Dew (2006) analyzes how different technological perspectives enforced by competing proponents have to find a synthesis in sector affected by relevant network economies thus underlining the importance of a system comprehensive approach to technology development.

The same conclusion about the necessity for entrepreneurs and managers to open up the innovation framework beyond the firm boundaries could be reached following the perspective of the **absorptive capacity** issues.

The debate, originated by Cohen and Levinthal (1990), about a firm's ability to value, assimilate, and apply new knowledge, is directly linked with the approach and the routines adopted to renewal corporate capabilities and to maintain a proper linkage with interesting sources of knowledge and innovation. The classical paper of Rosemberg (***1990)*** gives insights about the relationship between firms, universities and research centres and opens a remarkable stream of policy oriented literature. This approach was subsequently extended also to inter-firm relations and their characteristics coming from managerial culture and organizational learning.

In the general perspective of this survey, the impact of the absorptive capacity issue is indeed evident in the studies about R&D alliances and their feature to develop systemic absorptive capacity (Newley and Shulman, 2004).

The most recent contribution to the debate about knowledge sourcing and innovation beyond the firm boundaries comes from the "**user driven development**" stream. In this contemporary field of research, stimulated by the Internet related phenomena such as Creative Commons and Open Source, the final customers and their organized community are involved in inspiring new product development (Jeppesen and Molin, 2003). While in the Open Source software those users organizations affect directly the technological innovation creation, for example by producing new codes to enhance computer program features, in general they supply outstanding inputs to the firms' marketing departments. The strong and valuable diffusion of those practices (chats, blogs, news bulletins, etc.) seems to assert that smart communication channels between the firm and its users are a great opportunity, even becoming a tenet in high technology and mass market industries.

Development interdependence

An important branch of rationales that contributes to adopt a systemic focus to technological innovation is based on the interdependence that occurs in new product and technology development. The globalization effects have accelerated the competition pace and seems to reward rising rate of specialization thus opening the doors to even more sophisticated **core and complementary competences** management. In this context technological innovation becomes tightly related to the capacity of procuring the firm essential knowledge even from outside agents. This leads to two concerns: the exploration of external opportunities and the maintenance of internal core competences and core business control (Tiwana and Keil, 2007).

The trade-off balancing the firm stance between internal and external focus in technological innovation development is complicated by increasing **technological complexity**.

The technical progress is showing cross-fertilization between once remarkable independent engineering and scientific disciplines and even ancillary services requires nowadays complex IT infrastructure to deal efficiently with internal and supply chain interfaces. As underlined by Rycroft (2007) cooperation between firms could be the answer to absorb complexity and share risks even with contrasting results due to the variety of variables and events interfering in the overall process performance.

In products that have modular characteristics and in those who experience relevant network economies, a fundamental role in fostering the innovation outlook beyond the single firm boundaries is constituted by the **standard** issues and their central role in defining market and competition equilibrium (Van Wegberg, 2004). The standard setting processes oblige firms to reach agreement or entrust the fate of rival standards in product and services to market selections. In both the cases the firms work in a situation of strategic interaction that could generate hybrid form of coordination between competition and cooperation implying a systemic vision to be properly faced.

In many industries a notable determinant forcing managers to include elements external to their firm in technological innovation management is **regulation** from public authorities. In those cases the main impacts of regulatory issues are focused both on the budget constraints imposed by non-market conditions (as result of public intervention on services rate) and on the interactions between technological innovation and market structures. As pinpointed by Prieger (2007) the interdependence between regulated firms and the involved authorities can remarkably affect quality as well as timing of technological innovation introduction.

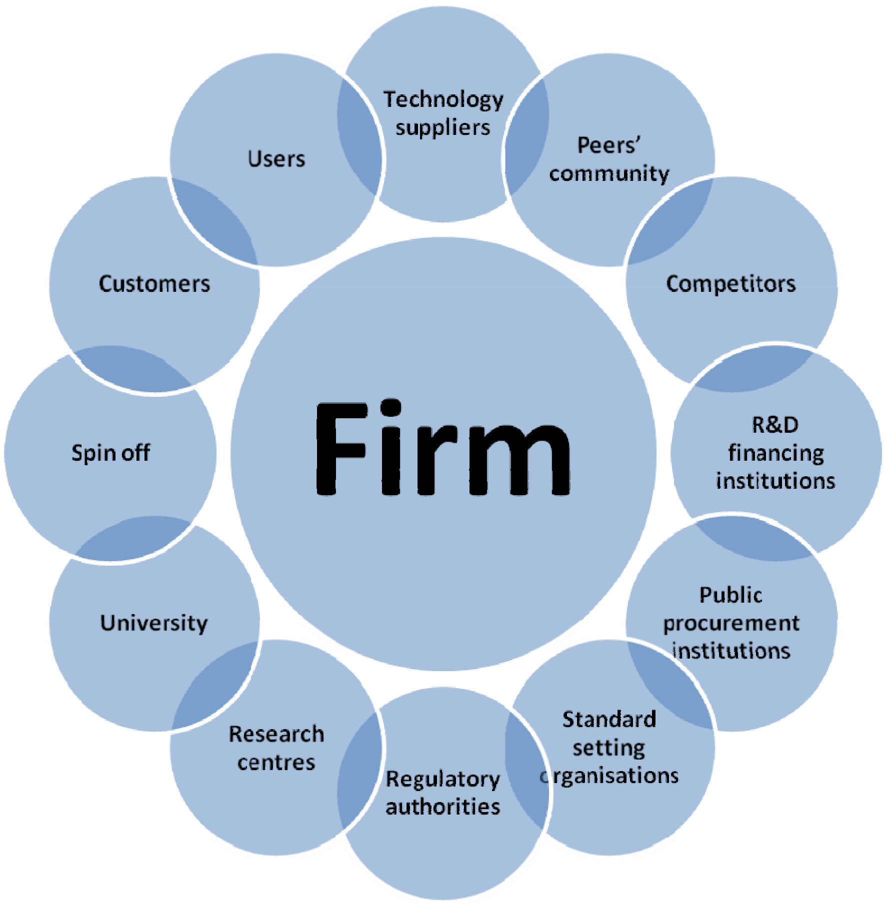

Figure 2 - Firm and external agents involved in innovation process

Exploitation opportunities

In the managerial literature a syndrome described with the sentence "not invented here" stigmatizes the resistances both to the adoption of innovation that are not internally developed and to the exploitation of a firm's inventions outside its walls. Especially in recent times, this landscape is fast changing, including in the appropriation of the value of innovation many **technology commercialization** options. As Lichtenthaler and Ernst (2007) underline, the outward technology transfer is a growing phenomenon in direct selling of technology transfer services toward non-rival firms and industries. In a relevant share of those cases, the technology knowledge that constitutes the matter of the deal is formalized and codified by IPR tools. Palomeras (2007) explicitly analyses pure-revenue technology licensing, pointing out the firm's attitude toward this option especially in the case where the internally developed technological knowledge is peripheral with reference of the firm core business.

Increasing technology complexity is further calling attention on the benefits coming from **knowledge sharing** at different levels. The IT industry offers a variety of knowledge management tools to let employees codify and share technical knowledge at plant or firm level. Furthermore in large multinational enterprises it is becoming worth investing in initiatives designed to facilitate technological knowledge exchanges. Grevesen (2007) pinpoints the importance of both lateral and hierarchical exchange of knowledge. In apparently flatter and democratic environment the knowledge sharing is a crucial feature of Open Source projects. This quite recent phenomenon is challenging many classical assumptions about value creation especially in the software industry. Leading to new conceptions of motivation and governance regarding the process of innovation (von Krogh and von Hippel, 2006), the openness of the economic perspective of research and development efforts is going to change also the industrial dynamic up to now characterised by collective invention regimes, usually ending when a dominant design emerges (Osterloh and Rota, 2007). The issue of research lines creating stable technological scaffolds inside firms, even repelling any external challenging technological solution, explains the undergoing mechanism of **knowledge ventures** such as corporate spin-off based on new technology development that can better develop their potential outside the parent firm.

As pointed out by Chesbrough and Rosenbloom (2002) the liveliness of new technology creation could be relevant enough to justify structured business models including spin-off nurturing and financing. The technology enterprises released by both high-tech leading players and technology-related universities are called to fully develop their promising technological capabilities integrating solution both technical skills and business attitudes in ready to be delivered (Zahra et al., 2007). The above survey intend to enumerate the main determinants pushing R&D managers to look beyond the firm boundaries thus leading to **business model reconfiguration**.

Wrapping up: open innovation ?

As the average publishing dates of the cited reference indicates, the debate about this aspect of innovation studies is growing thanks to the contributions of many independent streams of literature.

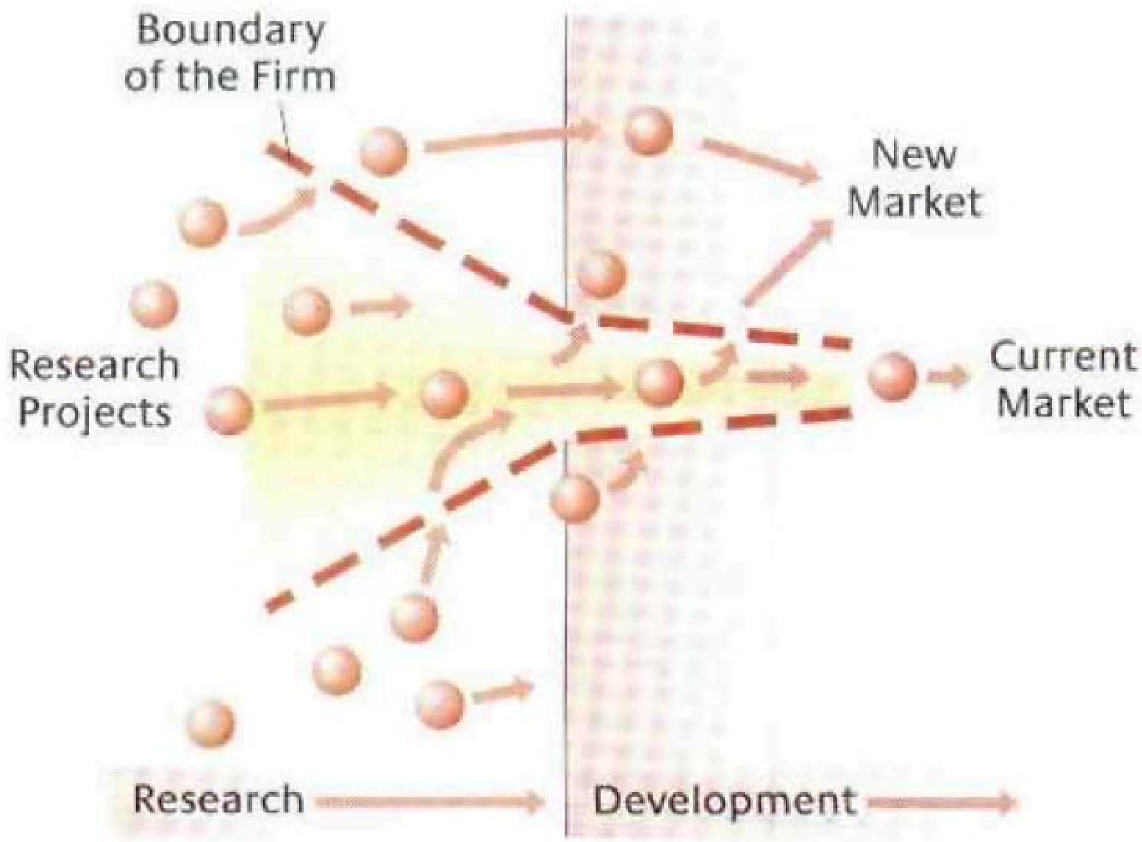

Figure 3 - Open innovation funnel (from Chesbrough, 2003)

The "Open Innovation" concept, proposed by Chesbrough (2003) and still in development (Chesbrough and Appleyard, 2007), is playing a prominent role in offering a structured synthesis of the majority of the above mentioned determinants. Even if Open Innovation is undoubtedly a fascinating label on which a variety of consulting practises, policy measures and literature articles have been founded with large variability in quality, it is to underline that is the one of the most popular framework entangling internal and external sources as well as exploitation opportunities of the innovation processes.

With reference to the front end of the innovation funnel illustrated in **Figure 3,** it is worth noting that the basic features of knowledge as an economic good in play are the complexity and the correlated complementary of technological innovation. Those input characteristics are reflected in the plurality of the exploitation paths presented by the back end of the innovation funnel. As both the sides of the funnel present more than one exit, this model easily fits in the representation of innovation organisation as a system. This is a radical evolution in the overall concept of innovation that, previously vertically integrated and confined in the single firm boundaries, now seems to be better represented by complex system models. Looking closely to this evolutionary trajectory, it seems that this is a non-reversible transformation as well as it is both aligned with the natural entropy growth and it makes sense with the mandatory logics of risk sharing and global opportunities capturing. For those reasons it is foreseeable a growth in the attentions devoted by scholars and practitioners to the different forms of innovation systems, according to a research agenda that presents a number of knowledge gaps, particularly in the quantitative evaluation of the undergoing phenomena.

1.2 Technological innovation systems: paradigms and experiences

The variety of literature streams on the determinants to overcome the firm's boundaries in technological innovation development that were surveyed in the previous chapter find reverberations, even with different intensity degrees, into a broad spectrum of models that aims at underlining the industrial performance in terms of system's output. In the following a survey of such paradigms is presented and discussed with respect to technological innovation.

Industrial clusters

As an evergreen issue in both the economic literature and research policy debate, the industrial cluster model could be considered as a tank of different paradigms rather than as a unique approach to the innovation geography. Alfred Marshall (1890) could be considered as the first scholar studying the spatial agglomeration of industries and introducing the term "industrial district" in order to describe the concentration phenomenon that he was observing in growing industries.

With a prominent positive approach rather than a managerial or policy oriented view, Marshall identified four elements leading to the agglomeration phenomena as source of economic advantage, namely a rich market of specialised manpower, the presence of well developed linkages across supply chains, the existence of ancillary trades and some general economic environmental effects. Even if in this initial model a specific reference to technological innovation could not be found the entire district concept tends to underline agglomeration of industries as a focusing mechanism leading to the development of fruitful linkages across different agents operating toward common objectives. Innovation technology, especially in hi-tech vertical industries (microprocessors, advanced materials, ecc…), tends to be the result of deep specialisation efforts that could come from an industrial systems clearly devoted to the production of a limited set of output. On the contrary, when an industry is operating on complex product involving a variety of disciplines, namely "synthetic" rather than "pervasive" technologies, different concentration path could be observed.

With respect to this issue, Ohlin (1933) identified two paths in the agglomeration trend, i.e. localisation economies (increasing share of an industrial sector into a given territory) and urbanisation economies (increasing business flows, even between heterogeneous sectors) both leading, in general, to relevant savings in input procurement.

With Scitovsky (1954), who studied the externalities underlying the clustering dynamics and divided them in pecuniary (influencing the inputs price when the size of an industry grows) and technological (affecting the production function of clustered enterprises without any market transaction), innovation was finally explicitly introduced in the cluster stream debate. An important phase in the cluster concept development was marked by the works about knowledge economic properties and flows (Arrow, 1962), opening the literature stream about localized knowledge spillovers that can find in industrial clusters a natural frame of occurrence. The explanations of agglomeration trends are at the center of the Romer (1986) and Krugmann (1991) insights about the linkages between economic activities concentration and growth as well as the increasing return due to positive industrial externalities.

Those concurrent lines of research were synthesized in the MAR (Marshall – geographical dimension, Arrow – knowledge as economic good, Romer – increasing returns in economic growth) paradigm adopted by Glaeser (1992).

This milestone contribution to the cluster concept clearly underlines the relevance of the systemic effects on the performance of firms including technological innovation development by knowledge sharing and increasing returns in R&D activities due to their spatial concentration. In the same line of reasoning, Camagni (1995) and Maillat (1998) used the term “innovative milieu” to identify clusters that are based upon knowledge and ideas sharing rather than on production flows, thus focusing on high technology and knowledge intensity. By far, the most influential contribution to the cluster concept popularity was given by Porter in a series of works in which he analyses the competitiveness of nations (1990), clusters (1998) and regions (2001) always underlining the role of business clustering to the productivity enhancement.

His vision, focusing on a more productive use of inputs, which requires continuous innovation, highlights the importance of local (regional) initiatives to develop knowledge, relationships and motivation as cluster grounded competitiveness factor into the globalised markets. This conceptual framework, broadly diffused into the communities of policy-makers and innovation practitioners at all levels, led to the adoption of cluster support as a key development factor by the World Bank (2000), the OECD (1999, 2001), national governments and regional development agencies all around the world.

Looking at the lifecycle of the industrial cluster concept it could be underline its migration from a classical economic analysis scheme, focusing on input procurement and availability, to a framework for industrial development policies based upon innovation and technology strategies. From the point of view of our initial enquiry it is worth noting that technological innovation within a broader than single firm perspective is a consistent through time characteristic of this literature stream.

Localised knowledge spillovers

The seminal works of Arrows (1962) about the nature and the properties of knowledge as an economic good, opened interesting research lines about the implication of the limited appropriability of technological creation and knowledge thus leading to positive externalities in R&D performance captured into a system-wide point of view.

In this line of reasoning a creative environment in which researchers from different firms shares both formal and informal contacts can lead to the enrichment of the local knowledge pool as well as its sharing (**Figure 4**).

Moreover the attention of the scholars was attracted by the spillover effects between academic research and corporate R&D. Their existence and potential (Jaffe, 1993) are remarkably associated with the spatial dimension as underlined by the "sticky knowledge" concept (Von Hipple, 1994).

The above mentioned concepts suggest that, joining the intellectual resources of firms together with academy would lead to more than additive local system performance. Even widely accepted, this approach should be used with caution as an agglomeration determinant (Breschi and Lissoni, 2001) due to the importance of cultural rather than physical proximity in knowledge sharing and transfer.

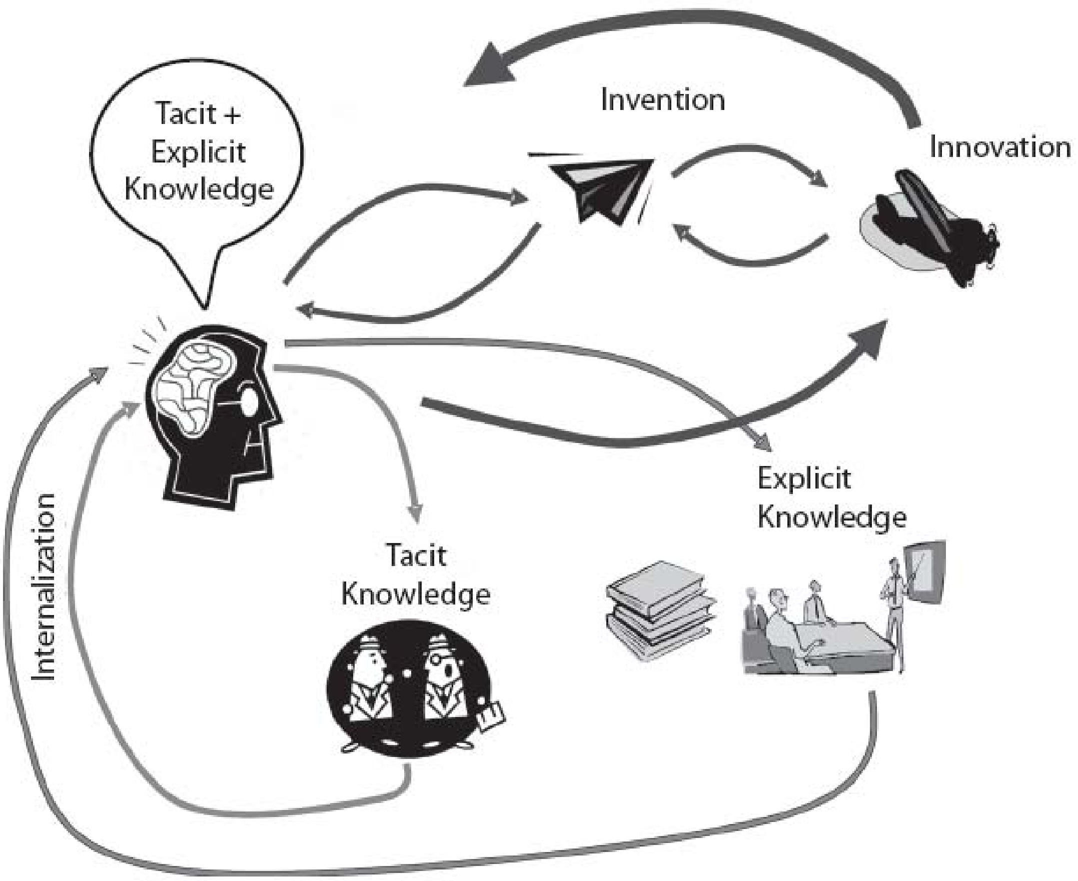

Figure 4 - Transformation of Knowledge to Invention and Innovation from Ibrahim and Fallah (2005)

At the same time, the intensity of knowledge flows and modality of its exchange is far from being clear even a relevant number of empirical studies had measured its effects. The contribution of this literature stream to the debate enlightened by the present survey is remarkable in identifying and describing knowledge dynamics as an underlying factor useful to explain location advantages coming from agents rooted outside but next to a given firm. Even if not prescribing recommendations to facilitate this positive externality effect, the local knowledge spillover concept helps in motivating a broader then firm-centric approach to technological innovation.

Regional Innovation systems

In the contemporary economic debate the usage of the expression “regional constructed advantage” is widely diffused to indicate the endogenous ability of a region to create an environment where innovation is nurtured and facilitated.

This concept is the keystone of what Cooke (2004) define as Regional Innovation System: «interacting knowledge generation and exploitation subsystems linked to global, national and other regional systems». The above mentioned model is based on the identification, development and interaction of different economic players grounded in a given region and interacting systematically and continuously. Looking close to the Regional Innovation System definition it could be found that it is based upon an institutional infrastructure that support innovation inside the industrial texture of a region. This policy enforced framework plays a major role in facilitate the interaction between two subsystems that, according to a number of previous works, can represent the two sides of an innovation system: a demand and supply (Braczyk et al., 1998).

The first one, namely the “production system”, is devoted to the knowledge exploitation and is composed mainly by firms, even agglomerated into clusters. The complementary one, called “cognitive infrastructure”, could be identified in academy, universities and technology transfer agencies. In this landscape two features are to be underlined: the institutional commitment to help knowledge flows be effective and the regional scale as the optimal size to let that happens. In fact, even largely different both within the same country and across international boundaries, the regions seems to be both a sizeable territorial unit, giving the policy maker concrete chances to develop proper public interventions, and a sufficiently homogeneous pool of converging knowledge stakeholders. As illustrated in **Figure 5** by the diagram reported in De Lauretis (2006) the model of Regional Innovation Systems explains a local advantage in technological innovation development including in its analysis complex systemic interaction.

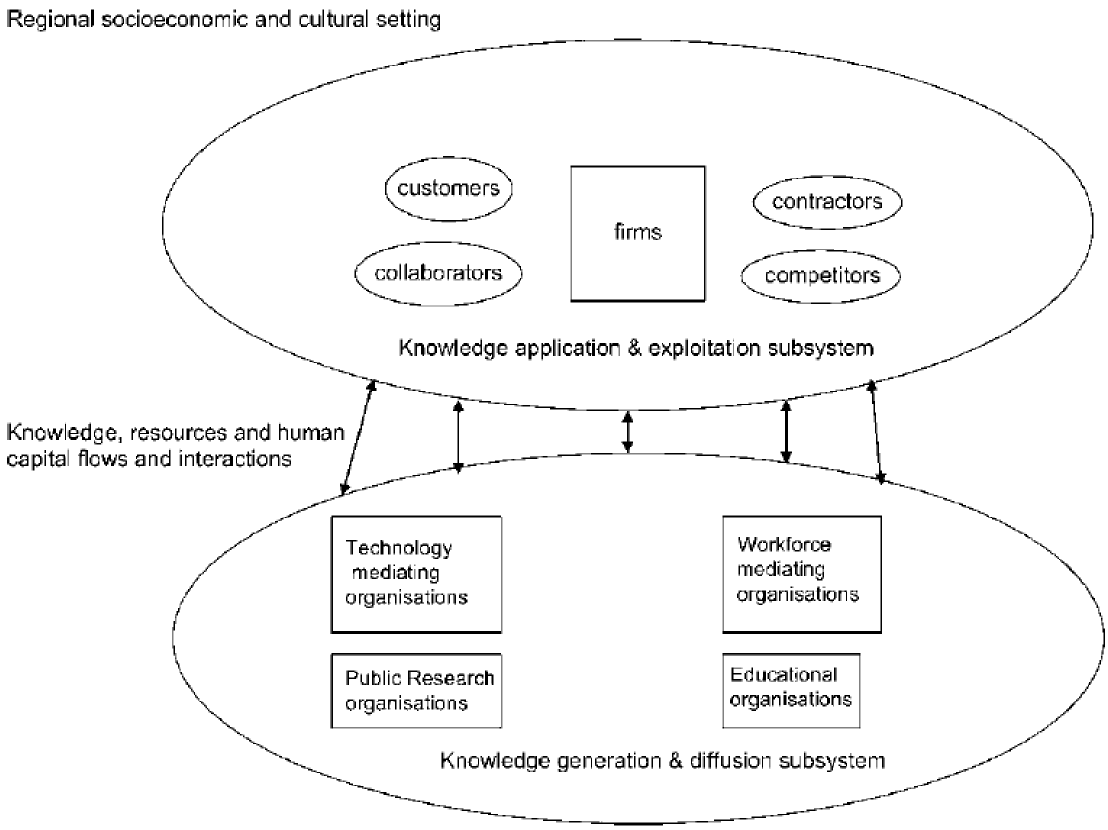

Figure 5 - RIS elements (De Laurentis, 2006)

Limits and research questions

The above surveyed models represent a core part of the existing literature about the technological innovation development as long as they face this issue from very different point of view. However it is worth noting that they present intrinsic limits both as considered like stand-alone paradigm and as an integrated body of knowledge.

The industrial cluster stream, even with its variety of definition, is always based on a geographical dimension where the availability of some inputs, in some cases intangible and non tradable, is relevant for the economic analysis. This feature is being eroded by the contemporary information technologies that are allowing distributed R&D organisation. Moreover also the industry / supply chain pillar of the standard cluster theory seems to tone down, especially in high technology business context, as the variety of technologies involved in the production of advanced goods is everywhere increasing. The localised knowledge spillover stream, on the contrary, as far as underpinning an economic phenomenon, shows a stronger resistance to the environmental evolution of business. However, beside this feature, it doesn't provide managerial hints to be used by decision maker in order to maximise the firms' profit or to choose the most proper R&D strategy. With respect to this aspect the Regional Innovation System approach provide an comprehensive scheme for regional policy maker, but, while stressing this kind of geographical dimension, it intrinsically could loose the global focus required to manage complex and globally competing technology environment.

