Corporate Strategic Technological Partnerships in the European Information and Communications Technology Industry

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Communication to

European Meeting on Applied Evolutionary Economics

7 - 9 June 1999, Grenoble, France

Organised by the Institute for Energy Politics and Economics
d'Economie et de Politique de l'Energie /
IEPE, BP 47, 38040 Grenoble Cedex 9, France

And the INRA-Unit of Sociology and Economics of Research and Development
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Abstract

In the era of "alliance capitalism", the increasing number of strategic technological partnerships (STPs) has been mainly recorded in the science-based fields, of which Information and Communication Technology (ICT) is a leading sector. The establishment of STPs has also characterised the European ICT industry. The growing technological interrelatedness and the need to acquire capabilities in related fields have been identified in the literature as major explanations for the increase in corporate technological co-operation.

This paper investigates the role of corporate technological specialisation factors in the conclusion of STPs in the European ICT industry by carrying out a dynamic analysis. Accordingly, the patterns followed by corporate technological partnerships in the industry in question are investigated since the late 1970s. Based on US patent data granted to the world's largest firms as well as strategic technological partnerships data, the results of the econometric analysis are consistent with the view that the more similar partners' technological portfolios are with one another, the easier it is to absorb each other's capabilities.

Keywords: Strategic technological partnerships; European ICT industry; absorptive capacity; co-ordinated learning vs. exchange of knowledge.

1. Introduction

In the 1980s, the increased adoption of strategic technological partnerships (STPs) as a form of organisation of economic activity has been identified as a main feature of a new phases of the capitalist system (Gerlach, 1992; Dunning, 1995, 1997), where competitiveness is increasingly pursuit through cooperation. The growth in the number of technology based inter-firm alliances has mainly been recorded in science-based fields (such as Information and Communications Technology – ICT) (Hagedoorn and Schakenraad, 1992; Hagedoorn, 1993b; Duysters and Hagedoorn, 1995). This trend may be interpreted as a new corporate strategic response to increasing technological interrelatedness and complexity in order to coordinate change and innovation effectively.

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Based upon a resource pooling strategy, corporate alliances promote synergies between allied companies, thus affecting the development of firms' internal capabilities and furthermore their technological profiles over time. Since inter-firm alliances tend to develop in areas in which firms shares complementary capabilities, partner's choice can be predicted by firms' technological overlap (Mowery *et al*., 1998). Nonetheless, a distinction should be made between complementary and close complementary firm-specific paths of development (Cantwell and Barrera, 1998). The fruitful exchange of knowledge requires the complemenarity of activities, but cooperative learning creates a closer complementarity between those activities. Technological collaborative agreements are likely to promote partners technological convergence by encouraging coordination between partners' internal paths of innovative learning. By contrast, in the former, firms' learning paths become more locaslised, although their activities remain complementary (*Ibid*.). However, if alliances enable firms to cope with the fast rate of technological development, they cannot substitute in-house investment in order to enhance firm's technological competencies. Multinational corporations (MNCs) still need to diversify in the range of technologies they master since a wider range of specialised knowledge is now required for the production and distribution of specific products (Granstrand and Sjölander, 1990; Granstrand *et al*., 1997).

The growth in STPs has also characterised the European ICT industry, where a cooperative strategic approach has been adopted to deal with the issue of European competitiveness in electronics. Unlike the earlier national champions' approach, the EU technology policy has focused on intra-European cooperative partnerships. This seems also to apply to European electrical corporations, which have increasingly targeted technological collaboration as a major strategy in their agenda. Nonetheless, in the latter case, the adoption of technological collaborative agreements has been highly influenced by the EU framework on technology policy as well by the overall European integration process.

Using data on patents granted in the US to the world's largest firms as well as data on strategic technological partnerships, this paper aims to evaluate the role of corporate technological specialisation factors in the completion of STPs in the European ICT industry. Strategic technological agreements are understood as inter-firm long-term co-operative relationships concerning one or more areas of activity, where combined innovative activity or an interchange of technology is at least part of the agreement and the contractual mechanisms can be more or less formally specified. The "strategic" character is given by the fact that the agreement improves the future value of the firm rather than simply minimising the net costs.

As discussed above, firms are willing to enter alliances in order to acquire partner's capabilities related to their fields of competencies. Therefore, firms with overlapping portfolios of

technological specialisation are likely to become partners. Combining the patent data drawn from the Reading database with the Advanced Research Programme on Agreements (ARPA) data on strategic technological partnerships, two hypotheses are tested over the period 1978-95 in the context of the European ICT industry,

Hypothesis 1: the degree of overlap between partners' technological specialisation profiles has a positive influence upon the formation of strategic technological partnerships. The closer companies' co-specialisation[1], the greater the likelihood of alliances between them for the purpose of technological co-operation; but, if firms are not co-specialised, the greater is the degree of technological dissimilarities between them, the less likely the formation of an alliance.

Hypothesis 2: partners' technological specialisation over time is likely to further converge in the case of alliances between firms that were co-specialised in the previous period, while already dissimilar partners are likely to further diverge if they have concluded alliances previously. Further technological convergence/divergence may be linked as well to the extent of technological diversification of firms over time.

The organisation of the paper is as follows. The role of STPs in the ICT-based paradigm is discussed in section 2. Section 3 sheds some light on the data on US patents and STPs used. The econometric methodology and the measures adopted are exposed in section 4. Section 5 deals with the empirical results. The sub-section 5.1 discusses the general trends in STPs in the European ICT industry during the 1980s. The sub-section 5.2 focuses on the specialisation dynamics in the European ICT corporate STPs by discussing the evidence of the econometric analysis. Section 6 draws some conclusions.

2. STPs in the ICT-based paradigm: the European ICT industry

Over the last decade systemic technological and political changes have promoted a new trajectory of market-based capitalism amidst the process of increasing globalisation. Unlike in the previous phases based on markets and firms as alternative organisational modes of production and transactions ("hierarchical capitalism"), in the new trajectory of the capitalist system co-operations between both economic and political agents has been identified as a new organisational mode. In this sense, corporate alliances are understood as a means of furthering capability creation, which requires non-market co-ordination of necessity rather than as a response to market failure.

[1] The term co-specialisation refers to the co-presence of partners' technological expertise in the same sectors.

Therefore, alliances represent more a flexible means of co-ordination. The adoption of collaborative agreements as organisational forms of economic activity characterised the early 1980s and increased sharply over the mid-1980s (Chesnais, 1988; Contractor and Lorange, 1988; Hagedoorn and Schakenraad, 1992; Hagedoorn, 1993a, 1995a, 1995b; Narula and Hagedoorn, 1997). This phenomenon has mainly involved the companies from the Triad - US, Japan and Europe - (Hagedoorn and Schakenraad, 1993;, Freeman and Hagedoorn, 1995). This trend seems to suggest that inter-firm alliances are a first-option rather than an alternative to hierarchical organisational forms (Ciborra, 1991). In this case, a shift away from hierarchical capitalism towards "alliance

Gerlach, 1992; Dunning, 1995, 1997) refers to the growing adoption of co-operative and collaborative organisational forms of corporate activity in order to increment partners' competitive advantage.

