FIRM SPECIALISATION AND GROWTH. A STUDY OF THE EUROPEAN SOFTWARE INDUSTRY

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Introduction[1]

This study compares internal corporate changes (new subsidiaries and other reorganisations) and external links (mergers and acquisitions, minority participations, joint ventures and other collaborative agreements) concerning 38 large European and US firms specialised in software and computer services during the period between 1984 and 1992.

The paper has two main objectives. First, to show the main objectives of external and internal growth and second, to analyse the relationship between firm specialisation in 1983 and the patterns of firm's growth and diversification in the subsequent period (1984-1992).

Why is the software industry an interesting case study in this field? Software is a 'pervasive' technology that is produced in many different sectors. Software users produce in-house a significant share of their software programs. According to some estimates, internally developed software represents about 59% of software expenditures in the largest European markets (Germany, France, the UK and Italy) as compared with 24% of external packaged software (acquired from specialised software producers) and 15% of outsourcing (contracted to independent contractors) (IDC, 1990).

Despite the importance of non traded software activities, an independent software industry has emerged since the 1970s as a consequence of 'vertical disintegration' from different business organisations and the entry of new firms.

This process of vertical disintegration is similar to that of mechanical engineering during the second half of the last century, which led to the spin-off of machine tool factories from many different industries, including firearms, bicycles and automobiles (Rosenberg, 1976). Today, many large suppliers of computer software and services have spun off from established electronic and computer firms (e.g., GSI from Generale Electricité and Sterling Software from Sterling Electronics) and from non electronic firms (e.g., EDS from General Motors, Scicon from British Petroleum and Istel from British Leyland/Rover Group). The entry of innovative start-ups also contributed to the rapid growth of the software industry during the 1980s. This has mostly occurred in sofware packages compared with computer services.

The specialisation of software activities has been spurred by two main factors.

The first is the advances of hardware technology and the “pervasiveness” of information technology in general, i.e. its rising use in all economic sectors. The number of software packages for minicomputers and larger systems in the US market increased from about 5000 in 1979 to 6200 in 1982 while the suppliers rose from 900 to 2000 (Gotlieb, 1985, p. 208). The introduction of personal computers, workstations and distributed computer networks (local area networks) in the 1980s, have created new windows of opportunities for software firms. Large opportunities for economies of scale have emerged in the production of software packages as a result of network externalities produced by the emergence of standard platforms for personal computers in the 1980s (IBM PC, IBM-Microsoft's MS-DOS and Microsoft's Windows) (Steinmueller, 1986). This has spurred vertical disintegration of software activities from hardware manufacturing. During the 1980s most computer manufacturers have reduced their in-house production of software and services. Moreover, the diffusion of compatible personal computers has favoured the 'portability' of software packages on a large installed base of computers from different producers and has accounted for the fast growth of firms which entered the market in this period, such as Lotus (electronic spreadsheet), Microsoft (operating systems and office applications),

Ashton-Tate (data base management systems) and Novell (local area network operating systems). In Europe the high market fragmentation, due to linguistic and cultural barriers across countries, has reduced the opportunities for economies of scale and scope in software packages. This is one of the factors, including the early entry and market pre-emption by US firms, that have hampered the start-up of a European industry of packaged software (cf. Malerba and Torrisi, 1996). Most European firms have thus specialised in services and customised software. This market segment is populated by many small and medium-sized firms, each serving few large customers.

The second main factor that has affected the evolution of this industry is the “unbundling” of software sales from those of computers, a practice introduced by IBM in 1969 in the US and followed by its main competitors worldwide. The unbundling effect has reinforced the technological change effect described above in that it has stimulated vertical disintegration of hardware manufacturers and the entry of many specialised computer software and services firms independent of hardware manufacturers.

As a consequence of these factors, the market for software and services has increased at a high rate over the last decade and the average net profits in software activity have been high compared with other information technology (IT) market segments, including computers. Software as a share of total revenues of the largest world IT companies classified in Datamation increased from 8.6% to 11.6% between 1988 and 1992. The share of computer services (excluding computers maintenance) increased over the same period from 8% to 15.6%. By contrast, the share of hardware products (excluding data communication equipment) of these companies has remained stable in this period (from to 34.2% to 34.8% of total revenues). The growth of software and services revenues was mainly accounted for by specialised software firms. Most hardware manufacturers have reduced software and services revenues as a share of their total revenues. For instance, Digital Equipment Corporation's software and services share passed from 25% in 1981 to 17% in 1992. Hewlett-Packard's share declined from 29% to 8% in

1992.[2] Moreover, the profitability of software firms is high compared with that of computer firms. Datamation has compared three samples of firms selected from the world largest IT companies. The returns on sales of software firms have passed from 12.4% in 1988 to 10.1% in 1992 while service firms' returns on sales remained stable (from 6.7% to 6.3%). Hardware firms showed a 10.5% returns on sales ratio between 1988 and 1990 which fell to 3% in 1992 (Datamation, June 15, 1993, pp. 12-15).

The progressive reduction of margins from hardware sales and the rising importance of open standards over recent years have spurred hardware manufacturers towards software and services. Some of these have tried to re-enter the software market through mergers & acquisitions. For instance, in 1995 IBM acquired Lotus Development, one of the largest US producers of software packages. Recently, software has increased significantly as a share of total sales for many hardware manufacturers such as IBM (from 17% in 1990 to 26% in 1992), Unisys (from 16% to 26%), Amdhal (from 2% to 20%) and Hewlett-Packard (from 3% to 8%) (Datamation, June 15, 1991 and 1993). Moreover, the largest European software firms have recently resorted to large capital partners. Istel has been acquired by AT&T from British Leyland, Logica has agreed to be acquired by British Telecom, Cap Gemini has sold 34% of its shares to Daimler-Benz Interservices (Debis) and Finsiel has tried to merge with Olivetti's software division[3]. These strategic alliances have been spurred by a reduced growth of the software market during the 1992-1994 and a lack of financial and managerial resources showed by many large European software firms.

However, this process does not seem to bring about a complete re-integration of software activities by hardware manufacturers or users. Hardware manufacturers that have increased their software and services activities face strong competition from firms like Microsoft, Computer Associates and Andersen Consulting, which are not integrated in hardware manufacturing. These firms have strong service and organisational capabilities that are important to coordinate the

activities of many subcontractors and to serve international markets. Moreover, most software firms have grown within the software sector or have diversified towards related activities (e.g., telecommunication services), whereas they have not diversified into hardware. This suggests that there are not significant economies of scope between hardware and software activities which justify their integration.

The paper is organised as follows. Section 2 describes vertical disintegration and diversification in the economic literature. Section 3 illustrates the data. Section 4 discusses the main empirical results: inter-firm linkages, internal restructuring and the trajectories of software firms' growth. Section 5 summarises the main results and concludes the work.

2. Vertical disintegration and industry specialisation: a survey of the literature

Economists and economic historians have explained specialisation and the division of labour among firms by focusing on market size, firm-specific assets (excess resources or quasi-public inputs) and learning[4].

Drawing on the classical contributions of Adam Smith and Allyn Young, Stigler (1951) has set forth the reasons why market extent for individual final products results in 'vertical disintegration' of upstream activities. Young industries internalise most phases of their production activities for several reasons, among which there is the lack of reliable supply of materials, components and machinery. By contrast, maturing industries rely on a larger market for their goods and externalisation of upstream activities becomes attainable because they enjoy economies of scale or economies of specialisation (due to learning by doing etc.). Thus, the economies enjoyed by the suppliers of inputs depend on the market size for final products. However, the market size for a single final product explains only in part the division of labour among industries. Another explanatory factor is represented by technological external economies. Rosenberg (1976) has argued that in the second half of last century the American machine tool

industry has spun off from many industries which utilised various machine tools for two main reasons: economies of specialisation and 'technological convergence'. With the latter he meant the process by which the skills and techniques for handling and shaping metals or for sewing fabrics became widespread among many different industries. Therefore the machine tool industry has enjoyed both internal economies of scale and the external economies arising from technological spillovers.

