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**Innovation and its diffusion:
The aeronautical case¹**

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INTRODUCTION

The industrial scenario, both in developed and emerging economies, can be characterized by the existence of two groups of industrial firms: large firms (LFs) which tend to participate in increasingly global oligopolistic markets where innovation is crucial and small and medium industrial firms (SMEs), inserted in a local milieu and operating mainly in competitive markets where product price is the crucial factor. This initial division of firms into two large categories not only provides us with a classification of firms by size, but also responds to concepts essential to the construction of an analytical model which will assist in explaining processes of generation and diffusion of innovation among entrepreneurs and industrial firms. This article therefore proposes to look into how innovation is created and how it is diffused in the industrial fabric.

The first part will expose the two economic problems which the economy in general and industrial firms in particular, must confront. The paper then explores how the two types of firms attempt to deal with these economic problems. The distinction we made between large and small firms will help to establish the predisposition of each group to create innovation and diffusion as well as the need to incorporate further group of firms into our initial clear cut model of only two types.

Once the analytical framework, with its foreseeable action and results, is put forth, it will then be applied to the aeronautical sector within the Madrid Region, in which what is referred to as a "hybrid model" of creation and diffusion of innovation is described. The need to introduce territorial variables to make the process of creation and diffusion of innovation in the aeronautical industry more realistic is also described. Specifically, the articulation and interaction among innovation nodes in the various European regions are analyzed as is their relation with the SMEs in the same territory. With this approach, the paper will hope to clarify how innovation in the sector is generated and diffused and what role the complementary and mutually beneficial action of the LFs and SMEs will play in the industrial fabric. Finally, some suggestions as to optimal policies will be proposed.

PRODUCTION OF INNOVATION: UNCERTAINTY AND COST

The results of all human activity are closely related to uncertainty both for the individual trajectory and for society's. Since the basic characteristic of uncertainty is the impossibility of defining and calculating its effects and results, individuals and society have found it necessary to develop social and material technologies to ultimately evade the impact of uncertainty, that is to say, it may not be possible to avoid risk and uncertainty, but one endeavors to construct foreseeable scenarios. Similarly, society pays the price that all human activity implies.

Risk and uncertainty are essential characteristics of innovation since only when the market validates the innovation can compensation be obtained for the idea developed. The history of technical change is plagued with errors as testified by the results obtained with ideas that seemed brilliant but later failed in the market. According to a study carried out in Canada in 2003, only 75 of the 1091 innovations analyzed reached the market and of these, six reached profitability of more than 1400% while 45 lost money (Astebrot, 2003). Moreover, the appearance of new knowledge and discoveries may even turn out to be useful in the development of processes and products that had nothing to do with the original conception of the idea (Rosenberg, 1996).

Another significant characteristic of technical change is the path dependence of innovative processes. If innovation generally involves uncertainty then it is logical to suppose that if the production of a new product or process is attempted and fails, the agents that launched on the new experience will either disappear or fall back to their initial position. That is, one starts from a given knowledge base from which one looks for new ways to do or combine things. The inherent uncertainty in all innovation will tend to generate dependence on the position of the agents in the market (Arthur, 1989; David, 1985).

However, it is a tried and proven statement that in the long run, productive earnings in the economy are determined by increments in knowledge (information) applied to the productive fabric. *Ceteris paribus*, the level and rate of accumulation of technological and organizational change will determine the position of the firm and its specific cluster

- if this is the case - among its competitors. Hence technological change, innovation in the broadest sense, becomes the central episode in all entrepreneurial development. Change emanates from individuals and/or from organizations (firms) which, with their incentives, motivations and capabilities, seek compensations (payment) for the effort made. Therefore, in the capitalist economic system, entrepreneurs and firms have responded with innovation, as the most appropriate vehicle to confront the problems of uncertainty and cost. More specifically and following Baumol (2002):

Large, oligopolistic firms, create R&D Departments within their structure as a way of promoting innovation and therefore the search for innovation becomes a recurring routine. Moreover LFs fiercely compete with each other to maintain their market share and avoid losing the race for innovation which will, in turn, guarantee they will, at the least, maintain market share and returns on their investments.

They compete more with each other in the technology incorporated into their products rather than in product price. It is therefore of great interest to have a constant flow of innovations available to reduce market uncertainty. Incremental product and process innovation aimed at reducing production costs are the most valued and provide these firms with innovation-based competitive advantages over their competitors. Therefore, LFs located in high value-added sectors use innovation to reduce the uncertainty inherent in their activity. Innovation is not a voluntary decision made by firm management but rather an indispensable necessity in order to survive in the industrial activity².