The reasons for concluding alliances have been differently identified by the literature.[2] The transaction cost approach (Williamson, 1990) suggests that alliances may eventually be preferred to pure hierarchies because of higher financial risks and barriers to entry in the latter case (Buckley and Casson, 1976, 1988; Mariti and Smiley, 1983; Kogut, 1988; Casson, 1990). Thus, according to these authors the advantage in adopting alliances relies on the minimisation of the sum of production and transaction costs due to the failure-prone characteristic of technological knowledge (Caves, 1982). However, as argued by the eclectic paradigm (Dunning, 1993), STPs may be a better strategy than subsidiaries if the location advantage cannot be completely captured by the foreign investor because it is specific to domestic firms. One of Chesnais' criticisms (1996) to the transaction cost approach as a framework for analysis of co-operative alliances is the fact that this approach ignores the firm as the central institution in capitalist economies for the transformation and creation of resources. In this context, it is worth distinguishing between a cost-economising agreement and a strategic alliance. As mentioned above, in the latter case the strategic element implies the improvement of the future value of the firm, not simply the minimisation of the net cost. Thus, the strategic element implies somehow the transfer of some knowledge as part of the agreement. In this sense, the agreement may take place in a location where traditional locational advantages are absent if the primary objective is to acquire firm-specific ownership advantage through partnering. This is all the more true in the case of technology development, where these advantages are often non-codificable and specific to intra-firm learning processes. Nonetheless, international strategic technology partnering may enable firms to spread their innovative capabilities over many countries, where local scientific and technological advantages expertise may

[2] For a brief review of the different approaches explaining the reasons for concluding alliances see Coombs *et al*. (1996).

be eventually used as outsourcing (Duysters and Hagedoorn, 1996; Hagedoorn, 1996, 1998; Narula and Dunning, 1998).

Recently, the goal of most strategic alliances has been identified in gaining access to new complementary types of technology in order to enrich the firms' innovatory and learning process rather than to enhance the overall prosperity of the partners (Hagedoorn, 1993a; Chesnais, 1988; Cantwell, 1998; Coombs and Metcalfe, 1998; Dyer and Singh, 1998; Inkpen, 1998). This may be interpreted as a result of the increasing technological interrelatedness (Pavitt *et al*., 1989), which has underlined the need for both corporate technological diversification (Granstrand and Sjölander, 1990, Granstrand *et al*., 1997) and strategic alliances with other companies in order to access capabilities closely related to their own profile of competencies. Access to competencies in fields unrelated to the firm's own capabilities is extremely costly and difficult since firms are able to learn to use and adapt effectively the knowledge they have access to only if they possess potential absorptive capacity (Cohen and Levinthal, 1989, 1990). These authors understand absorptive capacity as the accumulation of knowledge, skills and organisational routines necessary to identify and utilise externally generated knowledge (*Ibid*.). For these reasons, firms sharing some complementary capabilities are more likely to enter technological alliances, in which the interaction between partners' paths of innovative learning enhances their own respective internal development. Cainarca *et al*. (1992) develop an evolutionary model aiming to explain the dynamics of evolving collaborative links through the idea of technological cycles and trajectories. However, the degree of interaction largely depends on the organisational form of the alliance and, furthermore, on the technological similarity (or dissimilarity) between the partners' profiles of technological capabilities. As shown empirically by Cantwell and Colombo (1998), different technological profiles between allied firms require a greater effort to match partners' competencies, thus promoting more equity forms of agreement (i.e. joint ventures). Conversely, technologically similar alliances will find it easier to co-ordinate their competencies, thus preferring more arm's length forms of co-operation (e.g. licensing, non-equity agreements, etc.). Likewise, Narula and Hagedoorn (1999) demonstrate that the use of non-equity agreements grew in high-technology and fast-evolving sectors between the early 1980s and the mid-1990s. Accordingly, forms of co-operation based on co-ordinated learning tend to encourage convergence in the patterns of corporate technological competencies, whilst forms of co-operation organised in terms of exchange of knowledge tend to create divergent trajectories of corporate learning, which can eventually move further apart (Cantwell and Barrera, 1998).

In the overall explosion of STPs, the evidence of a steep increase in technological alliances in core technologies (such as ICT, biotechnology and new materials) since the early 1980s has been widely observed (Hagedoorn and Schakenraad, 1992; Hagedoorn, 1993b; Duysters and Hagedoorn,

1995; Powell, 1998; Narula, 1999). Among core technologies, ICT has been the largest field of co-operation especially during the first half of the 1980s. The development of the new socio-economic paradigm has been identified as a major explanation of this trend since it requires a wide application of a range of technological capabilities which may not be implemented on the grounds of the firm's individual competencies. As a result of the greater role of basic science in technology, firms need to have some mastery of a wider range of disciplines. Therefore, the new role of technological systems together with the rise in technological internationalisation and greater costs of R&D budgets marked a new avenue in technological development, which goes beyond the boundaries of a particular firm. As highlighted by Porter and Fuller (1986), the rate of technological change is a main determinant of the growth of STPs in the sense that corporate competitive advantage is mainly related to the rate of increase in knowledge rather than the absolute increment of the stock of knowledge. Due to the complexity of cutting-edge technologies (such as ICT), uncertainty, risks and R&D costs are consequently larger and product life cycles shorter. For these reasons, technology partnering in high-tech sectors is highly characterised by contractual agreements by comparison with medium- and low-tech sectors where the adoption of joint ventures is rather large (Harrigan, 1988; Hagedoorn and Narula, 1996). In this light, co-operation becomes a crucial factor in strengthening corporate competitiveness.

The 1980s increase in STPs in ICT fields characterised also Europe, where, besides private technology alliances, the growth in the so-called cost-sharing technology partnerships was registered (Sharp and Shearman, 1987; Mytelka and Delapierre, 1988). Cost-sharing technology partnerships refer to international R&D collaborations stimulated by international organisations' and/or governments' subsidies to companies. In Europe, international collaborative private research was subsidised by the European Commission with the launch of an increasing number of technology programmes since the mid-1980s.[3] As confirmed by the simultaneous start-up of joint R&D private and cost-sharing European projects (Hagedoorn and Schakenraad, 1993b), in this period both types of strategic technology collaborations expanded. Nonetheless, the subsidised European R&D networks for ICT companies appeared to resemble the privately established networks (*Ibid.*). These results seem to suggest that these subsidised R&D networks reproduced the structure of the European large firm-cooperations by adding to existing or emerging privately networks. In this sense, EU technology programmes are likely to have played a crucial role in promoting an oligopolistic structure in the European ICT industry, characterised by a small number of large European companies (*Ibid.*). In this light, it has been argued that strategic alliances appear

[3] Beginning with ESPRIT (European Strategic Programme for Research in Information Technology), the European technology policy developed with the launch of several technology programmes (e.g. RACE, BRITE/EURAM, BRIDGE, ECLAIR, and COMETT) targeting different fields and market applications. (For a review see Sharp and Pavitt, 1993).

to represent a process of "flexible integration" between major oligopolies in the 1980s (Amin, 1993). However, in the 1990s, intra-European alliances have run out of steam, and US-European alliances have been more buoyant (Narula, 1998). The decrease in intra-European alliances in the 1990s has been interpreted as due to the oligopolistic structure of the industry. This means that intra-European alliances are not longer as necessary as in the previous decade. According to Narula (*Ibid*.), these results seem to show that the Single European Market (SEM) failed to achieve the aim of closer competition among European firms in undertaking co-operative R&D.

