The New Geography of Corporate Research in Information and Communications Technology (ICT)

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Abstract – Innovation promotes change, development and transformation of capitalism through a continuous and incremental adaptation of economic and social organisation. In the development of new knowledge, firms have been identified as the main actors, without disregarding their interaction with territorial systems. Indeed, the significance of the local spatial dimension in the creation of new knowledge has been emphasised especially in the most recent literature. The global-local nexus that characterises the new ICT-based paradigm creates new conditions for knowledge creation as illustrated by the emergence of international corporate strategies to diversify the sectors of competence creation across locationally differentiated sources of innovation.

Using patent data granted in the US to the largest European-owned electrical and electronic corporations and all the largest companies in other industries for their research located in European regions, this paper aims to investigate the regional dispersion of European-located ICT research activity. Starting from the results of a previous study, the paper explores whether co-specialised European-owned electrical companies tend to develop related R&D in the same regional location. This research question is investigated here by taking into account a wider geographical span of European regions than in earlier work. Moreover, we can explain the co-specialisation-co-location issue as being related to the nature of inter-firm relationships (through the prevailing balance between competition and cooperation).

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1. Introduction

In the ICT-based paradigm, the role of innovation in promoting, change, development and transformation of the underlying socio-economic capitalist system has been clearly enhanced. Historically, the impact of innovation on the socio-economic system has taken place through a continuous and incremental adaptation of economic and social organisation. This can be observed by comparing the old paradigm, based on energy and oil-related technologies, and the new paradigm, based on ICT and related technologies. The former was grounded on mass production with its economies of scale and specialised corporate research and development (R&D), while the latter is characterised by economies of scope, derived from the interaction between flexible but linked production facilities and a great diversity of search in R&D. A distinctive feature of the current modes and forms through which innovation generates major systemic techno-socio-economic changes can be identified in the increasingly complex character of technology, the consequent rise in technological interrelatedness, and the great technological combinations made feasible by information and communications technologies (ICT). If these specific features have emphasised the role of the firm as the main actor in the development of new knowledge, in the most recent literature they have also let to the re-discovery of the significance of the local dimension in the creation of new knowledge.

Due to the increasingly complex nature of technology, the boundaries of the firm cannot fully encompass any longer the entirety of new knowledge generation required by an innovative company. This has promoted the adoption of corporate sectoral and spatial strategies aimed at outsourcing new knowledge creation from complementary technological sources and absorbing them into the firm’s technological portfolio through inter-firm relationships. With the ultimate aim of enhancing competencies for the sake of corporate competitiveness, firms are extremely sensitive in seeking out foreign centres of excellence for the creation of knowledge outside the primary fields of their own industry, while tending to avoid locating technology creation in their primary fields in the home centres of their major international competitors (Cantwell and Santangelo, 1999a, 2000; Cantwell and Kosmopolou, 2000). On the grounds of this strategic distinction, the relationships between firms and territorial units follow different patterns. The selection of locations by multinational corporations (MNCs) for the purpose of siting their corporate research and development (R&D) laboratories is highly influenced by the complementary capabilities of indigenous institutions and technological traditions, especially when local firms are not major competitors in the same final product markets. MNCs seem to be attracted most by the overall economic structure of regional systems and by the consequent opportunities for successful corporate performance. Therefore, local economic growth and external corporate spatial attraction are interdependent and mutually reinforcing phenomena as their interplay reproduces geographical hierarchies and corporate competitive performances over time through *vicious* and *virtuous* cycles.

Similarly, due to the complex character of technology and the increasing innovation potential from the fusion of formerly unrelated types of technologies through ICT, the link between the local and corporate dimension has gained a strategic importance in the generation of technologies that are core to the current paradigm (notably ICT). The need to develop these technologies is shared by the firms of all industries, and the knowledge spillovers between MNCs and local firms in this case may be inter-industry in character. Thus, ICT development in centres of excellence is not the prerequisite of firms of the ICT industries themselves, for which such activities

are primary and generally concentrated at home, but instead involves the efforts of the MNCs of other industries in these common locations (Cantwell, 1999). However, firms of the ICT industries may distinguish the varying degree of centrality to themselves of different technologies from within the whole basket of ICT fields when targeting centres of excellence for the purpose of siting research activity. ICT firms may locate abroad (in other centres for the industry) the development of some ICT fields which lay outside their own primary interests among the ICT sectors. In the learning process, the attraction to locationally separate and differentiated sites for the creation of different ICT fields is due to the complexity of combinations required within cutting-edge technology, the consequent uncertainty and risks linked to high R&D costs, and the need to cooperate between firms within a region while increasing knowledge flows within MNCs across regions or national boundaries in order to design the multi-technology systems which are brought together in part through ICT.

In this context, the aim of this paper is to analyse the spatial dispersion or concentration of ICT corporate innovative activity within the European ICT industry[1] at a sub-national (i.e. regional) level. Using patent data granted in the US to the largest European-owned electronic corporations for their research located in the most developed European regions, the present study is the latest development of a sequence of related studies building upon one another. The initial starting-point of the research were the results obtained in a previous analysis (Santangelo, 1998), from which clusters of European-owned electronic companies specialising in equivalent ICT technologies were identified over the period 1969-1995. On these grounds, a further investigation tested the hypothesis re-stated below in the context of three national groups of regions (Santangelo, 2001). Beginning from these results, the present study explores further the following hypothesis by taking into account a wider geographical span of European regions than in the earlier work just referred to.