At the same time, all decisions to routinely invest in R&D generate high costs (sunk cost), in the productive structure of firms which must be recovered in the market through product prices. The higher cost and prices will then deviate from the marginal conditions of perfect competition.

On the other hand, throughout the history of economy and, of course, of capitalism and industrialization, SMEs have drawn together in agglomerations within a given territory

² The flavor is clearly Schumpeterian and related to the literature on “creative destruction” models of growth. See (Aghion and Howitt 1998), and more recently (OECD 2003).

of entrepreneurial economic activity by specific sectors, whether mercantile (commerce or services) or manufacturing. The difference between craftsmen grouping together on streets named after their trades in the Middle Ages in any European, Mediterranean or Asian city and the concentration of industrial activity by sectors into the clusters of today lies in the new relations between labor and capital factors and ownership. In other words, property rights accepted and legitimized by society, and a very different internal organization of production within the firm are the key developments. In fact, Adam Smith's vision of the firm was that of a present-day SME since LFs are a capitalistic phenomenon emerging only after the second half of the 19th century.

Industrial SMEs consolidated in late 19th century where spontaneous agglomeration by specialty was meant to compensate for individual weaknesses. A set of specialized firms that interact within a sector (the definition of "cluster" used here) reduces uncertainty by guaranteeing that each and every one of the participating members of the group will share in the level and rate of knowledge creation of the industrial activity. The uniqueness of the cluster technology is that the various agents within a defined space with specific game rules not only know each other but also the capabilities of embedded knowledge (physical capital, tacit and human resources as well as production and organizational methods) existing within the cluster (Guth and Kliemt, 1998).

Cluster technology provides rapid, reliable and transparent information all of which reduces transaction costs and generates cooperation among the firms. Consequently, the cost of access to knowledge is lower than in LFs. In SME clusters, ideas float in the atmosphere and are inhaled by the relevant population. All knowledge is of concern to all the participating firms. The existence of this knowledge is clearly a public good, available to all and benefiting all.

SMEs in cluster also differ from LFs in that they mainly participate in price-competitive markets and therefore encounter serious difficulties in transferring any cost increase not classified as variable to the price of their products. If price-taking firms decide to invest in recurring innovation costs, they risk not being able to recover these expenditures with the prices they get on the market for their products. It is the cluster technology that allows SMEs to circumvent recurring innovation costs.

INNOVATION ADAPTATION AND DIFFUSION

It is assumed, then, that routine industrial innovation (understood as the creation of something new no previously known), is mainly developed in the R&D departments of LFs. This is not due to a greater availability of human or financial resources in the LFs but rather to an inherent characteristic of the capitalist system which determines an oligopolistic market structure in which firms are impelled to innovate as the only way to guarantee their present and future permanence in sectors that are highly competitive in technology (Baumol, 2006).

The market is oligopolistic because innovation requires departing from the conditions of $p = mc$ which prevail in markets approximating perfect competition. The reason is quite simple. If the innovating firm acts as a price-taker, it won't be able to recover the recurring costs of its R&D Department and, therefore, either its innovative activity will be detained or its permanence in a market of marginal conditions will be in danger. The innovating firm must charge $p > mc$ for its products to be able to recoup the sunk costs which, it should be remembered, are not included in the firm's variable costs.

Also, given the fact that all research tend to behave as a public good, firms are aware that any innovation they develop will only give them a temporary competitive edge over their rivals. Moreover, the exclusion of other firms from their innovations is difficult and, therefore, obtaining greater economic returns than usual is likely to be a passing phenomenon. That's why LFs tend to discriminate prices among clients in order to squeeze as much revenue for its products as possible

The appropriability rate, that is, the rate of profitability retained by the LFs in the industrial sector has been established at no more than 5 to 6% over time (Nordhaus, 2005), which indicates that profit obtained through innovation tends to be diluted and flow over into the rest of the industrial fabric. Innovation as a non-rival good leads LFs to accumulate a catalogue of viable technologies and thus maintain extra profit rates (Schumpeterian economic returns) over time in order to meet their commitments to innovate and recover the investment made in their R&D departments. For the same

reason, oligopolistic firms will be interested in establishing technological transfer contracts with other firms in exchange for economic compensation. Although it may seem paradoxical, if the logic of innovation in the capitalistic economic system is taken to extremes, it will become apparent that firms will find it profitable to reach agreements for technological transfer when facing a drastic reduction in their appropriability rate, thus maximizing the extraction of Schumpeterian returns in minimum time. In other words, LFs will be open to the diffusion of their innovations, thus reinforcing the natural diffusion taking place due to the nature of knowledge as a public good.