1.3 Technology platform: toward a new model ?

In the taxonomy of models useful to be taken into account in facing the phenomenon of technological innovation beyond the single firm boundaries, it is possible to add a new item that, even without an explicit academic and economic background, is already having a deep impact on both R&D organisation and financing in Europe.
The European Technology Platforms (ETPs) is a research policy making tool launched by the European Commission in March 2005 with the following definition and aims that constitute the initial statements of the model (http://cordis.europa.eu/technology-platforms/home_en.html):

European Technology Platforms focus on strategic issues where achieving Europe's future growth, competitiveness and sustainability depends upon major technological advances. They bring together stakeholders, led by industry, to define medium to long-term research and technological development objectives and lay down markers for achieving them. The achievement of these objectives, leaded by the following aims will significantly improve the daily lives of the European citizen in many areas:

- Provide a framework for stakeholders, led by industry, to define research and development priorities, timeframes and action plans on a number of strategically important issues where achieving Europe's future growth, competitiveness and sustainability objectives is dependent upon major research and technological advances in the medium to long term.

- Play a key role in ensuring an adequate focus of research funding on areas with a high degree of industrial relevance, by covering the whole economic value chain and by mobilising public authorities at national and regional levels. In fostering effective public-private partnerships, technology platforms have the potential to contribute significantly to the renewed Lisbon strategy and to the development of a European Research Area of knowledge for growth. As such, they are proving to be powerful actors in the development of European research policy, in particular in orienting the Seventh Research Framework Programme to better meet the needs of industry.

- Address technological challenges that can potentially contribute to a number of key policy objectives which are essential for Europe's future competitiveness, including the timely development and deployment of new technologies, technology development with a view to sustainable development, new technology-based public goods and services, technological breakthroughs necessary to remain at the leading edge in high technology sectors and the restructuring of traditional industrial sectors.

Figure 6 - ETPs implementation stages

Moreover a three stages implementation plan was described (**Figure 6**) to spark their creation process into the different stakeholders of Framework Programme VII, currently financing R&D activities for about 50.521 million to be invested in the period 2007 – 2013. At the beginning of 2007 there are 31 formally acknowledge ETPs that has gathered into their boundaries the major stakeholders of the technology to which they are devoted. With respect to the present analysis aims, it is worth analysing the outcomes of this policy making model looking close to one of the most prominent ETP, ACARE (Advisory Council for Aeronautics Research in Europe), that present a full description of its very young story and of its results in the websiste http://www.acare4europe.org/html/index.asp

This organisation is based upon over 40 members with very different background and goals as it could be found in the profile of participants table reported in **Figure 7**.

ACARE PARTICIPATION	
Nomination	**Profile of Participants**
Member States	Director in charge of national research programmes in favour of aeronautics industry
Commission	Directors in charge of research programmes related to aeronautics industry and air tran sport
Manufacturing Industry	Directors in charge of research and/or strategy (for smaller companies this can be CEO level)
Research establishments	Directors in charge of the aeronautics research programme
Airlines	Directors in charge of strategy
Airports	Director in charge of strategy
Regulators	Director in charge of research programme
EUROCONTROL	Director in charge of research programme
Academia	Senior professor with large international contacts

Figure 7 - ACARE participants categories

Their shared commitment in the development of aeronautics technologies has been the engine to develop a common Strategic Research Agenda in order to set the priorities (**Figure 8**) for the joint technology development that is required to let the European system compete in the global aeronautics market.

Quality & Affordability	Safety	Environment	European Air Transport System
Permanent trend monitoring	Flight hazard protection	Drag reduction through conventional and novel shapes	Innovative ATM operational concepts
Flexible cabin environments	Advanced avionics	Fuel additives	Advanced, intelligent and integrated ATM ground, airborne and space systems
Passenger services	Probability and risk analysis	Noise reduction	Rotorcraft integration in ATM systems
Anticipatory maintenance systems	Computational methods	Propulsion concepts	High density traffic systems capability in all weather conditions
Integrated avionics	Human error checking systems	Emission reduction	Airport capacity and advanced management
ATM related airborne systems		Environmentally friendly production, maintenance and disposal	Increased use of airspace capacity
Novel materials and structural concepts		Better aircraft/engine integration	
Lead time reductions			
Integrated design manufacturing and maintenance systems			
Advanced design methods			
System validation through modelling and simulation			
Concurrent engineering			

Figure 8 - ACARE Research challenges

This example clearly shows how both the industrial and the policy system are taking into account the importance of technological innovation beyond the single firm boundaries and within the context of a very broad innovation system including a large variety of stakeholders.

1.4 Conclusions

The overall landscape of innovation studies is rapidly changing due to the competition pressures as well as the technology advancements. One of the most important trend that could be observed is the enlargement of the scholars' focus in selecting the relevant analysis unit to develop their studies. The determinants to overcome the single firm as the right level from which start to develop technology management are acknowledge in many important literature streams mainly devoted to explain rather than to forge the contemporary dynamics.

The present survey, whose aims is to spotlight the bases of a growing both economic and managerial issue, leads to a very open research agenda on the issue that will mandatory include the linkage between technological complexity and innovation system management.

In particular one of the most interesting and yet unexplored side of this area of studies is the evaluation of an R&D project in the context of a larger innovation system. In fact, there are a lot of answers, even aging, about the value of an economic activity as a function of its geographical location but only a few hints about how a research line could be valuable with respect to the system to which the organisation who is working on it is affiliated.

Reference

Arnold, E. (2004), "Evaluating Research and Innovation Policy: a Systems World Needs Systems Evaluations", Research Evaluation, Vol. 13, Issue 1 (April 2004), 3-17

Arrow K. J. (1962), "The Economic Implications of Learning by Doing", Review of Economic Studies, 29:155-173.

Audretsch, D. B. and Feldman, M. P. (1996), "Knowledge spillovers and the geography of innovation and production", American Economic Review, 86(3): 630–640

Braczyk, H. J., Cooke, P. & Heidenreich, M. (Eds) (1998) Regional Innovation Systems: The Role of Governance in a Globalized World (London: UCL Press).

Breschi, S. and Lissoni, F. (2001), “Localised knowledge spillovers vs. innovative milieux: knowledge ‘tacitness’ reconsidered” Papers in Regional Science, 80: 255–273

Cesaroni, F., Di Minin, A. and Piccaluga, A. (2005), “Exploration and Exploitation Strategies in Industrial R&D”, Creativity & Innovation Management, Vol. 14, Issue 3 (Sep2005), 222-232

Chesbrough, H., Rosenbloom, R., S. (2002), “The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin- off Companies”, Industrial and Corporate Change, Vol.11, Issue 3, (June 2002), 529-555

Chesbrough, H. (2003) “The era of Open Innovation”, MIT Sloan Management Review

Chesbrough, H., Appleyard, M. (2007) “Open Innovation and Strategy”, California Management Review, Vol. 50, Issue 1 (Fall 2007), 57-76

Coase, R. H (1937), “The Nature of the Firm”, Economica, Issue 4, p. 386.

Cohen and Levinthal (1990), "Absorptive Capacity: a New Perspective on Learning and Innovation", Administrative Science Quarterly, Volume 35, Issue 1, 128-152.

Cooke, P. (2004) The regional innovation system in Wales: Evolution or eclipse?, in: P. Cooke, M. Heidenreich & H. J. Braczyk (Eds) Regional Innovation Systems: The Role of Governance in a Globalized World (second edition) (London: UCL Press).

David, P. (2005), “Designing the Boundaries of the Firm: from "Make, Buy, or Ally" to the Dynamic Benefits of Vertical Architecture”, Keynote Address "Innovation Europe's Universities: Institutional Reconfiguration and the Triple Helix", Triple Helix Conference, Turin 2005

De Lauretis, C. (2006), "Regional Innovation Systems and the Labour Market: A Comparison of Five Regions", European Planning Studies Vol. 14, No. 8, September 2006

Dew, N. (2006), "Incommensurate Technological Paradigms? Quarreling in the RFID Industry", Industrial and Corporate Change, Vol. 15, Issue 5, 785-810

Dosi, G. (1982), "Technological Paradigms and Technological Trajectories – a Suggested Interpretation of the Determinants and Directions of Technical Change", Research Policy, Vol. 11, 147

Fingleton, B., Igliori, D. C. and Moore, B. (2005), "Cluster Dynamics: New Evidence and Projections for Computing Services in Great Britain", Journal of Regional Science 45(2): 283–311

Fey, C. (2005), "External Sources of Knowledge, Governance Mode, and R&D Performance", Journal of Management, Vol. 31, Issue 4, (Aug. 2005), 597 – 621

Fujita, M., Krugman, P. and Venables, A. J. (1999), The spatial economy (MIT Press, Cambridge, Mass.)

Glaeser, E. L., Kallal, H.D., Scheinkman J.A.and Shleifer, A. (1992) 'Growth in cities', Journal of Political Economy 100(6): 1126–1152

Grevesen, C., Damanpour, F. (2007), "Performance Implications of Organisational Structure and Knowledge Sharing in Multinational R&D Networks", International Journal of Technology Management; Vol. 38, Issue 1/2, 113 – 136

Ibrahim S., Fallah S. H. (2005), "Drivers of Innovation and Influence of Technological Clusters", Engineering Management Journal Vol. 17 No. 3 September 2005

Jacobs, J. (1969) The economy of cities (Vintage, New York)

Jaffe, A. B. (1989) “Real effects of academic research”, American Economic Review 79(5): 957–970

Jeppesen L., Molin M. (2003), “Consumers as Co-developers: Learning and Innovation outside the Firm”, Technology Analysis and Strategic Management, Vol. 15, Issue 3, (Sept. 2003), 363 - 383

Krugman, P. (1991) “Increasing returns and economic geography”, Journal of Political Economy 99: 483–499

Lechner, C., Dowling, M. (2003), “Firm networks: external relationships as sources for the growth and competitiveness of entrepreneurial firms”, Entrepreneurship & Regional Development, , Vol. 15, Issue 1, (Jan-Mar2003), 1 – 26

Lichtenthaler, U., Ernst, H. (2007), “External Technology Commercialization in Large Firms: Results of a Quantitative Benchmarking Study”, R & D Management, Vol. 37, Issue 5 (Nov. 2007), 383 – 397

Lublinsky A. (2003), “Does Geographic Proximity Matter? Evidence from Clustered and Non-clustered Aeronautic Firms in Germany”, Regional Studies, Vol. 37.5, pp. 453–467, July 2003

Lundvall, B.A. (ed) (1992) National systems of innovation: Towards a theory of innovation and interactive learning (Frances Pinter, London)

Maillat, D. (1998) “From industrial district to innovative milieu: contribution to an analysis of territorialized productive organizations”, Geographische Zeitschrift 86(1): 1–15

Maillat, D., Lecoq, B., Nemeti, F.and Pfister, M. (1995) “Technology district and innovation – the case of the Swiss-Jura Arc”, Regional Studies 29(3): 251–263

Markusen A (1996) “Sticky places in slippery space: A typology of industrial districts”, Economic Geography 72(3): 293–313

Markusen, A. (2003) “Fuzzy concepts, scanty evidence, policy distance. The case for rigour and policy relevance in critical regional studies” Regional Studies 37(6–7): 701–717

Marshall A. (1890) Principles of economics. 8th Edition, 1986, (Macmillan, Basingstoke)

Nelson, R. Winter S. (1982), “An evolutionary theory of economic change” Harvard University Press.

Newey, L., Shulman, A. (2004), “Systemic Absorptive Capacity: Creating Early-to-market Returns through R&D Alliances”, R & D Management, Vol. 34, Issue 5 (Nov. 2004), 495 - 504

Nooteboom, B. (2000), “Institutions and Forms of Co-ordination in Innovation Systems”, Organization Studies, Vol. 21, Issue 5, 915 - 940

OECD (1999) Boosting Innovation: The Cluster Approach. Paris: OECD

OECD (2001) Innovative Clusters: Drivers of National Innovation Systems. Paris: OECD

OEDCD-DATAR (2001) World Confress on Local Clusters. Paris: OECD

Ohlin, B. (1933) Interregional and international trade (Harvard University Press, Cambridge)

Osterloh, M., Rota, S. (2007), "Open Source Software Development- Just Another Case of Collective Invention?", Research Policy, Vol. 36, Issue 2 (March 2007), 157 - 171

Palomeras, N. (2007), "An analysis of pure-revenue technology licensing", Journal of Economics & Management Strategy, Vol. 16, Issue 4(Winter 2007) 971 – 994

Porter, M. E. (1990) The competitive advantage of nations (Macmillan, London)

Porter, M. E. (1998) "Clusters and the New Economics of Competition", Harvard Business Review, 76, 77-90

Porter, M. E. (2001) "Regions and the New Economics of Competition" In: Scott AJ (ed) Global City-Regions Trends, Theory, Policy (Oxford University Press) 139–157

Prieger, J. (2007), "Regulatory delay and the timing of product innovation", International Journal of Industrial Organization, Vol. 25, Issue 2 (April 2007), 219 - 236

Rycroft, R. Kash, D. (2002), "Path Dependence in the Innovation of Complex Technologies", Technology Analysis & Strategic Management, Vol. 14, Issue 1 (March 2002), 21 - 35

Romer, P. M. (1986) "Increasing returns and long-run growth", Journal of Political Economy 94: 1002–1037

Romer, P.M. (1990) "Endogenous technical change", Journal of Political Economy 98: 71–101

Scitovsky, T. (1954) "Two concepts of external economies", Economic Journal, LXII, 54–67

Whitford, J. (2001) “The decline of a model? Challenge and response in the Italian industrial districts”, Economy and Society 30: 38–65

World Bank (2000) Electronic Conference on Clusters. Washington: World Bank

Van Wegberg, M. (2004), “Standardization Process of Systems Technologies: Creating a Balance between Competition and Cooperation”, Technology Analysis & Strategic Management, Vol. 16, Issue 4 (Dec. 2004), 457-478

von Krogh, G., von Hippel, E. (2006), “The Promise of Research on Open Source Software”, Management Science, Vol. 52, Issue 7 (July 2007), 975-983

Von Hipple, E. (1994) Sticky information and the locus problem solving: Implications for innovation, Management Science, 40, pp. 429–439.

Tiwana, A., Keil, M. (2007), “Does Peripheral Knowledge Complement Control? An Empirical Test in Technology Outsourcing Alliances”, Strategic Management Journal, Vol. 28, Issue 6 (June 2007), 623-634

Zahra, S., Van de Velde, E. and Larraneta, B. (2007), “Knowledge Conversion Capability and the Performance of Corporate and University Spin-offs”, Industrial and Corporate Change, Vol. 16, Isssue 4 (Aug. 2007), 569-608

2. Technological knowledge base and R&D cooperation potential: a patent based evaluation exercise from the EU aerospace sector

Abstract

Being an high technology sector that involves a very large pool of engineering disciplines, the aerospace industry presents a variety of interesting characteristics for technological innovation studies. A fundamental asset of this industry's companies is represented by the technological knowledge base, a variable difficult to be seized and analyzed even if clearly prominent in defining the competitive landscape. The paper, building on contemporary contributions in knowledge base diversification measurement and original datasets, offers a patent base methodological exercise with an application directed to analyze R&D cooperation potential from the difference in the technology diversification revealed by companies' patent portfolios.

2.1 Introduction

The aerospace industry is based on multi-layer supply chains reflecting different core competences differently allocated in a large number of companies. The technological knowledge base plays a prominent role in defining the position of companies and in explaining their commercial and research agreements. In the following after a methodological discussion about recent advancements in conceptualization and measurement techniques of firms' knowledge base a relation between the latter and R&D cooperation potential is described and tested. Section 2.2 and 2.3 present a brief outlook about of the most interesting feature of aerospace sector and of the innovation

processes acting inside it. Section 2.4 introduce and describe the research question and its literature context. Section 2.5 and 2.6 shows the conceptualization and the methodological path used to analyze the knowledge base of the aerospace industry.
In section 2.7 the original dataset created to seize the patent portfolio related to aerospace technology is presented together with a proximity matrix representing the relations between the engineering disciplines involved in the sector. Finally section 2.8 shows an application of the diversification measure related to R&D cooperation potential.

2.2 The aerospace sector at a glance

The aerospace sector deals with the manufacturing, testing and maintenance of a number of very complex systems, such as:

- commercial aircrafts and helicopters,
- military aircrafts and helicopters,
- launchers, spacecrafts and satellites,
- systems for command, control and communication.

Disregarding its central role with respect to the strategies of defense and foreign policy of each country, in the following the attention will be focused on the aerospace sector as source of innovation opportunities and on its contribution to the economic growth, that spreads well beyond its strict borders, thanks to the interrelations with other economic sectors.
The added value provided by the aerospace sector to the GDP of each country results to be surprisingly low: 3.3% in USA, 3.2% in Canada, 3% in France, 1.5% in Germany, 3.4% in UK, 1.3% in Italy, 1.6% in the EU11.
The specific weight of the sector and its impact on the innovation process is evidenced by an average yearly patent production around 10% of all filings, as result of investing in R&D about 14% of the yearly turnover. Aerospace results to be one of the most knowledge intensive industrial activities.

Looking at the R&D spending in the aerospace sector it could be found relevant differences between the share of public vs private investments between Europe and USA. On the contrary of many other industries, here the public intervention is much heavier in the USA than in Europe. This characteristics could be partially explained on the basis of structural difference in the composition of the aerospace sector that in USA presents a larger military share tightly connected to both public R&D and procurement. **Figure 9** illustrate those differences as could be evaluated by data offered in "Flight International" one of the main international business journal about this industry.

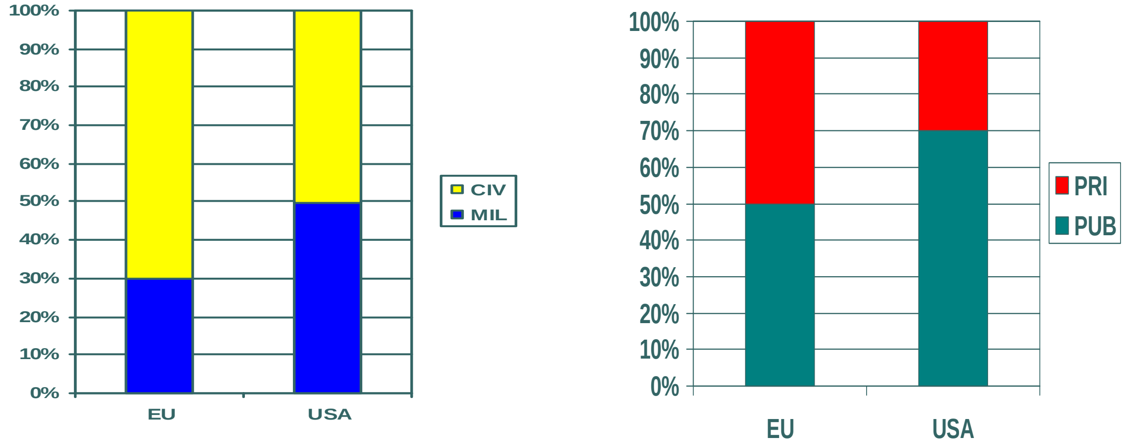

Figure 9 - Difference between EU and USA in R&D spending and nature of the industry

Indeed it is worth noting that in this industry strategic and political concerns play a major role especially in the military and state-anchored sectors.

Looking at the markets, a selection and concentration process took place both in USA and in Europe during the last 50 years, resulting in the survival of a few leading companies having the capability of managing the manufacturing program of very complex systems. Those companies are responsible of the overall program performance and results (in a public procurement) or of the commercialization and economic success (in a private venture).

A hierarchical structure shaped as a multilevel pyramid governs the economic and legal relations, the organization of the work and the knowledge and information flow (Esposito, 1996; Niosi and Zhegu, 2005). The big companies at the top of the pyramid

(e. g. Boeing, EADS, Lockheed Martin, Northrop Grumman) manage the overall production program, coordinating the information and material flow between the lower levels, and select the other companies participating to the program.

The second level of the pyramid is occupied by companies dealing with major subassemblies (typically engines/propulsion systems, avionics, hydraulics, landing gears, …). They are linked to leading enterprises by agreements of different nature, such as subcontracting, association, participation with risk, etc. (Esposito, 1996).

At the third level we find companies with a specific know-how for the production of components such as parts of wings, fuselage, tail, engines, etc.. They are often national leading companies usually linked to companies placed at the second level, seldom to the leading company.

At the base of the pyramid (and of the production process) many SMEs are located, with the mission of supplying parts to other companies placed at the third level.

Figure 10, from Niosi and Zhegu (2005) illustrates the above described aerospace productive structure underlining both its pyramid and multiple tiers structure.

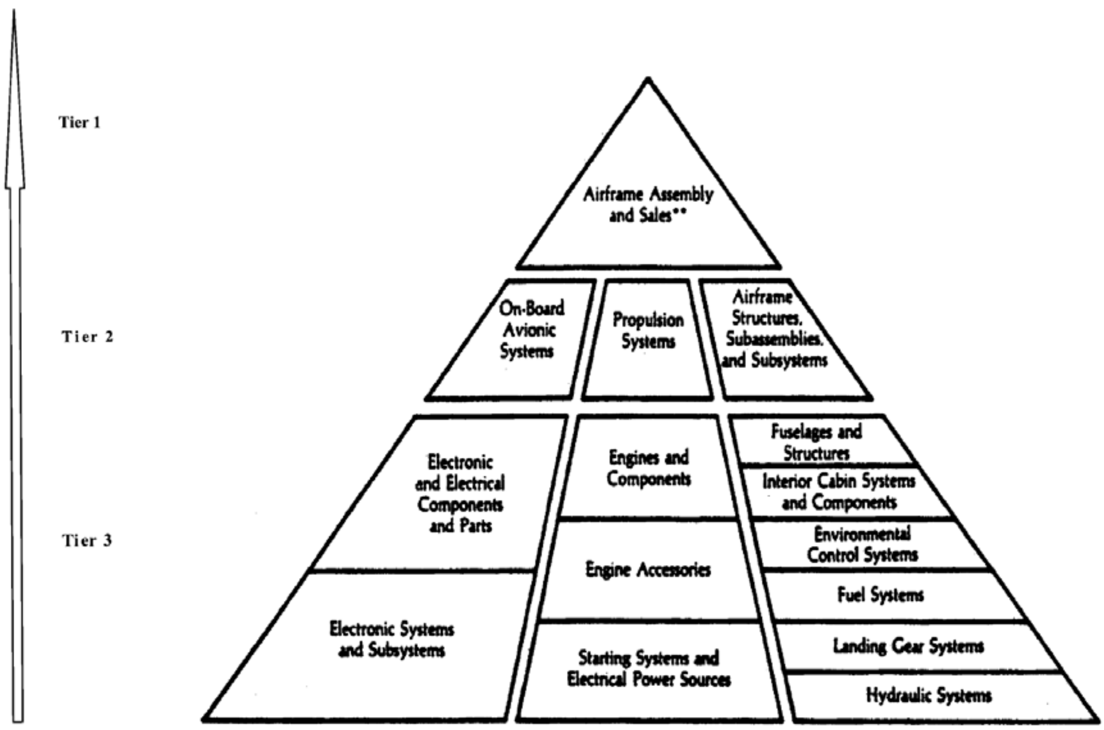

Figure 10 - the aerospace productive structure (Niosi and Zhegu, 2005)

Inside each pyramid an intensive vertical information flow supports the production process. But a significant information flow takes place also horizontally, toward sectors contributing to specific subsystems. In this way aerospace accelerated technology or methodology transfer to other sectors or stimulated their technological evolution by setting high-level goals to subcontractors. It is worth remembering the importance of "space qualification" for mechanical or electronic parts or the know-how on failure mechanisms cumulated to better understand the behavior of materials.

2.3 The innovation process in aerospace sector

The innovation process implies in every context a substantial amount of uncertainty. In fact, in the development of a new artefact not only information about some events are missing, but also the existence is implied of technical or economic problems whose solution procedure are unknown (Nelson and Winter, 1982). It is impossible to predict completely the consequences of some actions and to cast an a-priori view of the expected product performance.

In the case of aerospace sector, also the demand on the final products is difficult to predict, as the time frame of a new development can be ten years long and changes in requirements are likely to happen, in dependence of unforeseen circumstances (e.g. increase of fuel cost) or changes in customer specifications (e.g. low-cost flights). Moreover the R&D process is very costly and concentrated in the first years of the program, while the return of the investments takes place in later times only if a worldwide commercialization plan is successful (Hayward, 1986; Bonaccorsi, 1996). Funding of a new development can seriously challenge the capital available to the enterprise. A further distinctive feature of the aerospace sector lies in the importance of economies of learning, scale and scope.

Learning by doing and *learning by using* are at the basis of product improvement as long as the manufacturing experience grows (Alchian, 1963; Rosenberg 1976,1982) or following informal activities of problem solving, also in cooperation with final clients.

Scope and scale economies result from the possibility of extending a program to support the manufacturing of a family of products (e.g. several models of aircrafts designed to meet the requests of adjacent market segments) sharing the costs for R&D, design and use of production facilities, with limited changes. Extensive quantitative data support this view, particularly with reference to jet and turbo propeller engines (Bonaccorsi and Giuri, 2003).

Innovation in the aerospace sector is strongly affected by cumulative effects. Trends in technological changes are defined by the "state of the art" of used technologies, the improvement probability depending, among other factors, from the technology level already acquired. Scale, level and scope improvement are strongly cumulative, due to the legacy effect of past knowledge and activities. This feature is in contrast with the concept of technology as generally applicable information, easy to identify, to reproduce and exploit (Arrow, 1962). Enterprises do not innovate by accessing to a publicly available common stock of ideas. On the contrary, they produce and innovate on the basis of specifically owned knowledge and procedures, that cannot be easily reproduced.

Innovation in the aerospace sector is characterized by the concept of "*dual use*", that identifies technologies, know-how or products that can be exploited (even with changes or in different timeframes) both in civil or military applications. This concept grew up in '90 when U.S. Government decided to reduce the barriers between commercial and military industries in order to speed up the development of new products, yet reducing their procurement costs (Lorell et. al., 2000). The dual use practice, besides creating the conditions for important economies of scale and scope, facilitates the transfer of technologies between the two sides and approaches the civilian lifecycle (with frequent incremental changes) to the military one (with less frequent but radical changes). At the same time, this remarkable feature of the industry particularly affects innovation development. While military requirements are mainly focus on the performance side thus pushing technology to be exploited until the hardest limits, the civil technical specification take into account different kind of variables, such as fuel consumption or comfort that leads to complementary improvement of the final products.

2.4 Knowledge base of aerospace sector as driver for joint R&D platform development?

The aspects of the aerospace sector directly linked to its knowledge content have been studies from different viewpoints. The special role of leading firms acting as system integrators has been recognized by Grandstrand, Patel e Pavitt (1997) and Piscitello (2000). Such firms build on a wide and diversified know-how, cumulated along many years of activity. They must be able to modify and redesign a part if the interaction with the remaining body of the system raises problems during final commissioning and testing, to solve unforeseen problems or to cope with changes in the user demand (Hobday, 1997 e 1999; Prencipe 2000).