Hypothesis: in each of the three sub-periods under analysis (1969-77, 1978-86 and 1987-95) the technological clusters of companies identified as being grouped together in terms of common profiles of specialisation in ICT technology (co-specialisation)[2] also locate their related R&D in some common region (co-location)[3]. In other words, we test whether co-specialised European electronic companies co-locate investments in equivalent field/s of ICT technological co-specialisation in a common European region.

The paper is organised in 7 main sections. The following section elaborates upon the framework for analysing the implications of sectoral and spatial corporate strategies for competence accumulation. Section 3 describes the data used. Section 4 discusses the geographical evolution of ICT corporate research activity in the European regions. The empirical evidence on the hypothesis of co-location and co-specialisation is presented and discussed in the section 5. Section 6 reviews the analytical framework in the light of the findings. Some conclusions are drawn in section 7.

2. Strategic implications of sectoral and geographical aspects of corporate R&D: a preliminary theoretical framework

The construction of a complete economic theory of technological change grounded on the evolutionary tradition calls for a theory of the firm able to fully understand and explain the production, development and re-generation of corporate technological capabilities over time. This need arises from the evolutionary concept of technology, characterised by both a public (or codified) and a private (or tacit) element (Nelson,

1992). The former includes free and widely available knowledge (e.g. blueprints, books, etc.), while the latter attains to knowledge embedded in corporate *routines* upon which the firm's specific capabilities are built and reproduced over time. Therefore, firms play a crucial role in the process of knowledge creation, characterised by the path-dependency of firms' specific technological trajectories (Cantwell and Fai, 1999). If the specificity of corporate capabilities in generating innovation defines the firm's own trajectory of technological development, some general trends concerning corporate technological diversification and internationalisation have been identified in the literature (Cantwell and Piscitello, 2000).

As far as diversification is concerned, the complex character of technology, increasingly emphasised by interrelatedness and fusion between formerly separated technologies (Kodama, 1992), has promoted the rise of the model of the "multi-technology" firm (Granstrand and Oskarsson, 1994; Granstrand, 1996; Granstrand *et al*. 1997; Patel and Pavitt, 1997). This corporate "model" allows the firm to adapt in the new techno-socio-economic conditions, in which major new opportunities for innovation based upon corporate technological diversification have arisen. The technological base of the company needs to be wider than (and is now less well related to) its product base, as the development of corporate capabilities in a wider spectrum of technologies has become an essential condition for exploiting potential technological combinations made feasible by the current paradigm, and thereby to facilitate successful output performance. The reason lies in the growing number of technologies entering into the production of a single product. Nonetheless, if corporate multi-technological portfolios are a necessary requirement to perform successfully, the firm finds it difficult to develop competencies across an increasingly wide range of technologies. In this sense, technological complexity, interrelatedness and fusion affects inter-firm relationships which create opportunities for knowledge outsourcing and technology-based alliances.

The corporate outsourcing of new knowledge has also a spatial dimension, since the firm may enhance its capabilities by increasingly dispersing geographically its intra-firm networks across a range of locations. This internationalisation strategy is substantially different from the international strategy adopted in the early post-war period, in which the primary aim was the conquest of new markets through the adaptation of products to local consumer preferences. Conversely, the closer international corporate integration that has occurred in the leading MNCs since the 1960s, aims to establish geographically dispersed networks for the purpose of the transfer of technology, skills and assets across national borders between the parent company and its affiliates (Cantwell, 1995). The sustainable competitive advantage built on this transfer lies in the two-way interaction between parent and subsidiaries. The transfer goes from the parent to subsidiaries, but also from the subsidiaries to the parent company. Local laboratories played a new role within the whole corporate structure by sourcing new knowledge from the local environment rather than carrying out merely demand-oriented activities (Papanastassiou and Pearce, 1994; Barlett and Ghoshal, 1995). Moving from the idea that increasing returns are essentially a regional and local phenomenon arising from regional economic agglomeration and specialisation (Krugman, 1991a, b), different approaches[4] emphasising the role of local *spatial areas* for the purpose of global competitiveness, have flourished in recent economic theory. In analysing MNCs' internationalisation strategy, it emerges clearly that multinationals target local *spatial areas* where they can enjoy externalities and knowledge spillovers. This promotes, in turn, a ranking of the attractiveness of territorial units, which consequently engage in competition to attract foreign direct investment (FDI) as well as

to encourage a concentration of corporate activity in "higher" order territorial units. Therefore, corporate activity is more and more sensitive to the conditions of localised cumulative processes as multinationals aim to outsource knowledge by tapping into local expertise.