3. The data

In order to analyse the relationship between STPs and corporate technological specialisation in the European ICT industry, two datasets were jointly considered – the University of Reading and the ARPA (Advanced Research Programme on Agreements) databases. The data refers to 14 of the European largest ICT companies, which lie at the intersection of the two databases mentioned above.[4]

The data concerning technological specialisation relates to the corporate patenting in the US of the world's European largest ICT firms over the period 1978-95. These data are drawn from the University of Reading database, where each patent is classified by the year and technological activity with which is primarily associated according to a classification scheme derived from the US patent class systems. 26 of the 399 original patent classes identified by the US Patent and Trademark Office (USPTO) comprise the main field of the ICT development. Due to a post-1990 reclassification of the data, the number of the ICT patent classes was enlarged to 30.[5] In each case, patents were counted as belonging to a common corporate group when assigned to affiliates of a parent company. In the Reading database, a consolidation procedure has been carried out for the years 1969-95 in order to take into account regular changes in ownership. Therefore, all patents granted under the name of affiliates have been consolidated into the relevant corporate group of companies. It is worth noting that, in the Reading database, the technological classification of each patent is distinct from the industrial output classification of the firm to which the patent is granted. Indeed, each corporate group is allocated to an industry on the basis of its primary field of

[4] The firms in the sample of analysis are listed in Table A1.

production, while the primary field of technological activity of each patent derives from the US patent class system.

As emphasised in the literature (e. g. Soete and Wyatt: 1983, Archibugi and Pianta, 1992), the use of patenting in a common third country, that is, the US, allows a more reliable international comparison on a similar basis. Furthermore, foreign patents (e.g. European) are expected to be of a higher quality than domestic patents (i.e. US), as it is reasonable to assume that only inventions and innovations with the highest expected profits will be patented abroad due to the time and costs involved in doing so. Without going through the large literature on patent statistics (Schnookler, 1966; Scherer, 1983; Griliches, 1990; Archibugi, 1992), it should be pointed out that in an analysis focusing on ICT a major problem in using US patent data might be identified in the fact that software patents were successfully enforced in the US only since the mid-1990s (Merges, 1996). Until then, the patentability of software innovations was a rather controversial issue due to the nature of software technology itself. A large range of innovations, from computer game cartridges to advanced telecommunications switching programmes, are grouped under the label of software technology. The legal debate on the patentability of software concerned the fact that software inventions set out the sequences of steps necessary to perform an activity in terms of functions that are carried out by conventional computer hardware elements. Thus the novelty mainly relates to the steps of the programme. For the purpose of the present study, this is not a major issue when considering the weak European performance in software technology (Malerba *et al*., 1997). Highly fragmentation of the European software market, low degree of internationalisation and a specialisation profile mainly focused on custom software and services rather than software packages have been identified as the main factors explaining this pattern (Malerba and Torrisi, 1996).

The data on STPs are drawn from the ARPA database developed at Politecnico di Milano. The database surveyed agreements in the ICT industrial system for the entire world. The ICT industrial system comprises more specifically microelectronics, data processing and office automation, and telecommunications over the period 1980-86. The term *system* highlights the high range of interactions and innovative processes characterising the evolution of hardware, software and services within the ICT field (Cozzi *et al.*, 1988). Strategic technological agreements refer to inter-firm long-term relationships, which allow the parties to regulate *ex ante* their future conduct by means of more or less formally specified contractual mechanisms (Cainarca *et al.*, 1992). The agreement may determine a change in the firms' ownership structure (minority or parity shareholding) or promote a new company jointly owned by the partners (joint venture). In the ARPA database, this distinction is made on the grounds of their organisational form (equity *versus* non-equity agreements) as well of partnerships' final aim (defined in financial terms) - see Table

[5] The ICT original patent classes are listed in Tables A2.1 and A2.2 for both the periods1978-86 and 1987-95.

A3 – (Cainarca *et al*., 1989). As far as the organisational content is concerned, non-equity agreements (in all their subcategories) include technology transfer (in the form of patents, licensing or know-how) and product distribution (e.g. original equipment manufacturer - OEM), whilst equity agreements (in all their sub-categories) refer mainly to joint ventures. If the distinction between equity and non-equity concerns the contractual form of the agreements, the ARPA database classifies the agreement also on the grounds of the partnership's final aim or functional content (see Table A3). This paper focuses on research-based agreements. Therefore, the data on STPs used in the econometric analysis refer to agreements classified in the ARPA database as aiming at joint R&D development regardless of their contractual form. This means that, for instance, corporate venture capital can be taken into account (although classifies among equity forms of agreements) if aiming at the joint development of R&D activity. As far as the information technology industry is concerned, Carbonin and Maglione (1987) hold that the number of agreements in the ARPA database is clearly higher than in other databases. In this database, subsidiaries' nationality was established on the grounds of the geographical location of the parent company. For instance, IBM Italy has been considered as a US company.

This information was gathered through what may be called a "literature-based alliances counting" method, based upon the consultation of international press, technical magazines and specialist studies. Possible biases and distortions were reduced by adopting meticulous survey and cross-checking procedures. In this process of collection of inter-firm alliances, the coverage of local sources of information for all three most developed areas (US, Europe and Japan) allows a more balanced role for the Japanese firms, which seems to have been overlooked in most previous databases (Cainarca *et al*., 1992). However, this method of information gathering has its drawbacks and limitations even if the sample was further revised by the authors.[6] First of all, ARPA data accounts for agreements that are made public. Second, newspaper and journal reports are likely to be incomplete. Another related problem is that the sources used do not publish systematically the dissolution of agreements. One final problem, like the databases assembled following these procedures (e.g. MERIT and LAREA-CEREM), is that the sample is highly conditioned by an over-representation of European companies, for which information is also more complete. If the last point is not an issue in the analysis carried out in this paper for obvious reasons, the others should be taken into account when evaluating the econometric results reported

[6] Carbonin and Maglione (1987) acknowledge the fact that in 1984-85 the original sample of agreements was updated and revised on the grounds of a new gathering of information within a research project carried out by the consultancy agency Ruseau (Milan) and sponsored by the Olivetti Group.