In other words, system integrators must maintain a diversified technological basis (even if not a diversified productive basis) and outstanding abilities in organization and coordination. Another analysis (Dosi, Hobday and Marengo, 2000) based on patents as indicators of the technological competences, shows that integrators are characterized by a technological diversification greater than their productive diversification, because, no maters about collaboration agreements and subcontractors, they must maintain a research capability to monitor and include know-how and productive input coming from outside. The analysis of patents shows furthermore that the diversification is greater where the complexity of products increases (Patel and Pavitt, 1997). The aeronautical industry results to be one of the most diversified sectors, as only 8.3% of the patents belong to the macroclass “Transports” including microclass “Aeronautics”, while a substantial number of patents (48.5%) belong to the class “Non-electrical machinery” and “Electronics” (31,2%). In other sectors like chemistry or ICT the main share of patents (between 70% and 80%) belong to the same main class.

Detailed studies on engine manufacturers (Prencipe, 2002; Dosi and Giuri, 2004) evidence that they play the role of technological trajectory shapers because of the key function of the technology they are working on.

A common characteristic (Giuri, 2004) is that the technological competences of firms span a wide number of patent classes and the technological profile is persistent in time, as there is no trend to increase the technological specialization, e.g. by abandoning patents or exiting less attractive research areas. Recognizing the importance of the knowledge base in the evolution of the aerospace sector, in this paper an attempt is made to evaluate whether it can be exploited to understand (predict) the likelihood of aerospace companies to develop joint innovation programs. Furthermore, considering the increasing importance of EU-funded research projects in the aerospace sector, it is interesting to evaluate if there is any significant influence produced by the knowledge base on the setup of cooperation projects.

2. 5 The evaluation of the knowledge base of a firm

Although the importance of the technological base of a firm has been extensively recognized, few empirical studies have dealt with it, mainly due to difficulties in conceptualization and measurement. In recent times, the most influential approach at measuring the characteristics of firms' competencies has been based upon patent data.

Desrochers (2001) argues that the patent classification system would provide a very good indicator of technological diversity, apparently quoting Griliches (1990), because it "is based primarily on technological and functional principles and is rarely related to economists' notions of products or well-defined industries".

The composition of both the flow and the stock of patents of each firm, in terms of distribution across the existing technological and scientific fields, emerges as an important source of information, and eventually assessment, of the actual size and relevance of the innovations introduced by each firm (Granstrand, Patel and Pavitt, 1997, Fai and Von Tunzelmann, 2001).

The dispersion of patents across scientific and technological fields can be considered a reliable measure of the technological competence of a firm. The wider is the dispersion, the larger is the technological competence. The width of technological competence, however, can be the result of a variety of factors and processes included between the two extremes of business diversification and technological complexity (Fai, 2003).

A topic that has been seldom addressed is the degree of relatedness of the technological fields. In most of the works on diversification/specialization, the different technological fields in which a firm can be active are considered equally distant. The degree of technological diversification has been traditionally based on standard measures of variance, for instance through the Herfindahl index, implicitly assuming that the distance among classes is the same all through the patent portfolio, i.e. all technologies identified by a patent class are uniformly distributed over a hypothetical technological space.

On the contrary, common sense and experience would tell us that certain bits of technology are closer than others. Therefore, any measure of variance in scientific skills should be implemented by taking into account the distances between patent classes.

Of course, much depend on the level of aggregation of the classification adopted: if one uses a very fine patent classification (more than 4-digits in the IPC classification) the measure of variance will be deeply affected by the fact that each single knowledge area that has been considered is not equally distant from all the others; on the other side, if one adopts a more aggregated classification the measure of variance might suffer of a loss of (possibly relevant) information.

Hence, the key methodological problem shifts on the computation of distance measures between patent classes, in a matrix form, which might be further on used to carry out analysis of portfolio variance, keeping into account relative proximities among knowledge domains.

This topic appears to be very relevant, particularly in a context characterized by the importance of knowledge and intangible capital. As David and Foray (2002) highlight, "Knowledge has been at the heart of economic growth and the gradual rise in levels of social well-being since time immemorial.(…) Knowledge-based economy, however, is a recently coined term". Indeed, knowledge, technology and innovation have taken on an increased relevance and a different shape with the advent and deepening of the knowledge society. The knowledge society requires the smarter and more active use of data, information, knowledge and innovative practices, as well as new technologies, to propel societies in the development process and increase their competitiveness. This is true both at macroeconomic and microeconomic level.

In this context, the economic relevance of a measure of cognitive and technological proximity is twofold. On one hand, it can be useful to understand the dynamics of science and technology, especially for what concerns the emerging of new scientific fields that build upon the complementarities of previous knowledge domains. On the other hand, it can be a valuable tool to better evaluate firms' knowledge base, especially in terms of diversification and potential evolution through joint ventures and collaboration agreements.

Various attempts have been made to conceptualise "distance" among technological fields in terms of knowledge flows, and to find appropriate measures for it.

Mohnen (1996), in his review on international R&D spillovers, distinguishes between two kinds of technological proximities. In the first set of proximities, the distance measure is based on inter-firm or inter-industry flows of good and services, capital goods, R&D personnel, innovations or R&D cooperation agreements. As underlined by the author, these proximities follow the argument that the more *i* purchases intermediate inputs or capital goods from *j*, hires scientists from *j*, manufactures goods patented by *j*, uses innovations discovered by *j*, or cooperates with *j* on R&D, the more it is technologically close to *j*.

In this line of reasoning, for long the most influential approach has been Scherer's (1982) method for measuring inter-industry technology flows. It is based upon the use of a matrix reporting R&D outlays classified by industry of origin and industry in which the use of resulting products and processes was anticipated. According to this method, two industries have therefore to be considered as relatively close to each other if a rather high share of R&D made in one sector is actually embodied and used in the other sector. This approach has been more recently adopted to build the so-called "Yale-matrix" from Canadian Patent Office data (Putnam and Evenson, 1994), to assign patents to industries by sector of use and sector of production.

The second set of technological proximities, following Mohnen (1996), departs from the construction of vectors characterizing the firms' or industries' technological positions into different spaces. The rationale is that the closer firms are in such spaces, the more they can benefit from other research activities. Various vectors (or spaces) can be used, classifying patents across technological classes, lines of business, categories of R&D activities or qualifications of R&D personnel.

This approach has been further improved by Jaffe (1989), who measured technological proximity among a sample of US firms by looking at the distribution of their patents over 49 technological fields (each field representing a collection of 4-digit IPC codes).

In particular, Jaffe employed the so-called *cosine index* to measure the correlation between a number of vectors representing the distribution of firms' patents over the various fields. An alternative approach is presented in Adams (1990), who constructs technological proximities based on the number of scientists hired with the same type of qualification.

More recently, a third approach has been proposed by Verspagen (1996), who has suggested a method which is based upon the distinction between the main (or primary) classification code assigned to a patent document, and the supplementary (or secondary) classification codes that the examiners of the issuing patent office usually add to it, to specify in detail the technical content of the novelty claim. According to Verspagen, the main code refers to the object of claimed and appropriable knowledge, while the supplementary code refers to some non-appropriable additional knowledge. Following the distinction, Verspagen assumes that the main classification code "provide a good proxy of the producing sector of knowledge and that the listed supplementary IPC codes give an indication for technology spillovers to other industrial sectors".

In the same line of reasoning, Breschi et al. (2003) make use of the multiple classification codes assigned to patents, but take a position that differs from Verspagen's. In fact, they build upon Engelsman's and Van Raan's (1991, 1992) technique for building maps of technologies and scientific fields and measure knowledge proximity between 30 technological fields by analysing the co-occurrences of their codes in individual patent documents. They assume that the frequency by which two classification codes are jointly assigned to the same patent documents can be interpreted as a sign of strength of the knowledge relationship between the technological fields, which the codes refer to, i.e. as an inverse measure of the distance between the knowledge bases of the two fields. Contrary to Verspagen (1996), they make no assumption about the meaning of the main classification as opposed to the supplementary ones. As explained by Grupp and Schmoch (1992) the two kinds of codes cannot be used to distinguish between knowledge-producing and knowledge-incorporating fields. In fact, although the main classification code describes the central characteristics of the main claim of the patent, the supplementary codes indicate further features of the main claim as well as of the remaining claims of the patent, i.e. they also refer to knowledge creation. Therefore, nothing can be said about the direction of knowledge flows. Following these remarks, they do not attempt to distinguish between main and supplementary classification codes, and treat equally all classification codes assigned to a patent document. In the same line, Hinze et al. (1997) found no support for the spillover hypothesis between the classes, because this is not the way that patent examiners add the supplementary codes; rather, it reflects further claims of the patents and knowledge flows cannot be derived.

More recently, Ejermo (2003) uses the same approach of Breschi et al. (2003) to derive a measure of technological distance, which is then applied to assess the degree of diversity of patent portfolios.

2.6 A methodology to estimate and represent technological proximity

In this section, building on the main empirical contributions previously outlined, a methodology is presented to construct a distance matrix that can be used to measure knowledge proximities among patent classes.

Arguing that patents where co-occurrence of the same IPC class takes place are similar, in the sense that they rely on the same sources of knowledge or they build on the same innovations, it is proposed to derive a measure of technological and cognitive closeness by analysing the class co-occurrence in individual patent documents. We assume that the frequency by which two patents share the same technological classes can be interpreted as a sign of strength of the knowledge relationship between the technological fields to which the two patents are assigned. Hence, the relatedness of two patents is a function of the fact that they build upon a common knowledge base.

Let consider a sample of N patents.

N = number of patents granted in a certain period of time

Q = number of classification codes

F_{im} = 1 if patent application m holds classification code i

F_{im} = 0 if patent application m does not hold classification code i

F (i, m) is a rectangular matrix (, $1 \leq i \leq Q$, $1 \leq m \leq N$)

$N_i = \sum_m F_{im}$ is the number of patents with classification code i

$C_{ij} = \sum_m F_{im} F_{jm}$ is the number of patents with classification code i and j

By applying this count of joint occurrence to all possible pairs of classification codes, it is possible to obtain a square symmetrical matrix C (Q, Q), which can be used to derive a measure of proximity among technological fields.

To this purpose, one possible choice is to calculate:

$P(i/j) = C_{ij} / N_j$

which is the conditional probability that a patent is classified in class i given that it is classified in class j too.

The problem with this kind of measure is that it is not symmetric with respect to the direction linking technological classes; in general $P(i/j) \neq P(j/i)$ because $N_j \neq N_i$. This measure is also strictly dependent on the size of N_j and N_i, i.e. the absolute size of different technological classes in terms of patent applications. It is easy to note that the observed value of co-occurrences C_{ij} is likely to increase with N_j and N_i. This implies that, if the size of the two technological classes is large, one can expect to observe a fairly large number of patents co-classified in the two technological classes, even though the cognitive closeness among the two is very low. Conversely, if the size of the two technological classes is small, one can expect to observe a relatively low number of co-classifications even though the two technologies are cognitively very close to each other.

The measure should not depend on the absolute number of patent applications in different technological classes and should be symmetric with respect to the direction linking technological classes.

A measure that has these properties is the ***cosine index*** (Jaffe, 1989). The *cosine index* measures the "distance", i.e. the angular separation, between two vectors. In this case, the vectors represent all the co-occurrences of the patents of a certain technological

class. As outlined in the previous section, this measure has already been used to measure technological proximity.
In the equation below, we present the analytical expression of the *cosine index*.

$$S_{ij} = \frac{\sum_{k=1}^{\overline{K}} C_{ik} C_{jk}}{\sqrt{\sum_{k=1}^{\overline{K}} C_{ik}^2} \sqrt{\sum_{k=1}^{\overline{K}} C_{jk}^2}}$$

where, under the hypothesis of having split the whole set of patents into $\overline{K}$ classes:
C_{ik} = number of patents included in class i and class k
C_{jk} = number of patents included in class j and class k

The index measures the angular separation between the vectors representing the co-occurrences of technological classes i and j, respectively, with all other technological classes. The *cosine index* provides therefore a symmetric measure of profile likeness between two technological classes in terms of their mutual relationships with all technological classes and it therefore can be interpreted as a measure of the cognitive distance between these two classes. It is easy to note that S_{ij} is greater the more two classes co-occur with the same technological fields (i.e. the two classes are cognitively close to each other), since they build on a common knowledge area. The denominator standardises the measure to be one if the two vectors are identical (i.e. perfectly overlap). Conversely, S_{ij} will be zero for pairs of vectors with no overlap in cited classes. However the use of class co-occurrence as a measure of technological proximity is subject to some important caveats and, as highlighted in previous sections, there is not complete agreement on its meaning.
Hence, the hypothesis that co-occurrences are a good proxy for technological proximity has been tested against an alternative hypothesis, namely that co-occurrences are a purely casual phenomenon. In this perspective, the observed number of co-occurrences of class i and class j (C_{ij}) can be compared to the value that would be expected under the hypothesis that patterns of co-occurrences are random. This approach has been used in the literature on the measurement of inter-business relatedness and corporate coherence

(Engelsman and van Raan, 1991; Teece et al., 1994). The measure is derived from the so-called survivor principle, based on the idea that because of competition, inefficient organisational forms will disappear (Stigler, 1961). The underlying assumption therefore is that more related activities will be more frequently combined within the same firm. We adopt the same approach, assuming that, if patterns of co-occurrences are not random, more related technological fields would more frequently co-occur.
Following Breschi et al. (2003) and Nesta and Saviotti (2005) the following test is derived.

Let assume that in a population of T patents, a number of R_i of patents shows the characteristic of belonging to class i. This implies, of course, that $T - R_i$ patents do not show such characteristic. Now a sample of size R_j of patents is drawn from population of T patents and these patents are assigned in class j. Given this experiment, the probability of obtaining exactly x patents that are classified in both class i and j is distributed according to a hypergeometric random variable, with population T, special members R_i and sample size R_j:

$$\mathrm{P}[X_{ij} = x] = \frac{\binom{R_i}{x}\binom{T - R_i}{R_j - x}}{\binom{T}{R_j}}$$

The mean and the variance of X_{ij} are respectively:

$$\mu_{ij} = E(X_{ij}) = \frac{R_i R_j}{T}$$

$$\sigma^2_{ij} = \mu_{ij}\left(1 - \frac{R_i}{T}\right)\left(\frac{T - R_j}{T - 1}\right)$$

To test the random hypothesis we can use therefore the following indicator:

$$r_{ij} = \frac{O_{ij} - \mu_{ij}}{\sigma_{ij}}$$

where O_{ij} is the observed pattern of co-occurrences.

In this way, we can calculate a value r_{ij} for each of the possible pairs of classes, obtaining a new (k x k) matrix. The computed r_{ij} provide a measure of the extent to which the observed patterns of occurrence, namely O_{ij}, differ from what one would expect if the association of technological fields in patent classification were random. We can say that if the actual number O_{ij} of patents that falls in technological classes i and j greatly exceeds the expected number μ_{ij}, then there must be a strong (non casual) relationship between the two technological classes, i.e. they are strongly related. However, this index r_{ij} can also take negative values. In this particular case, we can interpret the result as indicating that the observed number O_{ij} of patents falling in technological classes i and j is even lower than the number we would observe if classifications were random, i.e. the two technological classes are very poorly related.

A major advantage of the relatedness index r_{ij} is that it has statistical significance (Engelsman and van Raan, 1991). In fact, it is possible to calculate the p-values for each element r_{ij} under the null hypothesis of independence between technological classes and therefore evaluate the statistical significance of the observed relationships among technological classes. If, for a given confidence level, the absolute number and the percentage of cases with statistically significant p-values is large enough it seems possible to reject the hypothesis that patent class occurrence patterns are a random phenomenon. Indeed, technological fields appear significantly more related (or unrelated) than it would happen under the hypothesis of randomness. Under the proof of this evidence it is possible to use the S matrix as a tool to represent and handle knowledge diversification.

2.7 Technological proximity in the aerospace sector: a methodological exercise

Even if there is no theoretical limitation to the usage of the construction path from matrix F to matrix R, to my best knowledge, the above mentioned methodology has never been applied to specific industry study. This feature leads to many previously unsolved problems to be overcome in order to achieve consistent results in the intended aerospace application.

The first problem in a single industry application is about how the sector perimeter can be identified in both fair and useful manner.

As illustrated before, the aerospace sector has a pyramid industrial structure with very few competitors at the system integrator level and a variety of largely different enterprises in tier 2 and 3. While the leading companies in the industry are easy to identify, the majority of firms, who holds a relevant knowledge and competence share of the sector are quite disperse and known quite exclusively by the aerospace sectors. Moreover a unique and objective criteria has to be adopted in order to develop a consistent and replicable methodology.

Moving from Maskell, Bathelt and Malmberg (2005) that underline how international industry events can be considered has global, temporary and filtering clusters of a given sector, the firms active in the aerospace sector have been identified starting from three data sources as illustrated in **Figure 11**.

The list of the exhibitors at Le Bourget Salon of 2007 (1889 companies) and Farnborough Air Show of 2006 (1489 companies), the most important global standing events of the aerospace sector, were merged with the Top 100 Companies list ranked by Flight International and Price Waterhouse Cooper.

In the resulting set of 2289 entries, Large Enterprises could be roughly identified within the elements common to the three lists, while SMEs as well as specialized research centers have been accepted also if quoted in only one of the above mentioned list.

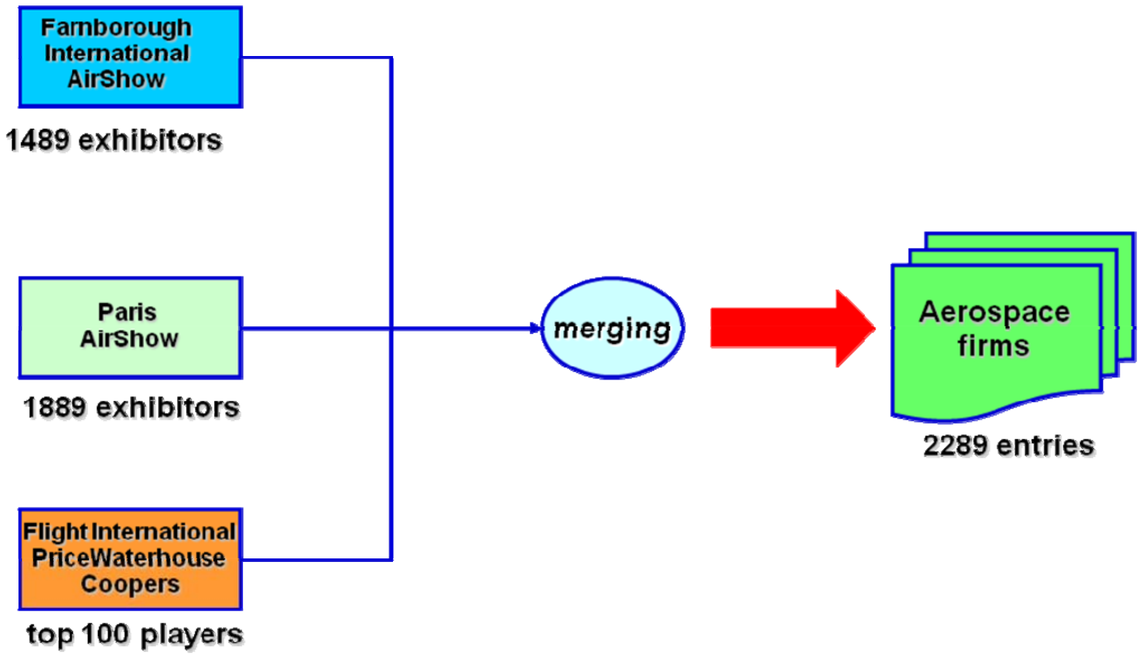

Figure 11 - Aerospace firms identification methodology

Furthermore, it should be considered that a number of very large multinational and multi-industry companies is present in the "top 100 players" list (reported in **Table 2**) thus leading to the problem of including in the aerospace knowledge base, namely the patents dataset to be employed in the following analysis, a relevant share of non-aerospace related data.

To overcome this undesired situation a special filter was applied only in patents retrieval of the large firms belonging to the Top100 list and operating in sectors different from the aerospace-related one. A list of 45 aerospace words was sorted starting from the segmentation keyword adopted by SBAC (Society of British Aerospace Companies) and from the patents claims keyword underlined by an initial patent retrieval from 50 completely aerospace devoted firms. This latter collection was calculated by the Data analyzer of the Thomson Delphion database suite.

This final list adopted in the study and illustrated in **Figure 12**, emerges from an interactive process that fairly resolve the trade-off between selection precision and technological knowledge coverage.

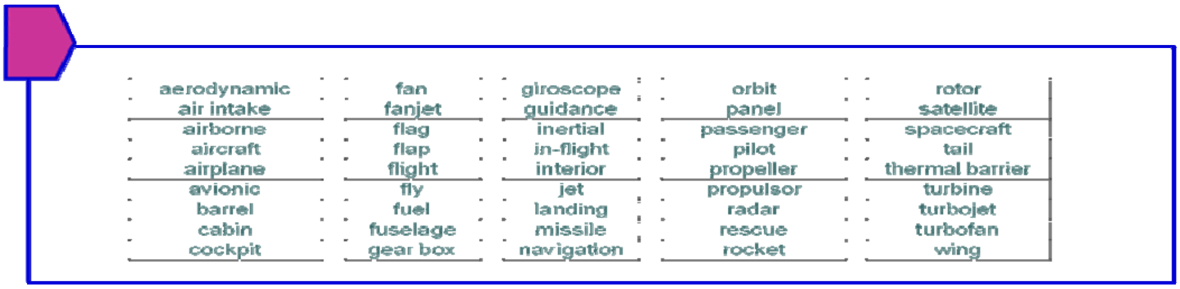

Figure 12 - keyword in patent filter for large multi-industry companies in the Top 100 list

Patent retrieval processing from the EPO database by filtering patent on the basis of the keyword presence in the patent description allows to select about 50% of Boeing corporation patent portfolio as well as 6% of the Ericsson one.

Using this attention in the case of large multi-industry enterprises, patents assigned in the time frame 1997 - 2007 to the above defined aerospace enterprises have been extracted from the EPO database. Three main groups can be identified in this way: big companies with a large patent portfolio, mid-sized companies with a sizable portfolio and single-patent small companies. A dataset of 10.075 patents with 727 assignees has been thus obtained as illustrated in **Figure 13**.

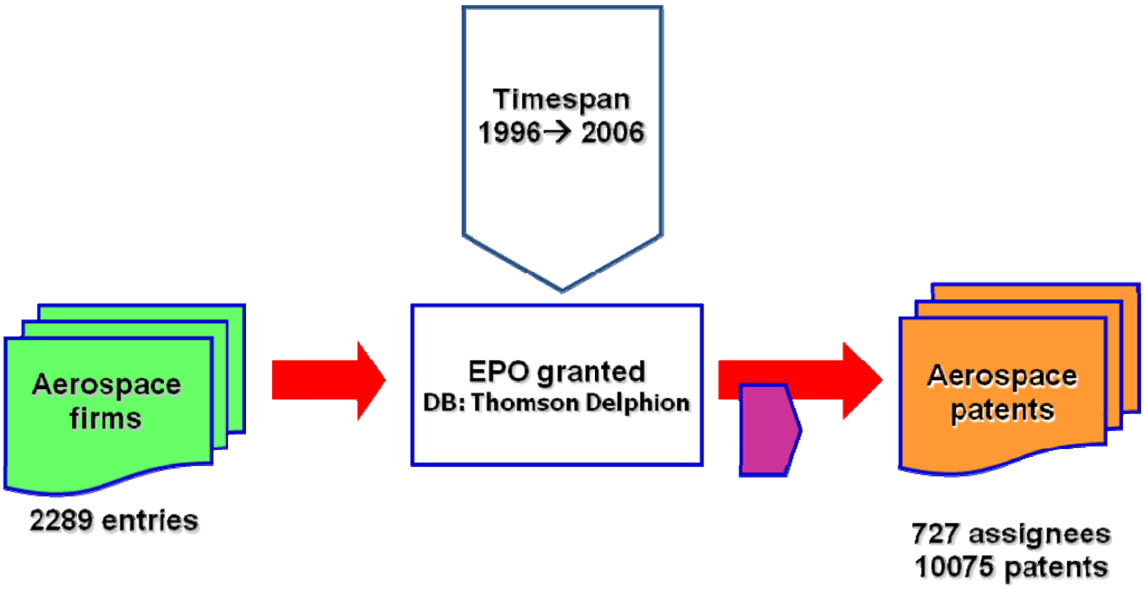

Figure 13 - Patents retrieval process

Another first key methodological issue deals with the adoption of a reasonable number of classes to perform the proximity computations and with the attribution of each patent to a specific technological sector. In this respect, we have adopted a technology-oriented classification, which distinguishes 30 different fields of technologies based on the International Patent Classification (IPC). This classification has been elaborated jointly by Fraunhofer Institute (FHG-ISI), the French Patent Office (INPI) and the Observatoire des Sciences and des Techniques (OST) and is internationally acknowledged to be a reference in this filed of studies. Each patent of the list has been brought back to the correspondent OST-ISI-INPI classification based on its IPC code (4-digit). The correspondence is reported in **Table 1**.

For each of the 30 sectors considered, the vector *F* containing the classification of each patent has been constructed, then, for the listed patents, the matrix F has been constructed with respect to the 30 considered sectors, thus producing a matrix F (N,Q) = F (10075, 30). As illustrated in **Figure 14**, the aerospace sector is characterised by an extremely complex knowledge base. While for ICT and chemistry the 80% of the total industry patents is concentrated in a few core classes leading to the involvement of a few of F classes, in the aerospace sector is present in 27/30 of OST-ISI-INPI classification of IPC codes.

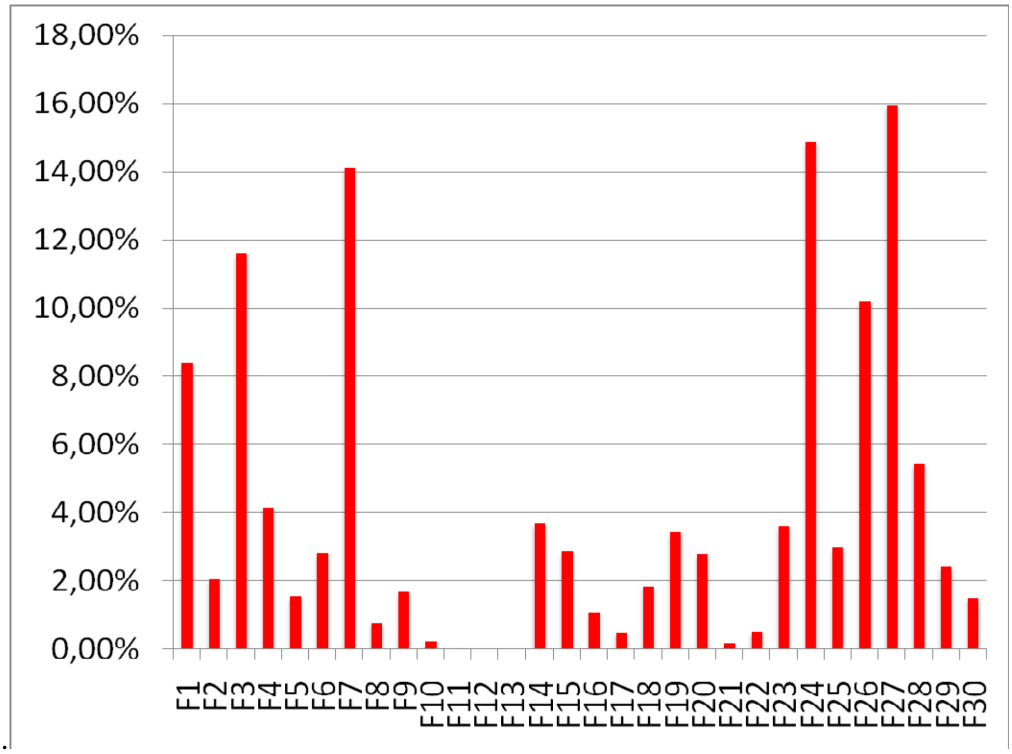

Figure 14 - Distribution of aerospace patents in the F classes

In using a single matrix during the analysis a relevant assumption has to be done: it is assumed that proximity among technologies is an intrinsic feature related to the properties of knowledge bases supporting the technologies and therefore relatively invariant across countries.