Therefore, the sectoral and spatial composition of corporate R&D impacts on the firm's strategic goal of competence accumulation. As the issue of the extent of co-location and co-specialisation with other firms attains to inter-company relationships, significant implications arise for inter-firm strategic dynamics which affect the pattern and degree of competence accumulation over time. The distinction between strong and loose co-specialisation between two (or more) companies helps to drive their spatial interaction in terms of either co-location or non-co-location, as well as to shape their corporate strategies with respect to one another in terms of either competition or cooperation respectively. Corporate competitiveness, understood as the outcome of a process of competence accumulation, can be derived from either competitive or cooperative linkages, the balance between which is dictated by the degree of overlap in firms' specialisation profiles and reflected in their spatial strategies. In this sense, the relationship between co-location and co-specialisation and its implications for corporate strategy can be summarised in Figure 1, as a framework for analysis. Figure 1 plots the "degree of co-location"[5] on the y-axis and the "balance between inter-firm competition and cooperation" on the x-axis. The former variable runs from co-location to no co-location, while the latter variable runs from high corporate competition to high corporate cooperation. Therefore, the closer to the origin, the greater the extent of no co-location (and the intensity of competition) between companies, while the further away from the origin the greater is the degree of co-location (and the intensity of inter-firm cooperation). The hypothesised relationship between the two variables is shown by the downward sloping trend line in Figure 1. This implies that if firms do not co-locate their research in a given field/s, the reason may be found in the strong co-specialisation of their technological profiles in the field/s in question which renders them principally as competitors to one another. The strong overlapping of the capabilities of two (or more) firms in a particular field/s acts as a deterrent to the common development of their related R&D in the same location. In this sense, few complementarities can be enjoyed by firms as they are competing around an equivalent spectrum of activity. Conversely, a pattern of co-location of R&D activity in a particular field/s is likely to be associated with a loose co-specialisation between two (or more) firms in the field/s in question. The lack of a complete technological overlap (and rather the presence of some areas of expertise that distinguish one firm from another) creates the conditions for inter-firm cooperation, through which complementarities can be enjoyed and competencies related to the firm's own technological profile can be absorbed from the external environment into its corporate technological path.

3. Some notes on the data

The data, upon which the empirical evidence provided in this paper is based, concern US patents granted to the world's largest firms, drawn from a database held at the University of Reading. For the purpose of the present paper, it is worth noting that the patent document records (among other useful information) the address of both the inventor and owner (assignee) of the invention. In other words, the location in which the R&D activity was carried out is provided by the patent records, and can be separated from the location of the headquarters of the parent company to which the patent is

ultimately assigned assigned, which can be inferred through the corporate consolidation of patents.[6]

At least two major advantages are associated with the use of these data. First, the data refer to patenting in a common third country - i.e. the US - which allows a more reliable international comparison on a commonly imposed standard and under a common legal framework. Second, foreign-owned patents (in this instance European-owned patents due to European-located research facilities) are expected to be of a higher average quality than domestic patents (i.e. US-owned from US-located facilities) as it is reasonable to assume that only patents that have survived preliminary testing in the home or host country will be extended abroad. The wider advantages and disadvantages of the statistical use of patent data have been covered extensively in the literature (see Pavitt, 1985; Griliches, 1990), and will not be discussed further here. However, in an analysis of ICT a drawback in the use of patent data lies in the fact that software innovations have started to be patented in a major way only since the mid-1990s. Nonetheless, for the purpose of the present study, the significance of this omission from the range of ICT fields included is somewhat limited by the weak European performance in software technology by comparison with their US competitors (Malerba, *et al*. 1997).

Going further into the detail of the structure of the Reading database, each patent is classified by the type of technological activity with which it is primarily associated. The 399 original classes identified in this way by the US Patent and Trademark Office can be collected together into 56 technological sectors, of which 6 sectors comprise the main field of ICT.[7] The data used refer to all 23 European-owned firms classified in the broad electrical corporate industrial group among the world's 784 largest firms. For the purpose of this paper, the empirical analysis was carried out at the level of the original

399 patent classes by selecting those 31 classes which make up the 6 ICT technological sectors.[8] The broad electrical[9] corporate industrial group includes the electrical equipment (communications) and the office equipment (computing) industries.[10] In this context, the corporate geographical distribution of ICT technological development is investigated across Europe over the period 1969-1995.

The spatial analysis of large corporate research activity in the European ICT industry is carried out at a sub-national level. The geographical distribution of European electronic corporate patenting activity in the ICT technological sectors is investigated across Belgium, Germany, France, Italy, the Netherlands, Sweden, Switzerland and the UK, for which regionalised patent data are available in the Reading database. For each of these countries, the sub-national entities identified correspond to territorial units as classified by the European Nomenclature of Territorial Units of Statistics (NUTS). In order to ensure as much comparability as possible, the NUTS 1 level is used to identify Belgian, Dutch, German and UK regions, while as far as French, Italian and Swedish regions are concerned, the NUTS 2 level is adopted. In the case of Switzerland, no NUTS subdivision is available for the Swiss territory as it is a non-European Union (EU) member. Therefore, in the Reading database, Switzerland is geographically subdivided in 12 regions according to proximity to big cities. As pointed out by Eurostat (1995) and Dunford (1996), despite the aim of ensuring that comparable regions appear at the same NUTS level, the same level of disaggregation in various countries still implies considerable differences between regions in terms of area, population, economic weight or administrative power, and so it is necessary to choose the most appropriate NUTS level in each case to reduce the effect of inter-country differences in the classification scheme. Thus, the 3 Belgian *régions*, the 4 Dutch *landsdelen*, the 22 French *régions*, the 16 German *länder*, the 20 Italian *regioni*, the 8 Swedish

riksområden and the 11 UK *standard regions* seem to allow some comparability as far as innovative activity is concerned (see Table A3).[11]