For the purposes of this paper, we began assuming that SMEs in cluster technology, do not innovate but rather adopt and adapt. The reasoning behind this assumption is consistent with that used in the case of oligopolistic firms where we stated that investment in R&D could only be sustained if its cost is recovered in the market with a product price greater than the marginal cost of its production. According to the model, firms participating in markets of near perfect competition, where price tends to equal the marginal cost and $p > mc$ is not an option, are not able to carry out routine and recurring innovation processes because of their high cost, the difficulty of recovering cost through price and uncertainty as to results. Consequently, industrial SMEs will tend to adopt and adapt (imitate) innovation created elsewhere.

But imitating also incurs cost and for the entrepreneurial world beyond the LFs, imitation requires specific funding of the sunk cost type for the adaptation of the innovative process, **just as would have occurred if the firm had invested in innovation.** That is, the task of industrial adaptation is similar to that of industrial innovation with the significant difference of having more control over the outcome. While uncertainty could decrease, not so with the cost of adaptation which will depend on the technological level existing in the imitating firm. The greater the technological lag, the lower the cost of imitation; the closer the technological level of the imitating firm to that of the innovating firm, the greater the cost of imitation. Taking this relation to the extreme, if the adapting firm's technological level approximates that of the innovating firm, the cost gap will close and the adaptor will assimilate to the innovator. That is, it will have become an innovating firm itself which will lead to the need for an

R&D department with the resulting recurring costs, the flight from $p=mc$, the rise of uncertainty, the evasion of that uncertainty through innovative products and, usually, the transformation from marginal firm to LF. The road is open but not lacking in chuckholes.

At any rate, given a process of dynamic adoption and adaptation, entrepreneurs and firms that adapt technology can be a determining force in the prosperity of a territory since the effects on worker's welfare and the general population may more than compensate the lack of innovation among its firms (Weil, 2005).

Returning to the question of how SMEs confront the innovative process and the possible dynamic path described above, cluster technology plays a key role in reducing both uncertainty and information costs for SMEs, as already mentioned. Therefore, it could be said that both LFs and SMEs follow different paths with the same goal of evading the pernicious effects of risk and cost on their industrial activity. If cluster technology guarantees non-exclusion from technology, firms will have less incentive to innovate and will innovate less. If the new innovation will be available to everyone tomorrow, why make the effort to innovate today? More important still, if SMEs tend to move in markets where conditions of competitive equilibrium ($p=mc$) prevail, how can sunk costs such as investment in routine R&D be recovered? Two forces tend to inhibit innovation: the guarantee of non-exclusion cluster technology offers its members and $p=mc$ conditions in markets where SMEs usually participate. Under the influence of these forces, firms maximize diffusion of innovation (its use), but minimize its production. Or, the appropriability rate inside the cluster is maximum and consequently, the rate of producing innovation is minimum.

Cluster technology does, however, adopt and adapt innovation created by others. By doing so, it assures that new innovations reach its participating firms and that the technological gap between creators of innovation and imitators remains minimal. Although not routinely, entrepreneurs do spend on imitation costs for given projects, often incorporating embedded knowledge in the form of capital goods.

Investment on capital goods has been a constant in the history of SMEs where the uncertainty of investment is drastically reduced due to the facts that the goods have already been tested in the market and financial credit lines are staunchly in place (Alfonso, Sáez, Vázquez, Viñas, 2002). Additionally, let it not be forgotten that any incorporation of physical capital brings with it a new organization of production, generating, at times inadvertently, productivity gains which, in the end, is what motivates technological change. The decision to be made by entrepreneurs between investing in new equipment already tested on the market or in innovation with uncertain results will clearly lean toward the purchase of equipment goods.

Firms not only benefit from belonging to cluster technology due to the reduction of information costs. Any specialization process leads firms to divide complex manufacturing processes into homogeneous sub-processes with the opportunity to obtain scope and scale economies, the source of decreasing manufacturing costs. Moreover, the reduced size of SMEs is an obvious advantage over the persistent problems of management which are often the cause of increasing costs in LFs. Finally, when many firms participate in the network, the law of large numbers indicates a decrease in individual risk and an increase in the survival rate.