4. The econometric methodology: the measures[7] and the models

In order to analyse the relationship between STPs and corporate technological specialisation in the European ICT industry, the RTA index, calculated across the original ICT patent classes, is used as a proxy for corporate technological specialisation. For each of the 14 European electrical firms, the index is defined by the share of the firm (*i*) in the ICT patent classes (*j*) of US patents granted to firms in the electrical industry to the firm's overall share of all US patents assigned to firms in the industry in question:

$$RTA_{ij} = (P_{ij}/\Sigma_i P_{ij})/(\Sigma_j P_{ij}/\Sigma_{ij} P_{ij}) \quad (1)$$

where P_{ij} is the number of US patents granted in a particular ICT patent classes (*j*) to a European company (*i*) in the electrical industry. For each of the European electrical companies in question, the index provides a measure of technological performance in the ICT patent classes relative to the other European firms in the same industry. Since the RTA index varies around unity, values greater than one suggest a technological comparative advantage of the firm in the selected patent classes, whilst values less than one indicate a position of comparative disadvantage. The technological similarity between allied firms' sectoral specialisation profiles is investigated with the use of the Pearson's correlation coefficient calculated between the RTA index distributions of all 91 possible pairwise combinations of firms in the sub-period 1978-86 (i.e. $r_{(78\text{-}86)}$).

Using the ARPA data, a dummy variable (ALLIES), equal to 1 for allied pairs of firms and to 0 otherwise, is built. A further distinction is made. To test the robustness of the econometric results, the two hypotheses stated in section 1 are investigated empirically by classifying these agreements in alliances between technologically similar and dissimilar partners (Classification 1), and between technologically co-specialised and non-co-specialised partners (Classification 2). Classification 1 is based on the results of a previous study (Santangelo, 1998). In this study, technological clusters of firms are identified on the grounds of the correlation between corporate RTA distributions as calculated in equation (1) in each of the sub-periods 1978-86 and 1987-95 (see Figure 1). For the sake of the present analysis, the technological clusters identified in the period 1978-86 are taken into account. Therefore, firms are classified as technologically similar if they are in the same cluster and if their RTA distributions across the ICT patent classes are positively correlated in the same period. If these two criteria are not met at the same time, the partners are classified as technologically similar/dissimilar on the grounds of the value of the Pearson's correlation coefficient. Likewise, if one of the partners (or both of them) is not in the clusters, the

[7] The variable used to test both hypotheses are briefly stated in Table A4.

technological similarity (dissimilarity) between them is established on the grounds of the correlation coefficient. Therefore, two dummy variables are set equal to 1 for technologically similar allied pairs of companies and 0 otherwise (SIMI and DIS respectively). Classification 2 is based on the RTA distribution of the 14 companies across the 6 ICT sectors. In this case, allied pairs are classified as co-specialised if they show RTA value > 1.5 in the same ICT sector. To take into account the profile of technological generalist of Philips, the Dutch company is defined as co-specialised with its partners if both of them show the three highest RTA values in the same ICT sectors. Therefore, two dummy variables are set equal to 1 for co-specialised allied pairs of companies and to 0 otherwise (COSP and NON-COSP respectively). The reason for classifying the firms in the sample as similar (dissimilar) and co-specialised (non-co-specialised) partners lies in the fact that co-operation may well occur through joint equity ventures between companies which, although active in the same broad technological area and with some similarity in their products, are quite different in their detailed individual fields of technological specialisation.

In order to investigate partners' overlapping technological specialisation and the likelihood of concluding alliances (Hypothesis 1), a logit estimation is carried out first by considering all allied firms as a whole (ALLIES) and, then, by distinguishing between alliances between similar (SIMI) and dissimilar (DIS) partners (Classification 1). The logit estimation is also run by distinguishing between co-specialised (COSP) and non-co-specialised (NON-COSP) partners (Classification 2).

An OLS regression analysis is adopted to test whether co-specialised partners converge over time as a result of an alliance in the previous period, while technological divergence is likely to increase further in the case of already dissimilar firms which enter an alliance in the previous period (Hypothesis 2). Hypothesis 2 is tested empirically by using the absolute changes in the coefficient of correlation between 1978-86 and 1987-95 ($Chr_{(78\text{-}86/87\text{-}95)}$) as a proxy for technological convergence (divergence). In this process, the role of technological diversification is also taken into account since most of the leading diversified companies play a prominent role in strategic partnerships in ICT (Hagedoorn and Schakenraad: 1992). Corporate technological diversification is proxied as

$$DIVE = 1/CV \qquad (1)$$

where CV is the coefficient of variation of the RTA index calculated across the USPTO original ICT patent classes.[8] For each pairwise combination of European electrical companies, whichever

[8] CV ($=\sigma_{RTA}/\mu_{RTA}$) measures concentration of technological activity among sectors for a firm in any particular time period. This measure is related to the Herfindahl Index (H), which has frequently been used as measure of concentration/dispersion across sectors within a firm (see Hart and Prais, 1956). The relation is given by $H= (CV^2+1)/n$, where 'n' is the number of sectors in the distribution. Thus, the use of the CV here for a fixed 'n' is in practice

company had the largest absolute changes in technological diversification between 1978-86 and 1987-95 ($ChDIVE_{(78\text{-}86/87\text{-}95)}$) is the change taken into account. Thus, using Classification 1 the regression function is specified as follows:

$$Chr_{(78\text{-}86/87\text{-}95)} = f\ (SIMI, DIS, D_{comp}, D_{tele}, ChDIVE) \qquad (2)$$

while, adopting Classification 2:

$$Chr_{(78\text{-}86/87\text{-}95)} = f\ (COSP, NON\text{-}COSP, D_{comp}, D_{tele}, ChDIVE) \qquad (3)$$

where D_{comp}, D_{tele} are two dummy variables introduced to control for industry divergence of alliances between similar/co-specialised partners. The variable D_{comp} takes into consideration allied pairs of European electrical companies where one of the two partners moves towards a computing specialisation. In equation (2), D_{comp} refers to the partnerships between GCE and CII-Honeywell Bull, Olivetti and CII-Honeywell Bull, and STC and Siemens, whilst in equation (3) the variable D_{comp} concerns the last two partnerships only. If, in the early 1980s, all three (two in the case of equation (3)) pairs of allied companies show similar/co-specialised profiles of technological specialisation, in the later 1980s their technological profiles diverged. The divergence between GCE and CII-Honeywell Bull may be attributed to the French colbertisme high-tech which pushed the latter to consolidate its specialisation in computing and drop its communications related activities. Accordingly, the consolidation of CII-Honeywell Bull's computing specialisation seems to be the reason for the divergence with Olivetti. As a result of the major difficulties the Italian company went through in the later period considered, Olivetti experimented a despecialisation in computing after transition from its mechanical to its electrical age. Instead, the case of STC and Siemens is driven by the 1990 acquisition of Nixdorf Computer by Siemens and the consequent move to a specialisation in computing technologies by the latter. The variable D_{tele} is introduced in both equation (2) and (3) in order to take into consideration allied pairs of European electrical companies where one or both partners moved towards non-defence telecommunications. In both equations, this is the case of General Electric co. and Plessey, General Electric co. and Racal Electronics, and LM Ericsson and Plessey. In the late 1980s and early 1990s, all three British corporations show a technological profile less focused on defence electronics and more oriented to telecommunications fields, which were, however, different from one another.