In addition, the sub-national units identified host almost completely the entire bulk of research activity conducted within the European electronic industry in Europe as shown by Table 1. In Table 1, the European regions are arranged by national groups and ranked according to the share of research activity carried out by European electronic companies relative to Europe as a whole (as measured by the corporate patents sourced from such research facilities).

4. The regional hierarchy in the corporate development of ICT research activity

In order to provide some general background on the regional geography of corporate development of ICT research activity within the European electronic industry, we begin by drawing a picture of the spatial dynamics concerning the distribution of R&D laboratories across European regions. The aim is to gather some of the major elements which can help us to analyse whether technologically co-specialised groups of firms are co-located in the regions considered.

As shown in Table 1, the regional areas under analysis account for almost 98% of the entire ICT research activity carried out in Europe by the largest European-owned electronic companies. Similarly, the figures in the Table provide us with some preliminary understanding of the geographical hierarchy in terms of the location of the corporate development of ICT research activity as shown by the top-ranked position of German, French, Dutch and UK regions. In order to have a more detailed overview of this trend, Table 2 ranks the regions considered by the percentage of European ICT technological activity located in each of them relative to Europe as a whole over the period 1969-1995. The figures reveal a pattern of strong concentration in a few major centres of ICT corporate technological development in the industry in question. Almost 70% of the research activity European-owned electronic companies conducted in Europe is due to facilities in six regions: Bayern, Ile de France, Zuid-Nederland, the South East (UK), Baden Württemberg and Stockholm. Therefore, the pattern of a strong concentration of R&D in Europe, suggested by Caniël's findings (1998) is also confirmed in the context of the European electronic industry. It is interesting to mention that the German, Dutch, Swedish and UK regions identified maintain their top position in the geographical hierarchy by comparison with the results obtained in previous empirical studies on this industry, focusing on an either small or different span of European regions (Cantwell and Santangelo, 1999b; Santangelo, 2001). This suggests that the inclusion of new regional data now available does not undermine the strength of these top-ranked regional units overall.

The six locations top-ranked in Table 2 hold also a leading position as major *spatial areas* for ICT knowledge creation across the ICT technological sectors considered individually as illustrated in Table 3, in which all the regional locations considered are ranked by the size of the European-owned research in each of the ICT technological sectors relative to Europe as a whole. From a glance at the figures, it emerges clearly that the six regional centres are at the top of the hierarchy in each of the technological fields analysed, allowing for some variance in their ranking across sectors. Nonetheless, a few exceptions should be mentioned as illustrated by the case of Zuid-Nederland in "special radio systems", and Stockholm in "image and sound equipment" and "semiconductors". The two regions seem to lose position in these sectors in the overall ranking, although they do not slip down much. It should also be mentioned that the six regional locations identified can be labelled "higher" order

regions as well in terms of production. Figure 2 illustrates their per capita GDP for 1994 by comparing them with the "Europe 15" total.

On average this cross-sectoral intra-industry analysis seems to provide further empirical support for the idea of "regional clubs" within Europe (Verspagen, 1997). If the geographical ranking across sectors is rather stable at the top of the hierarchy, stability also characterises to some extent lower ranked regions across ICT sectors. This stability over time may be interpreted as a result of cumulative causation mechanisms promoting *vicious* and *virtuous* circles and reinforcing geographical inequalities. A strong path-dependent character is found in the local ability to develop an entrepreneurial environment through expertise accumulation and, consequently, to attract the quality investments of MNCs (Metcalfe, 1996). In this sense, the global-local nexus shapes both the geographical distribution of corporate activity and the hierarchies of local areas. Thus, local (regional) systems of innovation do not undermine the globalisation process in terms of the production and diffusion of technology, but rather they reinforce it (Howells, 1999). Nonetheless, despite the stability of "higher" and "lower" order regions, there is still room for policy in infrastructure and education in order to facilitate the process of local growth through FDI strategies (Cantwell and Iammarino, 2000). On the host region perspective, Vence-Deza (1996) places great emphasis on the importance of diversity and complementarity in boosting local expertise in lagging regions.