Patel and Pavitt (1994) have measured the importance of technological convergence and vertical disintegration of technological activities, showing that technological capabilities in the field of mechanical engineering (and, to a lesser extent, other ones such as chemical and instrumentation engineering, computers, materials and biotechnology) are diffused in a wide range of industrial sectors. This indicates that firms specialised in mechanical engineering may access to a large pool of knowledge and benefit from technological externalities produced by different sectors. More recently, Malerba and Orsenigo (1996) have studied the organisation of technological activities for different technologies, showing that in mechanical engineering the concentration of innovative activity is low, the average size of innovators is small, the hierarchy of innovators is relatively unstable over time and the rate of entry of new innovators is high.

These studies show that the characteristics of the knowledge underpinning technological activities, including its pervasiveness, vary across sectors affecting the organisation of innovative activities and the evolution of the industry structure. A low concentration of innovative activities in mechanical engineering is associated with a low market concentration compared with other industries, such as electronics and chemicals, characterised by a high technological and market concentration.

The literature on technical change and the division of labour among industries, however, is not clear as to what the implications of market size and technological regimes are for the directions of firm growth and diversification. After the stage of take off an industry will enter a stage of

development and maturity. The theory of the firm suggests that with maturation the firms which are active in the industry begin to diversify their business activities to exploit their excess financial, technological and managerial resources (Penrose, 1959). However, this is not the case of mechanical engineering firms, which do not seem to have taken advantage of their knowledge and expertise to diversify into new businesses. Similarly, most established software firms maintain a high degree of specialisation or diversify in businesses closely related to their core activities. Why do they not diversify, for instance, in computer hardware or telecommunications equipment, despite the importance of software technology for these industries?

Diversification is a process resulting from the interaction between economic and institutional factors. In the last few years the economic literature and history of the firm have shown a renewed interest in the analysis of the scope of firms' diversification and growth (Chandler, 1990, Rotemberg and Saloner, 1994; Teece et alii, 1994). This interest seems to reflect the crisis of many large multi-product companies which during the past decades have diversified their activities in unrelated businesses. In the 1980s and 1990s, most multi-product firms have restructured their activities and re-focused their business portfolio. This suggests that the costs of diversification have probably increased due, for instance, to market globalisation. On the other hand, particularly in the US, the benefits of diversification may have decreased as a consequence of factors such as the reduction of the efficiency of firm's internal capital market compared with the external market and the relaxation of antitrust regulation, which before the 1980s imposed stringent limits on the possibility to reinvest profits in the main business (Markides, 1995).

Moreover, diversification varies across firms. The empirical evidence shows a bimodal or trimodal distribution of firms which have restructured in the 1980s (Hoskisson and Johnson, 1992) - related-diversified firms have reduced their diversification while unrelated-diversified (conglomerate) firms have increased their diversification. The level of diversification reflects the history of the firm (including its past diversification), its technical and organisational capabilities,

and its 'corporate culture'. This may explain why empirical investigations provide mixed results on the relationship between diversification and firm performance. Rumelt (1974), Markides (1995) and Robbins and Wiersema (1995) show that related diversification is conducive to a better economic performance as compared with unrelated or conglomerate diversification. However, other empirical works indicate a weak correlation between the relatedness of business portfolio and firm performance (Montgomery, 1985; Amit and Livnat, 1988).

The economic literature highlights several factors which limit diversification. First, there are increasing returns to specialisation which are linked to learning by doing and dynamic economies of scale. Second, related diversification allows the achievement of economies of scope from the exploitation of 'excess resources' or quasi-public inputs. Third, coordination costs increases with the variety of lines of business. That is, there are diminishing returns to diversification due to managerial bottlenecks in the exploitation of excess resources (Montgomery and Wernerfelt, 1988)[5]. Fourth, there are financial constraints that explain why firms from mature industries endowed with excess financial resources are more likely to become more diversified compared with firms operating in fast growing industries, which have strong incentives to invest their resources in the core sector because of high expected returns. Fifth, business relatedness (or a narrow business portfolio) facilitates the implementation of incentives schemes as demonstrated by Rotemberg and Saloner (1994). Finally, there are the firms limited cognitive resources and capabilities. The learning process is characterised by cumulativeness, path-dependency, idiosyncrasy and inertia which affect firms' ability to try unknown avenues of growth (Nelson and Winter, 1982; Teece, 1988; Pavitt, 1991a; Rumelt, 1995). As a consequence, when expanding their activities, firms attempt to do 'more of the same' or 'more of something closely related, something of which the firm has some degree of relevant knowledge' (Winter, 1993, pp. 190-191). This approach is consistent with the idea of the firm as an evolving stock of knowledge,

resources and capabilities, which are in part idiosyncratic and difficult to transfer across firms and sectors.

To diversify their business firms may rely on internal growth (e.g., new subsidiaries or divisions) or external growth (M&As, joint ventures and other collaborative agreements). This paper does not focus on the factors which affect the choice between different forms of growth - vertical or lateral integration, internal or external growth. In general, external growth may be thought of as a natural channel of diversification. Through external linkages, firms may gain access to scientific or technical knowledge required to develop new products. In a world of rapid technical change and increasing knowledge multidisciplinarity, it is difficult for a single firm to develop internal capabilities in many different fields. Thus, firms are spurred to set up linkages with external sources of knowledge, including the acquisition of firms endowed with specific capabilities.

Moreover, firms may seek to reach new markets through agreements or M&As with the aim to enjoy increasing returns to scale and scope from the use of their "excess resources", including technical knowledge. In this case, the choice of agreements or M&As as an alternative to internal growth may reflect the need to reduce the time and the costs for the accumulation of complementary capabilities (e.g., sales and post-sales service networks). Furthermore, the choice between non-equity agreements or minority participations and M&As may depend on the level of idiosyncrasy and market specificity of complementary capabilities. If there are economies of scope at the level of R&D activities but not at the level of commercialisation or post-sales services, diversification by collaboration will be more efficient than M&As. In these circumstance, two firms may set up a R&D joint venture and commercialise the results through their independent sales network. This solution allows a high level of autonomy to each business unit and reduce possible managerial diseconomies due to a large scale of operations.

3. Data and methodology

The analysis of the firm external linkages and corporate reorganisations in this paper focuses on 18 European firms specialised in software and computer services. The growth strategies of these firms were compared with those of 20 American software and computer services firms. Our analysis draws on a database containing 997 operations concerning the sample firms. Integrated software and hardware firms (e.g., IBM, Siemens and Olivetti) are not included in the database. The operations were conducted by the sample firms during the period between 1984 and 1992. 640 of these operations are *external linkages* - joint ventures (JV), minority participations, licensing agreements, others collaborative agreements, mergers and acquisitions (M&A). There are 275 operations which refer to *internal corporate changes* - creation and shutdown of new subsidiaries, and other internal reorganisations (e.g., the merger of two divisions, jobs cuts or improvements). 82 operations concern the stipulation of new contracts (particularly with large customers).