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equivalent to the Herfindahl Index (see Hart, 1971).

5. The empirical results

This section is organised into two parts. The first provides an overview on the phenomenon of STPs in the European ICT industry in the 1980s. The second reports the results of the econometric analysis on the specialisation dynamics in the STPs in the European industry in question.

5.1 General trends in strategic technological partnerships in the European ICT industry during the 1980s

Despite the technological convergence among the companies from the Triad countries (Freeman and Hagedoorn, 1995), the increase in STPs during the 1980s seems to correspond to a rise in intra-bloc partnering (i.e. intra-US, intra-Japanese and intra-European technological alliances) (Hagedoorn, 1993a, 1996). It has been argued that the strong regional nature of inter-firm R&D collaboration may be attributed to the additional complexity that the internationalisation of R&D activity creates in STPs' organisation (Duysters and Hagedoorn, 1996). This trend also seems to have characterised the European ICT industry (Hagedoorn, 1996). Figure 2 shows the distribution of European ICT partnerships over the period 1980-86. STPs between European electrical companies appear to be far larger than STPs between these companies and US and Japanese electrical firms. It is worth noting that these data drawn from the ARPA database do not include alliances made in the context of European technology programmes such as ESPRIT and Eureka. Therefore, the higher percentage of intra-European technology co-operation in ICT may be explained by the attempt of the European electrical companies to fill the gap with US and Japanese competitors. However, as suggested by Cainarca *et al*. (1989), the role played by the overall economic integration process should not be understated when considering the launch of the SEM with the 1986 Single European Act (SEA). By creating an imperative for competitiveness within Europe, the SEM initiative required a restructuring of the various individual European firms. As far as innovative activities are concerned, Cantwell (1992) shows that the degree of interdependence among the MNC's distinct units is relatively higher in Europe than in other areas of the world. This may explain the adoption of a more "regionally" rather than "globally" oriented strategy by European corporations (Hagedoorn, 1993a; Duysters and Hagedoorn, 1996). Nonetheless, within the European context, there are substantial cross-country differences. For instance, UK and German owned firms are more US-oriented than Dutch or Swedish owned firms (Cantwell and Janne, 1999). Despite the cross-country differences, the integration process has created an imperative for intra-

area rationalisation of innovative activity. This argument is confirmed in Figure 3, where 86% of the European electrical companies appears to be involved in intra-block partnering within the European ICT industry. The empirical evidence proposed in Figures 2 and 3 seems to be consistent with Narula's study (1998) on intra- and inter-European alliances over the decade 1980s-1990s. The author confirms a sharp increase in intra-European alliances in the 1980s, which reinforced the oligopolistic industrial structure within Europe. According to Narula, (*Ibid*.) the increase in the number of agreements in the 1990s is due to the fact that these were now in place informally to an extent that intra-European alliances have fallen off.

As the establishment of STPs seems to have characterised the European ICT industry since the 1980s, it is worth investigating the distribution of alliances in the industry by nationality of both parent and partner company. The aim is to trace the main networks of intra-European partnerships in the ICT industry by distinguishing between European and home partners and, in the former case, going into details of nationality of the partner company.

For each European national group of electrical companies, Table 1 records the distribution of alliances within ICT partners from other European member states and from the same home country relative to the European electrical industry as a whole over the period 1980-86. In Table 1, the overall total depicts a clear preference for partners from other European member states. 80% of the alliances concluded within the European electrical industry seem to involve parent companies located in different European countries. The launch of the SEM may have speeded up the movement towards co-operation in order to compete in a global environment characterised by globalisation of competition and increased rate of innovation (Urban and Vendemini, 1992). This pattern is mainly led by German ICT companies and to a lesser extent by Dutch, Italian and Swedish corporations. For all these national groups of firms, the figures show a clear preference for other European partners rather than for partners from the same home country. In the case of the German companies (i.e. AEG-Telefunken, Siemens and Nixdorf Computer), this trend might be explained by a corporate approach to international competitiveness based on globalisation of R&D activity (Cantwell and Harding, 1998). Moreover, as in all other European countries, the largest national electrical corporations have historically dominated the national ICT market by operating in different markets and technological segments. Thus, for each of them, it was easier to found technological capabilities complementary to their technological specialisation profile in foreign companies active in the same types of technology than in other German companies.

Partnerships by French and British electrical corporations appear to follow a different pattern. As reported in Table 1, both these ICT national groups of firms are the most active in entering STPs relative to all others accounting for 36.0% each of the total alliances concluded in the European ICT industry as a whole. However, even if French and British corporations seem to prefer

European partners, they still enter alliances with home firms. This trend is more marked for the British than for the French electrical corporations. For the former, alliances with a home partner count for 12.0% of the total STPs entered by electrical companies within the European ICT industry. In the latter case, home partnership counts slightly less (8.0%) on the total STPs entered by electrical companies within the European ICT industry. National champions' policies and a "fortress Europe" approach to the competitiveness issue in ICT foreign markets may provide an explanation for the fact that intra-French partnerships still play an important role. As a result of the national champions' policies, the largest French electrical corporations (i.e. Thomson-Brandt, CGE and CII-Honeywell Bull) have grown accustomed to work primarily for the domestic market. In this sense, the European arena represents an extension of this national logic to the regional market (Delapierre and Zimmerman, 1991). Therefore, strategic partnerships are aimed at defining the existing market base in a context of globalising industries. Nonetheless, the high percentage of European partnerships concluded by French electrical companies may be read as an indirect effect of the early European technology policy, which promoted the adoption of a "springboard Europe" strategy (*Ibid*.). This strategy is mainly characterised by the preference for partnerships with European firms which could then be expected to evolve into or be supplemented by commercial and global agreements in order to structure the complementarity of the two partners. In this context, a rather wide spread technological specialisation is likely to explain the overall greater degree of technological collaboration with European ICT companies by French multinationals.

The British situation is somehow different when considering the high percentage of intra-UK ICT alliances by comparison with all other national groups of firms. Following the finding of a previous empirical study on similarities between corporate technological specialisation profiles in the European ICT industry (Santangelo, 1998), the reason for this may be identified in closer technological complementarity among British ICT companies in the period considered. Likewise, in the UK ICT industry, there is a long history of co-operation, in which academic and industrial communities interact closely (Oakley, 1984). However, it is worth noting that STPs concluded by UK electrical companies with European partners' account for a relevant percentage of the total alliances in the ICT industry, thus confirming somehow an active role of UK corporations in the European electrical industry.