The previous assumptions are based on the results obtained by different authors searching for a technological relatedness measure. In particular, Hinze, Reiss and Schmoch (1997), adopting an approach based on co-occurrences of patent classification codes, examined whether technological distance is affected by differences between various countries and the kind of technology produced there or whether, conversely, technological distance is a characteristic independent from national patterns.

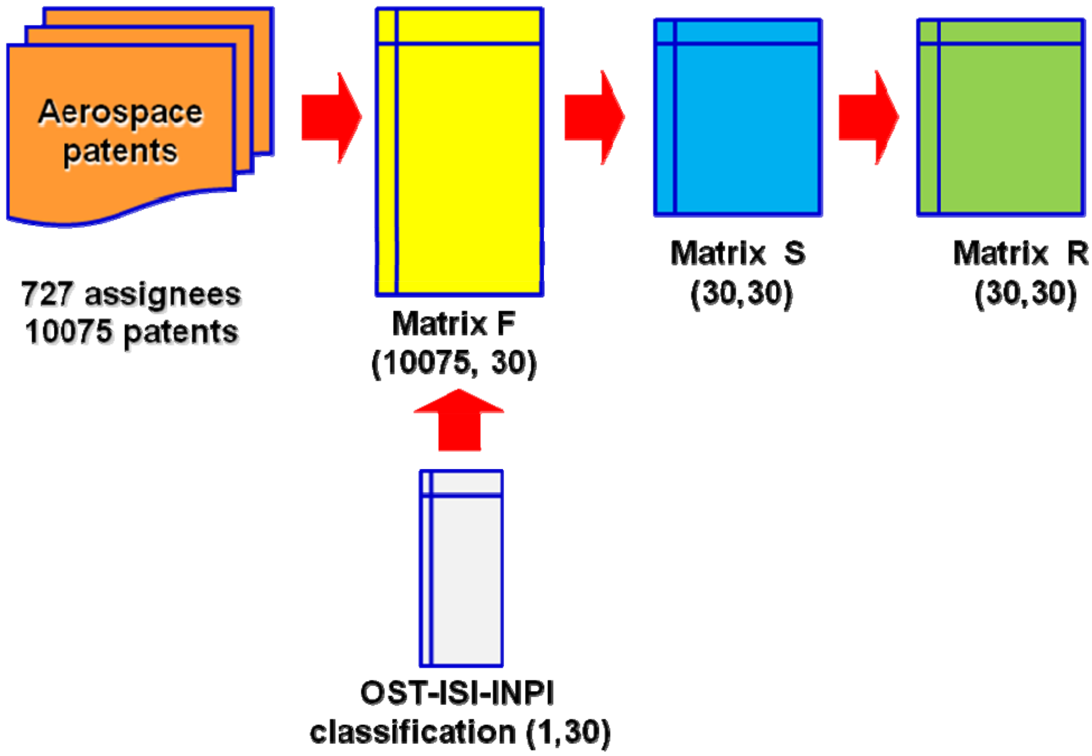

Figure 15 - Knoledge base analysis process

The results suggest that no difference can be identified in the distance between fields of technology using worldwide patent data compared to country-specific data. Furthermore, the relations between technology areas remain stable for the different periods considered. The authors concluded that technological proximity seems to be an intrinsic feature of technology which is valid for industrial countries and which remains rather stable even for long observation periods. Breschi et al. (2003) have obtained a similar result: "from the calculations no difference seems to emerge using world-wide patent data compared to individual country data. Furthermore, the relationships among technological fields seem to remain highly stable over the different time periods considered". Always according to the previously described methodology (**Figure 15**), from matrix F(N,Q) the matrix C(Q,Q) = C(30,30) was obtained and the S matrix, based on the *cosine index* previously presented, was computed. The matrix S(30,30) is reported in **Table 3** while matrix R (30,30) is illustrated, with values multiplied by 100 to make them more readable, in **Table 4**.

While the matrix R has 435 independent cells (due to symmetric construction over the principal diagonal they are a half of 900 total cells – 30 diagonal cells been equal to 1 by definition) and over 72% of them have a significant p-value (10% confidence level) we can not reject the hypothesis that the S matrix capture a systematic correlation effect between classes, namely technological proximity.

2.8 Knowledge base and R&D cooperation potential

So far a tool to represent and handle the technological complexity resident in the knowledge base of the aerospace sector firms has been developed. In the following an application of the matrix S above calculated is presented to show one of the possible usage of the industry-specific cognitive distance matrixes.
Reporting the example of Bossi (2004) it become clear the advantages of using this kind of methodology compared with the standard Herfindahl index diversification measures:

Indeed, the simple Herfindahl index measures diversification as:

$$\sum_{j=1}^{J}\left(\frac{N_j}{N}\right)^2$$

where $\frac{N_j}{N}$ is the share of patents in class *j*

The proximity matrix can be interpreted as a correlation matrix. Taking a normal multivariate with covariance Σ, for any linear combination such as $Z = \sum_i \alpha_i X_i$, the variance of the variable Z is $\sum_{i,j} \alpha_i \sigma_{ij} \alpha_j = \alpha^T \Sigma \alpha$

If we consider the vector α as representing the distribution of patents through the classes, our weighted measure of diversification turns out to be:

$$\alpha^T \Sigma \alpha$$

where $\sum$ is the proximity matrix.
It is straightforward to note that the value of our weighted measure changes according to the composition of patent portfolios and to the distance between classes.

Let consider for example two firms with the following patent portfolio composition:

$\beta_1 = [0.5 \quad 0.5 \quad 0 \quad 0 \quad 0]$ firm 1

$\beta_2 = [0 \quad 0 \quad 0.5 \quad 0.5 \quad 0]$ firm 2

And consider a proximity matrix ∑:

1.00	**0.70**	0.02	0.03	0.80
0.70	1.00	0.05	0.07	0.90
0.02	0.05	1.00	**0.06**	0.20
0.03	0.07	**0.06**	1.00	0.20
0.80	0.90	0.20	0.20	1.00

The simple Herfindahl index would be equal to 0,5 for both firms.
If we now calculate the weighted diversification index, we obtain:

$D_1 = 0.1500$ firm 1

$D_2 = 0.4700$ firm 2

that is exactly what we expected since class 1 and class 2 are more closely related than class 3 and class 4.
In the same line of reasoning, leveraging on the matrix S reported in Table 2 it is possible to develop more reliable calculation of an aerospace company technological diversification profile measuring it by a single number. Using this feature, cognitive distances between firms, in terms of degree of diversification, and their relation with R&D cooperation agreements become investigable. Following the research path proposed by Wuyts et al. (2005) a methodological exercise is presented using the data on R&D projects of VI Framework Programme of European Union (FP6).
This policy measure, that involve a time span of seven years (2000-2006), has financed the technological innovation in the aerospace sector for 1182 million of Euros splitted in 212 different projects. The general data about them, including research consortia

composition are available through the publications of the Community Research & Development Information Service (CORDIS).

Selecting the 34 legally European based companies from the top 100 players list of Flight International and interrogating the Cordis databes by project partners coming from the industry, it was possible to obtain 561=(34*33)/2 observations of couple of aerospace firms together with some basic data describing them and a dummy variable indicating (with value equals 1, otherwise 0) the presence of FP6 of a joint R&D project between them as illustrated in **Figure 16**.

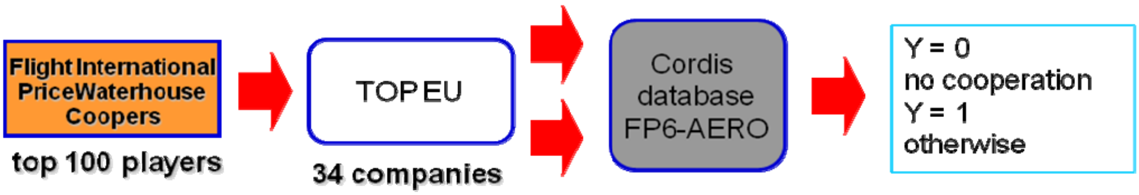

Figure 16 - R&D project retrieval

From this dataset a logit model to estimate the impact of technological diversification rate in the likelihood to firms cooperate into R&D project was estimated involving the following variables:

Y: the dependent variable, equals 0 if the two firms under consideration did not cooperate with each other, otherwise equal 1.

Same_country: dummy equal 1 if partners have different country

Diff_sales: absolute difference in sales between two companies

Diff_hr: absolute difference in headcount

Diff_diversification: absolute difference in Diversification measured by the previously described methodology and using the matrix S.

Even if the above presented methodological exercises, is intended to explore new tools rather than to test or assert causal relationship, some comments on the model calculation could be made.

While Diff_sales and Diff_hr seems to have no substantial significance in the model estimation reported in the following results, Same_country and Diff_diversification show a negative correlation with the likelihood that an R&D project will occur between two firms.

Logistic regression	
Number of obs	561
LR chi^2(4)	20.92
Pseudo R^2	0.0438
Log likelihood	-387.7699

Variable	**95% Conf. Interval**	
Same_country	-6.79423	-2.76845
Diff_sales	- 0.13986	1.00974
Diff_hr	-0.19942	1.12067
Diff_diversification	-4.93181	-1.96502

For the first variable the result is consistent with the general incentives ruling the European bids for research funds and encouraging cross-national partnership to develop the European Research Area. The negative correlation associated with Diff_diversification fits well in the theoretical and empirical framework previously presented that underlines two knowledge base characteristics widely common in the aerospace firms. The companies of the sector shows a consistent trend to have a highly diversified knowledge base. However, system integrators presents higher level of this characteristics thus leading to greater diversification rates. Tier 2 and tier 3 companies, even with multidisciplinary technological background tends to develop partnership between them while competing to gain contracts from final system integrator. This trend can be detected looking at the R&D projects in the FP6, thus acquiring the significance of being more “competence enhancing and deepening” that “competence integrating and widening”, a feature that is confirmed also by the contemporary industrial trend to let companies focus mainly in developing their specific core competences.

2.9 Conclusions

The aerospace sector has many prominent characteristics that make technological innovation a key variable. In this competitive environment, that has an “attitude toward technology synthesis”, a variety of engineering disciplines are called to give their contribution to the final product performance. At the same time this industry both reward and help the development of technological innovation by relevant knowledge flows inside and outside its boundaries.

Moreover, in such a complex products manufacturing, innovation systems are fundamental to define the competitive landscape because no companies could actively play on the entire involved technology frontier to be handled for cutting edge innovation development. Following this line of reasoning the evaluation of technological knowledge base is receiving growing attention both from the strategic and financial perspective. Besides the above presented methodological exercises, that intend to explore new tools rather than to test or assert causal relationship, is worth noting that the quantitative and empirical research in knowledge base present very promising research perspective especially in the evaluation of innovation systems and the adoption of analysis unit, such as R&D platform alliances or industrial districts, overcoming the single firm boundaries.

Table 1 - Correspondence between patent classes and technological groups in OST-ISI-INPI classification

	Patent Classes	IPC patent codes
I	ELECTRICAL ENGINEERING	
1	Electrical machinery and apparatus, electrical energy	G05F H01B H01C H01F H01G H01H H01J H01K H01M H01R H01T H02 H05B H05C H05F H05K
2	Audiovisual technology	G09F G09G G11B H03F H03G H03J H04N-003 H04N-005 H04N-009 H04N-013 H04N-015 H04N-017 H04R H04S
3	Telecommunications	G08C H01P H01Q H03B H03C H03D H03H H03K H03L H03M H04B H04H H04J H04K H04L H04M H04N H04Q
4	Information technology	G06 G11C G10L
5	Semiconductors	H01L B81
II	INSTRUMENTS	
6	Optics	G02 G03B G03C G03D G03F G03G G03H H01S
7	Analysis, measurement, control technology	G01B G01C G01D G01F G01G G01H G01J G01K G01L G01M G01N G01P G01R G01S G01V G01W G04 G05B G05D G07 G08B G08G G09B G09C G09D G12
8	Medical technology	A61B A61C A61D A61F A61G A61H A61J A61L A61M A61N
9	Nuclear engineering	G01T G21 H05G H05H
III	CHEMISTRY, PHARMACEUTICALS	
10	Organic fine chemistry	C07C C07D C07F C07H C07J C07K
11	Pharmaceuticals, cosmetics	A61K A61P
12	Biotechnology	C07G C12M C12N C12P C12Q C12R C12S

	Patent Classes	IPC patent codes
13	Agriculture, food chemistry	A01H A21D A23B A23C A23D A23F A23G A23J A23K A23L C12C C12F C12G C12H C12J C13F C13F C13J C13K
14	Materials, metallurgy	C01 C03C C04 C21 C22 B22 B82
15	Surface technology, coating	B05C B05D B32 C23 C25 C30
16	Macromolecular chemistry, polymers	C08B C08F C08G C08H C08K C08L C09D C09J
17	Chemical industry and petrol industry, basic materials chemistry	A01N C05 C07B C08C C09B C09C C09F C09G C09H C09K C10B C10C C10F C10G C10H C10J C10K C10L C10M C11B C11C C11D
IV	PROCESS ENGINEERING, SPECIAL EQUIPMENT	
18	Chemical engineering	B01B B01D (without -046 to -053) B01F B01J B01L B02C B03 B04 B05B B06 B07 B08 F25J F26
19	Materials processing, textiles, paper	A41H A43D A46D B28 B29 B31 C03B C08J C14 D01 D02 D03 D04B D04C D04G D04H D05 D06B D06C D06G D06H D06J D06M D06P D06Q D21
20	Handling, printing	B25J B41 B65B B65C B65D B65F B65G B65H B66 B67
21	Agricultural and food machinery and apparatus	A01B A01C A01D A01F A01G A01J A01K A01L A01M A21B A21C A22 A23N A23P B02B C12L C13C C13G C13H
22	Environmental technology	A62D B01D-046 to -053 B09 C02 F01N F23G F23J
V	MECHANICAL ENGINEERING, MACHINERY	
23	Machine tools	B21 B23 B24 B26D B26F B27 B30
24	Engines, pumps, turbines	F01B F01C F01D F01K F01L F01M F01P F02 F03 F04 F23R
25	Thermal processes and apparatus	F22 F23B F23C F23D F23H F23K F23L F23M F23N F23Q F24 F25B F25C F27 F28

	Patent Classes	IPC patent codes
26	Mechanical elements	F15 F16 F17 G05G
27	Transport	B60 B61 B62 B63B B63C B63H B63J B64B B64C B64D B64F
28	Space technology, weapons	B63G B64G C06 F41 F42
29	Consumer goods and equipment	A24 A41B A41C A41D A41F A41G A42 A43B A43C A44 A45 A46B A47 A62B A62C A63 B25B B25C B25D B25F B25G B25H B26B B42 B43 B44 B68 D04D D06F D06N D07 F25D G10B G10C G10D G10F G10G G10H G10K
30	Civil engineering, building, mining	E01 E02 E03 E04 E05 E06 E21

Table 2 - Top 100 aerospace companies

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	2005	2004	2005	growth	2005	growth	2004	2005	2004
1	(1) Boeing (USA)	54,845	52,457	54,845	5%	2,812	40%	2,007	5.1%	3.8%
	Commercial Aerospace			22,651	8%	1,432	90%	753	6.3%	3.6%
	Integrated Defence Systems			30,791	1%	3,89	33%	2,925	12.6%	9.6%
	Boeing Capital/Other			1,403	47%	-2,51		-1,671	-178.9%	-175.0%
2	(2) EADS (Netherlands)	42,5	39,489	42,522	8%	3,545	17%	3,025	8.3%	7.7%
	Airbus			27,275	12%	2,868	20%	2,387	10.5%	9.8%
	Military Transport Aircraft			658	-51%	60	85%	32	9.1%	2.4%
	Eurocopter			3,825	15%	264	5%	250	6.9%	7.5%
	Defence and Security Systems			6,373	3%	250	-11%	281	3.9%	4.6%
	Space			3,341	4%	72	544%	11	2.2%	0.3%
	Other Business			1,027	-3%	-213			-20.7%	
3	(3) Lockheed Martin (USA)	37,213	35,526	37,213	5%	2,986	43%	2,089	8.0%	5.9%
	Aeronautics			11,672	-1%	994	11%	899	8.5%	7.6%
	Electronic Systems			10,58	9%	1113	15%	969	10.5%	10.0%
	Space Systems			6,82	7%	609	25%	489	8.9%	7.7%
	Integrated Systems & Solutions			4,131	7%	365	9%	334	8.8%	8.7%
	Information & Technology Services			4,01	5%	351	23%	285	8.8%	7.5%
4	(4) Northrop Grumman (USA)	30,679	29,624	30,721	3%	2,178	9%	2,006	7.1%	6.7%
	Electronic Systems			6,042	2%	710	6%	670	11.8%	11.3%
	Information Technology			4,999	2%	355	18%	301	7.1%	6.2%
	Mission Systems			4,959		381	19%	321	7.7%	6.9%
	Ship Systems			5,784	-7%	241	-38%	389	4.2%	6.2%
	Integrated Systems			5,55	18%	474	15%	412	8.5%	8.8%
	Space Technology			3,345	4%	255	15%	222	7.6%	6.9%
5	(5) BAE Systems (UK)	28,023	24,229	28,023	17%	2,149	16%	1,862	7.7%	7.7%
	Programmes			5,126	27%	242	1,23%	18	4.7%	0.5%
	Customer Solutions & Support			5,315	2%	762	-16%	911	14.3%	17.4%

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	**2005**	**2004**	**2005**	**growth**	**2005**	**growth**	**2004**	**2005**	**2004**
	Commercial Aerospace			5,877	11%	325	-11%	368	5.5%	6.9%
	Integrated Systems and Partnerships			3,351	-9%	198	15%	174	5.9%	4.7%
	Electronics, Intelligence & Support			6,722	21%	589	27%	469	8.8%	8.4%
	Land & Armaments			2,309	163%	76	0%	-15	3.3%	-1.7%
	HQ/Operations			125	-5%	-44		-64	-34.8%	-47.9%
6	(6) Raytheon (USA)	23,437	21,867	21,894	8%	1,687	22%	1,388	7.7%	6.9%
	Integrated Defense Systems			3,807	10%	548	31%	417	14.4%	12.1%
	Intelligence and Information Systems			2,509	7%	229	16%	198	9.1%	8.5%
	Missile Systems			4,124	7%	431	-1%	436	10.5%	11.3%
	Network Centric Systems			3,205	5%	333	22%	274	10.4%	9.0%
	Space and Airborne Systems			4,175	3%	606	7%	568	14.5%	14.0%
	Technical Services			1,98	0%	146	-3%	151	7.4%	7.6%
	Aircraft			2,856	18%	142	125%	63	5.0%	2.6%
	Other			781	16%	-117		-40	-15.0%	-5.9%
7	(7) General Dynamics (USA)	20,975	18,926	21,244	11%	1,944	0%	1,941	9.2%	10.2%
	Aerospace			3,433	14%	495	26%	393	14.4%	13.0%
	Combat Systems			5,021	14%	576	10%	522	11.5%	11.8%
	Marine Systems			4,695	-1%	249	-15%	292	5.3%	6.2%
	Information Systems and Technology			7,826	16%	865	20%	718	11.1%	10.7%
8	(8) United Technologies (USA)	16,479	14,737	42,752	14%	5182	20%	4,301	12.1%	11.5%
	Engines (Pratt & Whitney)			9,295	12%	1449	34%	1,083	15.6%	13.1%
	Flight Systems (Sikorsky, Hamilton Standard)		7,184	12%	925	18%	783	12.9%	12.2%	
9	(9) General Electric (USA)	11,904	11,094	149,702	11%	16,353	-3%	16,819	10.9%	12.5%
	Aircraft Engines		11,904	7%	2,573	15%	2,238	21.6%	20.2%	
10	(13) Finmeccanica (Italy)	11,491	8,861	13,615	24%	914	58%	578	6.7%	5.3%
	Aeronautics		2,224	8%	206	42%	146	9.3%	7.0%	
	Space		914	-4%	32	13%	29	3.5%	3.0%	
	Helicopters		3	71%	338	109%	162	11.3%	9.2%	
	Defence Electronics		3,933	53%	334	74%	193	8.5%	7.5%	
	Defence Systems		1,421	0%	139	1,14%	11	9.8%	0.8%	
11	(12) Honeywell International (USA)	10,497	9,748	27,653	8%	3,409	15%	2,974	12.3%	11.6%

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	**2005**	**2004**	**2005**	**growth**	**2005**	**growth**	**2004**	**2005**	**2004**
	Aerospace International		10,497	8%	1,703	15%	1,479	16.2%	15.2%	
12	(10) Thales (France)	10,274	10,342	12,758	0%	896	3%	871	7.0%	6.8%
	Aerospace			2,97	9%	259	16%	223		
	Air Systems			1,986	5%	157	0%	157		
	Land & Joint Systems			3,266	3%	174	-10%	194	5.3%	6.1%
	Naval Systems			2,052	-19%	183	7%	172	8.9%	6.8%
13	(16) L-3 Communications (USA)	9,444	6,898	9,444	37%	997	33%	749	10.6%	10.9%
	Command, Control and Communications (C3) and ISR	2,17	30%	250	15%	218	11.5%	13.1%		
	Government Services	1,82	72%	168	35%	124	9.2%	11.7%		
	Aircraft Modernization and Maintenance	2,289	20%	227	22%	186	9.9%	9.7%		
	Specialized Products	3,165	40%	351	60%	220	11.1%	9.7%		
14	(14) Rolls-Royce (UK) 8,952 8,089	12,007	11%	1,595	110%	764	13.3%	7.0%	10,932	15%
	Civil Aerospace			6,382	15%	1,198	240%	356	18.8%	6.4%
	Defence Aerospace			2,569	3%	322	-1%	328	12.5%	13.0%
15	(11) Safran (France)	8,422	10,342	10,81	-16%	-383		892	-3.5%	6.9%
	Propulsion			5.585	-27%	-445		428	-10.8%	7.6%
	Equipment			2,601	-20%	-48		208	-1.9%	6.4%
	Defence and Security			1,717	19%	137	7%	128	8.0%	8.9%
16	(15) Bombardier (Canada)	8,087	7,98	14,369	-8%	357	458%	64	2.5%	0.4%
	Aerospace			8,087	1%	266	31%	203	3.3%	2.5%
17	(18) Textron (USA)	6,361	4,727	10,043	21%	1,028	30%	791	10.2%	9.5%
	Bell			2,881	28%	368	47%	250	12.8%	11.1%
	Cessna			3,48	41%	457	71%	267	13.1%	10.8%
18	(19) Goodrich (USA)	5,396	4,7	5,396	15%	533	34%	397	9.9%	8.4%
	Airframes Systems			1,854	14%	76	-16%	90	4.1%	5.5%
	Engine Systems			2,238	15%	400	51%	265	17.9%	13.7%
	Electronic Systems			1,304	13%	146	6%	138	11.2%	11.9%
19	(17) Alcatel (France)	4,78	4,78	16,328	7%	1,416	61%	880	8.7%	5.8%
	Private Communications			4,78	0%	341	3%	332	7.1%	6.9%
20	(20) Dassault Aviation (France)	4,261	4,303	4,261	-1%	511	-12%	581	12.0%	13.5%
	Defence			2,209	32%					

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	2005	2004	2005	growth	2005	growth	2004	2005	2004
	Business Aircraft			2,052	-22%					
21	(22) Mitsubishi Heavy Industries (Japan)	4,05	3,639	25,359	8%	644	380%	132	2.5%	0.6%
	Aerospace			4,05	9%	150	90%	78	3.7%	2.1%
22	(23) ITT Industries (USA)	3,933	3,111	7,427	17%	500	-18%	610	6.7%	9.6%
	Defense Electronics and Services			3,224	34%	364	43%	254	11.3%	10.5%
	Electronic Components			709	2%	-217		30	-30.6%	4.3%
23	(21) Embraer (Brazil)	3,805	3,72	3,805	-11%	189	-55%	368	5.0%	9.9%
24	(25) Rockwell Collins (USA)	3,445	2,93	3,445	18%	624	29%	482	18.1%	16.5%
	Commercial Systems			1,81	30%	328	64%	200	18.1%	14.3%
	Government Systems			1,635	7%	296	5%	282	18.1%	18.4%
25	(24) Eaton (USA)	3,24	3,098	11,115	13%	1,398	21%	1,153	12.6%	11.7%
	Fluid Power			3,24	5%	339	0%	338	10.5%	10.9%
26	(26) Alliant Techsystems (USA)	3,198	2,645	3,217	15%	327	15%	285	10.2%	10.2%
	ATK Thiokol		943	12%	130	7%	61	13.8%	14.4%	
	Ammunition		1,125	27%	109	28%	28	9.7%	9.6%	
	Precision Systems		594	15%	49	9%	45	8.2%	8.7%	
	Adavanced Propulsion & Space Systems		536	36%	53	66%	32	9.9%	8.1%	
27	(29) Smiths Group (UK)	2,751	2,424	5,464	10%	687	21%	572	12.6%	11.4%
	Aerospace			2,084	14%	215	18%	183	10.3%	9.9%
	Detection			667	16%	122	22%	101	18.3%	17.4%
28	(27) Saab (Sweden)	2,75	2,43	2,586	8%	221	-11%	239	8.6%	10.4%
	Defence & Security Solutions			731	20%	75	40%	52	10.3%	8.8%
	Systems and Products			990	8%	111	23%	86	11.2%	9.8%
	Aeronautics			1,029	13%	30	-70%	97	2.9%	11.1%
29	(31) Alcoa (USA)	2,7	2,2	26,159	13%	1,233	-10%	1,377	4.7%	5.9%
	Engineered Products (Aerospace)			2,7	23%					
30	(30) MTU Aero Engines (Germany)	2,67	2,386	2,67	12%	73	743%	9	2.7%	0.4%
31	(34) Precision Castparts (USA)	2,488	1,993	3,546	21%	557	32%	421	15.7%	14.4%
	Forged Products			879	39%	108	42%	76	12.3%	12.0%
	Investment Cast Products			1,609	18%	322	26%	256	20.0%	18.8%
32	(32) Ishikawajima-Harima (Japan)	2,402	2,08	10,237	3%	198	105%	95	1.9%	1.0%