Firms were selected from the International Data Corporation (IDC) classification of the largest European and North American software and services firms operating in Europe in 1989. The sample includes the largest European firms in 1990, such as CAP Gemini Sogeti (France), Finsiel (Italy), SD-Scicon (UK-France) and Software AG (Germany) from six EU countries - France, Germany, Italy, Netherlands, Sweden and UK. As Table 1 shows, European firms are specialised in computer services, except for SAP and Software AG of Germany which specialise in packaged software. Finally, the sample includes the largest US firms such as Microsoft, Computer Associates, Oracle and Lotus. In contrast with their European counterparts, US firms specialise in packaged software - only five sample firms specialise in computer services.

The data on firms' growth have been collected from Predicast database, which is based on information drawn from press sources (see references). Firms for which information is provided are classified by Predicast according to their main business area. The sample firms were

classified under the SIC codes 7370 to 7379 (packaged software and computer and data processing services). Each operation is also classified by Predicast according to SIC classification. This allows the comparison between the firms' area of business and the business sector of each operation. Finally, Predicast provides information about the partner(s), its nationality (although not systematically), and a brief description of the operation. On the basis on this qualitative information, a database was set up. This provides the following data: four digit SIC code of the operation, year to which each operation refers, type of operation (M&A, JV, etc.), country of the partner (or the new subsidiary), number of citations in the press, content (R&D, Production, Marketing, Financial). These qualitative, nominal-level data were then transformed into quantitative, ratio-level data. When possible these data have been integrated with other information from annual reports concerning other structural features of the firms' economic activities (e.g. sales).

Unfortunately, in the case of software firms data on R&D and annual revenues are available only for few firms and for some years. This represents a major constraint on the possibility to account for firm-specific fixed effects.

Revenues in computer software and services in 1989 (or 1990) were utilised as an indicator of firm competencies in software technology (cf. table 1). Data provided by Datamation and IDC allow to separate software and services revenues from total revenues. Software and services represent over 50% of total revenues for all sample firms, except for McDonnel Douglas, which drew only 2.45% of its total revenues from services (system integration), and Mentor Graphics, a hardware-software manufacturer has focused its business into software and services - these represented 39% of its total revenues in 1990 and 74% in 1992 (Datamation, June 15, 1993). Moreover, many established package producers rely on one or a few products. For instance, Ashton-Tate in 1990 drew 74% of its revenues from its dBase, a database management system and Cap Gemini over 95% of its revenues from professional services (IDC, 1990). To analyse

firm specialisation, I also compared 1990 revenues with the 1983 stock of subsidiaries classified by SIC code by Predicast's Thesaurus (see references).

Although, in general, revenues or the SIC code of Corporate subsidiaries are not direct measures of technical competencies, these can be used as a proxy of technical capabilities for several reasons. One is the lack of other reliable indicators, such as patents and copyright, particularly for firms specialised in services, which do not make substantial use of these instruments for the protection of their innovations. Even large software package producers rely on other means for appropriating the rents of innovations, such as lead time (to reach the market first with an innovation), continuous product improvements and, to a lesser extent, copyright (Malerba and Torrisi, 1992; Torrisi, 1994).

Another reason for using sales specialisation as an indicator of technological capabilities is linked to the nature of software production. In general, firms specialised in a given business sector may have to accumulate technological capabilities in upstream activities (e.g., componentry). However, this is not the case with software because these activities are mostly a process that produces 'software by means of software'. A software producer or a system integrator may have to develop new software development tools to improve its production, but they are unlikely to develop competencies in, for instance, solid state physics or in chemicals. The number of computer science graduates or system engineers, and mathematicians in principle provides a more accurate measure of the firm's technological competencies. But this indicator has also some important drawbacks, including the fact that, for instance, mathematicians or system engineers can be employed in purely commercial activities, where their scientific and technological capabilities are not fully exploited.

4. Firm growth, restructuring and diversification: empirical evidence

4.1. The relative importance of internal and external growth

Table 1 shows the total number of new external linkages (M&A, joint ventures, minority participations and other agreements) activated by the sample firms during the period 1984-1992. The sample includes large producers of packaged software like Microsoft, Computer Associates and SAP, and service providers like McDonnell Douglas and Cap Gemini. Over the period under consideration, the 18 European firms included in the sample set up on average about 1.6 linkages per year against about 2.2 of the 20 US firms, as indicated by the third column of table 1. This difference is related to the different average size of the two groups of firms - there is a positive correlation between the number of links and firm's size (OLS coefficient = 0.45; t = 4.50).

There are no significant differences across firms with different specialisation in terms of the propensity to become involved in inter-firm linkages[6]. Among the firms with a propensity significantly above the average there are service providers, like Logica and Sema-Group, and firms specialised in software packages, like Novell and Ashton-Tate.

Relevant differences emerge between European and US firms in terms of the geographical horizon of their linkages. About 63.3% of the linkages set up by European firms involved foreign partners (either other European firms or non European ones), against 31.4% of the linkages devised by US firms. This can be easily explained by the large US domestic market compared with the fragmentation of the European market. Moreover, some large US firms like Andersen Consulting and Microsoft have probably established long term relationships with foreign partners before the period under examination. Furthermore, for many European software firms external linkages have represented an important strategy for reaching a 'minimum' efficient scale that is required for competing with the larger US firms. Given the limited size of the European national

markets, international linkages may represent an important way to increase the size of business activities.

Table 1 - Sales and total external links of the sample firms

Firm	Revenues ($ million)(1)	Total linkages	Annual average (2)	New subsids.	Annual average
CAP-Gemini-Sogeti	889.20	51	5.67	18	2.00
Finsiel	628.90	15	1.67	1	0.11
SD-Scicon	431.50	11	1.22	1	0.11
Sligos	400.70	24	2.67	1	0.11
Sema Group	378.60	36	4.00	0	0.00
Concept	288.20	7	0.78	0	0.00
Datev	285.10	1	0.11	0	0.00
Hoskyns	277.10	17	1.89	0	0.00
GSI	267.00	4	0.44	1	0.11
Programmator	259.10	2	0.22	0	0.00
Volmac	256.50	7	0.78	0	0.00
Logica	225.40	32	3.56	7	0.78
Telesystemes	212.00	13	1.44	0	0.00
Thorn EMI Software	209.20	2	0.22	1	0.11
SAP	183.10	6	0.67	2	0.22
CGI	166.30	11	1.22	0	0.00
Istel	166.20	10	1.11	1	0.11
Software AG	154.20	11	1.22	3	0.33
Total Europe (and AVG)		260	1.60	36	0.22
SD			1.49		0.48
Microsoft	1323.00	67	7.44	9	1.00
Computer Associate	1310.70	35	3.89	0	0.00
Oracle	1002.00	11	1.22	12	1.33
Lotus Development	664.00	49	5.44	11	1.22
D&B Software Services	539.00	1	0.11	0	0.00
WordPerfect	452.40	4	0.44	1	0.11
McDonnell Douglas	398.00	20	2.22	3	0.33
Novell	388.00	67	7.44	5	0.56
Policy Management	272.00	3	0.33	0	0.00
American Management	261.90	2	0.22	2	0.22
ASK Computer Systems	249.70	4	0.44	0	0.00
SAS Institute	240.00	3	0.33	1	0.11
Autodesk	237.90	12	1.33	4	0.44
Ashton-Tate	230.50	17	1.89	2	0.22
Pansophic Systems	228.80	14	1.56	0	0.00
Cadence Design Systems	178.00	15	1.67	2	0.22
Mentor Graphics	170.00	21	2.33	6	0.67
Computer Sciences	160.00	3	0.33	0	0.00
Sterling Software	155.00	12	1.33	0	0.00
Computer Services	na	18	2.00	1	0.11
Total US (and AVG)		378	2.10	59	0.33
SD			2.25		0.42
Grand Total (and AVG)		638	1.87		
SD			1.92		

Notes:
(1) 1989 or 1990 revenues.
(2) Average annual links in the period 1984-1992. Total external links include mergers and acquisitions, joint ventures, minority partecipations, licensing agreements and other agreements.