5. Co-specialisation and co-location

By considering a span of regions wider than in the earlier work mentioned above, in order to analyse whether in each of the three sub-periods – 1969-77, 1978-86 and 1987-

95 - the technological clusters of co-specialised firms identified in the study referred to above (Santangelo, 1998) are co-located, for each firm a cross-regional RTA index was calculated at the level of the ICT patent classes[12] as a proxy for the geographical division of labour within the firm. For each European electronic firm (*i*), the index is defined as the share of its US patents granted in a patent class (*c*) in all European regions which are attributable to research in region (*r*), relative to its share of patents granted in all ICT patent classes over all European regions which is due to its activity in the same region (*r*). Thus, the index can be formalised as:

$$RTA_{irc} = (P_{irc}/\Sigma_r P_{irc})/\ (\Sigma_c P_{irc}/\Sigma_r \Sigma_c P_{irc}) \qquad (1)$$

where P_{irc} is the total number of patents granted to firm (*i*) in region (*r*) in a patent class (*c*). It is worth emphasising that while we confine our attention here to just some regions, the RTA index has been calculated relative to activity in all European regions. As the index is a comparative measure, high (low) values of RTA_{irc} indicate corporate advantage (disadvantage) in locating research activity in a specific patent class in the region in question. Therefore, the index enables one to evaluate for each European electronic firm the significance of the regional location in a patent class in Europe relative to the overall European significance of the same region in all ICT patent classes. As such, it maps the profile of corporate technological specialisation across the ICT fields in each region.

The analysis tests whether co-specialised firms co-locate their research activity in the technological fields of co-specialisation. As in the previous study (Santangelo, 2001), the criterion adopted to identify eventual co-location of corporate co-specialised research in ICT requires that, in each of the three sub-periods, at least 50% of the firms

in each technological cluster show the highest RTA_{irc} value in the relevant patent class (around which the cluster is formed) in the same regional location, and that this regional location is common to all other firms in the cluster (which all conduct at least some activity there).

Figure 3 depicts the clusters of ICT European-owned corporate groups which were found to be specialised in the same technological classes (see Santangelo, 1998). In the present study, technological clusters of firms which were found to be also co-located are reported through the use of a grey background. By comparison with the earlier work conducted on a small number of European regions (Santangelo, 2001), the number of co-located groups of co-specialised firms is reduced to cluster B2.2, still hosted in the South East (UK). Conversely, the co-location of the clusters C, C1 and C2, in the South East (UK) has not been confirmed by the present analysis.

Therefore, despite the high concentration of European ICT technological development revealed in Tables 2 and 3, the average trend emerging from our earlier study that European electronic firms specialised in the same patent class/es carry out the related R&D in geographically separate regional locations is confirmed and further reinforced by the present analysis, based on a wider geographical span of European regions. Given the stability of the regional hierarchy discussed in the previous section, these results seem to suggest that, although firms do not locate R&D activity in fields of co-specialisation in the same region, on average the production of ICT innovative activity is concentrated in a small number of regional centres. Therefore, if R&D in ICT as a whole is concentrated in a few regions, ICT fields of corporate co-specialisation follow a pattern of geographical dispersion.

As illustrated elsewhere by both of us (Cantwell and Santangelo, 1999a, 2000; Cantwell and Kosmopolou, 2000), MNCs are likely to disperse geographically the development of technologies which lie mainly outside their core fields of competence, as the creation of technology in which tacit knowledge carries a greater weight is harder to coordinate across long distances. Therefore, firms tend to concentrate at home industry-specific core technologies in which they are heavily dependent on tacit knowledge, and to disperse the development of technologies outside their primary field of activity. This implies that firms (or groups of firms) that show loose co-specialisation are most likely to cooperate in fringe sectors, while separating spatially the development of core technologies owing to mutual deterrence. Consequently, the general pattern emerging can be defined as an inter-regional interchange, as behind each of these regions there are companies which focus regional technological specialisation in some fields rather than others. In these cases, co-location is deterred by region-specific capabilities.

The relationship between regions follows trajectories of either cooperation or competition. In the latter case, very close co-specialisation generates competition, which in turn leads to an absence of corporate co-location. Companies strong in the same field/s do not co-locate their most related R&D activity because of mutual deterrence. Since in this case indigenous firms and regions are technologically co-identified, a dynamic of inter-regional interchange develops. In the former case, weaker co-specialisation generates cooperation, which may lead to a pattern of spatial co-location. Thus, in this event firms need not be synonymous with regions, and regions can gain an identity which goes beyond that of indigenous firms. This applies to the exception to the general trends found in the empirical analysis and represented by the cluster B2.2 hosted in South East England (UK). In this case, sectoral and spatial corporate interactions follow a pattern of intra-regional cooperation between co-specialised firms in a common locational pole of attraction. In this special case, the common location –

i.e. the South East (UK) – does gain an identity of its own with respect to localised interaction between indigenous and foreign European-owned firms as a major centre for the development of the technologies of common specialisation.

6. The theoretical framework revisited

The results of the empirical analysis allow us to elaborate upon the theoretical framework proposed in section 2 and sketched in Figure 1. Graphically this has been done in Figure 4, in which clusters (illustrating the relationship between the "degree of co-location" and the "balance between inter-firm competition and cooperation") have been mapped by taking into account the patterns of sectoral and spatial corporate interaction corresponding to the two antithetical forms of inter-firm relationship (competition and cooperation). As discussed above, competitive corporate relationships, dictated by a strong technological co-specialisation, are likely to promote inter-regional competition in equivalent lines of technological development as discussed in the case of the general trend revealed by the empirical analysis. Conversely, cooperative corporate relationships, generated by loose technological co-specialisation, may lead conceptually to three alternative potential patterns of sectoral and spatial corporate interactions:

- inter-regional cooperation,
- inter-regional inter-industry cooperation and
- intra-regional cooperation.