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	2005	2004	2005	growth	2005	growth	2004	2005	2004
	Aero-Engines & Space Operations			2,402	13%	2,402	26%	116	6.2%	5.6%
33	(35) Harris (USA)	2,342	1,936	3,001	19%	321	53%	210	10.7%	8.3%
	Government Communications			1,805	20%	203	33%	153	11.3%	10.2%
	RF Communications			537	25%	167	40%	119	31.0%	27.7%
34	(33) Israel Aircraft Industries (Israel)	2,34	2,06	2,34	14%	25	400%	5	1.1%	0.2%
35	(36) Kawasaki Heavy Industries (Japan)	1,998	1,679	12,011	7%	310	38%	221	2.6%	2.0%
	Aerospace			1,998	17%			54		3.2%
36	(37) Cobham (UK)	1,764	1,525	1,764	17%	278	8%	260	15.8%	17.1%
	Aerospace Systems			460	8%	95	-2%	97	20.6%	22.6%
	Flight Operations & Services			358	4%	25	-30%	37	7.1%	10.6%
	Chelton (Avionics)			946	27%	158	26%	126	16.7%	16.9%
37	(41) DRS Technologies (USA)	1,74	1,309	1,74	33%	193	35%	143	11.1%	10.9%
38	(39) Zodiac (France)	1,711	1,505	2,277	17%	311	20%	259	13.6%	13.3%
	Aerosafety Systems			379	9%	57	12%	51	15.1%	14.6%
	Aircraft Systems			568	16%	85	33%	63	14.9%	12.9%
	Cabin Interiors			510	27%	63	4%	61	12.4%	15.2%
	Technology			254	-5%	20	13%	18	7.8%	6.6%
39	(40) BBA Group (UK)	1,622	1,466	2,746	10%	236	2%	233	8.6%	9.2%
	Aviation			1,622	9%	171	8%	159	10.5%	10.6%
40	(38) Avio (Italy)	1,592	1,518	1,592	5%	-10		-14	-0.6%	-0.9%
41	(43) Parker Hannifi n (USA)	1,359	1,14	8,215	17%	1,028	49%	688	12.5%	9.8%
	Aerospace			1,359	12%	199	26%	158	14.6%	13.0%
42	(42) Vought Aircraft Industries (USA)	1,297	1,215	1,297	7%	-175		-112	-13.5%	-9.2%
43	(44) Hindustan Aeronautics (India)	1,218	1,002	1,218	19%	227	32%	168	18.6%	16.7%
44	(45) Teledyne Technologies (USA)	1,179	992	1,207	19%	101	51%	67	8.4%	6.6%
	Electronics and Communications			718	26%	84	56%	54	11.7%	9.5%
	Systems Engineering Solutions			264	9%	28	4%	27	10.6%	11.2%
	Aerospace Engines and Components			197	8%	14	133%	6	7.1%	3.3%
45	(28) GKN (UK)	1,14	2,426	6,633	5%	178		-44	2.7%	-0.7%
	Aerospace			1,14	10%	80	57%	51	7.0%	4.9%
46	(47) Elbit Systems (Israel)	1,07	940	1,07	14%	67	2%	66	6.3%	7.0%

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	2005	2004	2005	growth	2005	growth	2004	2005	2004
47	(48) Volvo (Sweden)	1,009	893	32,205	14%	2,43	24%	1,892	7.5%	7.0%
	Aero			1,009	9%	112	107%	52	11.1%	5.8%
48	(53) Meggitt (UK)	991	747	1,12	29%	185	24%	150	16.6%	17.2%
	Aerospace			835	36%	147	31%	114	17.6%	18.4%
	Defence Systems			156	25%	25	17%	22	16.3%	17.4%
49	(46) Ruag (Switzerland)	959	967	959	-1%	15	-64%	43	1.6%	4.4%
50	(50) CAE (Canada)	913	804	913	12%	111	42%	77	12.2%	9.6%
	Civil Simulation and Training			478	11%	73	83%	39	15.2%	9.2%
	Military Simulation and Training			436	13%	39	0%	38	8.9%	10.1%
51	(49) Sequa (USA)	898	814	1,998	7%	121	51%	80	6.1%	4.3%
	Aerospace			898	10%	65	51%	43	7.2%	5.3%
52	(54) B/E Aerospace (USA)	844	734	844	15%	94	47%	64	11.1%	8.7%
	Commercial Aircraft Products			550	7%	51	28%	40	9.3%	7.8%
	Business Jet Products			120	60%	8		-1	6.7%	-1.3%
	Fastener Distribution			174	21%	35	35%	26	20.1%	18.1%
53	(65) Esterline (USA)	835	613	835	36%	82	64%	50	9.8%	8.2%
	Avionics & Control			261	25%	37	16%	32	14.2%	15.3%
	Sensors & Systems			320	77%	34	325%	8	10.6%	4.4%
	Advanced Materials			254	14%	34	21%	28	13.4%	12.6%
54	(52) Liebherr (Switzerland)	823	777							
	Aircraft Equipment			823	6%					
55	(55) Triumph Group (USA)	760	688	760	10%	56	70%	33	7.4%	4.8%
56	(51) Standard Aero (Canada)	752	786	761	-4%	-13		64	-1.7%	8.0%
	Aviation			752	-4%	7	-93%	101	0.9%	12.8%
57	(74) Fuji Heavy Industries (Japan)	743	505	13,409	2%	530	39%	375	4.0%	2.9%
	Aerospace			743	38%	25	1,33%	2	3.4%	0.3%
58	(58) Singapore Technologies Engineering (Singapore)743	662	2,005	13%	279	20%	229	13.9%	13.1%	1,169
59	(60) Hexcel (USA)	738	656	1,161	8%	104	17%	89	9.0%	8.3%
	Commercial Aerospace			529	14%					
	Space and Defence			209	8%					

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	2005	2004	2005	growth	2005	growth	2004	2005	2004
60	(56) Orbital Sciences (USA)	711	684	703	4%	53	-4%	55	7.5%	8.1%
	Launch Vehicles and Advanced Programs			335	4%	35	17%	30	10.4%	9.3%
	Satellites and Related Space Systems			349	5%	16	-24%	21	4.6%	6.3%
	Transportation Management Systems			27	-7%	1		1	3.7%	3.4%
61	(61) Ball (USA)	695	653	5,751	6%	463	-14%	539	8.1%	9.9%
	Aerospace and Technologies			695	6%	55	12%	49	7.9%	7.5%
62	(63) Stork (Netherlands)	685	622	2,259	5%	160	23%	131	7.1%	6.1%
62	-63	Aerospace			685	10%	78	37%	57	11.4%
63	(64) Indra (Spain)	670	614	1,494	11%	177	23%	143	11.8%	10.7%
	Information Technology/Defence and Security Forces		316	10%						
	Simulators & Automated Testing Systems		143	8%						
	Defence Electronic Equipment		211	8%						
64	(69) Curtiss-Wright (USA)	664	567	1,131	18%	138	25%	110	12.2%	11.5%
	Motion Control		465	20%	50	11%	45	10.8%	11.6%	
	Metal Treatment		199	12%	34	21%	28	17.1%	15.7%	
65	(67) Korea Aerospace Industries (South Korea)	659	571	659	4%	54	113%	23	8.2%	4.0%
66	(66) Matsushita Electrical Industries (Japan)	657	592	80,782	2%	3,372	50%	2,203	4.2%	2.8%
	Matsushita Avionics Systems			657	9%					
67	(70) EDO (USA)	648	536	648	21%	53	1%	53	8.2%	9.9%
	Electronic Systems & Communications			408	49%	42	56%	27	10.3%	9.9%
	Engineered Systems & Services			240	-9%	13	-50%	26	5.4%	9.9%
68	(68) Ultra Electronics (UK)	622	570	622	10%	93	19%	79	14.9%	13.8%
	Aircraft and Vehicle Systems			153	8%	29	7%	27	19.0%	19.2%
	Information and Power Systems			213	1%	33	20%	27	15.4%	12.9%
	Tactical and Sonar Systems			256	7%	31	31%	24	12.1%	9.8%
69	(75) GenCorp (USA)	617	492	624	25%	-133		42	-21.3%	8.4%
	Aerospace and Defence			617	25%	-137		30	-22.2%	6.1%
70	(57) Denel (South Africa)	593	676	593	-15%	-195		25	-32.9%	3.6%
71	(72) Moog (USA)	580	528	1,051	12%	123	16%	106	11.7%	11.3%
	Aircraft Controls			452	10%	64	2%	63	14.2%	15.3%
	Space & Defense Controls			128	10%	11	244%	3	8.6%	2.8%

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	2005	2004	2005	growth	2005	growth	2004	2005	2004
72	(71) Lord (USA)	564	530	564	6%	64	23%	52	11.3%	9.8%
73	(73) Crane (USA)	554	512	2,061	9%	214	15%	186	10.4%	9.8%
	Aerospace			554	8%	86	-8%	93	15.5%	18.2%
74	(79) Umeco (UK)	511	445	533	21%	0		27	0.0%	6.2%
	Components			245	10%	5	50%	4	2.2%	1.6%
	Composites			231	25%	11	30%	8	4.7%	4.5%
	Repair and Overhaul			35	6%	2		2	5.3%	5.6%
75	(78) Telefl ex (USA)	493	453	2,515	5%	265	25%	212	10.5%	8.9%
	Aerospace			493	9%	33		-11	6.7%	-2.4%
76	(85) United Industrial (USA)	480	355	517	34%	67	63%	41	13.0%	10.6%
	Defence			480	35%	59	44%	41	12.3%	11.5%
77	(84) Britax (UK)	478	363	835		135		-84	16.1%	-10.8%
	Aerospace Interiors			478	33%					
78	(77) Magellan Aerospace (Canada)	469	468	469	-1%	46	-7%	49	9.9%	10.5%
79	(76) ITP (Spain)	469	471	469	-1%	83	49%	56	17.8%	11.9%
80	(101) Aeroflex (USA)	463	178	463	12%	32	-11%	36	6.9%	8.7%
81	(59) Loral Space & Communications (USA)	444	660	429	-18%	-67		-214	-15.6%	-41.0%
	Satellite Services			111	-50%	40	74%	23	36.0%	10.3%
	Satellite Manufacturing			319	-27%	15		-13	4.7%	-3.0%
82	(87) Latécoère (France)	441	330	441	34%	39	-18%	47	8.7%	14.3%
83	(83) Amphenol (USA)	434	367	1,808	18%	343	24%	277	19.0%	18.1%
	Aerospace			434	18%					
84	(80) Kongsberg (Norway)	398	417	885	-2%	56	63%	34	6.3%	3.8%
	Defence & Aerospace			398	-5%	18		-5	4.6%	-1.1%
85	(81) Gamesa (now Aernnova) (Spain)	389	376	2,169	32%	281	10%	256	13.0%	15.6%
	Aeronautical			389	4%	41		-126	10.5%	-33.4%
86	(86) K&F Industries (USA)	384	353	384	9%	104		-12	27.1%	-3.4%
	Aircraft Braking Systems			320	9%	99	15%	86	30.9%	29.3%
	Engineered Fabrics			65	10%	7	-22%	9	10.8%	15.3%
87	(82) Pilatus (Switzerland)	374	373	374	0%	27	386%	6	7.3%	1.5%
88	(88) Sonaca (Belgium)	359	357	359	1%	-2		20	-0.7%	5.6%

Rank	(Rank 05) Company (country)	Aero sales ($m)		Total sales ($m)		Operating result ($m)			Operating margin	
	Divisions	**2005**	**2004**	**2005**	**growth**	**2005**	**growth**	**2004**	**2005**	**2004**
89	(90) LISI (France)	303	264	767	14%	78	9%	72	10.2%	10.7%
	Aerospace			303	15%	46	9%	42	15.2%	16.0%
90	(89) Woodward Governor (USA)	295	270	828	17%	79	61%	49	9.5%	6.9%
	Aircraft engine systems			295	8%	64	8%	59	21.7%	21.7%
91	(92) Kaman (USA)	288	252	1,101	11%	29		-17	2.6%	-1.7%
	Aerospace			288	14%	33		-14	11.5%	-5.6%
92	(91) Senior (UK)	284	257	616	10%	36	18%	31	5.9%	5.5%
	Aerospace			284	11%	24	18%	20	8.3%	7.9%
93	(93) Doncasters (UK)	278	249	851	19%	82	114%	38	9.6%	5.4%
	Aerospace			278	13%	70	-1%	72	25.2%	28.8%
94	(97) DeCrane (USA)	275	217	271	27%					
	Cabin Management			188	18%					
	Systems Integration			87	50%					
95	(62) Ericsson (Sweden)	268	629	20,325	15%	4,429	24%	3,442	21.8%	20.2%
	Defence Systems			268	-59%					
96	(96) Circor (USA)	251	219	450	18%	33	50%	22	7.3%	5.8%
	Instrumentation and Thermal Fluid Controls			251	15%	28	17%	24	11.2%	11.0%
97	(95) Ducommun (USA)	250	225	250	11%	21	40%	15	8.4%	6.7%
98	(94) Chemring (UK)	240	231	240	5%	31	0%	31	12.9%	13.4%
99	(102) Garmin (USA)	229	172	1,028	35%	338	25%	271	32.9%	35.5%
	Aviation			229	33%	100	69%	59	43.7%	34.3%
100	(99) Martin-Baker (UK)	209	210	209	0%	31	21%	26	14.8%	12.2%

Table 3 - Matrix S

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30
F1	1,00	0,05	0,09	0,07	0,20	0,05	0,09	0,04	0,04	0,00	0,01	0,02	0,01	0,10	0,09	0,06	0,08	0,10	0,06	0,03	0,01	0,04	0,06	0,07	0,07	0,09	0,13	0,06	0,05	0,07
F2	0,05	1,00	0,29	0,13	0,06	0,11	0,09	0,04	0,01	0,00	0,01	0,02	0,00	0,00	0,01	0,02	0,01	0,02	0,01	0,01	0,01	0,00	0,00	0,00	0,01	0,01	0,04	0,03	0,03	0,03
F3	0,09	0,29	1,00	0,25	0,08	0,18	0,17	0,04	0,05	0,00	0,02	0,03	0,00	0,01	0,02	0,01	0,01	0,01	0,02	0,03	0,01	0,00	0,01	0,01	0,01	0,02	0,05	0,09	0,04	0,10
F4	0,07	0,13	0,25	1,00	0,10	0,07	0,32	0,21	0,03	0,00	0,05	0,09	0,01	0,01	0,01	0,01	0,03	0,03	0,03	0,07	0,03	0,01	0,02	0,02	0,02	0,02	0,07	0,07	0,08	0,04
F5	0,20	0,06	0,08	0,10	1,00	0,12	0,10	0,03	0,04	0,01	0,01	0,03	0,00	0,04	0,05	0,04	0,04	0,04	0,02	0,02	0,01	0,01	0,04	0,01	0,03	0,05	0,03	0,05	0,02	0,03
F6	0,05	0,11	0,18	0,07	0,12	1,00	0,16	0,13	0,01	0,05	0,02	0,05	0,02	0,03	0,03	0,06	0,03	0,02	0,03	0,07	0,02	0,01	0,02	0,01	0,01	0,04	0,07	0,12	0,11	0,07
F7	0,09	0,09	0,17	0,32	0,10	0,16	1,00	0,11	0,06	0,00	0,19	0,37	0,01	0,01	0,03	0,01	0,03	0,10	0,05	0,11	0,11	0,02	0,04	0,06	0,04	0,08	0,18	0,26	0,14	0,05
F8	0,04	0,04	0,04	0,21	0,03	0,13	0,11	1,00	0,06	0,06	0,02	0,04	0,05	0,03	0,02	0,03	0,03	0,12	0,03	0,05	0,01	0,03	0,03	0,02	0,05	0,04	0,05	0,03	0,08	0,02
F9	0,04	0,01	0,05	0,03	0,04	0,01	0,06	0,06	1,00	0,00	0,01	0,02	0,01	0,11	0,09	0,02	0,02	0,06	0,03	0,02	0,01	0,07	0,06	0,02	0,04	0,03	0,02	0,02	0,02	0,03
F10	0,00	0,00	0,00	0,00	0,01	0,05	0,00	0,06	0,00	1,00	0,21	0,38	0,03	0,01	0,02	0,43	0,38	0,10	0,01	0,00	0,00	0,09	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,01
F11	0,01	0,01	0,02	0,05	0,01	0,02	0,19	0,02	0,01	0,21	1,00	0,64	0,00	0,00	0,00	0,02	0,03	0,02	0,00	0,02	0,02	0,00	0,00	0,00	0,00	0,01	0,02	0,03	0,02	0,00
F12	0,02	0,02	0,03	0,09	0,03	0,05	0,37	0,04	0,02	0,38	0,64	1,00	0,00	0,00	0,00	0,03	0,05	0,03	0,01	0,03	0,04	0,01	0,01	0,01	0,01	0,01	0,03	0,07	0,04	0,00
F13	0,01	0,00	0,00	0,01	0,00	0,02	0,01	0,05	0,01	0,03	0,00	0,00	1,00	0,03	0,03	0,01	0,06	0,42	0,01	0,02	0,00	0,08	0,03	0,01	0,05	0,01	0,01	0,01	0,42	0,03
F14	0,10	0,00	0,01	0,01	0,04	0,03	0,01	0,03	0,11	0,01	0,00	0,00	0,03	1,00	0,31	0,06	0,19	0,24	0,13	0,02	0,03	0,16	0,18	0,12	0,24	0,08	0,05	0,04	0,05	0,03
F15	0,09	0,01	0,02	0,01	0,05	0,03	0,03	0,02	0,09	0,02	0,00	0,00	0,03	0,31	1,00	0,12	0,15	0,19	0,25	0,04	0,14	0,13	0,13	0,21	0,12	0,11	0,15	0,05	0,11	0,19
F16	0,06	0,02	0,01	0,01	0,04	0,06	0,01	0,03	0,02	0,43	0,02	0,03	0,01	0,06	0,12	1,00	0,17	0,05	0,13	0,01	0,01	0,08	0,03	0,02	0,03	0,01	0,05	0,04	0,02	0,04
F17	0,08	0,01	0,01	0,03	0,04	0,03	0,03	0,03	0,02	0,38	0,03	0,05	0,06	0,19	0,15	0,17	1,00	0,22	0,03	0,03	0,03	0,19	0,04	0,13	0,15	0,03	0,04	0,02	0,03	0,05
F18	0,10	0,02	0,01	0,03	0,04	0,02	0,10	0,12	0,06	0,10	0,02	0,03	0,42	0,24	0,19	0,05	0,22	1,00	0,09	0,05	0,03	0,27	0,13	0,15	0,28	0,10	0,08	0,05	0,12	0,06
F19	0,06	0,01	0,02	0,03	0,02	0,03	0,05	0,03	0,03	0,01	0,00	0,01	0,01	0,13	0,25	0,13	0,03	0,09	1,00	0,07	0,08	0,10	0,11	0,07	0,10	0,15	0,17	0,05	0,08	0,12
F20	0,03	0,01	0,03	0,07	0,02	0,07	0,11	0,05	0,02	0,00	0,02	0,03	0,02	0,02	0,04	0,01	0,03	0,05	0,07	1,00	0,07	0,02	0,07	0,02	0,02	0,05	0,10	0,07	0,10	0,09
F21	0,01	0,01	0,01	0,03	0,01	0,02	0,11	0,01	0,01	0,00	0,02	0,04	0,00	0,03	0,14	0,01	0,03	0,03	0,08	0,07	1,00	0,02	0,03	0,12	0,03	0,02	0,02	0,03	0,03	0,08
F22	0,04	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,07	0,09	0,00	0,01	0,08	0,16	0,13	0,08	0,19	0,27	0,10	0,02	0,02	1,00	0,05	0,16	0,29	0,06	0,11	0,04	0,06	0,04
F23	0,06	0,00	0,01	0,02	0,04	0,02	0,04	0,03	0,06	0,00	0,00	0,01	0,03	0,18	0,13	0,03	0,04	0,13	0,11	0,07	0,03	0,05	1,00	0,22	0,08	0,11	0,11	0,02	0,14	0,06
F24	0,07	0,00	0,01	0,02	0,01	0,01	0,06	0,02	0,02	0,00	0,00	0,01	0,01	0,12	0,21	0,02	0,13	0,15	0,07	0,02	0,12	0,16	0,22	1,00	0,25	0,22	0,15	0,07	0,07	0,07
F25	0,07	0,01	0,01	0,02	0,03	0,01	0,04	0,05	0,04	0,01	0,00	0,01	0,05	0,24	0,12	0,03	0,15	0,28	0,10	0,02	0,03	0,29	0,08	0,25	1,00	0,11	0,14	0,06	0,10	0,05
F26	0,09	0,01	0,02	0,02	0,05	0,04	0,08	0,04	0,03	0,00	0,01	0,01	0,01	0,08	0,11	0,01	0,03	0,10	0,15	0,05	0,02	0,06	0,11	0,22	0,11	1,00	0,28	0,09	0,13	0,15
F27	0,13	0,04	0,05	0,07	0,03	0,07	0,18	0,05	0,02	0,00	0,02	0,03	0,01	0,05	0,15	0,05	0,04	0,08	0,17	0,10	0,02	0,11	0,11	0,15	0,14	0,28	1,00	0,12	0,15	0,27
F28	0,06	0,03	0,09	0,07	0,05	0,12	0,26	0,03	0,02	0,00	0,03	0,07	0,01	0,04	0,05	0,04	0,02	0,05	0,05	0,07	0,03	0,04	0,02	0,07	0,06	0,09	0,12	1,00	0,07	0,06
F29	0,05	0,03	0,04	0,08	0,02	0,11	0,14	0,08	0,02	0,01	0,02	0,04	0,42	0,05	0,11	0,02	0,03	0,12	0,08	0,10	0,03	0,06	0,14	0,07	0,10	0,13	0,15	0,07	1,00	0,14
F30	0,07	0,03	0,10	0,04	0,03	0,07	0,05	0,02	0,03	0,01	0,00	0,00	0,03	0,03	0,19	0,04	0,05	0,06	0,12	0,09	0,08	0,04	0,06	0,07	0,05	0,15	0,27	0,06	0,14	1,00