Table 2.a shows the evolution of different types of external links made by the European firms over the period in examination. Agreements (joint ventures, minority participations, licensing agreements and other agreements) represent 60% of total external operations, against 40% of mergers and acquisitions (M&As). Total external operations have increased over this period, showing that the sample firms increasingly rely on external sources of technical and market-specific knowledge. Table 2.b shows a similar pattern for the US firms. However, these relied more on M&As than agreements until 1989, while their European counterparts mostly focused on agreements (cf. figures 1.a and 1.b).

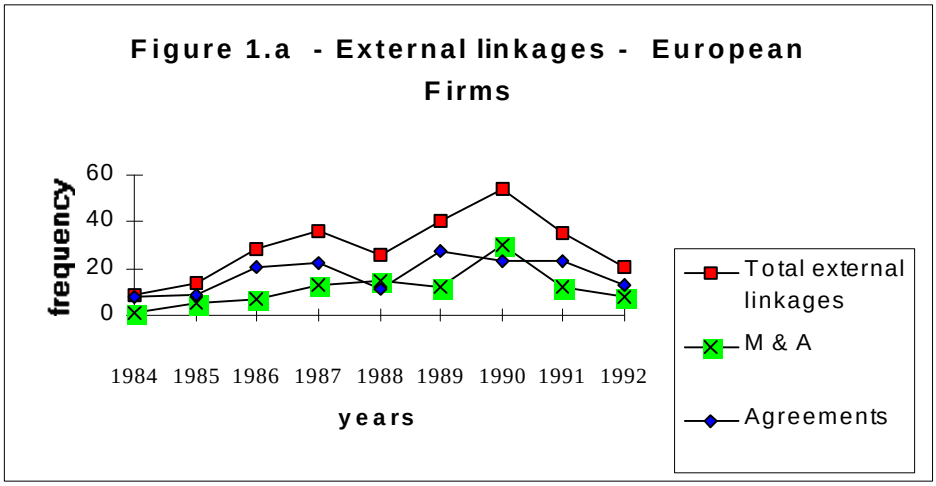
Table 2.a - External Links and Corporate Change - European Firms

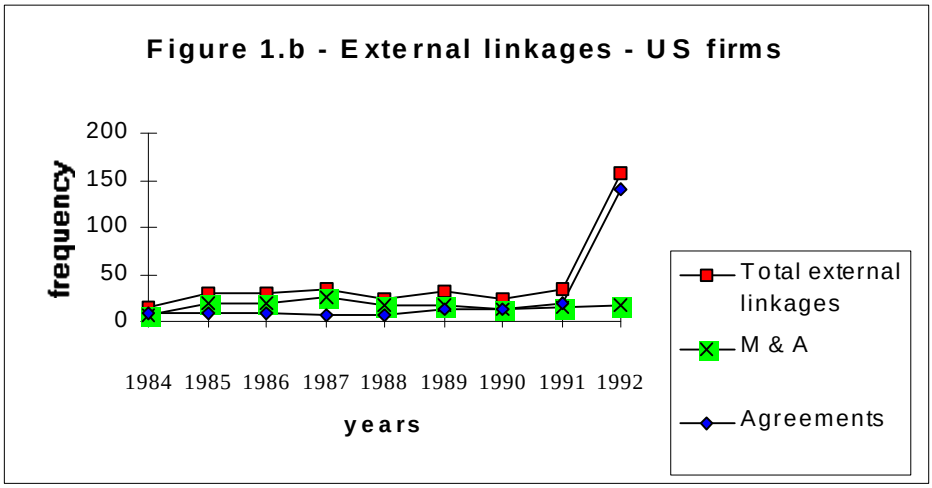
	1984 - 86	1987 - 89	1990 - 92	1984 - 1992	%	CAGR (2)
Total external links	50	100	110	260	100.00	10.97
of which:						
Mergers & Acquisitions	12	41	51	103	39.62	29.68
Agreements (1)	38	59	59	157	60.38	6.26
Corporate change	42	28	47	117	100.00	-6.76
of which:						
New subsidiaries	23	6	7	36	30.77	-14.99
Sold subsidiaries	2	3	5	10	8.55	10.40
Disinvestements	7	10	13	30	25.64	-8.29
Reorganisations	10	9	22	41	35.04	9.05

Table 2.b. External Links and Corporate Change - US Firms

	1984 - 86	1987 - 89	1990 - 92	1984 - 1992	%	CAGR (2)
Total external links	73	88	217	378	100.00	34.00
of which:						
Mergers & Acquisitions	47	61	45	153	40.48	13.00
Agreements (1)	26	27	172	225	59.52	43.00
Corporate change	34	56	67	157	100.00	-1.00
of which:						
New subsidiaries	15	14	30	59	37.58	-2.00
Sold subsidiaries	2	3	6	11	7.01	0.00
Disinvestements	4	18	13	35	22.29	0.00
Reorganisations	13	21	18	52	33.12	8.88

Notes
(1) Agreements include joint ventures, minority partecipations, licensing agreements and other agreements
(2) Percentage annual compound growth rate 1984-1992, except for sales of subsidiaries by European firms and disinvestments by US firms (1985-1992). The growth rate of reorganisations by US firms was calculated for the period 1985-1991.





These differences reflect the different specialisation of US and European firms. As mentioned before, a large domestic market and other factors have prompted US firms to specialise in packaged software. In this market segment firm size is particularly important to achieve economies of scale and scope, as compared with services and customised software. Thus, US firms, many of which specialise in packaged software, have a strong incentive to increase their size through M&As.

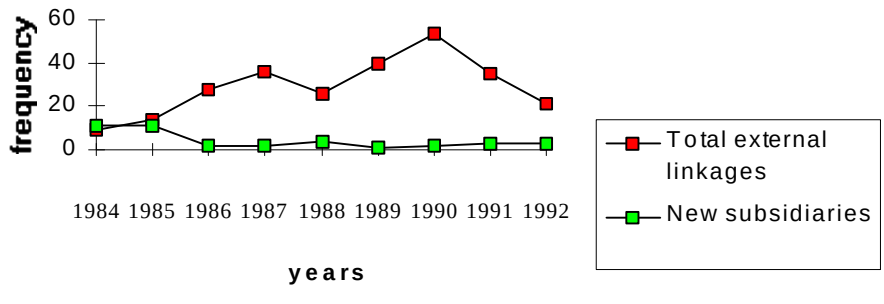
By contrast, European firms specialise in services and system integration. For these activities they have to set up many collaborative agreements with several suppliers of hardware and software technologies. It is worth noting, however, that the number of collaborative agreements is larger than M&As for both European and US firms. This reflects the fact that M&As have a strong impact on the firm's organisation, which has a limited ability to manage an increasing