For each national group of European ICT companies, Table 2 reports the cross-country distribution of alliances with partners from other European countries. A glance at the figures reveals that French and British electrical firms are the favoured allies of German-owned corporations. Following the findings of the empirical study referred to above (Santangelo, 1998), the establishment of alliances between these national groups of companies may be due to the fact that these partners moved along similar technological trajectories in the period in question. In this

context, STPs may have been viewed as a forum to combine different corporate partners' competencies. From Table 2, it is also possible to depict the existence of alliances between German ICT companies (namely Siemens) and Philips.

Like the German ICT corporations, Philips shows a strategic alliance profile oriented to European rather than to home partners. In evaluating the figures in Table 2, the company's corporate strategy should be taken into consideration as well as its position in the European ICT industry. Philips focused its resources on its most profitable and fast-growing product lines by implementing a policy of acquisitions and joint ventures. This strategy promoted the Dutch corporation as a technological leader in the European ICT industry in terms of technological size and specialisation (Santangelo, 1998) as well as market share. The high degree of internationalisation of Philips' R&D activity (Cantwell and Janne, 1998) may also provide a further explanation for the company's preference for European partners. The range of nationalities of Philips' allies confirms the profile of technological generalist of the Dutch company. If product and technological diversification are key factors in explaining the leading position of Philips in the European ICT industry, they also provide a major explanation for the company partnering strategy, since Philips' product and technological corporate competencies complement a large number of European competitors' capabilities.

In contrast, French partners seem to absorb completely Olivetti's alliance profile. This pattern is fully driven by the specialisation in computing technology between CII-Honeywell-Bull and Olivetti. The Italian pattern is fully led by Olivetti's partnering strategy defined by its chief executive, Carlo De Benedetti. STPs have played a major role in Olivetti's history since it was believed that links with high technology companies were vital in allowing a relatively modest size firm such as Olivetti to keep updated with advanced development, whilst concentrating its own R&D in specialist areas (Jowett and Rothwell, 1986). European collaborations appeared to be appealing also when considering the structure of the Italian electrical industry mainly dominated by Olivetti and characterised by small and medium size enterprises.

Accordingly, the figures in Table 2 illustrate that the UK electrical companies enter alliances with French companies and to a lesser extent with German, Dutch and Swedish. In the case of LM Ericsson, the preference for British partners may be due to the complementary expertise in communications technology as well as to the Swedish corporation strategy. LM Ericsson seems to choose its partners according to its market targets (Jenkins, 1991).

5.2 Specialisation dynamics in corporate strategic technological partnerships in the European ICT industry

To test Hypothesis 1 a logit estimation is run, while an OLS model is used to test Hypothesis 2. In both cases, the econometric analysis is carried out by adopting the two classifications of the 91 pairs of allied companies illustrated in section 4 in order to guarantee the robustness of the results.

As far as Hypothesis 1 is concerned, the results suggest that the degree of overlap between partners' technological specialisation profiles does not seem to influence positively the formation of STPs when considering all allied firms as a whole without further distinction (Tables 3 and 4). However, when one distinguishes between technologically similar (dissimilar) or co-specialised (non-co-specialised) pairs of allies, the more partners are technologically similar or co-specialised, the greater is the likelihood of an alliance between them for the purpose of technological co-operation (Tables 3 and 4). These results are consistent with the view that the more similar partners' technological portfolios are to one another, the easier it is for them to absorb each other's capabilities (Mowery *et al*., 1996, 1997). "Absorptive capacity" has been identified as a necessary condition for inter-firm learning through alliances since it facilitates the acquisition of outside capabilities in related technological areas (Cohen and Levinthal, 1989, 1990). Corporate capacity in absorbing outside capabilities is the result of an internal process of accumulation of knowledge. This capacity develops over time following path-dependent avenues. In this light, the capacity to absorb new corporate competencies from the range of the ally is greater if partners' technological portfolios overlap with one another. Similar/co-specialised partners need proximity, as they are more likely to cooperate in learning, while other kinds of alliances involve merely an exchange of knowledge such that distance becomes an advantage. While in the former case alliances enhance corporate learning through coordination of partners' close complementarities, in the latter alliances are facilitators of corporate change through the coordination of knowledge spillovers between increasingly separate activities (Cantwell and Barrera, 1998). Therefore, as already shown empirically by Mowery *et al*. (1998), partner selection can be predicted by firms' technological overlap. This may provide further explanation for the fact that subsidised European R&D networks for ICT companies seem to match with privately established networks (Hagedoorn and Schakenraad, 1993b). Firm-specific technological competencies are crucial in co-ordinating change and innovation efficiently. For this reason, partners' choices are likely to be mainly dictated by close technological profiles which facilitates collaboration in highly technologically complex fields such as ICT. This is all the more true in the case of the European electrical companies which seem to lag behind by comparison with the US and Japanese competitors. In this case, the attempt to gain

access to partners' technological capabilities may be rather costly because of the lack of common expertise.

Moving to the testing of Hypothesis 2, as shown in Tables 5 and 6, the results of the regression analysis confirm the findings of previous empirical studies (e.g. Mowery *et al*., 1997), according to which partners' technological similarities are reinforced over time through strategic alliances. Similar technological profiles seem to converge as a result of the acquisition of partners' capabilities. Following Cantwell's and Barrera's (1998) argument, inter-firm co-operations between technologically similar/co-specialised partners are likely to promote technological learning since mutual research efforts in the shared field of specialisation may create a detailed division of labour. By contrast, inter-firm co-operation between dissimilar/non-co-specialised partners cannot go beyond exchange of knowledge since there are no common capabilities promoting coordination of research and learning processes. In the latter case, inter-firm co-operation is likely to lead to a much broader division of labour, which may move the allies' specialisation profiles further apart. However, as suggested by Nakamura *et al*. (1996), in the case of divergent technological portfolios, partners' competitive capabilities are complementary even if becoming more dissimilar. In this sense, alliances represent a mean of corporate specialisation since companies focus more on some areas. In the case of convergent alliances, the leading capabilities of the European electrical partners are mutually enhanced, thus enabling them to deal with the increasing level of technological complexity. In turn, this should push them to improve their productivity and competitiveness, thus expanding their share of non-European markets. In this sense, co-operative management of knowledge has been identified by the European Commission as a key tool in promoting the European ICT industry.