Table 4 - Matrix R

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30
F1	100	-2,9	-6,5	-3,8	3,5	-3,9	-8	-1,9	-2,6	-1,5	-0,7	-0,4	-0,6	-1,8	-2,2	-1,4	-0,6	-0,7	-3,5	-4,3	-1,3	-1,7	-4	-9,5	-3	-6,2	-7	-5,1	-3,4	-2,3
F2	-2,9	100	5,9	0,9	-0,1	0,9	-3,2	-0,5	-1,9	-0,7	-0,3	-0,2	-0,3	-2,8	-2,5	-0,8	-1	-1,5	-2,7	-2,5	-0,6	-1	-2,8	-6,1	-2,5	-4,9	-5,4	-3,2	-1,8	-1,8
F3	-6,5	5,9	100	3,7	-2,5	1,1	-5,5	-2,9	-3,3	-1,7	-0,8	-0,5	-0,7	-6,8	-5,7	-3,8	-2,5	-5	-6,2	-5,2	-1,5	-2,6	-7	-15	-6	-12	-14	-4,9	-4,9	-1,4
F4	-3,8	0,9	3,7	100	0,6	-2,7	6,6	5,5	-2,3	-1	-0,5	-0,3	-0,4	-4,1	-3,6	-2,2	-0,7	-2,5	-3,1	-1,4	-0,9	-1,5	-3,5	-8,2	-3,4	-6,7	-6,9	-4,1	-1	-1,8
F5	3,5	-0,1	-2,5	0,6	100	2,7	-2,3	-1,1	-0,4	-0,6	-0,3	-0,2	-0,3	-1,6	-0,2	0,2	0,3	-1,1	-2,4	-2,1	-0,5	-0,9	-1,1	-5,3	-1,3	-2,6	-5,3	-2	-2	-0,9
F6	-3,9	0,9	1,1	-2,7	2,7	100	-0,9	3,2	-2,2	0,4	-0,4	-0,2	-0,3	-2,4	-2,2	0,5	-0,3	-2,3	-2,2	-0,3	-0,7	-1,2	-3	-7	-3	-4,8	-5,5	0,4	1,6	-0,1
F7	-8	-3,2	-5,5	6,6	-2,3	-0,9	100	-1,3	-3,5	-1,9	0,4	1,5	-0,8	-8	-6,5	-4,3	-2,4	-2,4	-6,4	-2,7	-0,4	-2,9	-6,5	-14	-6,1	-10	-7,2	3	-1,5	-4,5
F8	-1,9	-0,5	-2,9	5,5	-1,1	3,2	-1,3	100	1,5	1,9	-0,2	-0,1	-0,2	-1,1	-1,5	0,2	-0,6	3,8	-1,1	-0,1	-0,4	-0,6	-1,1	-3,4	-0,2	-2,3	-3	-2,1	0,8	-1,1
F9	-2,6	-1,9	-3,3	-2,3	-0,4	-2,2	-3,5	1,5	100	-0,6	-0,3	-0,2	-0,3	2	1,4	-0,6	-0,9	-0,1	-1,6	-1,7	-0,6	1,3	-0,5	-5	-0,9	-3,7	-5,5	-2,8	-2,1	-1
F10	-1,5	-0,7	-1,7	-1	-0,6	0,4	-1,9	1,9	-0,6	100	9,3	15	-0,1	-0,9	-0,8	18	18	2,4	-0,9	-0,8	-0,2	2,6	-0,9	-2	-0,8	-1,6	-2,1	-1,2	-0,8	-0,6
F11	-0,7	-0,3	-0,8	-0,5	-0,3	-0,4	0,4	-0,2	-0,3	9,3	100	32	-0	-0,4	-0,4	-0,2	-0,2	-0,3	-0,4	-0,4	-0,1	-0,2	-0,4	-0,9	-0,4	-0,8	-1	-0,5	-0,4	-0,3
F12	-0,4	-0,2	-0,5	-0,3	-0,2	-0,2	1,5	-0,1	-0,2	15	32	100	-0	-0,3	-0,2	-0,1	-0,1	-0,2	-0,3	-0,2	-0,1	-0,1	-0,3	-0,6	-0,2	-0,5	-0,6	-0,3	-0,2	-0,2
F13	-0,6	-0,3	-0,7	-0,4	-0,3	-0,3	-0,8	-0,2	-0,3	-0,1	-0	-0	100	-0,4	-0,3	-0,2	-0,1	7,2	-0,4	-0,3	-0,1	-0,1	-0,4	-0,8	-0,4	-0,7	-0,9	-0,5	6,2	-0,2
F14	-1,8	-2,8	-6,8	-4,1	-1,6	-2,4	-8	-1,1	2	-0,9	-0,4	-0,3	-0,4	100	12	-0,5	3,9	7,1	1,5	-2,7	-0,8	2,3	4,4	-3,6	7,7	-3,8	-7,1	-3,3	-2,1	-2,4
F15	-2,2	-2,5	-5,7	-3,6	-0,2	-2,2	-6,5	-1,5	1,4	-0,8	-0,4	-0,2	-0,3	12	100	2,8	2,2	4,7	8,5	-1,8	2,1	1,3	0,5	1	-0,6	-3,1	-2,2	-2,6	1,2	5,7
F16	-1,4	-0,8	-3,8	-2,2	0,2	0,5	-4,3	0,2	-0,6	18	-0,2	-0,1	-0,2	-0,5	2,8	100	6,2	-0	3,3	-1,8	-0,4	2	-1,5	-4,1	-1,3	-3,5	-3,5	-1,2	-1,7	-0,5
F17	-0,6	-1	-2,5	-0,7	0,3	-0,3	-2,4	-0,6	-0,9	18	-0,2	-0,1	-0,1	3,9	2,2	6,2	100	6,5	-1,3	-0,3	-0,3	5,6	-1,4	-0,5	2,1	-2,4	-2,7	-1,7	-1,1	0,3
F18	-0,7	-1,5	-5	-2,5	-1,1	-2,3	-2,4	3,8	-0,1	2,4	-0,3	-0,2	7,2	7,1	4,7	-0	6,5	100	-0,2	-0,5	-0,6	8,4	1,7	-1,2	9,8	-2	-4,4	-2,3	2,2	-0,5
F19	-3,5	-2,7	-6,2	-3,1	-2,4	-2,2	-6,4	-1,1	-1,6	-0,9	-0,4	-0,3	-0,4	1,5	8,5	3,3	-1,3	-0,2	100	-0,5	0,5	1	0,7	-6,1	-0,1	-0,6	-1,5	-3,3	-0,8	0,8
F20	-4,3	-2,5	-5,2	-1,4	-2,1	-0,3	-2,7	-0,1	-1,7	-0,8	-0,4	-0,2	-0,3	-2,7	-1,8	-1,8	-0,3	-0,5	-0,5	100	0,7	-1,2	-0,4	-6,8	-2,6	-4,5	-4,1	-1,7	1,3	0,9
F21	-1,3	-0,6	-1,5	-0,9	-0,5	-0,7	-0,4	-0,4	-0,6	-0,2	-0,1	-0,1	-0,1	-0,8	2,1	-0,4	-0,3	-0,6	0,5	0,7	100	-0,3	-0,8	-0,4	-0,7	-1,4	-1,8	-1	-0,7	1,4
F22	-1,7	-1	-2,6	-1,5	-0,9	-1,2	-2,9	-0,6	1,3	2,6	-0,2	-0,1	-0,1	2,3	1,3	2	5,6	8,4	1	-1,2	-0,3	100	-1,4	-0,2	7,8	-1,9	-1,2	-1,1	-0,2	-0,9
F23	-4	-2,8	-7	-3,5	-1,1	-3	-6,5	-1,1	-0,5	-0,9	-0,4	-0,3	-0,4	4,4	0,5	-1,5	-1,4	1,7	0,7	-0,4	-0,8	-1,4	100	1	-2,1	-3	-4,7	-4,7	2,9	-1,1
F24	-9,5	-6,1	-15	-8,2	-5,3	-7	-14	-3,4	-5	-2	-0,9	-0,6	-0,8	-3,6	1	-4,1	-0,5	-1,2	-6,1	-6,8	-0,4	-0,2	1	100	2,9	-2	-10	-7,2	-5	-4
F25	-3	-2,5	-6	-3,4	-1,3	-3	-6,1	-0,2	-0,9	-0,8	-0,4	-0,2	-0,4	7,7	-0,6	-1,3	2,1	9,8	-0,1	-2,6	-0,7	7,8	-2,1	2,9	100	-2,8	-2,9	-2,1	1,1	-1,7
F26	-6,2	-4,9	-12	-6,7	-2,6	-4,8	-10	-2,3	-3,7	-1,6	-0,8	-0,5	-0,7	-3,8	-3,1	-3,5	-2,4	-2	-0,6	-4,5	-1,4	-1,9	-3	-2	-2,8	100	0,9	-4,5	-1	-0,4
F27	-7	-5,4	-14	-6,9	-5,3	-5,5	-7,2	-3	-5,5	-2,1	-1	-0,6	-0,9	-7,1	-2,2	-3,5	-2,7	-4,4	-1,5	-4,1	-1,8	-1,2	-4,7	-10	-2,9	0,9	100	-5,4	-1,9	2,9
F28	-5,1	-3,2	-4,9	-4,1	-2	0,4	3	-2,1	-2,8	-1,2	-0,5	-0,3	-0,5	-3,3	-2,6	-1,2	-1,7	-2,3	-3,3	-1,7	-1	-1,1	-4,7	-7,2	-2,1	-4,5	-5,4	100	-2,4	-1,5
F29	-3,4	-1,8	-4,9	-1	-2	1,6	-1,5	0,8	-2,1	-0,8	-0,4	-0,2	6,2	-2,1	1,2	-1,7	-1,1	2,2	-0,8	1,3	-0,7	-0,2	2,9	-5	1,1	-1	-1,9	-2,4	100	2,9
F30	-2,3	-1,8	-1,4	-1,8	-0,9	-0,1	-4,5	-1,1	-1	-0,6	-0,3	-0,2	-0,2	-2,4	5,7	-0,5	0,3	-0,5	0,8	0,9	1,4	-0,9	-1,1	-4	-1,7	-0,4	2,9	-1,5	2,9	100

References

Adams, J. (1990), "Fundamental Stocks of Knowledge and Productivity Growth" Journal of political Economy 98(41), 673-702

Alchian A. A. (1963), “Reliability of progress curves in airframe production”, Econometrica, 31:679-693.

Arrow K. J. (1962), “The Economic Implications of Learning by Doing”, Review of Economic Studies, 29:155-173.

Bonaccorsi A. (1996), Cambiamento Tecnologico e Competizione nell’Industria Aeronautica Civile. Integrazione delle Conoscenze e Incertezza, Guerini e Associati, Milano.

Bonaccorsi A. e Giuri P. (2003), “Increasing returns and network structure in the evolutionary dynamics of industries”, in Saviotti P.P. (Ed.), Applied Evolutionaryp.p.(Ed), Applied evolutionary Economics: New Empirical Methods and Simulation Techniques, Edward Elgar, pp. 50 – 92

Bossi G. (2004), “The Economics of Knowledge: Essays on the Main Characteristics of Knowledge and Their Impact on Innovation”, PhD thesis

Breschi, S., Lissoni, F. and Malerba, F. (2003), “Knowledge proximity in firms' technological diversification” Research Policy, 32, 69-87

David, P., Foray, D. (2002), "An introduction to economy of the knowledge society" International Social Science Journal, march 2002

Desrochers, P. (2001), “Local Diversity, Human Creativity, and Technological Innovation” Growth and Change, 32, 369-394

Ejermo, O. (2003), “Patent diversity as a predictor of regional innovativeness in Sweden” CESPRI Working Papers 140

Engelsman, E., Van Raan, A. (1991), Mapping of technology, Policy Studies on Technology and Economy (BTE), 15

Engelsman, E., Van Raan, A. (1992), “A patent-based cartography of technology” Research Policy 23

Esposito, E. (1996), Economia delle imprese ad alta tecnologia, Napoli, Edizioni Scientifiche Italiane.

Fai, F. (2003), Corporate technological competence and the evolution of technological diversification, Cheltenham: Edward Elgar

Fai, F., von Tunzelmann, N (2001), “Industry-specific competencies and converging technological systems: evidence from patents”, Structural Change and Economic Dynamics 12, 141-170

Giuri P., Tomasi C., Dosi G. (2007), L' industria aerospaziale. Innovazione, tecnologia e strategia economica, Il Sole24 ore – Collana Innovatione & Competitività della Fondazione Cotec

Grandstrand O., Patel P. and Pavitt K. (1997), “Multi-Technology Corporations, Why they have ‘distributed’ rather than ‘distinctive core’ competencies”, California Management Review, 39:8-25.

Griliches, Z. (1990), “Patent statistics as economic indicators: a survey”, Journal of Economic Literature 28, 1661-1707

Grupp, H., Schomch, U. (1992), “Perception of scientification of innovation as measured by referencing between patents and papers” in Grupp, H.(ed.), Dynamics of Science-Based Innovation, Heidelberg: Spring Verlag

Hayward K. (1986), International Collaboration in Civil Aerospace, Frances Pinter Publishers, London.

Hinze, S., Reiss, T. and Schmoch, H. (1997), “Statistical Analysis on the Distance Between Fields of Technology,” Innovation Systems and European Integration (ISE), Targeted Socio-Economic Research Program, 4th Framework Program of the European Commission (DGXII)

Hobday M. (1998), “Product Complexity, Innovation and Industrial Organization” Research Policy, 26,689-710

Jaffe, A. (1989), "Real Effects of Academic Research" American Economic Review, 79, 957-978

Bathelt H, Malmberg A, Maskell P (2004), “Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation” Progress in human geography 28 (1), 31-56

Mohnen, P. (1996), “R&D externalities and productivity growth” Science Technology Industry Review 18, 39-66

Nelson R., Winter S. (1982), An Evolutionary Theory of Economic Change, The Belknap Press of Harvard University Press, Cambridge.

Niosi, J., Zhegu M. (2005) “Aerospace Clusters: Local or Global Knowledge Spillovers?” Industry and Innovation, Vol. 12, No. 1, 1–25.

Patel, P., Pavitt, K. (1997), “The technological competencies of the world’s largest firms: complex and path-dependent, but not much variety” Research Policy, 26, 141-56

Piscitello L. (2000) “Relatedness and coherence in technological and product diversification of the world’s largest firms”, Structural Change and Economic Dynamics,11, 295-315

Prencipe, A. (2000) “Breadth and depth of technological capabilities in complex product systems: The case of the aircraft engine control system”. Research Policy, 29, 895–911.

Putnam, J., Evenson, R. (1994), “Intersectoral technology flows: estimates from a patent concordance with an application to Italy” Yale University Press

Rosenberg N. (1976), Perspectives on Technology, Cambridge University Press, Cambridge.

Rosenberg N. (1982), Inside the black box: Technology and Economics, Cambridge University Press, Cambridge.

Scherer, F. (1982), “Inter-industry technology flows and productivity growth” The Review of Economics and Statistics 64 (4), 627-634

Verspagen, B. (1996), “Measuring inter-sectoral technology spillovers: Estimates from the European and US patent office databases” Research Memorandum 2/95-007

Verspagen, B., De Loo, I. (1999), “Technology Spillover Between Sectors and over Time,” Technological Forecasting and Social Change 60, 215-235

Wuyts, S., Colombo, M. G., Dutta, S., Nooteboom, B. (2005), “Empirical tests of optimal cognitive distance” Journal of Economic Behaviour and Organization, forthcoming

3. Aerospace clusters and innovation management: a platform approach

Abstract

Even coming from a hundred year long tradition of debates, the “cluster” concept is interesting both scholars and planning practitioners due to the increasing focus on knowledge economy formulas. The paradigm of industrial cluster, born as an analysis unit for economic studies, has been transformed into an answer to globalization dynamics heavily reconfiguring the competitive landscape in many economies. Moreover it well fits in the rising importance acquired by the regional dimension of policy making. The aerospace sector is shaped as a cluster formed around leading industries, where new industries are generated by entrepreneurial innovation. This distinctive feature has been recognized only in recent times by the institutions and organizations especially devoted to support the industrial development. This aspect is quite uncovered by the academic literature even in case study analysis. To give a contribution in filling this gap, an original dataset of formally organized aerospace clusters was collected.

Then a study was carried out underlining aerospace features that influence cluster formation and identifying the most common policy supports. An empirical outlook to the phenomenon on the global scale allows to formulate a correlated taxonomy between cluster organizations and policy support measures

3.1 Introduction

Indeed the cluster paradigm has a long lasting history in the economic, geographic and business literature. When reviewing the main milestones of its evolution, it is easy to measure the topic complexity and at the same time to gain better insights about the implementation challenges currently experienced by policy makers and innovation practitioners trying to transfer the concept into real situations all around the world.

The first scholar studying the spatial agglomeration of industries was Marshall (1890) who used the term "industrial district" in order to describe the concentration phenomenon that he was observing in growing industries. To explain this phenomenon, Marshall identified four sources of agglomeration advantage, namely a rich market of specialised manpower, the presence of well developed linkages across supply chains, the existence of ancillary trades and some environmental effects that have been identified by the subsequent literature as spillover effects.

Following the agglomeration concept, Ohlin (1933) identified two paths in the agglomeration trend, i.e. localisation economies (increasing share of an industrial sector into a given territory) and urbanisation economies (increasing business flows, even between heterogeneous sectors).

Scitovsky (1954) studied the externalities underlying the clustering dynamics, dividing them in pecuniary (influencing the inputs price when the size of an industry grows) and technological (affecting the production function of clustered enterprises without any market transaction).

Those categorizations gave rise to a wide subsequent debate about the importance and the effects of localization versus urbanization dynamics (Jacobs, 1969) that, even if revised by several authors with empirical case studies (Henderson, 1986; McCann and Fingleton, 1996; Henderson et al., 1995) do not allow drawing sharp conclusions.

An important phase in the cluster concept development was marked by the works about knowledge economic properties and flows (Arrow, 1962), opening the literature stream about localized knowledge spillovers that can find in industrial clusters a natural frame of occurrence.

The explanations of agglomeration trends are at the center of the Romer (1986) and Krugmann (1991) insights about the linkages between economic activities concentration and growth as well as the increasing return due to positive industrial externalities.

Those concurrent lines of research were synthesized in the MAR (Marshall – geographical dimension, Arrow – knowledge as economic good, Romer – increasing returns in economic growth) paradigm adopted by Glaeser (1992).

A special attention was devoted by scholars to the spillover effects between academic research and corporate R&D. Their existence and potential (Jaffe, 1993) are remarkably associated with the spatial dimension as underlined by the "sticky knowledge" concept (Von Hipple, 1994), even if those mechanisms should be used with caution as a main agglomeration determinants (Breschi and Lissoni, 2001) due to the importance of cultural rather than physical proximity in knowledge sharing and transfer.

Another contribution including cultural effects was developed by the economic and sociological literature (Beccatini, 1990) whose aim is to connect the cluster birth and growth with the social framework underlying the production systems. The action of non economic institutions, such as the family and the school, and mutual trust resulting from shared values and cultural commonalities give to the cluster system the typical flexibility that characterizes its competitiveness.

Considering the variety of the approaches by which the cluster concept was analysed, it is not surprising that it leads to fuzzy definition of both its distinctive properties and boundaries.

For instance, Camagni (1995) and Maillat (1998) used the term "innovative milieu" to identify clusters that are based upon knowledge and ideas sharing rather than on production flows, thus focusing on high technology and knowledge intensity.

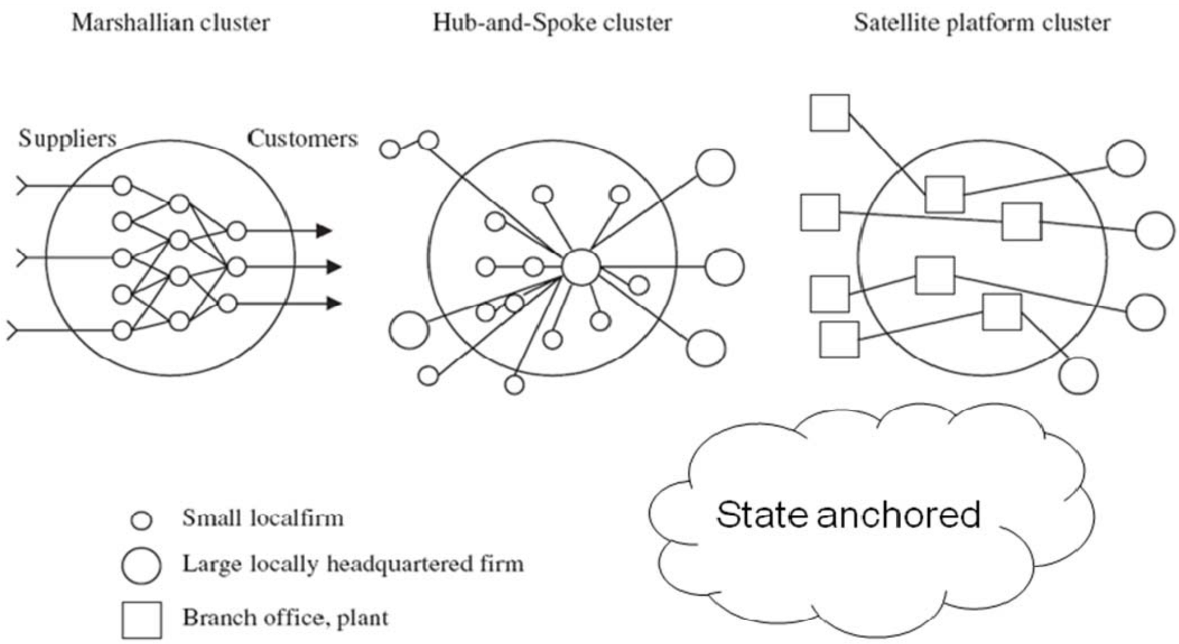

Figure 17 - Markusen (1996) industrial cluster taxonomy

Another systematization of the cluster theory was build by Markusen (1996) who identified, using agglomeration drivers as discriminating factor, three types of cluster: the “hub-and-spoke” model originating from the subcontracting of a main player acting as a system integrator, the “satellite platform” resulting from the exploitation of local attractors (e.g. specialized manpower, natural resources) by local divisions of large enterprises and the “state anchored” where public bodies drive a particular demand feeding the cluster business (**Figure 1**). Starting from a transaction cost perspective, Gordon and McCann (2000) build up a different scheme dividing the cluster universe into three categories: “pure agglomeration” in which companies experience the benefit of urbanization externalities, “industrial complex” based on a closed set of partner with stable contractual relationships and “social network” where the intangible assets such as trust, loyalty and joint lobbying play a major role.

To avoid overlapping definition, ultimately leading to confusion, Rosenfeld (1997) suggested a cluster classification scheme based upon performance criteria according to which an industrial cluster could be “self-aware”, “working” or “overachieving” depending on the difference between its actual production compared with its single elements output acting as atomistic units.

By far, the most influential contribution to the cluster concept popularity was given by Porter in a series of works in which he analyses the competitiveness of nations (1990), clusters (1998) and regions (2001) always underlining the role of business clustering to the productivity enhancement (**Figure 2**).

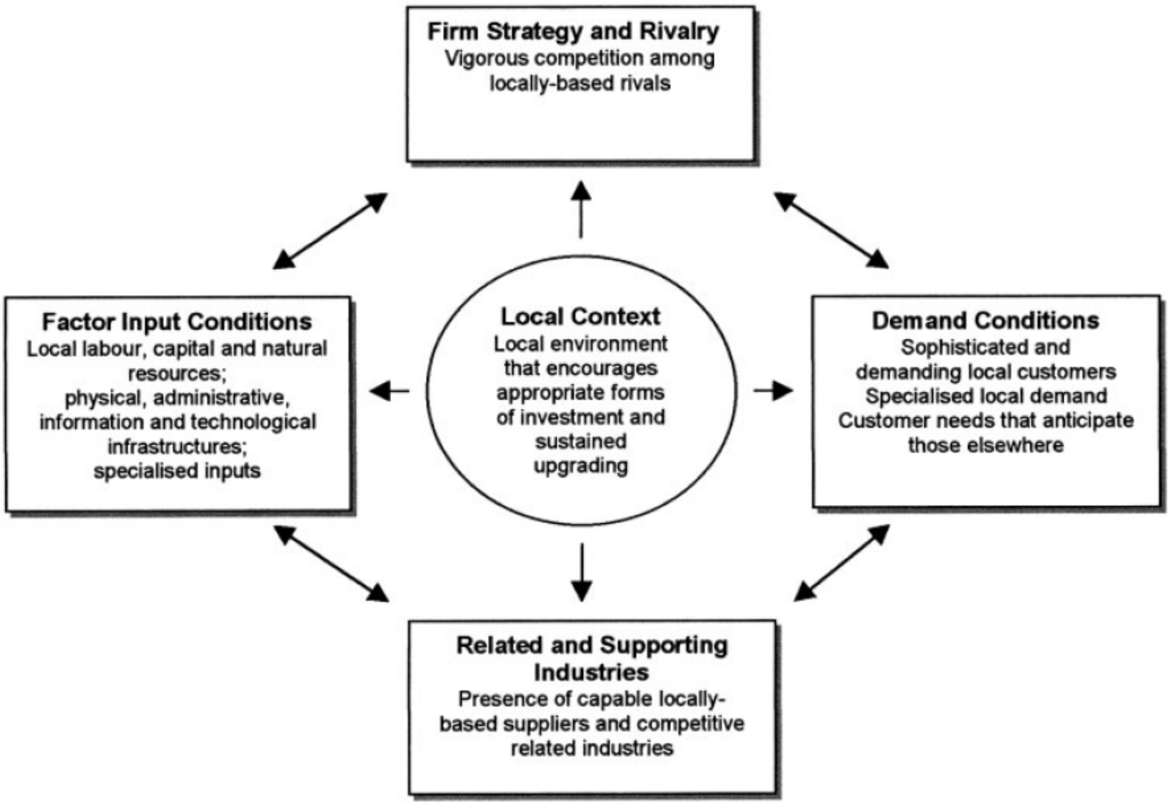

Figure 18 – Porter's competition diamond of local industrial clustering (1998)

His vision, focusing on a more productive use of inputs, which requires continuous innovation, highlights the importance of local (regional) initiatives to develop knowledge, relationships and motivation as cluster grounded competitiveness factor into the globalised markets. This conceptual framework, broadly diffused into the communities of policy-makers and innovation practitioners at all levels, led to the adoption of cluster support as a key development factor by the World Bank (2000), the OECD (1999, 2001), national governments and regional development agencies all around the world.

The widespread usage of a concept at the same time as rich as fuzzy gave rise to several criticism, such as the Bergman (1999) opinion: "It is difficult to indentify another equally obscure concept that appeals to such a broad spectrum of academic disciplines, professions and even lay people".

Moreover Temple (1998) observed that this trend has a better fit with the needs coming from decentralization of policy responsibility, fuelling the popularity of cluster as catching scheme for local potential, more than as tool for economics explanation.

Porter (1998a, p. 199) 'A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities.'

Crouch and Farrell (2001, p. 163) 'The more general concept of "cluster" suggests something looser: a tendency for firms in similar types of business to locate close together, though without having a particularly important presence in an area.'

Rosenfeld (1997, p. 4) 'A cluster is very simply used to represent concentrations of firms that are able to produce synergy because of their geographical proximity and interdependence, even though their scale of employment may not be pronounced or prominent.'

Feser (1998, p. 26) 'Economic clusters are not just related and supporting industries and institutions, but rather related and supporting institutions that are more competitive by virtue of their relationships.'

Swann and Prevezer (1996, p. 139) 'Clusters are here defined as groups of firms within one industry based in one geographical area.'

Swann and Prevezer (1998, p. 1) 'A cluster means a large group of firms in related industries at a particular location.'

Simmie and Sennett (1999a, p. 51) 'We define an innovative cluster as a large number of interconnected industrial and/or service companies having a high degree of collaboration, typically through a supply chain, and operating under the same market conditions.'

Roelandt and den Hertag (1999, p. 9) 'Clusters can be characterised as networks of producers of strongly interdependent firms (including specialised suppliers) linked each other in a value-adding production chain.'

Van den Berg et al. (2001, p. 187) 'The popular term cluster is most closely related to this local or regional dimension of networks . . . Most definitions share the notion of clusters as localised networks of specialised organisations, whose production processes are closely linked through the exchange of goods, services and/or knowledge.'

Enright (1996, p. 191) 'A regional cluster is an industrial cluster in which member firms are in close proximity to each other.'

Figure 19 - Martin and Sunley (2003) collection of cluster definitions

More recently Martin and Sunley (2003) offered a systematic review of the questions overlooked in the enthusiastic applications of the cluster idea, not to be considered as a universal panacea, and called for a more cautious usage of the concept, in particular when advocated in support to planning operations.

Regarding to the prescriptive indications, Schmitz and Nadvi (1999) put in evidence that the only academically agreed recommendation from an operational point of view is that policy initiatives are not likely to reach automatically the success, when designing new clusters from the scratch without considering the real situation.

Cluster concept	Conceptual/ definitional depth	Empirical methodology	Ease of measurement	Empirical support
Co-location	Shallow	Top-down	Easy to measure (quantitative)	Indirect evidence
Co-location and technological proximity	↓	↓	↓	↓
Input–output table and complementarities	↓	↓	↓	↓
Co-location and superior performance	↓	↓	↓	↓
Marshallian externalities	↓	↓	↓	↓
Network firms	↓	↓	↓	↓
Explicit collaboration	↓	↓	↓	↓
Informal knowledge spillovers	Deep	Bottom-up	Hard to measure (qualitative)	Direct evidence

Figure 20 - Taxonomy of cluster dimension (Swan, 2002)

On the same topic, special attention should be paid to the work of Swan (2002) who proposed a taxonomy of cluster features and their measurement showing that this matter is objectively complex and far from being a concluded debate.

3.2 Aerospace cluster academic review

Due to both its crucial role in technology development and strategic equilibrium, the aerospace sector has been deeply analyzed from different point of view by economists and policy geographers. Nevertheless it presents also a remarkable clusterisation in its industrial shape that is heavily conditioned by distinctive industry features giving to it a separated and interesting position in the cluster landscape.

For instance, Brown (2000) compares the automotive and the aerospace cluster in the Fyrstad region. The latter one, risen around the Volvo Aero Corporation, seems to belong to the "hub and spoke" model defined by Markussen (1996) due to the presence of a large enterprise tightly linked with a wide industrial texture of SMEs acting as suppliers.

This configuration appears to be enforced by aerospace sector characteristics including low production volumes and a fundamental asymmetry in the knowledge share between the system integrator company and SMEs in the supply chain. The latter lack in design competence and capability or autonomy, thus are bounded to a low adding value activity profile and full dependency in the supply tier. New knowledge procurement is essentially carried out by technology transfer from the central hub company.

This competence lag appears to be one of the major drawbacks in the local cluster development. The remedies include the adoption of technological innovation or "state of the art" process capabilities, international commercial scouting and the relevant quality accreditation that is essential to compete in the global aerospace market.

While in the above study the local linkages seems to play a major role in explaining both the cluster birth and operation, Lublinsky (2003) by a comparative survey across German aeronautical firms tries to identify the role played by geographical proximity in supporting inter-firm linkages and cooperation agreements. His results underline four basic dimensions in which the cluster system seems to be relevant: labour market pooling, knowledge spillovers, demanding local customers and trust-based effects.