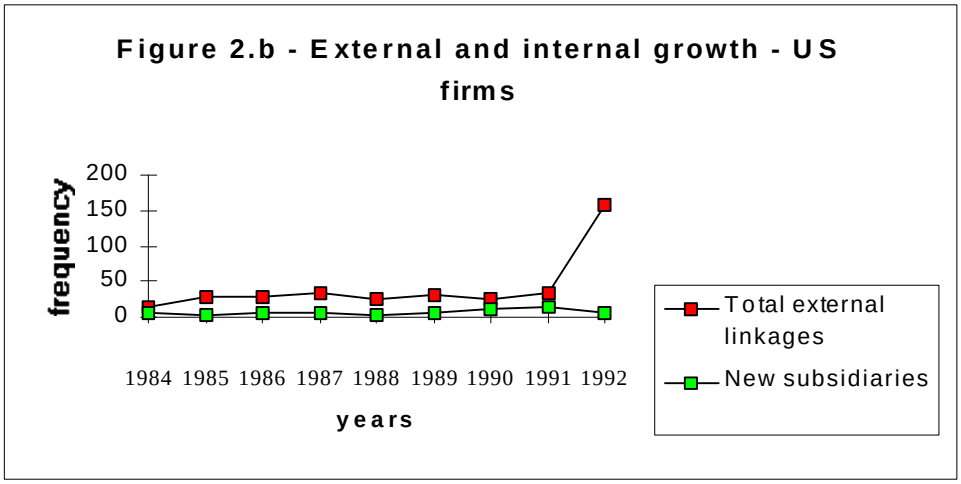
number of different business units. On the other hand, collaborative agreements in general have a smaller and less direct impact on corporate organisation compared with M&As.

Tables 2.a and 2.b compare the evolution of external linkages with that of internal corporate changes or restructuring (new subsidiaries, sale of subsidiaries, dismantling of operations and reorganisation of activities). Restructuring occurs jointly or as a response to external growth. Firms that grow by M&A and, to a less extent, agreements have to reorganise the scale and scope of their activities and may be prompted to modify their organisational structure. However, these organisational changes show a less regular trend than agreements and M&As over the same period, for reasons that include a less accurate diffusion of information in the press.

Figures 2.a. and 2.b also compare the evolution of external growth (M&As and agreements) with internal growth (new subsidiaries), which represent an important share of total internal corporate changes or restructuring discussed before. Both US and European firms have mostly centred their growth on external linkages rather than internal growth. This is explained by the need to reach fast a minimum efficient scale. External linkages allow firms to increase the scale of their operations (particularly M&As) and to exploit the external economies of being part of a network of collaborative agreements.

Figure 2.a. External and internal growth - European firms





4.2. The objectives of external linkages

External linkages may be used to face two types of failure in the market for knowledge: the lack of private incentives to undertake innovations and the lack of capabilities complementary to innovative skills (e.g., commercialisation capabilities)[7]. Accordingly, external linkages can be classified as *research-oriented linkages*, which mainly focus on the first type of market failure, and *market-oriented* or *complementary resource-seeking linkages*, aiming to cope with the second form of market imperfection.

Research-oriented linkages, may involve rival firms (e.g., consortia for the definition of common standards or joint R&D agreements) or firms specialised in different stages of a technological 'filière'. They allow firms to share the risks and the costs associated with the production of multidisciplinary, complex knowledge, thus increasing the private incentive to invest in R&D activities. Moreover, they allow the acquisition of new technological capabilities whose in-house development would require a longer time and higher costs.

Market-oriented linkages are usually set up by firms that operate in different stages of a technological 'filière' (e.g. operating systems suppliers and turn-key systems developers) or in different regional markets. They may provide access to complementary capabilities (e.g., distribution capabilities) that cannot be acquired in the market (because

of complex interdependencies between these capabilities and technological or production capabilities) and cannot be accumulated in-house for various reasons, including the time required for their accumulation[8]. These linkages may help to reduce a specific form of market failure, that is a socially insufficient production of assets complementary to R&D capabilities. This has important implications for innovators because the commercial success of an innovation depends on the supply of specialised and co-specialised inputs (Teece, 1986, Geroski, 1992). The access to complementary assets may take the form of M&As, minority participations, joint ventures and other agreements, reflecting the importance of different factors (including economies of scale and scope, the degree of complex interdependencies among complementary knowledge and capabilities and appropriability conditions).

Table 3 shows the main objective of agreements and internal re-organisations. The operations have been grouped in accordance with the classification discussed earlier: operations that involve research and development activities (RESEARCH), operations that do not involve any R&D activity (MARKET) and purely financial operations (FINANCIAL)[9] . All these operations may involve competitors or firms located in different stages of this 'technological filiére'.

Table 3 - Total external lilnkages and corporate change by objective
(1984 - 1992)

	European firms							
	RESEARCH (1)		MARKET (2)		FINANCIAL		TOTAL	
		%		%		%		%
Total external links (3)	62	24	186	73	8	3	256	100
Corporate changes (4)	17	14	73	61	29	25	119	100
	US firms							
	RESEARCH (1)		MARKET (2)		FINANCIAL		TOTAL	
		%		%		%		%
Total external links (3)	128	34	246	65	2	1	376	100
Corporate changes (4)	16	10	114	73	25	17	155	100

Notes:
(1) Research includes the links with a R&D content.
(2) Market includes all links without any R&D content. Joint production agreements are included
(3) Total links include mergers and acquisitions, joint ventures, minority partecipations, licensing agreements and other agreements. Eight links cannot be classified.
(4) Corporate changes includes new subsidiaries, sold subsidiaries, disinvestments and reorganisations. One operation cannot be classified.

Over 70% of external operations signed by the European firms were *market-oriented*, against about 24% of *research-oriented* operations involving R&D activities. The sample firms have signed market-oriented linkages to gain access to specialised commercial assets or service expertise, and new markets. A case in point is the cross marketing deal between Sema Group and Finsiel signed in 1992. Active licencing agreements were also classified as market-oriented operations because they aim to find new markets for the licensor's technology. Examples of research-oriented linkages are the joint development of a videotext software package for IBM mainframes by Cap Gemini and IBM in 1984 and the acquisition of 80% stakes of Technologies Machine Art robot manufacturer by Cap Gemini in 1987.

It is worth noting that the share of *research-oriented* operations is higher for the US firms as compared with the European firms (34%). This difference is probably due to the large number of US firms specialised in packaged software which show a comparatively high involvement in R&D activities. An insignificant share of total operations have a pure financial content (3% and 1% for the European and the US firms, respectively).

Overall, the difference between market and research operations was expected. A firm may aim to set up many external linkages with different partners to achieve economies of scale and scope in the extensive use of its knowledge and capabilities. By contrast, the number of potential research partners is limited by the distribution of scientific and technological capabilities across firms. Moreover, a firm that looks for a research partner may want to focus on few firms endowed with the best scientific or technical capabilities available on the market.

These data indicate that through external linkages software firms aim to gain access to both technical knowledge and to more context-specific knowledge (linked to particular, markets, users and applications). The software firms use different types of external links (from M&A to technological and co-operative agreements) along with internal investments (e.g., new subsidiaries). This suggests that there is not a standard model for organising the transactions and sharing of knowledge in the software industry. Different forms of coordination are adopted according to the objectives and competencies of firms involved in the knowledge exchange and pooling. For example, Novell, a US company specialised in Local Area Network (LAN) operating Systems (NetWare) in 1989 acquired another US firm with competencies in networking software, Excelan. Novell's NetWare gateway to IBM's SAA network architecture is based on Excelan expertise (Datamation, June 15, 1994, p. 76). The acquisition in this case is justified by the relatedness of the two firms' core businesses. A second example is that of Cap Gemini, a large French firm specialised in computer services which in 1990 jointly developed with Nynex International, a telecommunication services firm, a network control system for France Telecom. The complementary capability of these firms and the fact that telecommunication services were outside Cap Gemini's main business may explain the choice of an agreement as an alternative to M&A. By contrast, Cap Gemini has resorted to M&As and minority stakes to gain access to the resources of software firms such as Volmac, Programmator, Hoskyns and Sema Group, whose activities fall within Cap Gemini's core business.