However, inter-firm co-operation can only partially explain the process of technological convergence (divergence) since the specialisation profiles of the European electrical companies seem to have became more similar or have moved further apart also as a result of corporate technological diversification strategies. The results seem to suggest that technological diversification has played a crucial role in the process of technological convergence (divergence) (Tables 5 and 6). In the development of technology, alliances and in-house investments in new technological competencies should be understood as complements, rather than substitutes. Both strategies enable large multi-technology companies to develop (besides their *core*) technological competencies that are *distributed* across an increasing number of technical fields in order to avoid failures in product development, production, marketing and organisational adaptation (Granstrand *et al*., 1997). The importance of technological diversification as a crucial determinant of corporate co-specialisation within the European ICT industry is also confirmed in Figure 4, where the changes in technological co-specialisation between European ICT partners relative to the total number of

alliances are shown. It turns out that there was a 12% increase in the number of technologically co-specialised partners between 1978-86 and 1987-95. This implies that previously negatively technologically co-specialised partners most likely came closer together over time as a result of corporate diversification strategies when combining the impression gained from Figure 4 with the results of the regression analysis (Tables 5 and 6). Thus, in the European ICT industry, partnering and technological diversification strategies appear to be major factors in promoting closer technological integration. Nonetheless, the role of European technology policy as well as the on-going integration process in orienting and directing corporate technological trajectories in the European ICT industry should not be understated.

6. Conclusions

Collaborative partnerships have been increasingly adopted as a form of business operation in the early 1980s. The 1980s increased adoption of strategic technological partnerships as a form of organisation of economic activity has been identified as a main feature of a new phase of the capitalist system (Gerlach, 1992, Dunning, 1995, 1997), where competitiveness is increasingly pursued through co-operation. This phenomenon has mainly characterised science-based fields of technological activity such as ICT as a result of the growing technological interrelatedness and complexity. In geographical terms, while the 1990s were characterised by an increase in inter-bloc STPs, the 1980s trends in strategic technological partnership showed a clear intra-bloc specificity (Narula, 1998). During the 1980s, the growth in the number of technological alliances was greater between partners from the same regional area. Thus, even if the phenomenon involved mainly Triad countries and corporations, there appeared to be a strong regional connotation. In the European case, in the 1980s this trend might have also been strengthened by the on-going economic and political integration process as well as by the European technology policy, which has became more structured over time.

In this so-called alliance capitalism phase, technological overlap between similar European ICT companies is found to be a major factor in the conclusion of strategic technological partnerships. Based upon a resource pooling strategy, corporate alliances promote synergies between allied companies, thus affecting the development of firms' internal capabilities and furthermore their technological profiles over time. Since inter-firm alliances tend to develop in areas in which firms share complementary capabilities, a partner's choice can be predicted by firms' technological overlap (Mowery *et al.*, 1998). Companies sharing technological commonalties can

enhance their intra-learning development through collaborative agreements. The co-operative option allows firms to face the increasing pace of technological change by absorbing each other complementary technological competencies. Nonetheless, a distinction should be made between complementary and close complementary firm-specific paths of development (Cantwell and Barrera, 1998). The fruitful exchange of knowledge requires the complementarity of activities, but co-operative learning creates a closer complementarity between those activities. In the latter case, partners' technological profiles converge as collaborative agreements encourage co-ordination between partners' internal paths of innovative learning. By contrast, in the former case, firms' learning paths become more localised, although their activities remain complementary (*Ibid*.). However, if alliances enable firms to cope with the fast rate of technological development, they cannot substitute in-house investment in order to enhance firms' technological competencies. Multinational corporations still need to diversify in the range of technologies they master since a wider range of specialised knowledge is now required for the production and distribution of specific products (Granstrand and Sjölander, 1990, Granstrand *et al*., 1997).

Accordingly, it is found that, in the European ICT industry, participation in STPs and corporate technological diversification are major determinants of technological convergence between already similar/co-specialised partners. As far as technological collaboration is concerned, this is the case if corporate co-operation involved a transfer of knowledge rather than a simple exchange. In the former case, a complementary division of labour is likely to develop between the partner companies, which come closer together in terms of specialisation profiles. The positive influence of technological diversification on partners' technological convergence is consistent with the view that large firms are required to master a wide range of technologies in order to be able to match radical changes in technology with equivalent changes in production. Thus, technological specialisation profiles of European electrical partners are also found to be convergent as a result of the technological diversity developed within collaborative agreements.

From the overall findings, it is possible to draw the conclusion that a collaborative approach to the issue of European competitiveness in ICT fields seems to have been rather successful in promoting common technological trajectories within the European electrical industry in the 1980s. This is likely to lead to a more structurally defined European ICT industry since collaborative agreements allow European electrical corporations to combine synergies and develop a division of labour between them. In addition, as in the 1980s privately established networks resemble subsidised European companies (Hagedoorn and Schakenraad, 1993b), the growth of STPs promoted an oligopolistic industry structure in the 1990s. It is the fact that agreements were now in place informally to an extent that intra-European alliances have fallen off in the early 1990s

(Narula, 1998). In this sense, European technology policy seems to have facilitated rather than imposing this process which has already taken place at corporate level.

Acknowledgements – The author is grateful to Professor John Cantwell and Professor Massimo Colombo for having provided the US patent data and the Advanced Research Programme on Agreements (ARPA) data respectively. Needless, to say the end product is the author's own responsibility particularly any areas of remaining obscurity.

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Table 1 - Distribution of alliances within the European ICT industry relative to the total number of alliances concluded in the industry, by nationality of the parent and partner company, 1980-1986 (%)

nationality of the parent company	other European partner	Home partner	**Total**
France	28,0%	8,0%	36,0%
Germany	14,0%	0,0%	14,0%
Italy	4,0%	0,0%	4,0%
Netherlands	8,0%	0,0%	8,0%
Sweden	2,0%	0,0%	2,0%
UK	24,0%	12,0%	36,0%
Total	80,0%	20,0%	100,0%

Table 2 - Distribution of alliances between European ICT partners[a] relative to the total number of alliances concluded in the European ICT industry, by nationality of the parent and partner company, 1980-1986 (%)

nationality of the parent company			
France		Germany	21,4%
		Italy	14,3%
		Netherlands	14,3%
		Sweden	0,0%
		UK	50,0%
	Total		**100,0%**
Germany		France	42,9%
		Italy	0,0%
		Netherlands	14,3%
		Sweden	0,0%
		UK	42,9%
	Total		**100,0%**
Italy		France	100,0%
		Germany	0,0%
		Netherlands	0,0%
		Sweden	0,0%
		UK	0,0%
	Total		**100,0%**
Netherlands		France	50,0%
		Germany	25,0%

		Italy	0,0%
		Sweden	0,0%
		UK	25,0%
	Total		**100,0%**
Sweden		France	0,0%
		Germany	0,0%
		Italy	0,0%
		Netherlands	0,0%
		UK	100,0%
	Total		**100,0%**
UK		France	58,3%
		Germany	25,0%
		Italy	0,0%
		Netherlands	8,3%
		Sweden	8,3%
	Total		**100,0%**

[a] Alliances between European ICT companies from the same home country are excluded.
Source: Author's calculation on ARPA database, Polietcnico di Milano.