An example of the latter has been identified in the cluster B2.2 which is co-located in the South East (UK), the first can be conceptually understood as the counterpart of the competitive pattern of sectoral and spatial corporate interactions discussed as the general trend captured by the empirical analysis in section 5. Its distinctive feature lies in the fact that non-co-specialised firms locally cooperate in technical development in fields outside the primary sector of one of the (two or more) cooperating firms. The second alternative conceptually identified concerns sectoral and spatial corporate interactions characterised by a concentration of research in specific regional locations to benefit from untraded externalities, which may well go beyond intra-industry knowledge spillovers as in the Marshall-Arrow-Romer (MAR) model, involving inter-industry and industry-university knowledge spillovers (Feldman, 1993; Audretsch and Feldman, 1994; Audretsch and Stephan, 1994; Anselin *et al*., 1997; Audretsch, 2000).

This conceptual case is illustrated in Tables 4 and 5, in which for each of the six selected top-ranked regions RTA values across ICT patent classes[13] are reported for European-owned electronic and non-electronic firms respectively[14]. In each of the six selected regions, non-electronic companies have a much higher degree of focus in what they do within the ICT fields (which for them lie outside their fields of primary activity) than do European-owned electronic firms, as illustrated by the respective standard deviations and coefficients of variation in the RTA index across the relevant sectors (which are measures of the extent of concentration of activity). However, the fact that despite this the non-electronic companies still conduct quite a wide dispersion of ICT research in these centres supports the argument that research activity in firm- or industry-non-core fields (as ICT are for the non-electronic companies) is geographically dispersed and most likely localised in "centres of excellence" (such as the six regions identified in Tables 2 and 3). Non-electronic companies need to develop some expertises in ICT (although it lies outside their core technologies) as this is the pervasive technology of the new paradigm. Therefore, they locate a significant part of their R&D effort in the relevant "higher" order regions for these activities in order to

enjoy knowledge spillovers from the local environment as well as from indigenous electronic companies.

As Feldman and Audretsch (1999) argue, diversity across complementary industries showing a common base is a source of greater innovation potential. Following Camagni (1988), this seems to be all the more true in the current techno-socio-economic paradigm in which the creation of spatial synergies is amplified by the new complexity of technological combinations adopted. Innovation potential is enhanced by spillovers from firms that have their principal fields of specialisation in other technologies and which are not deterred so much by the presence of strong electronic indigenous companies. Considering the ICT classes in which the RTA index is greater than one (there is a positive technological specialisation) for both European-owned electronic and non-electronic firms, only a few cases of matching are found (reported in italics in both Tables 4 and 5). This implies that there are relatively few cases in which electronic and non-electronic firms co-locate the directly equivalent category of R&D. It is not by chance that the higher number of matching cases is found in the South East (UK), which has been already identified as a major centre for ICT technology development in the analysis that tested the hypothesis of a co-existence of co-specialisation and co-location. However, non-electronic companies do not engage in direct competition with indigenous electronic firms. Rather, inter-industry cooperative relationships develop, amplified by the local strength in the fields in question and the dynamic local environment. Therefore, inter-firm interaction follows a regional inter-industry cooperation pattern, characterised by the absence of direct competition. The nature of technology linkages within each region between the two groups of firms and between different (but presumably related) ICT fields remains to be investigated more closely in future research.

7. Conclusions

The attempt to adopt a broader approach to the study of innovation is currently on the agenda due to a wider awareness of the advances that have recently been made from the perspective of evolutionary economics in our understanding of this essential feature of capitalism. The great emphasis placed on the firm as major actor in knowledge creation as well as on the local dimension – in which spatially defined networks and infrastructure generate localised knowledge spillovers – can be defined as a distinctive feature of the current techno-socio-economic conditions. This calls for a broader research approach to corporate spatial organisation of innovation in order to provide a more coherent interdisciplinary social science, geographical or historical analysis of innovation as the engine of the change, development and transformation of capitalism. In this context, the empirical analysis carried out in this paper as well as our analytical framework, suggested by the literature and clarified by our findings, attempts to make a contribution to the construction of a more comprehensive theory of technological change. In this spirit, this paper proposes a theoretical structure in which to situate the implications of the co-location and co-specialisation of innovation for inter-firm relationships that follow either mainly competitive or cooperative forms.

The results are consistent with previous empirical investigations. European-owned electronic firms do not tend to locate in the same region R&D activity in field/s in which they are co-specialised. This average tendency suggests there must be instead an inter-regional interchange of technological development, which defines the competitive pattern of sectoral and spatial corporate interaction as firms become co-identified with regions in terms of their respective profiles of technological

specialisation. Therefore, the complete overlap of corporate technological portfolios acts as a deterrent to concentrate geographically research activity in the fields of common specialisation. Conversely, the special case represented in our analysis by the only cluster co-specialised and co-located reveals an intra-regional cooperation pattern of sectoral and spatial corporate interactions as in this case, the region of common location - i.e. the South East (UK) - gains its own identity in the creation of new knowledge in the technologies of common corporate co-specialisation.