The evidence of a large share of external operations aiming at the reorganisation of commercial networks and the creation of new market opportunities indicates that the diffusion or replication of the firm's stock of knowledge and competencies on a larger scale represents a major objective of inter-firm agreements. In a context of high economic complexity and uncertainty firms are forced to interact with other agents, which are potential sources of tacit knowledge and specific information. In the computer software industry there is a large number of firms between software producers and the customers, e.g. distributors, commercial agents, retailers, value-added retailers, etc. Although with the evolution of the industry some of these firms will probably disappear, many will survive because, on the whole, they have knowledge of a variety of specific phases, applications and user needs that no single software producer can economically control. In some cases, the relationships between those agents and the software producers represent a traditional division of labour, as in the case of a software package distributor who knows the evolution of users' requirements and transmits this kind of information to the software producer. In others, there is a closer interaction, as in the case of a 'value added retailer' who demands specific product performance and sometimes cooperates in the development of new applications with suppliers.

A similar share of the operations classified as internal restructuring has a MARKET content for the European and the US firms (61% and 73% of total internal restructuring operations, respectively), confirming the importance of commercialisation activities in this industry and the linkages between internal growth and internal restructuring. Unlike external operations, a large share of internal restructuring operations shows a financial dimension, particularly for the European firms (25% of total operations against 17% of the US firms) (see table 3). This category of internal restructuring includes equity issues to finance firms' expansion, management acquisitions of share capital, etc. It is worth noting that, besides the management and other company stockholders, operations with a financial object often involve external institutions. For

instance, in 1984 Cap Gemini announced that 37.5% of its stake would be acquired by the company management, in 1986 issued shares and convertible bonds to finance its growth and in 1987 was acquired for 8% of its stakes by Financiere Suez.

4.3. The trajectories of growth in software firms

Table 4 shows external operations (separated into M&As and agreements) classified into three categories: operations in the firm's main business, operations in related business sectors (computer hardware, telecommunications equipment and services or electronic components), and operations in unrelated business sectors. The latter also include general corporate consulting (for instance, in 1990 Cap Gemini acquired a 67.5% holding in Gamma International, a French management consulting firm)[10].

European firms in the sample signed over 76% of total external linkages in the area of their main business (SIC code 7370 to 7379). Only 2% of total external linkages were made in unrelated business sectors. The remaining linkages focused on related sectors (about 20% of total linkages). A similar pattern is shown for the US firms.

A large share of agreements in the area of the firms' main business also emerges when one looks at the number of agreements with an R&D content. About 77% of the RESEARCH linkages (both M&A and agreements) were signed in the main business by the European firms, against about 20% of RESEARCH links in related business sectors and only 3% in unrelated business sectors. Moreover, there are no significant differences between RESEARCH and MARKET links with respect to the area of business. The US and European firms, again, show a similar pattern of diversification through external linkages.

Some differences emerge between M&A and agreements with respect to this issue. Agreements represent a privileged channel for diversifying into related business sectors compared with M&A, particularly for the European firms (28% of their total agreements were drawn up in sectors related to the firms' main business against 12% of M&A). This may be explained by the

fact that agreements are a more flexible form of investment as compared with M&A in that they generate less 'sunk' costs. Therefore, they may be utilised to monitor related business areas or new market niches and as an option. However, the majority of agreements are also in the firm's core business and in related sectors (only 3% are in unrelated sectors).

Finally, our empirical analysis indicates that external and internal growth do not differ significantly with respect to the direction of diversification.

So far we have described the diversification of external linkages during the period 1984-1992. The next step of our analysis is centred on the relationship between this pattern of diversification and diversification before 1984.

Table 5 compares the diversification of 1983 subsidiaries with that of external growth during 1984-1992. The diversification is measured with the specialisation rate and the Herfindhal index.

Table 4. a - External Links by Distance from the Firms' Main Business - European firms
(1984 - 1992)

	Links in the main business sector		Links in related business sectors		Links in unrelated sectors		Total links (1)	
		%		%		%		%
Tot. external links	190	76	55	22	5	2	250	100
of which:								
Mergers & Acquisitions	85	87	12	12	1	1	98	100
Agreements (2)	105	69	43	28	3	3	152	100

Table 4. b - External Links by Distance from the Firms' Main Business - US firms
(1984 - 1992)

	Links in the main business sector		Links in related business sectors		Links in unrelated sectors		Total links (1)	
		%		%		%		%
Tot. external links	285	78	72	20	7	2	364	100
of which:								
Mergers & Acquisitions	128	83	25	16	1	1	154	100
Agreements (2)	157	75	47	22	6	3	210	100

Notes:
(1) 24 external links cannot be classified.
(2) Agreements include joint ventures, minority partecipations, licensing agreements and other agreements.

Table 5.a - 1983 diversification and 1984-1992 external growth (mergers & acquisitions) - European firms

	Hsub1983	H1984-92	SR83	SR1984-92	HM&A84-92	HAgr84-92	SRM&A8492	SRAgr8492
CAP-Gemini-Sogeti	0.57	0.73	0.73	0.84	0.80	0.67	0.88	0.79
Finsiel	1.00	0.68	1.00	0.80	1.00	0.64	1.00	0.77
SD-Scicon (1)	0.68	0.50	0.80	0.55	0.56	0.50	0.67	0.50
Sligos (2)	1.00	0.72	1.00	0.83	0.88	0.56	0.93	0.67
Sema Group (3)	0.63	0.54	0.75	0.67	0.50	0.56	0.67	0.67
Concept (4)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Datev (4)	1.00	1.00	1.00	1.00	-	1.00	-	1.00
Hoskyns Group	1.00	0.88	1.00	0.94	1.00	0.76	1.00	0.86
GSI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Programmator	0.56	1.00	0.67	1.00	1.00	-	1.00	-
Volmac	1.00	0.76	1.00	0.86	1.00	0.72	1.00	0.83
Logica	0.52	0.73	0.60	0.84	0.72	0.73	0.83	0.84
Telesystemes	0.56	0.56	0.67	0.67	0.50	0.58	0.50	0.70
Thorn EMI Software (5)	1.00	1.00	1.00	1.00	1.00	-	1.00	-
SAP (4)	1.00	0.72	1.00	0.83	1.00	0.56	1.00	0.67
CGI (4)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Istel (6)	1.00	0.46	1.00	0.60	0.52	0.68	0.60	0.80
Software AG	1.00	0.60	1.00	0.73	1.00	0.68	1.00	0.80
AVG	0.86	0.77	0.90	0.84	0.80	0.65	0.84	0.72
SD	0.20	0.19	0.15	0.15	0.28	0.29	0.27	0.29

Table 5.b - 1983 diversification and 1984-1992 external growth (mergers & acquisitions) - US firms