Table 3 - Results of the logit analysis (standard errors in parentheses)
based on the clusters classification

Dependent Variables	ALLIES		SIMI		DIS	
Constant	-4,228 (0.249)	*	-5,485 (0.502)	*	-5,594 (0.332)	*
r(78-86)	1,343 (0.793)		3,702 (1.239)	*	-2,312 (1.390)	**
No. obs.	91					
Log-likelihood	-52,589		-26,5391		-33,834	

* significant at 1% level
** significant at 5% level

Table 4 - Results of the logit analysis (standard errors in parentheses)
based on the RTA values classification

Dependent Variables	ALLIES		COSP		NON-COSP	
Constant	-1,0566 (0.2498)	*	-2,189 (0.3891)	* *	-2,010 (0.3419)	*
r(78-86)	1,066 (0.794)		3,231 (1.037)	*	-2,456 (1.334)	***
No. obs.	91					
Log-likelihood	-52,589		-33,6089		-31,565	

* significant at 1% level
** significant at 5% level
*** significant at 10% level

Table 5 - Results of the OLS regression analysis based on the clusters classification

Regressor	Coefficient	Standard Error	T-Ratio	
Intercept	-0,038	0,048	-0,796	
SIMI	0,260	0,150	1,735	***
DIS	0,016	0,100	0,156	
Dcomp	-0,941	0,241	-3,901	*
Dtele	-0,466	0,215	-2,168	*
DIVE	0,005	0,003	2,001	**
R-Squared	0,188			
R-Bar-Squared	0,141			
No. obs.	91			

* significant at 1% level
** significant at 5% level
*** significant at 10% level

Table 6 - Results of the OLS regression analysis based on the RTA values classification

Regressor	Coefficient	Standard Error	T-Ratio	
Intercept	-0,038	0,047	-0,817	
COSP	0,211	0,113	1,864	***
NON-COSP	-0,071	0,106	-0,668	
Dcomp	-1,045	0,253	-4,134	*
Dtele	-0,483	0,212	-2,278	**
DIVE	0,005	0,003	2,068	**
R-Squared	0,203			
R-Bar-Squared	0,156			
No. obs.	91			

* significant at 1% level
** significant at 5% level
*** significant at 10% level

Table A1 - List of companies in the sample (nationality of ownership in brackets)

AEG-Telefunken (G)
CII-Honeywell Bull (FR)
General d'Electricite (FR)
Genral Electric co. (UK)
LM Ericsson (SE)
Nixdorf Computer (G)
Olivetti (IT)
Philips (NL)
Plessey (UK)
Racal Electronics (UK)
Siemens (G)
Standard Telephone and Cables (STC) (UK)
Thomson-Brandt (FR)
Thorn EMI (UK)

Table A2.1 - List of the technological patent classes in the period 1978-86*

telegraphy	1
demodulators	2
modulators	3
communications, electrical: acoustic wave systems and devices	4
multiplex communications	5
pulse or digital communications	6
telephonic communications	7
telecommunications	8
communications: electrical	9
code data generation or conversion	10
image analysis	11
communications: directive radio wave systems devices	12
communications: radio wave antennas	13
music	14
acoustics	15
pictorial communication: television	16
electrical audio signal processing system and devices	17
electrical transmission or interconnection systems	18
active solid state devices	19
register	20
dynamic magnetic information storage or retrieval	21
electrical computers and data processing systems	22
static information storage and retrieval	23
dynamic information storage and retrieval	24
error detection/correction and fault detection/recovery	25
electrical pulse counters, pulse dividers or shift register circuits and systems	26

Table A2.2 - List of the technological patent classes in the period 1987-95*

telegraphy	1
demodulators	2
modulators	3
communications, electrical: acoustic wave systems and devices	4
multiplex communications	5
pulse or digital communications	6
telephonic communications	7
telecommunications	8
communications: electrical	9
code data generation or conversion	10
image analysis	11
selective visual display systems	12
communications: directive radio wave systems devices	13
communications: radio wave antennas	14
music	15
acoustics	16
pictorial communication: television	17
electrical audio signal processing system and devices	18
television	19
electrical transmission or interconnection systems	20
active solid state devices	21
electrical digital logic circuit	22
register	23
dynamic magnetic information storage or retrieval	24
electrical computers and data processing systems	25
static information storage and retrieval	26
dynamic information storage and retrieval	27
error detection/correction and fault detection/recovery	28
electrical pulse counters, pulse dividers or shift register circuits and systems	29
information processing system organisation	30

Table A3 - Taxonomy of partnerships.
Contractual forms and contents.

contents	equity forms								non-equity forms				
	PAR	MIN	CVC	JOV	SUB	FRN	LIC	OEM	VAR	TRS	SRC	CON	ACC
FIN	x	x	x	x								x	
RES	***x***	***x***		***x***							***x***	***x***	***x***
KHE	x	x		x			x			x			x
PRD	x	x		x	x		x				x	x	x
PER								x					
COM	x	x		x		x	x	x	x		x	x	x
SER	x	x		x							x	x	x
ASS	x	x		x			x						x
ALT	x	x		x							x	x	x

Note:

Contents

- FIN financial resources
- RES research and development
- KHE know-how and engineering
- PRD production
- PER customisation
- COM marketing and distribution
- SER services
- ASS post-selling assistance
- ALT others

Forms

- PAR parity participation
- MIN minority participation
- CVC corporate venture capital
- JOV joint venture
- SUB sub-supply
- FRN supply
- LIC licence
- OEM original equipment manufacturing
- VAR value added retailing
- TRS sources and know-how transfers
- SRC implementation and joint development
- CON consortia
- ACC other agreements

Source: Cainarca *et al.* : 1989.
Bold Italics indicates the partnerships which this paper focuses on.

econometric models

r	Coefficient of correlation across 26 technological each allied pair of
ALLIES	Dummy variable; it equals 1 for allied pairs of firms, 0 otherwise.
SIMI	Dummy variable; it equals 1 for similar allied pairs of firms, 0 otherwise.
DIS	Dummy variables; it equals 1 for dissimilar allied pairs of firms, 0 otherwise.
COSP	Dummy variable; it equals 1 for co-specialised allied pairs of firms, 0 otherwise.
NON-COSP	Dummy variables; it equals 1 for non-co-specialised allied pairs of firms, 0 otherwise.
$Chr_{(78\text{-}86/87\text{-}95)}$	Absolute changes in the coefficient of correlation between 1978-86 and 1987-95.
$ChDIVE_{(78\text{-}86/87\text{-}95)}$	Larger absolute change in technological diversification* within each allied pairs between 1978-86 and 1987-95.
Dcomp	Dummy variable; it equals 1 if one partner move its technological specialisation towards computing, 0 otherwise.
Dtele	Dummy variable; it equals 1 if one partner move its technological specialisation towards nc defence telecommunications, 0 otherwise.