Longhi (2004), deeply analyzing the Toulouse aerospace cluster in historical perspective, underline one of the most important characteristic of aerospace sector: the public procurement and policy guidance performed by the state to influence the national industry development dynamics. This prominent case study underline a policy driven passage from a merely manufacturing approach to a contemporary high tech cluster that, combining private and public, even academic, research efforts, shifted the cluster focus from assembly to innovation and design. From an economy of knowledge perspective, Niosi and Zhegu (2005) investigate both centripetal (clustering) and centrifugal forces playing a significant role in the aerospace sector geographical distribution.

Their focus on knowledge spillover gives insights about the importance of the international rather than local dimension of the technology development in the aerospace sector, showing proofs of how specialization dynamics are conditioning and differentiating the R&D and manufacturing geographical distribution according to the globalization dynamics.

Smith and Ibrahim (2006) introduce in the debate the role of the regional policy making.

Assuming as case study the organization "Midland Aerospace Alliance", a governance body for the implementation of support policies for the Midlands aerospace industry, they identified a "hub and spoke" cluster structure and analyzed possible development policy measures to support the local industry.

3.3 Research questions and methodology

The scientific reference about the cluster phenomenon, both in general and in the aerospace sector, is mainly devoted to the investigation of agglomeration determinants, cluster typology and relationship dynamics between the cluster's agents. In this literature puzzle, the fact that, in a remarkable number of cases, the aerospace cluster are not only an analysis unit but also a formalized organization set up as policy tool to address industrial and economic development is negligibly observed and taken into account.

Not surprising there is very little literature coverage describing clusters management and policy operations to start and let them run properly.

In order to give a contribution in filling this gap, an original database of aerospace cluster was collected by different means including desk research (Internet scanning, scientific literature review, commercial publishing check, EU Framework Programme projects database consultation), direct interviews with leading industrial experts of the sector, main global aerospace events attendance (**Figure 5**).

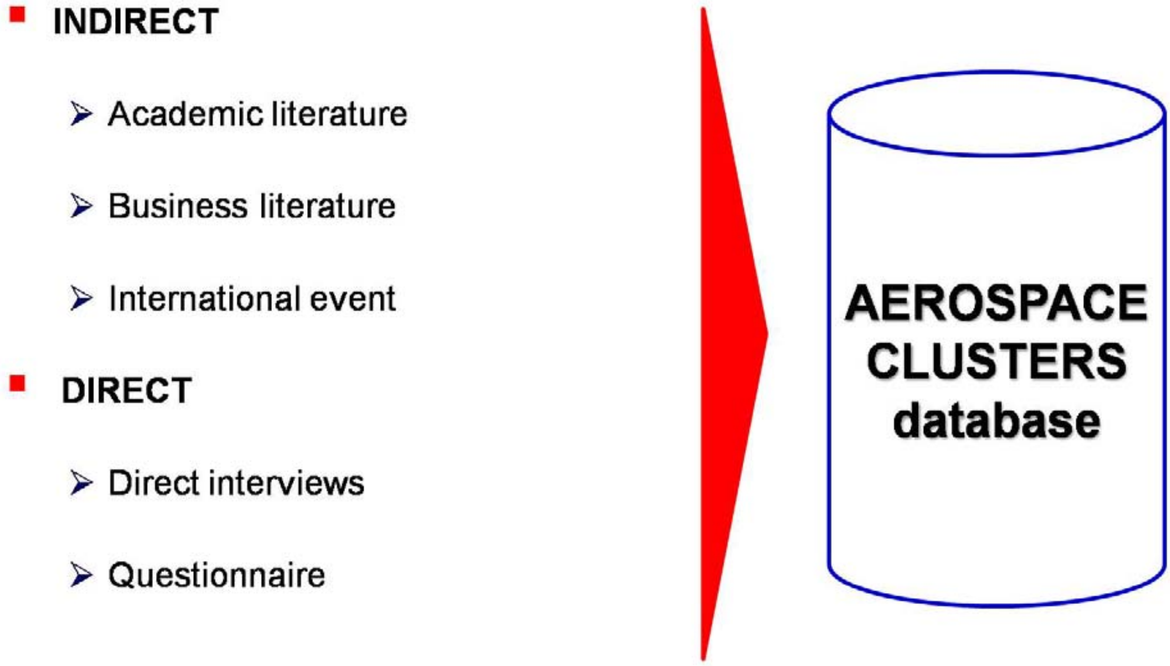

Figure 21 - Aerospace cluster data gathering

This investigation allowed to find 39 "hot spots" (**Figure 6**) that, due to their local concentration of aerospace firms, are widely acknowledged as aerospace cluster *de facto* and, by large, totally account for more than the 70% of the contemporary entire world turnover in the industry. Moreover, 31 of them (more than the 60%) are "official" aerospace clusters in the sense that, even if with a variety of different configuration and underlying industrial sectors, they presents either an organization devoted to their promotion and development or, at least, a specific policy program that clearly identify them as an industrial pool well worth of public acknowledgement and support.

The resulting information base was gathered in a database structured into 4 consecutive branches (environment, organization, activities, performance). **Figure 7** illustrates the database structure until the second level of details. Of course, due to largely heterogeneity both in the underlying industrial texture as well as in the organizations managing aerospace clusters, the completion degree varies in a remarkable way from case to case.

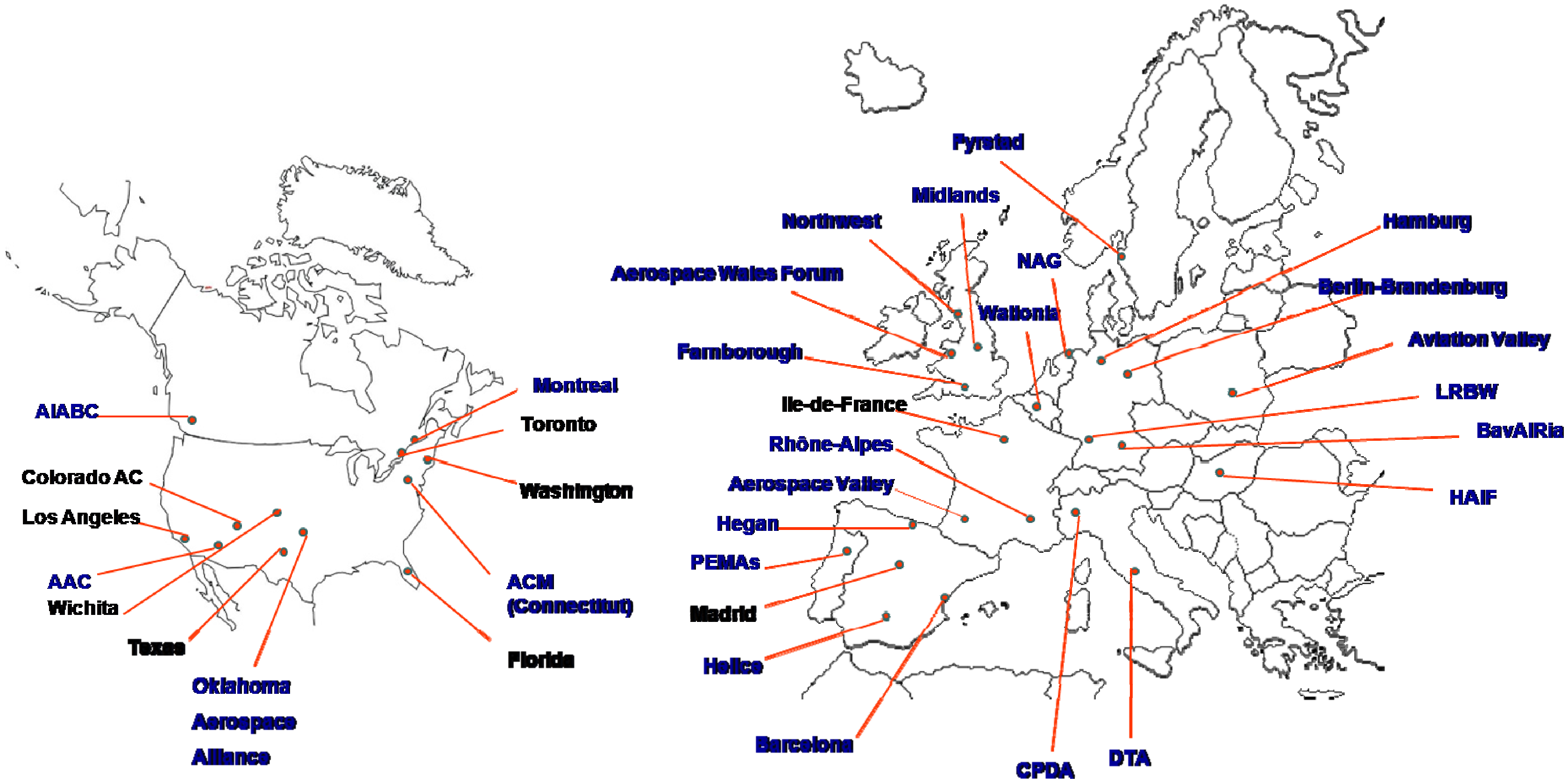

Figure 22 - Aerospace cluster in EU and USA

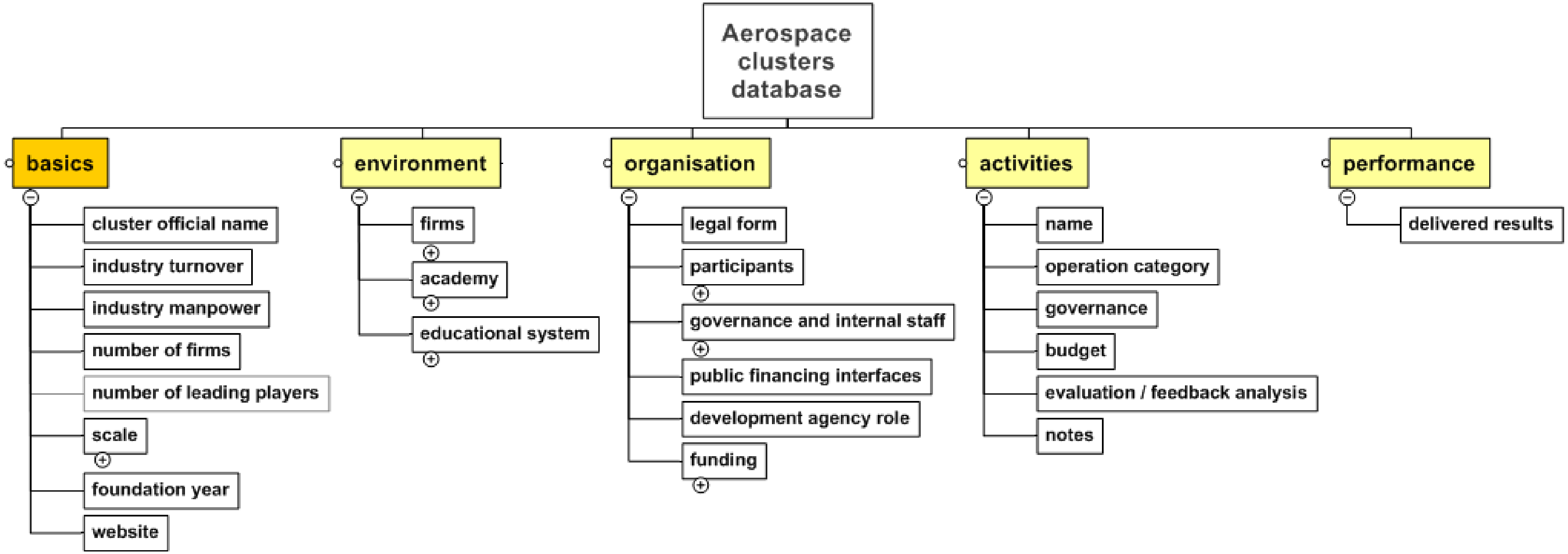

Figure 23 - Aerospace cluster database structure

3.4 Aerospace clustering paths

In the following chapter four paradigmatic aerospace clusters, namely Aerospace Valley (France), Midlands Aerospace Alliance (United Kingdom), Hegan (Spain) and BavAiria (Germany) are presented to show different possible path in formal clustering and to gather a fairly representative list of both aerospace cluster goals and their subsequent policy support operations.

Aerospace Valley (France)

Aerospace Valley includes the Aquitanie and Midi-Pyrénées regions, where the full range of actors in the aerospace sector (enterprises, educational entities, research centers and political institutions) are represented at the top European level.

The Valley hosts prominent industries (Airbus, ATR, Thalès, …) with a great number of SMEs as suppliers, three Universities, three Grandes Ecoles of the aerospace sector, several Ecoles Nationales and private training centers and more than eighty public research centers. Institutional organizations include two regional Development Agencies and two Innovation Agencies for the SME development.

The interest for aerospace in the region dates back to 1918, but most of the development started in '60, as state-led exogenous process of direction of the activities of the local system. The legal arrangement as a cluster, formally ruled by the Aerospace Valley Association, dates to July 2005, when the Association is awarded by the French Government the management of the Pôle de Compétitivité "Aéronautique, Espace et Systèmes embarqués" .

The objective of the Association is the support of the excellence position of the territory in the aerospace sector by networking activities and development of joint projects. The some 300 members of the Association are divided into 7 colleges, namely Big Industries, SMEs, Research Centers, Educational Organizations, Local Institutions, Development Agencies, Professional Organization and Affiliated Members. Each of them is represented (not equally) in the General Assembly electing the 33 members of the Administrative Council, in turn selecting the Executive Committee running the day-by-day activities. A Strategic Committee with industry, education and research representatives selects the initiatives to be included in the Association project portfolio.

The activities (as depicted in **Figure 8**) are arranged in a matrix scheme with 9 Strategic Areas (columns) and 3 Fields of Activities (rows): Education, Economic Development and Research. As far as the Economic Development is concerned, the main projects deal with the development of regional supplier enterprises, the setup of local competence centers with shared infrastructures and services, the setup of an aircraft recycling plant, an helicopter maintenance center and a advanced manufacturing platform.

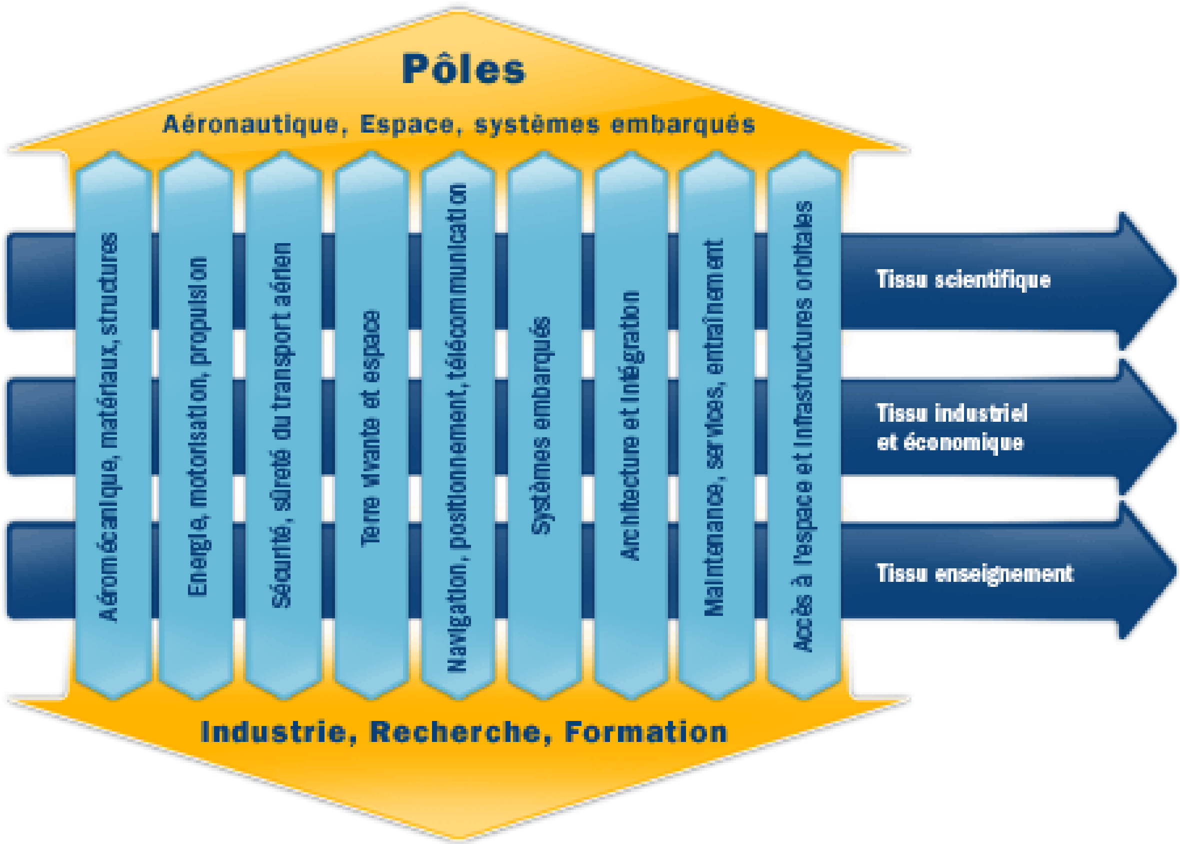

Figure 24 - Aerospace valley activities

Networking and coordination activities are organized around a members-only data base including employment information, commercial offers and technology and market analysis and forecast. The Association is building up partnerships with other Pôles de Compétitivité in order to increment the transfer of complementary technologies.

Two years of existence are a too short period to evaluate the effectiveness of the Association actions. However it must be noticed the huge amount of the mobilized economic resources

(90 million Euro for R&D, one third of them from state and local authorities, 140 million Euro for the building of local infrastructures) and the project of an Aerospace Campus joining the Universities and R&D institutions. Moreover the Association initiatives do not disregard any section of the aerospace sector.

Midlands Aerospace Alliance

Midlands Aerospace Alliance (MAA) covers two regions of UK center, West Midlands and East Midlands, with 700 enterprises focused on propulsion systems, control systems and materials: among them Rolls Royce, Thales and Alcoa. It includes 10 universities, the 4 Rolls Royce technology centers, a center of competence in advanced manufacturing and two regional Development Agencies.

MAA, established in 2003 as an association, become in 2005 a Limited Company and has a Board of Directors representing permanent members (enterprises and Development Agencies), elected members (selected according to an heterogeneity criteria from firms, universities and institutions) and nominated members.

MAAs' objective is threefold: knowledge transfer, enterprise support, strategies definition at regional and national level. In 2003 the first Cluster Strategy has been published, stating guidelines for the activities up to 2006 toward the main objective of increasing the local competitiveness, according to a holistic approach where the cluster potential is greater than the simple sum of the components potential. The activities are arranged in a matricial scheme (**Figure 9**) with four areas (rows), Business Development, Innovation and Technology, Best Practices, Skills, and three lines (columns), Knowledge, Programmes and Strategy: the different initiatives are located at the intersection.

The Programmes line includes the most significant operations, where a major role is played by the Development Agencies. Examples are the Market Consortium Project, dealing with the sharing of knowledge and resources between suppliers, Technologies Exploitation Programme, introducing new technologies in the supply chain with the support of universities and major companies, the Business Strategy Programme, addressing advanced management techniques for complex projects. Special attention is devoted to the SMEs, whose birth and growth is granting the cluster development, with a specific funding for the performance and quality assurance improvement, infrastructure and facility sharing, job matching services, revision of curricula offered by educational institutions in the area. Networking and communication activities are mainly concentrated on meetings and thematic workshops.

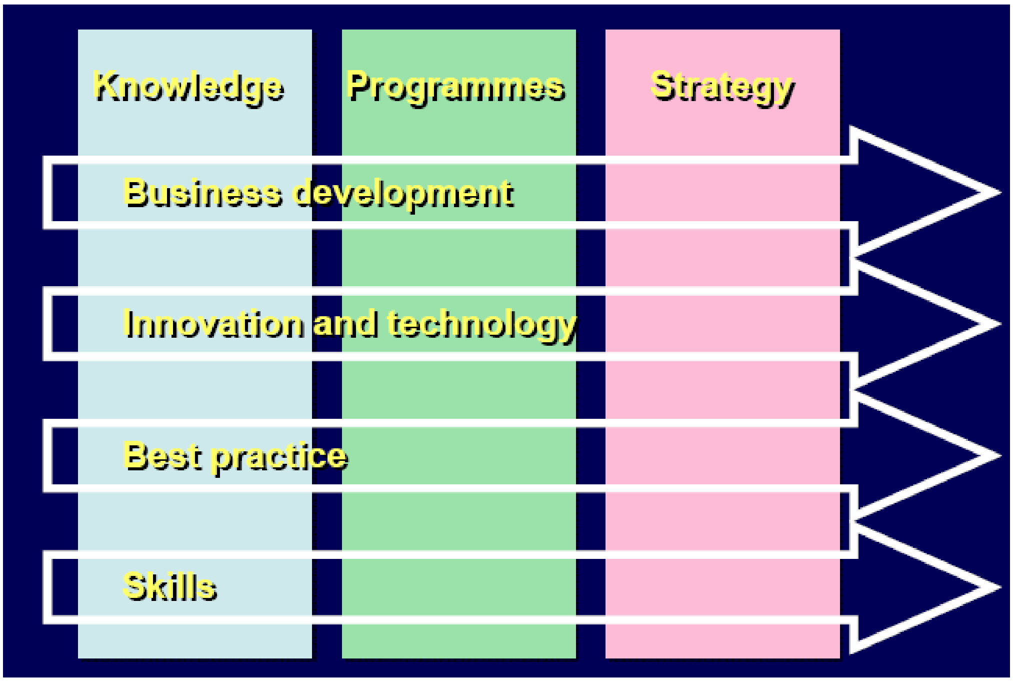

Figure 25 - Midlands Aerospace Alliance – activities

Over the last two years the Midlands aerospace industry shows a positive dynamics of the overall economic turnover and workforce. This positive situation can be attributed in part to the MAAs' operations. Particular effort is invested in evaluating every year the evolution of the territory economy, withy the goal of adjusting the cluster strategy, with an interview to 100 enterprises.

Hegan

Pais Vasco features 40 aerospace industries, a high density over a limited territory, with about 25% of the sector total turnover in Spain. Over a decade (1995 – 2005) the sector showed a fourfold growth of workforce and a sevenfold growth of total revenues, thus resulting as one of the most dynamic cluster in the world. The region offers 4 universities, 3 technological parks and a number of research centers focused on materials and mechanics. The Regional

Government founded its Development Agency back in 1981, with the goal of supporting entrepreneurship and innovation, and a regional venture capital society in 1985, managing today 7 investment funds.

The aerospace cluster is originated from a specific governmental mandate, with the goal of achieving a European excellence in the sector. In 1997 the Hegan association is founded, with the 4 leading firms as founding members and the support of Ministry of Industry, and since then manages the cluster of aerospace enterprises including at present 27 SMEs.
The governance (as represented in **Figure 10**) is built around a General Assembly, which designates the Executive Committee (9 members from industries, academia and local institutions). The operational structure is based on 5 divisions: Finance, Internationalization, Human Resources, R&D and Quality.

Figure 26 - Hegan organisational scheme

The main activities are devoted to technology dissemination and transfer and to the supply chain performance (quality, reliability, security and economics), the association takes a significant participation in several European R&D projects in order to promote the internationalization of SMEs.
It is worth noting that most of production activities of the cluster enterprises are included in manufacturing programs coordinated from outside the region, by Airbus, Boeing and Embraer.

This is the result of an effort of assuring international visibility to the cluster and maintaining it at the top level of performance in the supply chain, a mandatory condition for the cluster survivability.

BavAIRia

Bayern excellence in aerospace is built on more than 300 enterprises including EADS, Eurocopter and MT Aerospace, with about 23.000 employed people and a yearly turnover in the order of 5 billions Euro (one third of the total in Germany). The activities (**Figure 11**) are concentrated on three topics: aeronautics (civil and military), space propulsion and satellite applications (navigation and environmental monitoring).

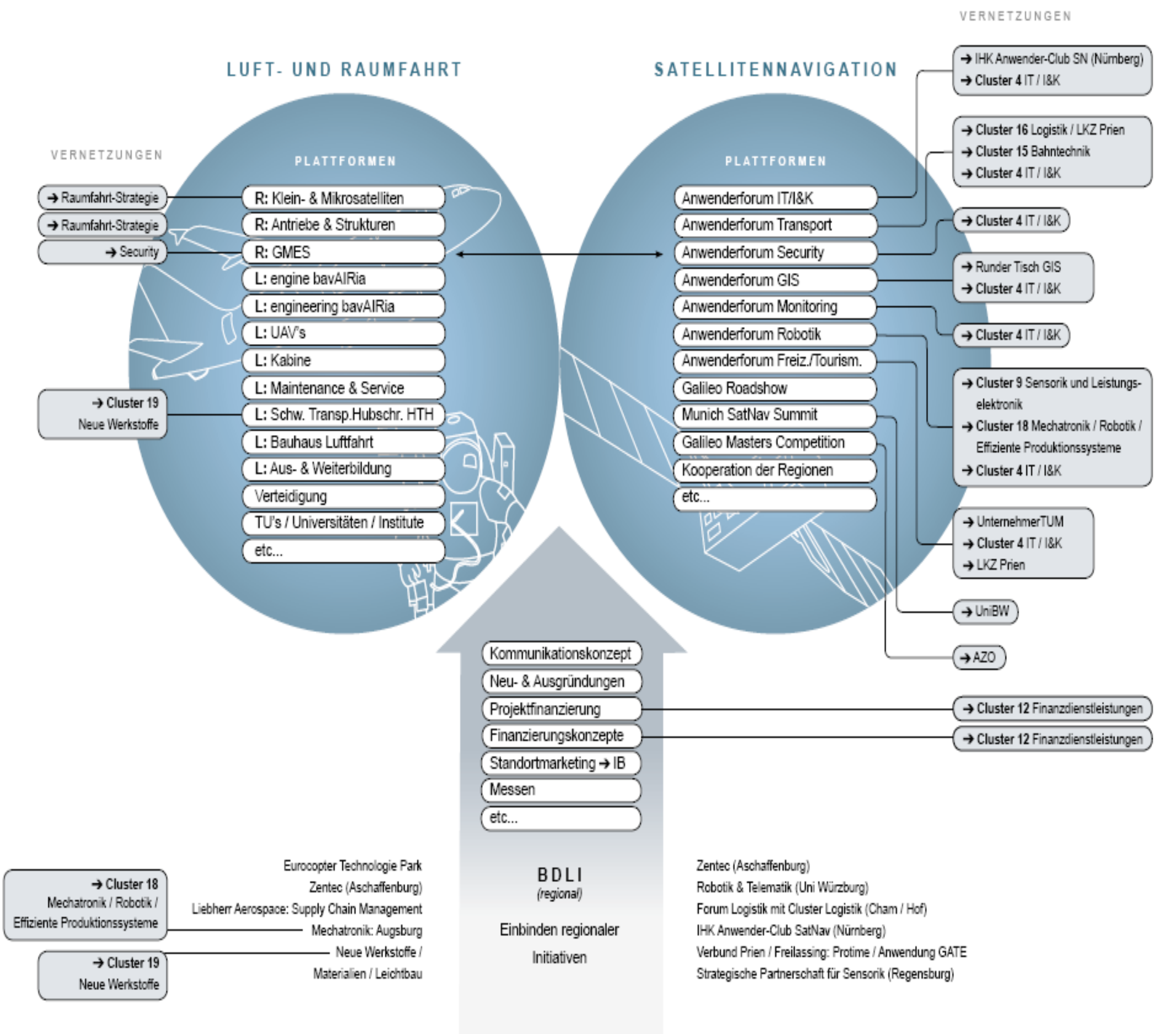

Figure 27 - BavAIRia organisational scheme

The region hosts 5 Universities, a significant section of the federal aerospace research centre DLR and several European institutions headquarters, such as Galileo Industries and ESO. Even if the aerospace industry presence dates back to 1916, the BavAIRia association was established only in 2007, as result of a recognition phase initiated by Ministry of Economic Affairs, Infrastructures and Technology in 2001 and the identification of some 19 high-technology clusters in 2006. Built around the two clusters of Aerospace and Satellite Navigation, BavAIRia results to be the youngest formally organized aerospace cluster in Europe. At the moment it counts 70 associated entities, coming from enterprises and academic institutions. The objective of the association is the implementation of networking activities in support of both the sector and the single associated enterprises.