EUROPEAN INDUSTRY: CONTRASTING DATA

If the hypothesis that routine innovation is mainly developed by LFs is true, R&D investment will be significantly greater in LFs than in SMEs³. Contrasting this hypothesis would, in principle, support the position held throughout this paper. To do so, the Amadeus database, providing homogenous information on more than a million and a half firms, was consulted to select industrial firms from 1999 to 2003 (groups 15 to 41 in the NACE nomenclature). Of a total of 269,451 industrial firms, the SMEs of up to 250 employees (243,024 units) were separated from the LFs of 250 to 100,000 employees (26,327 units) (Amadeus, 2006).

The database's accounting and financial information includes, among other relevant data, the profits and loss accounts and the aggregate balance of the firms. Specifically,

³ There are many studies that corroborate the positive relation between innovation and size. One of the first work on the subject was made by (Scherer, 1965).

the entries under Fixed Intangible Assets of the balance include mainly, firm spending on R&D as well as patents, industrial secrets, etc., that is, as a proxy, everything involving innovation in the broadest sense⁴. The results confirm the substantial difference in R&D spending from one group to the other. While the SMEs show a relation between Intangibles and the rest of Fixed Assets from 7.8% to 8.1% between 1999 and 2003, the values for the LFs are between 13% for the year with the lowest figure (1999) and 15.5% for 2003, doubling the budgetary commitment to innovation in SMEs (Table 1).

Table 1
Total European Industry
Intangibles Fixed Assets/Total Fixed Assets

	1999	2000	2001	2002	2003	2004
L.F.	13'0%	15'2%	16'6%	16'1%	16'5%	20' 7%
SMEs	7'3%	7'49%	7'0%	7'4%	8'1%	5'9%

Does this mean that the creation of innovation, **understood as the creation of technology previously non-existent**, grows at a rate double that of imitation? Certainly not. First, the numbers shown belong to the aggregate entries of intangibles of a sample of European industries for a specific period. Although the magnitude of the sample guarantees it's robustness, it cannot be said that all entries under Fixed Intangible Expenditure are only related to innovation processes. Second , if we assume the existence of decreasing returns for innovation, the various rates of spending on intangible assets will disguise increasing difficulties in LFs to produce innovation when resources per production unit (of innovation) are on the rise. And third, and probably more important, the numbers show that SMEs also expend a great deal on intangibles assets and some of them, and in key sectors such as IT, Software Programs, Pharmaceuticals are Knowledge Intensive. So even though SMEs expend in Intangibles a smaller proportion than LFs, ¿does that mean that we have to modify our two group model of firms behavior?.

Adaptation and Marginal Conditions

⁴ Further work to see what else is inside the "Intangibles Assets Account" and more elaborate statistical work, is obviously needed.

Ceteris paribus, adopt, adapt and diffuse, is what any SMEs in Clusters does best. Entrepreneurs are always looking for opportunities to improve their firms position on the market and, as a result, creativity, productivity, employment and growth are high within and among these types of firms but, and these is crucial, they are compelled by the market to remain on competitive pricing. At least we can identify four sources of creativity through adaptation in industrial SMEs: First and already said, the entrepreneur actions are vital for any firm; it will be important to differentiate the entrepreneur as a manager from the entrepreneur as a creator of productivity through changes in his production methods. Second, any productivity gains is conditional of tacit knowledge among the firm's labor force. Third, most of the firms will react to market conditions incorporating new and more efficient capital goods (embedded knowledge) that bring new ways of manufacturing, improving productivity and reducing costs. And four, occasionally, many of them and certainly in some key sectors (IT, Programming, Pharmaceuticals, etc), will engage in formal R+D activities, that is, systematically looking for new products or processes but, in its day to day business, merely will adapt its resources to increase efficiency.

Therefore, given the existence of entrepreneurs and labor force's tacit knowledge, looking for opportunities translates in new ways to manufacture either through investment in capital goods and the changes it brings to the floor firm or through occasional R+D, or both. Furthermore, SMEs improve and are required to improve the way of doing business just to stay in the pool of firms with marginal conditions where $p=mc$ puts a cap on its prices. Remember that $m. c.$ pricing reflects today's tendency of a long run backward and forward processes generated by firms acting in the market. The price is, among other things, a signal reflecting the technological and efficiency considerations of the industrial fabric; that is, a moving target always with differences and opportunities to arbitrate (through the individual firm's cost). It's there where any SMEs could and must act. In brief, it's there where the firm should adapt.