	Hsub1983	H1984-92	SR83	SR1984-92	HM&A84-92	HAgr84-92	SRM&A8492	SRAgr8492
Microsoft	1.00	0.53	1.00	0.67	0.59	0.53	0.71	0.67
Computer Associate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Oracle Corp.	1.00	0.70	1.00	0.82	1.00	0.68	1.00	0.80
Lotus Development	1.00	0.81	1.00	0.89	0.79	0.82	0.88	0.90
D&B Software Services	1.00	1.00	1.00	1.00	1.00	-	1.00	-
WordPerfect (4)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
McDonnell Douglas (7)	1.00	0.44	1.00	0.54	0.46	1.00	0.58	1.00
Novell	1.00	0.72	1.00	0.83	0.88	0.68	0.93	0.80
Policy Management Sys.	1.00	0.56	1.00	0.67	0.50	1.00	0.50	1.00
American Management	1.00	1.00	1.00	1.00	-	1.00	-	1.00
ASK Computer Systems	1.00	0.50	1.00	0.50	0.56	1.00	0.67	1.00
SAS Institute	1.00	1.00	1.00	1.00	1.00	-	1.00	-
Autodesk (4)	1.00	0.71	1.00	0.83	0.78	0.63	0.88	0.75
Ashton-Tate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pansophic Systems	0.50	1.00	0.50	1.00	1.00	1.00	1.00	1.00
Cadence Design Systems	1.00	0.54	1.00	0.64	0.72	0.50	0.83	0.50
Mentor Graphics	1.00	0.51	1.00	0.55	0.56	0.78	0.67	0.88
Computer Sciences	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sterling Software	1.00	0.72	1.00	0.83	0.78	0.63	0.88	0.75
Computer Services	1.00	0.50	1.00	0.53	0.52	0.50	0.60	0.50
AVG	0.98	0.76	0.98	0.82	0.76	0.74	0.81	0.78
SD	0.11	0.22	0.11	0.19	0.27	0.32	0.25	0.31

Notes

(1) - The number of 1983 subsidiaries was calculated by aggregating the subsidiaries of Systems Designers (SD) and Scicon Scicon Computer Services, which was taken over by SD in 1988 from British Petroleum.

(2) - In 1983 Sligos was a Tymshare's subsidiary, a US computer services firms, acquired by Mac Donnel Douglas in 1985.

(3) - Sema Group was born in 1989 by the merger between the British UK CAP Group and the French Sema Metra.

(4) - Predicasts' data available for 1990 or 1992.

(5) Thorn-Emi Software was created after 1983 by Thorn-EMI, which in 1983 had four subsidiaries in the computer sector.

(6) In 1983 Istel was a British Leyland's subsidiary (BL Systems). It was acquired by AT&T in 1989.

(7) - Formerly McDonnel Douglas's Data Suystem division

(8) H = Herfindal index was calculated for 1983 subsidiaries (Hsub1983), total external operations (H1984-92), M&As (HM&A8492) and Agreements (HAgr84-92). SR= specialisation rate (percentage of the largest line of business) was calculated for 1983 subsidiaries and 1984-92 external operations.

The first is the share of the firm's largest sector, while the latter is the sum of the squares of the shares of the variable. In this case the Herfindal index was calculated on three classes corresponding to the main business, related sectors and unrelated sectors. The Herfindhal then varies between 0.33 (max diversification - equal shares) to 1 (maximum specialisation - share of the highest sector equal to 1). This analysis was also performed by using another measure of diversification - entropy (sum of the logs of one over shares of the variable in each class). These produce very similar results.

All firms, except for Cap Gemini, Programmator, Logica and Pansophic, increased or maintained stable their diversification degree during the 1984-1992 compared with 1983. This is shown by the comparison of the Herfindal index (H) and the specialisation rate (SR) for total 1984-1992 external growth operations with the corresponding indexes for 1983 subsidiaries.

This comparison, however, confirms that the majority of external operations have centred on software activities, thus reinforcing the starting specialisation. The average SR index is above 80% and its minimum value is 53% for the US firms (Computer Services) and 55% for their European counterparts (SD-Scicon). As expected, agreements are more diversified than M&As for reasons discussed above. But, again, over 70% of total agreements focused on computer software and services.

It is interesting to note the different degree of specialisation of US firms compared with European firms in 1983. All US software firms, excepted one (Pansophic), were perfectly specialised in 1983. By contrast, European firms were more diversified (the average H83 is 0.86 compared with 0.98 for US firms). This difference may depend on two factors. First, the large extension and homogeneity of the US market which has favoured the achievement of economies of scale and specialisation by local firms. Second, the large number of US firms which entered the market as start-ups early in the 1980s. Firms such as Lotus Development, founded by people spun off from Visicalc in 1981, Autodesk (founded in 1982) and Sterling Software (1983) have

grown during the 1980s by exploiting the high technological and market opportunities arising from software activities and related ones (including computers). The presence of network externalities has represented an important reinforcing mechanism which has given rise to increasing returns and the emergence of market leaders which have built their fortune on few software products (packages). For instance, Microsoft in 1994 held over one-third of the world market for personal computer's applications (Business Week, January 9, 1995, p. 46).

In Europe, many software firms have spun off from electronics and non electronics firms, often maintaining close links with their parent companies. For example, Finsiel was affiliated to Istituto Bancario S. Paolo and IRI in 1983, Scicon Computers was taken over by Systems Designers (SD) from British Petroleum in 1988, and Istel was a British Leyland's subsidiary (BL Systems) in 1983. These firms did not have a market large enough to allow a degree of specialisation and growth comparable to that of their US counterparts. Moreover, as mentioned before, most of them have positioned in different market niches of limited size by offering customised, ad hoc software and professional services for large customers. In some cases, their largest customer is still the parent company (e.g., the public administration for Finsiel) and most revenues arise from the regional or national market. The opportunities to enter the larger, global market for packaged software were limited by the early entry and market pre-emption by the US firms.

External growth during the period 1984-1992 made European and US firms more similar than in 1983. On average, both European and US firms have become more diversified. To a closer look, however, few software firms, including those that have grown fast through M&As and other external linkages, have tried to diversify their activities in businesses unrelated to software activities. Few software firms have tried to enter the computer (hardware) business. For instance, Cap Gemini has acquired IBAT, a process control and robotics manufacturer in 1986. In the same year, Microsoft has acquired Citation, a CD-ROM manufacturers, and has subsequently

increased its efforts in the multimedia business. In 1992 Microsoft signed an agreement with Compaq Computer to joint develop computer audio functions and Novell has signed a agreement with Stratus to joint develop fail-tolerant PC networks.

Another target of diversification for software firms were telecommunication services such as electronic mail. This is the case of the joint ventures between Computer Associates and MCI Communications in 1986 and with Radio Schweiz in 1989. In 1984 Mc Donnel Douglas announced a joint venture with Marubeni of Japan for the development of value added network services and in 1985 Scicon acquired 80% of Telecom International, a satellite communications company.

4.3. Discussion

During the 1980s and part of the 1990s software firms tried to increase the scale of their operations through external growth and internal restructuring. Scale is particularly important in market for software packages, where market concentration is relatively high and the market leaders are all US firms. In customised software and services, where European firms specialise, size is increasingly important as well. This explains the importance of market-oriented linkages. External linkages enable firms to increase the size of their operations and to achieve economies of scale and scope. This is true in particular for firms which have made significant investments in structured development methodologies and have developed large libraries of documentation and programs that can be re-used for different customers. The fixed costs associated with these intangible assets are an important source of economies of scale and scope which can be exploited through either direct commercial channels or indirect channels, like in the case of minority participations or non-equity commercial agreements with other service providers located in a specific market.