Conceptually, cooperative inter-firm relationships can be also shaped in terms of inter-regional, and inter-regional and inter-industry patterns. The former is characterised by the cooperative co-location of non-co-specialised firms for the purpose of outsourcing new complementary knowledge. The latter refers to regional concentration of loosely co-specialised firms in order to enjoy *untraded* externalities.

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[1] The reasons for focusing on the European ICT industry are twofold: first the strategic significance of this industry in the current techno-socio-economic paradigm, and second the specific importance of the European ICT industry for historical and political evolution as well as its market structure (e.g. the conditions under which the industry has developed and operated and its oligopolistic structure).

[2] As can be inferred from the text, the term co-specialisation refers to the co-presence of technological expertise of two (or more) firms in the same technological field/s.
[3] The term co-location refers to the co-presence of R&D activity of two (or more) firms in the same territorial space.
[4] For a critical overview see Boschma and Lambooy, 1999 and Martin, 1999.
[5] The variable refers to the co-location of R&D activity carried out in fields of (either close or loose) corporate co-specialisation.
[6] Mergers and acquisitions are largely recognised in the data through the practice in most groups of centralising the patent application procedure in the parent company. In other important cases affecting the ultimate ownership of significant numbers of patents, the change in ownership structure has been incorporated into the organisation of the data, which involves in some cases the creation of a new corporate group and, in others, the expanded consolidation of groups with newly acquired subsidiaries.
[7] A list of the 6 ICT technological sectors is provided in the appendix (Table A1).
[8] A list of the ICT original technological patent classes is provided in the appendix (Tables A1a and A1b).
[9] Hereafter, this corporate industrial group will be named as “electronic” in order to take into account the technological historical development. The definition of “electrical” attains to a historical classification of the data.
[10] Some of the 23 electronic corporations were dropped from the analysis on the grounds of the relatively small number of patents in the technological patent classes considered, the outcome being that the firms in the sample vary from one sub-period to another. As listed in Table A2, 20 firms were examined in the sub-period 1969-77, whilst 21 and 19 were taken into account in the two later sub-periods respectively.
[11] These territorial levels of analysis have also been adopted by Cantwell and Iammarino (1998, 2000) in the case of Italy and the UK respectively, by Cantwell and Noonan (1999) in the case of Germany and by Cantwell and Santangelo (1999) in the case of Belgium, the Netherlands, Sweden and Switzerland.
[12] A selection of ICT patent classes is considered in this paper. The analysis focuses on the patent classes labelling the technological clusters in Figure 3 in each of the sub-periods (1969-77, 1978-86 and 1987-95) rather than all ICT patent classes recorded in the Reading database.
[13] As the RTA has been calculated for the whole period under analysis (i.e. 1969-95), the difference in the number of ICT patent classes due to a post-1990 re-classification of the data has been accounted for by merging together groupings that were treated differently before and after 1990.
[14] For both European-owned electronic and all non-electronic firms (k=1 or 2), the RTA index is calculated as the share of research carried out in a particular ICT class (c) in all European regions which is attributable to research in region (r), relative to their share of activity in all ICT classes over all European regions which is due to activity in the same region. Thus, for the whole period 1969-95 the index can be formalised as follows:

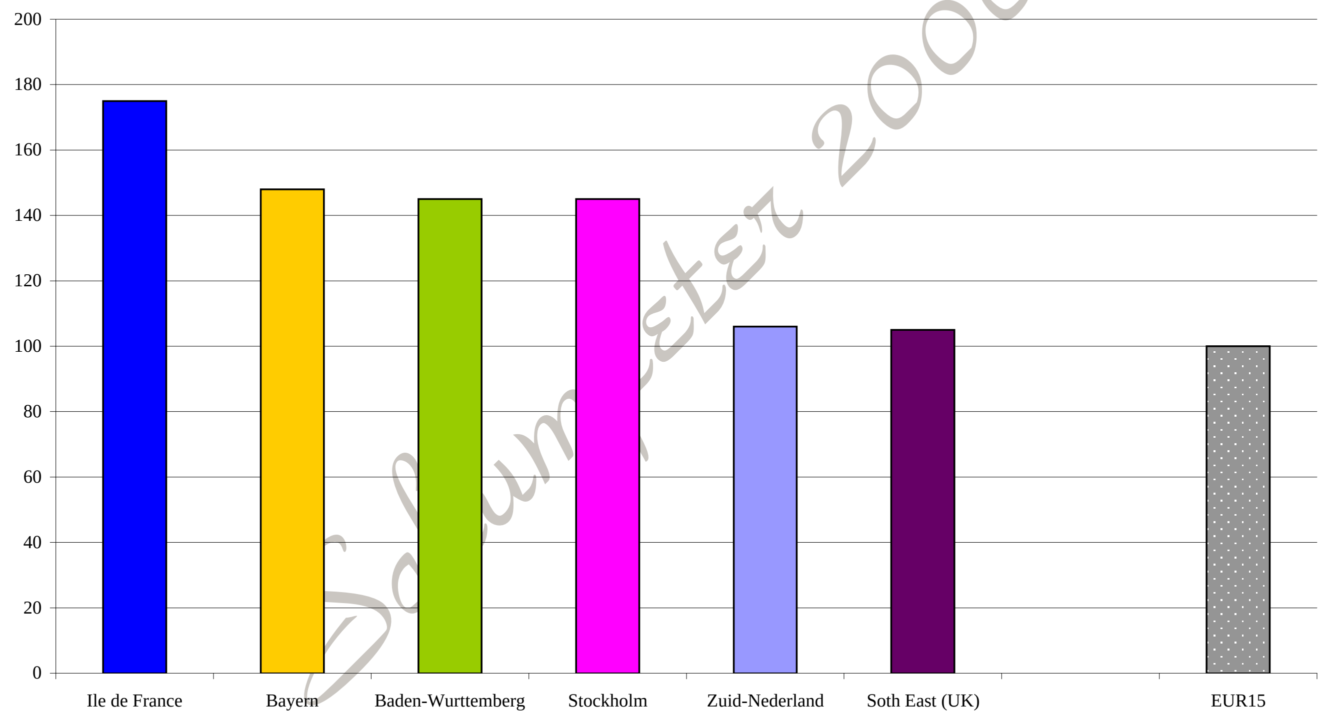
$$RTA_{krc} = (P_{krc}/\sum_r P_{krc})/ (\sum_c P_{krc}/\sum_{rc} P_{krc}) \qquad (2)$$

where P_{krc} is the total number of patents granted to either European-owned electronic or all non-electronic firms (k) in region (r) in a patent class (c). It is worth emphasising that while our attention is confined here to just some regions, the RTA index has been calculated relative to activity in all European regions.

Figure 1 – The theoretical framework

* The variable refers to the co-location of R&D activity carried out in fields of (either close or loose) corporate co-specialisation.

Figure 2 - Per capita GDP (ECU) - 1994, by "higher" order region



Source: Eurostat, 1997.

Figure 3 – European electrical firms specialised in the same patent class/es and located in the same region (reported in grey background), by sub-period, 1969-1995.

1969-77	1978-86	1987-95
(A) Telegraphy CGE Olivetti Siemens STC	**(A1)Telegraphy** Olivetti Siemens STC	**(B2.1) Pulse or digital Communications, Telecommunications & Registers** AEG-Telefunken ABB LM Ericsson Siemens STC
(B) Modulators & Multiplex communications AEG-Telefunken CGE LM Ericsson Plessey Siemens STC	**(B1.1) Multiplex communications** ASEA AB CGE LM Ericsson Nixdorf Computer Plessey **(B1.2) Multiplex communications, Pulse or digital communications & Communications: electrical** CGE Nixdorf Computer Zanussi Group	**(B2.2) Communications: directive radio waves systems devices, Communications: radio wave antennas, Multiplex communications, Pulse or digital communications & Telephonic communications*** General Electric Co. *LM Ericsson* Racal Electronics STC *(Thorn EMI)*
(C) Communications: directive radio wave systems devices* *General Electric Co.* Racal Electronics Thomson-Brandt *(Thorn EMI)*	**(C1) Communications: directive radio wave systems devices*** General Electric Co. *LM Ericsson* Plessey Racal Electronics Thomson-Brandt	**(C2) Communications: directive radio wave systems devices, Communications: radio wave antennas & Information Processing system organisation*** General Electric Co. Philips *Plessey* STC Racal Electronics Thomson-Brandt Thorn EMI
	(E) Acoustics AEG-Telefunken Bosch-Siemens-Hausgerate Brown Boveri	**(E1) Acoustics** ABB Electrolux Siemens
	(F) Telecommunications BICC Bosch-Siemens-Hausgerate Brown Boveri	**(F1) Telecommunications & Communications: radio wave antennas** Bosch-Siemens-Hausgerate LM Ericsson Plessey STC
(D) Image Analysis, Dynamic magnetic information storage and retrieval & Electrical computers and data processing systems CII-Honeywell Bull ICL		**(D1) Electrical Computers and data processing systems, Error detection/correction and fault detection/recovery & Information Processing system organisation** CII-Honeywell Bull ICL
	(G) Registers CII-Honeywell Bull Olivetti Thorn EMI	**(G1) Registers** CII-Honeywell Bull Nixdorf Computer Sagem
Image analysis AEG-Telefunken ICL Thorn EMI		**Demodulators & Information Processing system organisation** Bosch-Siemens-Hausgerate Philips Plessey
Dynamic magnetic information storage and retrieval AEG-Telefunken Philips Zanussi Group		**Telephonic Communications** CGE LM Ericsson Plessey Racal Electronics STC

* Italics denote consideration of sector-specific factors, which create correlation problems between each of the companies, whose name is in italic, and all the others and between each others in the case of the 1969-77 cluster.