The relatively low rates of spending on imitation by SMEs would suggest that these firms are very efficient in adopting/adapting and, particularly, in diffusing new technology. In effect, if the economy is considered as a whole, it becomes apparent that

the existence of both LFs and SMEs responds to a complementary productive logic. As postulated above, increasing internal resources committed to formal R&D means that remuneration for LFs can only come from price mark-ups on their products which initially impedes that significant proportions of the population are able to consume the product. Although the success of the product on the market has been proven, if increased and generalized demand is desired, prices should go down.

Once the technology is adapted, it is in this instance that the SMEs find a fertile field of action. They can generalize production of components of the product, or the product itself, at lower prices than the LFs and therefore significantly bring the price of the final good down. Hence, LFs control the final good and the innovating processes while SMEs diffuse and cheapen the components of the final good or of an "imitated" final good. Mutual necessity make these actions complementary.

Although the declivity of SMEs from the industrial panorama was predicted throughout the entire 20th century, in fact their capability of creating jobs and entrepreneurial potential have made them extremely resistant to the passage of time (Capellin, 2003). For reasons describe above, the task of innovating, quintessence of the capitalist system and crucial to increased productivity, usually falls to the LFs while that of diffusion is generally in the hands of the SMEs. Of course, the innovation chain originates with the LFs, is then transmitted to SMEs and eventually filters into the rest of the productive process. Not all SMEs are equally able to adopt and adapt innovation, but once innovation is launched on the road of diffusion, the cost of imitating decreases, particularly due to cluster technology as shown above.

Adopting and adapting can be highly efficient activities. By saving resources, entrepreneurs can act freely in competitive markets with prices that tend toward marginal cost, but are still profitable. In fact, when costs of imitation are relatively low, the contribution of these firms to the productive system and to the welfare of society is highly positive as shown in the sheer number of SMEs, the jobs they create, their investments, assets, sales, etc. (see Amadeus, *ibid*).

The aeronautical sector is characterized by three main aspects: 1) a historical trajectory closely linked to the State, although oligopolistic firms have recently moved nearer to market conditions; 2) high technological and organizational complexity of many participating firms; and 3) a dual local - global geographic projection. This is the profile of the Spanish sector and, most likely, of the European sector as well.

The sector's proximity to States has been present since its origin. Due to the sector's strategic nature the incipient industry rapidly became "state policy". Even today this proximity has not disappeared although the sector has gradually approached the market thanks to "peace dividends" and the rapid development of commercial aviation.

The market is dominated by a small number of manufacturers. If Russian production is excepted, only four firms operate in the market as producers of aircraft for civil aviation and only two in aircraft of more than 100 seats. The oligopolistic nature of the sector is obvious, as is the heated competition in the area of innovation. Finance, technology, size, security and quality levels in production processes are barriers to entry which is why economic literature considers the sector a canon of industrial complexity.

In aeronautics, industrial organization has been transformed from production units with an arsenal mentality, where in-house production prevailed, to increasing processes of externalization (outsourcing, spin offs, internationalization) over the last 30 years. This process is attributable to increasing financial needs involved in the launching of a new aircraft, greater technical complexity required by external technological partners and the need to control costs.

Financial needs have motivated explicit state support, usually in the form of reimbursable credits for R&D investment, as well as the need to share risk in future industrial products through alliances with other large technological firms either in the same geographical area or in the international scenario. These firms are not necessarily experienced in the sector of aeronautics.

Again, an analysis of data from the Amadeus database of spending on Fixed Intangible Assets in the European aeronautical industry (group 354 in the NACE classification) indicated the same behavior and bias as with the sum total of European industry observed above (Table 2). That is, the percentage of the intangible assets in LFs in relation to total fixed assets is much higher than the figure for SMEs. Moreover, the gap in intangible assets spending is much higher in the aeronautical industry than that

registered for total European industry. A ratio from 19.8% to 15.5% was found for SMEs in the period from 2000 to 2004 while the values for LFs in the same period are between 44.8% and 38.6%. The findings for European wide aeronautical sector tell us that for the reasons postulated above, if LFs spend more on R&D they should innovate more than SMEs.

Table 2
European Aeronautical Industry
Intangibles Fixed Assets/Total Fixed Assets

	1999	2000	2001	2002	2003	2004
L.F.	44'10%	44'8%	39'10%	39'7%	39'4%	38'6%
SMEs	12'3%	19'8%	13'8%	14'4%	17'1%	15'5%

If instead of looking at the above ratio, we focus on some key financial ratios by firm employees (table n° 3), we see the same pattern of increasing financial values with increasing firm labor force. Apparently, the bigger the enterprise the bigger their margin, their labor cost and their profit per employee. That is, they flee from price competition towards innovative competition and oligopolistic behavior.