The association governance is very simple and built around two basic functions, Project Management and Marketing and Event Management. The executive board and the managers are professionals independent from both enterprises and academia. In fact the main activity of the association seems to be the setup of collaborative actions. Those originated by the Aerospace Cluster are mainly internal and devoted to the strengthening of specialized sectors like engines, UAV, aircraft maintenance, etc. ("platforms"), while those pertaining to the Satellite Navigation ("user forum") are mainly oriented toward the other high-tech clusters identified in the Bavarian industrial landscape, thus stressing the interdisciplinary nature of aerospace technology, in particular as far as the satellite applications are concerned. It is worth noting that the association is closely linked to a number of initiatives, both public and private, aiming at supporting the growth of high-tech SMEs. They include funding of high-risk research projects, grants for technology transfer and venture capital services. Networking and coordination activities are organized around a members-only section of the association site, where market analyses and forecasts, technology roadmaps and meeting or workshop proceedings can be found. The limited activity time do not allow to evaluate the performance of the newborn association. The main challenge for the BavAIRia management will be the effective integration of the collaborative actions they launch with the partners plans, so acting as main aggregating entity of the territory for R&D promotion and SMEs support.

3.4 Organizational forms and operations in aerospace clusters

Beyond the four mentioned case studies, the information collected about the 39 aerospace clusters identified all around the world show that in the vast majority of cases (81%) they acquire an official structured form. This phenomenon seems to be quite new, as long as the median of foundation year is 2004, and involves industrial texture of very different sizes (ranging from 600 to 16.000 Mln Euros of yearly turnover). The extreme variety of the experiences of such organization as well as the short historical series and multiple sources of evidences suggest a qualitative and exploratory approach the topic.

To further develop the analysis, a terminological distinction should be made between aerospace cluster and their organization. The research interest of the article, even starting from the first concept, is focused on the latter, spotlighting the practical form of support developed all around the word to enhance local aerospace industry competitiveness.

In the following, the above mentioned concepts will be associated with the meaning stated by those definitions:

Aerospace cluster

A territorial concentration of aerospace-related players acknowledged as relevant by at least one of those information sources:

- ✓ Official government documents
- ✓ International academic journals
- ✓ International business journals
- ✓ Official statistical reports

Aerospace cluster organisation

Organisation formally devoted to the development of the aerospace industry grounded into a given territory.

The definitions presented allow to discriminate between the industrial texture being the base of any judicious support action and the tools used to enforce it. With reference to this aspect a taxonomy of cluster organizations, presented in **Figure 12,** is proposed reflecting the qualitative differences between the 31 experiences of aerospace cluster organizations collected.

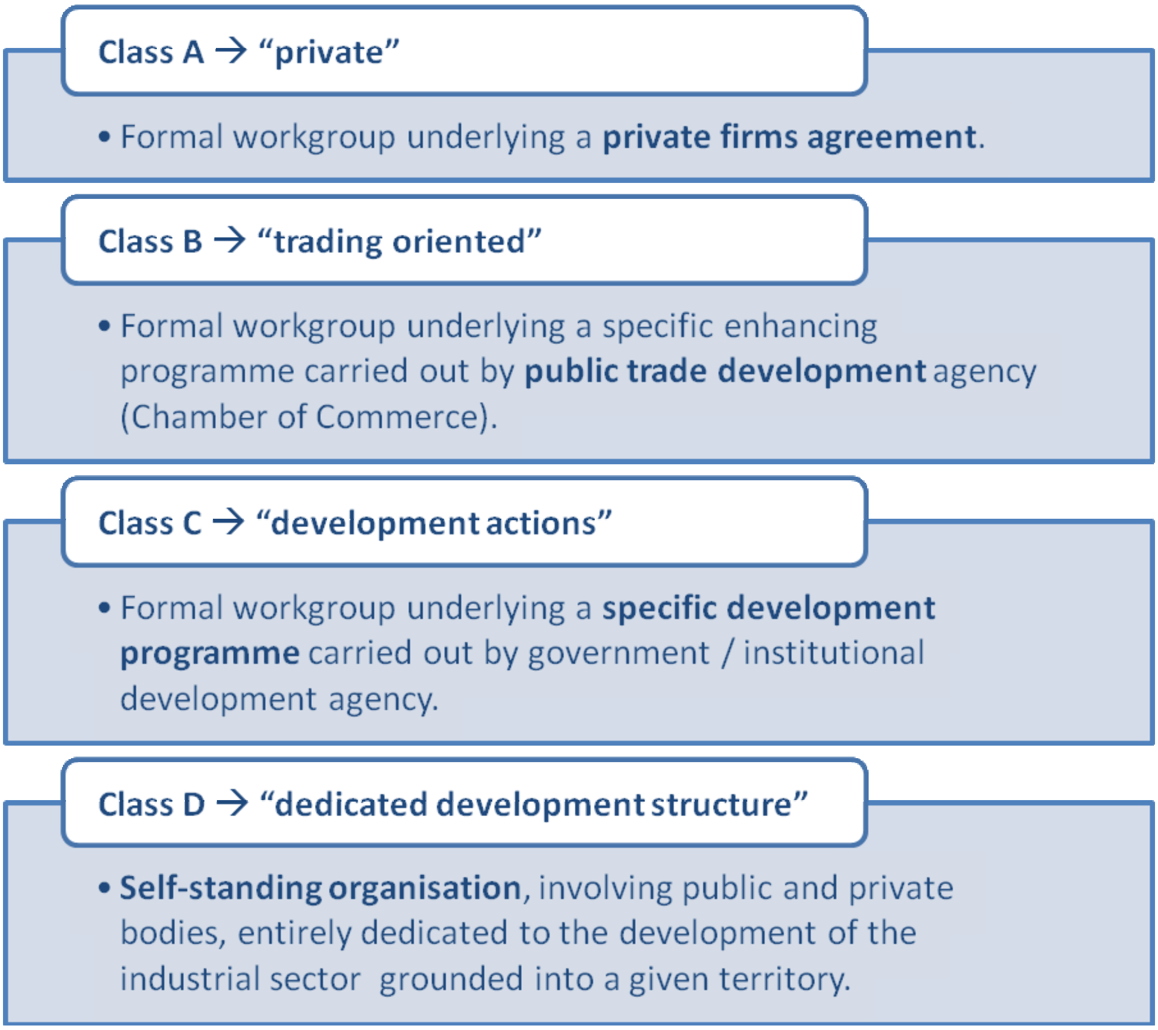

Figure 28 - Taxonomy of cluster organizations

This classification scheme is sorted by a criteria of both irreversibility and engagement of the involved stakeholders and helps in avoiding confusion between strategic efforts of different magnitudes.

According to the identified cluster classes, the taxonomy can be safely used as a nominal scale, meaning that the nature of an aerospace cluster organization is enough to identify which of the four category fits in its characteristics without overlapping risks.

However, a deeper analysis shows that in the taxonomy a relevant degree of ordinal property can be identified. To this purpose in **Figure 13** a classification of cluster operations is presented.

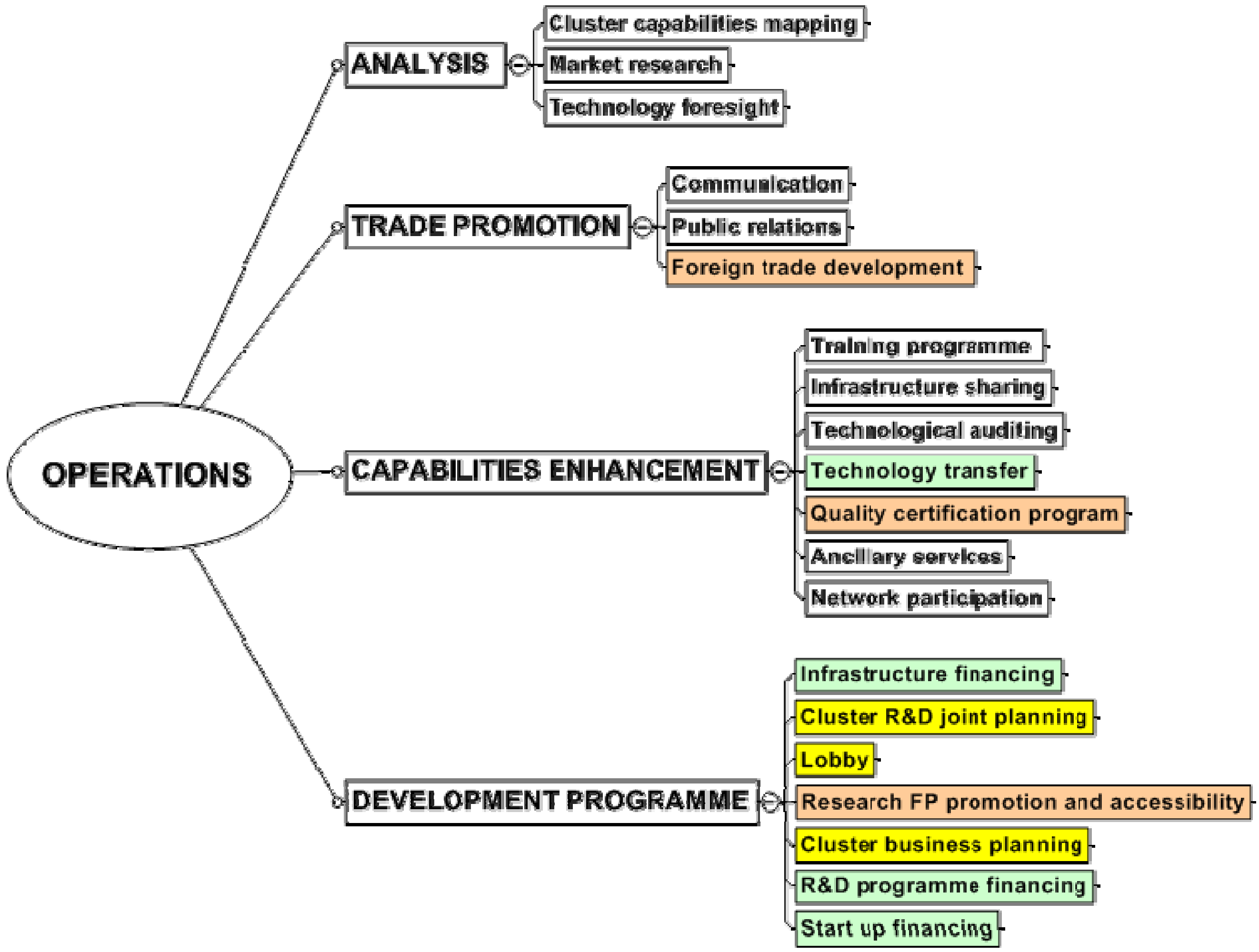

Figure 29 - Classification of cluster operations

This scheme divides the operations deployed by the aerospace cluster organization in 4 areas articulated into 20 elementary classes. While any of the 31 analyzed organizations presents at least one of the above mentioned interventions, there are remarkable differences in the share of each operation if the aerospace cluster organization classes are taken into account. The capabilities analysis and basic trade promotion seems to be quite a “commodity” feature of all kind of aerospace cluster organizations, some interventions like foreign trade development initiatives as well as quality certification programs and research partner searching become available from the “B” class of cluster organizations.

Likewise, strong financial efforts are a prerogative of prominent aerospace cluster organizations involving public Development Agencies. At the top of ranking, class D organizations can practice medium term joint planning as well as institutional lobby activities structured and consistent through time. It should be underlined that any actions taken by the more unstructured organization can be equally be performed by the most advanced and independent institutes. **Figure 14** allows to evaluate the relative frequency of implementation of the different operations among the various classes of clusters

Area	Operation	A	B	C	D	
ANALYSIS	Cluster capabilities mapping	3	5	9	13	30
	Market research	2	4	8	9	23
	Technology foresight	1		2	5	8
TRADE PROMOTION	Communication	4	5	9	13	31
	Public relations	4	4	9	13	30
	Foreign trade development		5	8	13	26
CAPABILITIES ENHANCEMENT	Training programme	1	3	7	11	22
	Infrastructure sharing	1	2	6	5	14
	Technological auditing	2	3	5	8	18
	Technology transfer			7	11	18
	Quality certification program		3	5	8	16
	Ancillary services		3	4	8	15
	Network participation	2	4	9	13	28
DEVELOPMENT PROGRAMME	Infrastructure financing			7	10	17
	Cluster R&D joint planning			4	11	15
	Lobby			3	13	16
	Research FP promotion and accessibility		4	8	12	24
	Cluster business planning				11	11
	R&D programme financing			7	13	20
	Start up financing			6	8	14
		4	5	9	13	31

Figure 30 - Cluster classes and operations

In **Figure 15**, the aerospace cluster organizations are enumerated and represented with the set of colors (white → A, red → B, green → C and yellow → D) used in the previous figures and showing the difference in operations adoption by classes.

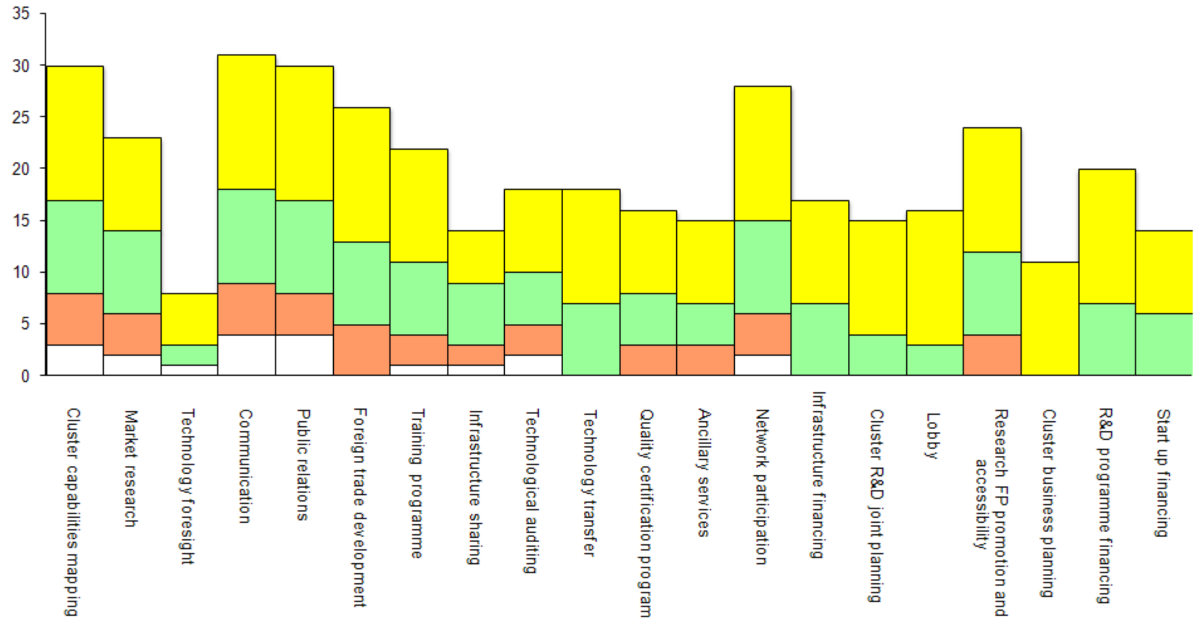

Figure 31 - Operations by number and class of aerospace cluster implementing them

3.5 Conclusions

Looking across the four illustrated case studies as well as the entire population analysed, a fundamental commonality could be found in their structure, shaped according to the "hub and spoke" model described by Markussen (1996).

The Triple Helix model could be easily applied to those innovation systems since the joint presence of firms, academy and involved institutions is a common characteristic suggesting policy tool to promote and enhance knowledge transfer across the different agent classes. This richness is seized also in the cluster organization governance including them all in their leading bodies.

This feature occurs in almost all the cases gathered in the aerospace cluster database and it could be identified as a direct consequence of the pyramidal production system that characterizes the industry, thus generating around big players a broad texture of SMEs acting as their suppliers.

The presented taxonomy of aerospace cluster organizations and support operations permits to underline the added value that a proper formalization could provide. Besides implicit information sharing, thus increasing local competitiveness, the formal structure can assure the complementing of different capabilities otherwise difficult to seize like the involvement of University and SMEs. A structured organization can also enhance territorial brand promotion as well as exercise lobbying activity toward different government levels promoting the aerospace industry interests. Inside the organized clusters it could be recognized different intervention levels enabled by progressively developed structural forms (**Figure 16**).

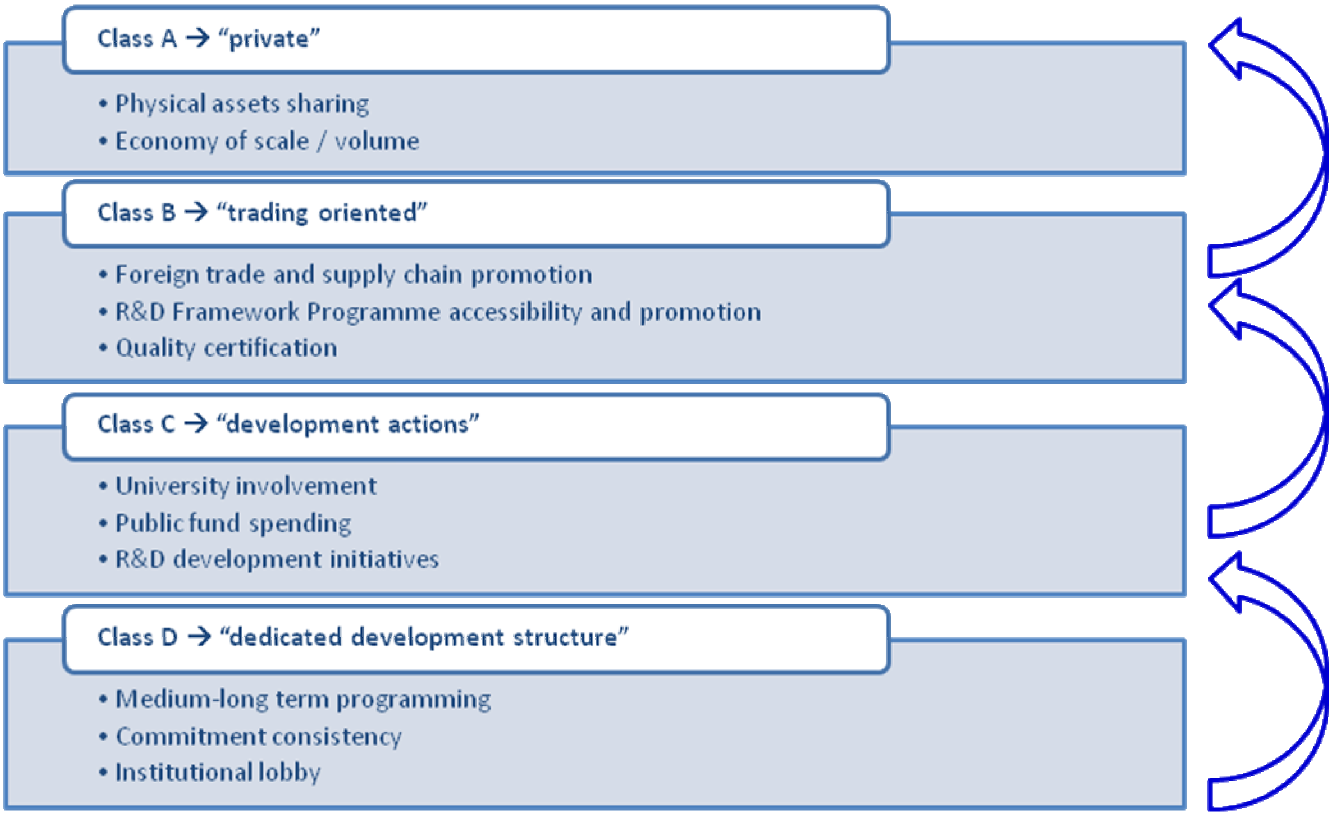

Figure 32 - Elements enabled by the different organisational form in aerospace cluster organisations

As promising field of investigations as well as key point in an efficient aerospace industry promoting effort, it worth noting that in the observed cases there is a substantial weakness in the self-evaluation mechanism and feedback loop on performance. This is a central problem to be solved in order to both steering and monitoring the cluster organization actions and constitutes an interesting managerial issue.

References

Asheim, B. (1996), "Industrial districts as "learning regions": a condition for prosperity?", European Planning Studies, 4: 379–400

Audretsch, D. B. and Feldman, M. P. (1996), "Knowledge spillovers and the geography of innovation and production", American Economic Review, 86(3): 630–640

Breschi, S. and Lissoni, F. (2001), "Localised knowledge spillovers vs. innovative milieux: knowledge 'tacitness' reconsidered" Papers in Regional Science, 80: 255–273

Brown, R. (2000), "Clusters, Supply Chains and Local Embeddedness in Fyrstad", European Urban and Regional Studies 2000; 7; 291

Brusco, S. (1990) "The idea of the industrial district: its genesis", in: Pyke. F. and Sengenberger, W. (eds): Industrial districts and local economic regeneration (International Institute for Labour Studies, Geneva) 177–196

Camagni, R. (1995), "The concept of innovative milieu and its relevance for public policies in European lagging regions", Papers in Regional Science, 74(4): 317–340

Feldman, M. (1999), "The new economics of innovation, spillovers and agglomeration: a review of empirical studies", Economics of Innovation and New Technology , 8: 5–25

Fingleton, B., Igliori, D. C. and Moore, B. (2005), "Cluster Dynamics: New Evidence and Projections for Computing Services in Great Britain", Journal of Regional Science 45(2): 283–311

Fujita, M., Krugman, P. and Venables, A. J. (1999), The spatial economy (MIT Press, Cambridge, Mass.)

Glaeser, E. L., Kallal, H.D., Scheinkman J.A.and Shleifer, A. (1992) 'Growth in cities', Journal of Political Economy 100(6): 1126–1152

Gordon, I., McCann, P. (2000) 'Industrial clusters: complexes, agglomeration and/or social networks?', Urban Studies 37(3): 513–532

Henderson, V. (1986) 'Efficiency of resource usage and city size', Journal of Urban Economics 19: 47–70

Henderson, V., Kuncoro, A. and Turner, M. (1995) "Industrial development in cities", Journal of Political Economy 103(5): 1067–1085

Jacobs, J. (1969) The economy of cities (Vintage, New York)

Jaffe, A. B. (1989) "Real effects of academic research", American Economic Review 79(5): 957–970

Krugman, P. (1991) "Increasing returns and economic geography", Journal of Political Economy 99: 483–499

Longhi, C. (2004), "The French Revolution : technology management in the aerospace industry. The case of Toulouse", Int. J. Technology Management, 29(3/4), 194-205

Lublinsky A. (2003), "Does Geographic Proximity Matter? Evidence from Clustered and Non-clustered Aeronautic Firms in Germany", Regional Studies, Vol. 37.5, pp. 453–467, July 2003

Lundvall, B.A. (ed) (1992) National systems of innovation: Towards a theory of innovation and interactive learning (Frances Pinter, London)

Maillat, D. (1998) "From industrial district to innovative milieu: contribution to an analysis of territorialized productive organizations", Geographische Zeitschrift 86(1): 1–15

Maillat, D., Lecoq, B., Nemeti, F.and Pfister, M. (1995) "Technology district and innovation – the case of the Swiss-Jura Arc", Regional Studies 29(3): 251–263

Markusen A (1996) "Sticky places in slippery space: A typology of industrial districts", Economic Geography 72(3): 293–313

Markusen, A. (2003) "Fuzzy concepts, scanty evidence, policy distance. The case for rigour and policy relevance in critical regional studies" Regional Studies 37(6–7): 701–717

Marshall A. (1890) Principles of economics. 8th Edition, 1986, (Macmillan, Basingstoke)

Martin, R. and Sunley, P. (2001) "Deconstructing clusters: Chaotic concept or policy panacea?" Paper presented at the Regional Studies Association's Conference on Regionalising the knowledge economy, London, 21. November 2001

Niosi, J. and Zhegu, M., (2005) "Aerospace Clusters: Local or Global Knowledge Spillovers?" Industry and Innovation, Vol. 12, No. 1, 5–29, March 2005

OECD (1999) Boosting Innovation: The Cluster Approach. Paris: OECD

OECD (2001) Innovative Clusters: Drivers of National Innovation Systems. Paris: OECD

OEDCD-DATAR (2001) World Confress on Local Clusters. Paris: OECD

Ohlin, B. (1933) Interregional and international trade (Harvard University Press, Cambridge)

Porter, M. E. (1990) The competitive advantage of nations (Macmillan, London)

Porter, M. E. (1998) "Clusters and the New Economics of Competition", Harvard Business Review, 76, 77-90

Porter, M. E. (2001) “Regions and the New Economics of Competition” In: Scott AJ (ed) Global City-Regions Trends, Theory, Policy (Oxford University Press) 139–157

Romer, P. M. (1986) “Increasing returns and long-run growth”, Journal of Political Economy 94: 1002–1037

Romer, P.M. (1990) “Endogenous technical change”, Journal of Political Economy 98: 71–101

Sabel, C. (1994) “Flexible specialization and the re-emergence of regional economies” In: Amin A (ed) Post-Fordism. A Reader (Blackwell, Oxford) 101–156

Scitovsky, T. (1954) “Two concepts of external economies”, Economic Journal, LXII, 54–67

Solow, R.M. (1957) “Technical change and the aggregate production function”, Review of Economics and Statistics 39: 312–20

Whitford, J. (2001) “The decline of a model? Challenge and response in the Italian industrial districts”, Economy and Society 30: 38–65

World Bank (2000) Electronic Conference on Clusters. Washington: World Bank

Von Hipple, E. (1994) Sticky information and the locus problem solving: Implications for innovation, Management Science, 40, pp. 429–439.