Table 3
European Industry
Financial Ratios

	1- 50	50 - 250	250-100.000
Profit Margin (%)	2,69	3,38	5,31
Return on capital employed (%)	8,12	10,14	11,58
Return on total assets (%)	2,44	4,12	5,71
Aver. Cost of empl./years (Ths.)	27	23	29
Profit per employee (Ths.)	6	6	12
Gross Margin (%)	3,84	6,85	9,59
EBIT Margin (%)	3,45	3,67	6,08
EBITDA Margin (%)	6,41	6,73	10,36

Export turnover/ Total turnover (%)	3,45	5,89	13,78
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The process of internationalization is presently consolidated as shown in an analysis of the EADs/Airbus case which has assembly plants in at least four countries and collaborating firms in many other geographical locations. Moreover, competition for work load among the various factories and plants is fierce, a structural factor of the firm's industrial strategy. The central headquarters of the group annually assigns the work load to each one of its divisions and international sub-headquarters according to the number of work/hours assigned to each center as a control variable. From that point on, each EADS assembly center is defined by its work load and, therefore, its production and job potential. Decisions made by the central headquarters of the company reverberate in cascade fashion throughout the entire production and supply chain whether the firm belongs to EADS or is external to it. Consequently, there is strong pressure on firms that produce for EADS to reduce costs, an added risk for those that operate near competitive equilibrium. EADS has recently launched a widespread program to reduce costs, with goals placed at a 15% decrease, which will particularly affect SMEs with a low level of technical knowledge.

The Madrid aeronautical sector is clearly constrained by de “physical budget restriction” imposed from EADS/AIRBUS central headquarters. SMEs within the cluster (second and third level subcontractors), are struggling to keep prices and costs down to comply with higher up subcontractors which translates in lack of maneuver to engage in any type of formal R+D. They mostly do either work under blue print or some specific design for tooling development. These enterprises are both technologically and functionally dependent. The first level subcontractor are the ones who are able to produce new applied knowledge (innovation), usually working together with the research department of the main enterprises. Even though they are mainly related with aircraft construction, new ones are coming from unexpected fields due to increasing complexity of the sector.

Additionally, increased outsourcing has the disadvantage of a significant increase in governance problems and transaction costs. For EADS, globalization not only means its products are easily demanded, but also that the transaction costs of having to manage complex and distant organizations (governance problems) will increase. With the new

program, there will be fewer suppliers although they will probably have a greater work load. EADS intends to establish direct relations through Communication and Information Technologies with its group of suppliers in an effort to avoid the more than 90 kilos of paper, on the average, required to present a bid for collaboration with EADS. This project will require adequate technical formation not always within the reach of all SMEs. The sector in Madrid is lobbying to develop a common platform for SMEs to coordinate the subcontractors bids and monitor the work in progress within the suppliers value chain.

EADS is developing a "model of industrial relations" with its suppliers centered on the capability, quality, competitiveness and security of the deliveries by the companies that make up the industrial framework related to the title company. Beyond any wishful thinking that the concepts put forth in this model may awaken, their implantation in the aeronautical sector in Madrid will not be a simple task. The complex industrial and organizational requirements intrinsic to the sector are compounded with the requirements arising from the internationalization of production of aircraft sub-components. The sector will undergo adjustments in its composition whether as a compensation to win contracts or, more likely, due to outsourcing in search of lower costs for equal quality, capability and delivery time. As today, we have not seen that movement in the aeronautical cluster of Madrid but, if it happens, would put additional pressure in the existing SMEs in the industry.

The model of innovation and diffusion in the aeronautical sector shows, and the Madrid Region reproduces, a hybrid structure made up, on the one hand, of those firms of an oligopolistic nature that produce innovation and those that adopt and adapt innovation⁵. The entire model forms an industrial ensemble of a pyramidal nature at the service of the final product. The architecture is closed within the model, but can open to foreign markets through internationalization of the final producer and its network of global collaboration.

POLYCENTRIC INNOVATION NODES: LOCAL AND GLOBAL IMPACT

⁵ As mentioned, it could exist SMEs with an active role on innovation specially in sectors such as drugs (pharmaceuticals), IT development, and even aeronautics but, their numbers, so far, are low.

Innovation in the cluster flows horizontally among the R+D centers of the eight or ten large multinational firms involved in producing the components assigned for the aircraft. Reciprocal activity among Airbus and the LFs and, to a lesser degree, the SMEs in the sector has brought about the figure of "innovation nodes" in the regions (in our case Madrid), where EADS/Airbus production units are located. The nodes agglutinate and interact among themselves through the R&D departments of the final builder organized into Centers of Concurrent Engineering (C.C E.s), the Research Centers created by the firm in Hamburg, Toulouse and Getafe, and the innovation departments of the rest of multinational firms. These nodes concentrate all the innovation effort carried out in the territory where firms are engaged. Of course, the creation and transmission of information throughout the nodes would have been impossible without advanced information technology.

At the same time, innovation in the sector also flows vertically from the innovation nodes of the final producer and first level firms toward the multitude of firms articulated in clusters. Depending on its technical capabilities, each firm has access to a given level of knowledge and the position of the firm on the quality ladder determines its position in the structure of prices to be charged/received. The SMEs compete in price whose margins depend on their contribution within the value chain.

Specifically, the aeronautical cluster of Madrid is formed by a geographical concentration of very different firms, inter-related and specialized in the production of specific parts of the products that the two large oligopolies of the aeronautical industry commercialise, particularly EADS, as well as auxiliary firms, and firms and organizations that supply services to the cluster.

- At the center of the aeronautical cluster of Madrid is the EADS consortium, through two of its firms EADS-CASA and Airbus España.
- Around this central nucleus exists a set of firms that are related to the EADS group, but who also work with Boeing and other firms and organizations of other aeronautical, aerospace and industrial activities, as is the case of Indra, Gamesa, Sener and Tecnobit, that have been studied in the sample.

- In the aeronautical cluster of Madrid there exists another group of firms specialized in the manufacture of goods and services for the aeronautical industry, among which the following have been studied: Cesa, Tegraf, Gasc and Aerlyper.
- A relatively important part of the firms in this sector manufacture products and supply services for other industrial activities, and some of them even come from industries that have undergone a strong restructuring process as occurs with Tam, Aprim and Ramen, who previously produced for the automobile sector.
- Finally, a group of firms exist that shape the auxiliary sector of the aeronautical industry, among which we find Industria Carmona and Quality Metal.

The aeronautical cluster of Madrid, still underway, it appears to display an organization that obeys the Hybrid Model just described, given that around the large firms of the EADS group the cluster firms organize themselves to supply goods and services that allow construct airplane parts designed by EADS-CASA and Airbus. Furthermore, it is an example of a productive system of goods that incorporate modern knowledge and whose strength lies in the fact that the firms create and share this knowledge between them. Yet the cluster of Madrid also forms part of a network of centres and clusters located in different territories of Europe, influenced by the decisions of EADS.

The relations between the aeronautical firms in Madrid vary greatly. In some cases the relations are formal and explicit, and obey the decisions of the firms and actors and seek clear objectives, as occurs with commercial exchange of goods and services, the commercial relations between suppliers and clients and the technical relations between firms.

One of the keys to the functioning of the aeronautical productive system in Madrid is undoubtedly the commercial relations established between the firms of the cluster, as well as with the suppliers and clients from other clusters and activities with whom local firms relate.

Change in the organization model of aeronautical production has promoted important changes in the aeronautical firms by outsourcing a part of the production phases and developing subcontracting to different levels.

Subcontracting can be carried out in different ways and its content will depend on the type of product or service under contract. Thus, the Tam group specifies the forms most commonly used:

- Realization of complete packages: from the conceptual design to the final product certified and delivered.
- Establishment of mixed teams (firm-client) in charge of accomplishing complete packages
- Mobility of human resources to the client premises for engineering, trials, assembly, metrology and manufacture.
- Logistic support for the product, from the design phase to the results of the material.
- Partial subcontracting of design activities, manufacture, assembly or verification of mechanical components.

The relations among subcontractors and suppliers are characterized by strong competition between them for obtaining contracts to participate in the manufacture of specific products. Thus, competition between firms that manufacture final products has shifted to the subcontracted firms that supply parts of the product. Nevertheless, cooperation among competing firms is not uncommon, particularly when there is much work or one of the subcontracted firms needs the help of another member of the network to get the job done.

The formation of the network and the consolidation of relations is based on agreements, contracts, alliance between firms in the network that allow firms obtain scale economies in the production and in the research and development of products and processes, and on the other hand, reduce production costs. This kind of relations also affects the subcontracting firms who allow the territorial takeoff of the large aeronautical firms. In this sense, the attraction of the Madrid region has much to do with the availability of skilled human resources, the existence of firms and organizations that accumulate

knowledge and know-how, as well as the existence of a manufacturing productive fabric that has taken shape during decades.

Access to innovation is not free in these complex aeronautical clusters. There are entry barriers that can only be overcome with the compliance of firms belonging to the innovation node which predetermines an asymmetrical contractual relationship among firms. The lower the technological capability of the SME, the more entry barriers it must overcome and, consequently, the greater the sacrifice it must make in the industrial margins of its products and the greater its organic and technological dependence. The firm will be passive in formal innovation and its position will be within marginal conditions. Contrarily, the higher the level of the SME on the quality ladder, the greater the possibility that it will be assigned value-added tasks and receive remuneration above marginal cost. Table n° 4 shows a list of the aeronautical firms studied in Madrid and their position in the quality (innovation) ladder.

This hybrid model, with its innovation nodes, is based on two spatial realities. On the one hand, final producers, many of the large multinational firms and the SMEs tend to locate in a given territory near other agents active in the sector (professional associations, research centers, public authorities, etc.), forming the **local** framework of the sector. On the other, the search for financial and technological support, clients and improved production costs have opened an inevitable process of internationalization which profiles the **global** nature of the sector. Moreover, the global factor will be increasingly significant and will require adaptation on the part of the local framework.

Table n° 4
Madrid Aeronautical sector: Innovation ladder

ENTERPRISE	Workforce	R+D employees	Sales V° (million €)	Knowledge Flow
MAIN ENTERPRISE				
EADS / CASA	5141	10% (514)	813 €	Capacity to produce complete processes of aircraft manufacture. Innovation firms with formal R+D
AIRBUS	2272	19% (432)	468 €	

1st LEVEL SUBCONTRACTOR				
GAMESA AERONAUTICA	1552	17% (263)	233 €	
INDRA	5200	8% (416)	607.4 €	Innovation firms with formal R+D. Technologically independent but Functionally dependent.
SENER (BOREAS)	89	6% (5)	4 €	
CESA	212	23% (49)	32 €	
2nd LEVEL SUBCONTRACTOR				
TECNOBIT	159	2% (3)	22 €	SMEs and occasional R+D. but very active adaptation firms. Functional and technological dependent. Capacity of design and specific engineering development.
AERLYPER	51	4% (2)	7 €	
TGA/TEGRAF	100	5%(5)	10,10 €	
GRUPO TAM	300	1% (3)	11,90 €	
3rd LEVEL SUBCONTRACTOR				
APRIM	46	2% (1)	5 €	SMEs. Functional and technological dependent. Work under blue print. Adaptation firms.
INDUSTRIA CARMORA	19	0	2 €	
RAMEN	19	16% (3)	1.5 €	
QUALITY METAL	17	0		
GAZC	11	0	4.9 €	

CONCLUSION

The industrial sector is mainly based on a complementary action of two groups of firms sharply separated by the requirements of the markets in which they participate. On the one hand, oligopolistic large firms in high technology sectors must innovate to remain competitive and to retain their market share and profits. For LFs, innovation, rather than price, is the key variable to be considered. On the other hand, SMEs in Clusters mainly adapt and diffuse innovative processes throughout the industrial fabric by means

of price reduction. These firms mainly participate in markets where price competition is the priority.

Moreover, the aeronautical industry has added to these characteristics the action of polycentric nodes in which its engineering centers work together in real time with indispensable information technologies to develop the various parts and components of the aircraft. Local action of the innovation node facilitates connection to the territorial cluster and the certainty of cost reduction per production unit of each sub-component, while global action of the node links local industry to the other innovation centers with the ultimate goal of obtaining a final product with the highest content of innovation possible.

Given the existence of innovation gaps among the various groups of firms in the industry, the most appropriate policies should guarantee a continual flow of new innovations toward the SMEs in the sector. These policies should focus on minimizing the time involved in adopting and adapting innovation on the part of SMEs. At the least, policies should try to keep the innovation gap from becoming wider. We must run to stay in the same place, as occurred in Lewis Carroll's famous book.

Agents involved in the model of creation and circulation of innovation proposed here should be aware of the ultimate cause of their existence which is a capitalist system that endows itself with an institutional framework aimed at propitiating innovation. Providing technological transfer policies do not contradict this institutional framework, they should aim to generate greater opportunities while minimizing the time needed to adopt and adapt innovation.

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