Software firms have not diversified in unrelated business sectors, except for few cases such as Microsoft's acquisition of 26% share of the book publisher Dorling Kindersley in 1991. Similar

to other forms of knowledge acquisition (e.g., innovative or imitative R&D), the absorption of new information through the establishment of external links is a costly activity that requires previous investments in evalutation and absorptive capabilities (Cohen and Levinthal, 1989). The costs of acquisition of knowledge are positively related to the distance between the firm's stock of knowledge and the new information. Besides the computational and organisational costs associated with the acquisition of new pieces of information, there are additional costs due to the evaluation of the quality of information (which increase with the distance from the firm's stock of knowledge)[11]. This is one explanation for the difficulties to diversify shown by several firms from different sectors. In the history of the computer and software industry there are several examples of attempts at diversifying business activities. Philips is a notable one: after several attempts to remain in the computer industry (including numerous agreements) it has abandoned this sector to focus on its main business (which is still quite diversified). During the 1980s many firms in the IT sector re-focused their activities too. Despite technological convergence among different branches of the IT sector, most attempts to diversify through alliances and M&As between firms specialised in telecommunications, computers and electronic components have failed (e.g., IBM's acquisition of Rolm). A major reason for these failures is linked to the high fixed costs to acquire market and user-specific knowledge, which give rise to increasing returns to scale. For instance, the limited market share of Rolm has not enabled IBM to reach the minimum efficient scale in the market for private branch exchange (Gambardella and Torrisi, 1996).

Some software firms have also re-focused their activities after attempts at diversifying within the same software sector. For instance, in 1989 Pansophic, a US firms specialised in system software, tried to diversify into graphics applications but it failed because, as claimed by its chief executive, the firm 'got dispersed' (Datamation, 1991, p. 128). This failure may be linked to different reasons, including the costs and time for the acquisition of technological and market knowledge, and managerial bottlenecks. More recently, Cap

Gemini, a computer service provider which grew through M&As during the 1980s, has started a restructuring plan to sell activities outside its core business, including Cisi, a French computer services firms acquired few years before (Tribune-Cote-Desfosses, March 10, 1994, p. 12). Finally, SD-Scicon has sold its US energy systems business to Combustion Engineering in 1988, its scientific control systems subsidiary to Cap Gemini in 1990 and its artificial intelligence activities to former employees (which founded a new firm, Integrated Solutions) to focus on manufacturing process control systems and financial communications services (Computer Weekly, 1990).

Finally, many software firms (e.g., Cap Gemini and Logica) have refocused their activities towards telecommunication services and multimedia. The business area resulting from the convergence between software and telecommunication services creates new windows of opportunities for new firms and established firms, including Europen services providers. This explains the number of external linkages established by the sample firms in this field.

5. Conclusions

This paper has analysed the process of growth and external linkages of large European software firms in comparison with their US counterparts. This is a relatively young industry that grows rapidly at an annual rate which is high compared with other IT segments, including computers. Important factors that have shaped the evolution of this industry and the specialisation of software producers are represented by the positive externalities coming from technological convergence, the unbundling of software sales from that of hardware products and the rising complexity of software applications which have spurred the outsourcing of software activities from many user firms.

The conclusions emerging from the analysis can be summarised as follows.

First, the analysis of the collaborative agreements and other external growth operations provides some insights into the reasons why software firms set up these linkages. A large share of these external links represent for the sample firms a way to reach new markets and to exploit economies of scale and scope in the use of the firm's stock of knowledge (*market-oriented* links). These operations provide software firms with the access to complementary capabilities that they do not possess (and maybe they do not have incentives to develop) in-house. A smaller number of external growth operations aim to absorb or develop jointly new technological knowledge (*research-oriented* links). These linkages provide firms with private incentives to undertake innovative activity that they would not try alone. Both market and research-oriented links give firms the opportunity to exchange and share imperfectly codifiable knowledge and to allow for informal and tacit knowledge that cannot be organised through the market mechanism.

Second, this study shows that software firms have increased their diversification through external growth during the period in examination. However, at a closer analysis most operations appeared to focus on technologically related activities (e.g., telecommunication services). Moreover, there are not significant differences among different forms of external growth with respect to the directions of diversification. Although collaborative agreements, particularly joint R&D agreements, are more diversified than M&As, they also focus on software and related businesses. This contrasts the hypothesis that collaborative agreements, particularly joint research agreements and minority stakes, represent an important way to explore unfamiliar business sectors. The evidence provided in the paper may be explained by the high

growth rate of the software market which offers significant investment opportunities compared with other sectors. Moreover, there are decreasing returns to unrelated diversification due to loss of managerial control, misallocation of internal resources and organisational inertia that firms may experience even when they diversify in related businesses, as showed by some examples mentioned in this paper. Future research on this topic should try to test more carefully the association between decreasing returns to diversification and the factors mentioned above.

Finally, the differences between US and European firms are significant in terms of their production profile and the degree of 1983 diversification. European firms were more diversified in 1983: many of them belonged to an electronics or non electronics group and focused on computer services. By contrast, US firms were very specialised. Most of them produced one or few software packages and did not belong to any industrial group. The different diversification degree between US and the European firms has reduced as a consequence of the 1984-1992 operations. However, European and US software firms have maintained their different product profile. In particular, only one European firm, SAP of Germany, has maintained an international position as a producer of software packages (Software AG, the second German software packages producer in 1990, has recently re-focused its activities towards services). The remaining firms have reinforced their activities in computer services and, more recently, have diversified in telecommunication services. On the other hand, US firms have maintained a leading market position in either software packages or services. This shows the difficulty of diversifying from software services to packaged software. Most of this difficulty arises from the strength of increasing returns in the production of software packages which is

linked to dynamic economies scale and network externalities. Moreover, the commercial capabilities required in services and packaged software are very different.

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Note

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[2] IBM represents an exception to this trend towards vertical disintegration of software and services. Its share of software and services increased from 17% to 28% between 1981 and 1992 (Datamation, June 15, 1982 and 1993).

[3] The latter agreement has not been concluded for various reasons, including Olivetti's serious financial difficulties showed since 1991.

[4] Another research line has focused on transaction costs. This literature explains the degree of vertical (or lateral) integration and the division of labour among firms as a function of variables such as the frequency of transactions, asset specificity and appropriability of innovative rents (Williamson, 1975; Teece, 1986).

[5] However, the separation between propriety and control may cause excessive diversification. To maximise their utility function, managers may push diversification beyond the level which is optimal for firm's profitability (Jensen and Meckling, 1976).

[6] At this level of the analysis I refer to total external linkages for the sake of simplicity. Later, the differences between different types of external linkages will be explored. Chi-squared statistics shows that there is not any significant association between firm's specialisation and external linkages. Chi-square was also calculated for agreements, mergers & acquisitions and new subsidiaries. Finally, chi-squared test indicates no association between the nationality of the firm (European or US) and the variables mentioned before.

[7] In economic literature, imperfections in the market for knowledge are associated with the public good nature of knowledge and with imperfect information (and its consequences such as adverse selection and moral hazard). More recently, the literature has analysed knowledge as an imperfect public good, by pointing to the fact that knowledge, even the scientific, codified one, is rarely available off-the-shelf. This explains why firms accumulate "absorptive capabilities" which are used to monitor and utilise external sources of knowledge (see Cohen and Levinthal, 1989, Rosenberg, 1990, and Pavitt , 1991b).

[8] The economic literature has provided other explanations for the adoption of alternative organisation of economic activities which draw on transaction costs (Williamson, 1975).

[9] MARKET operations may include commercial and production activities. RESEARCH operations may include production and commercial activities.

[10] The analysis of internal growth shows similar results.

[11] We do not take into account the costs of monitoring the behaviour of the supplier of knowledge. These costs may induce firms to internalise the source of knowledge through M&As. But vertical integration does not necessarily reduce these costs because of asymmetric information and moral hazard. After all, there are not sufficient reasons to believe that "integration transforms a hostile supplier into a docile employee" (Grossman and Hart, 1986, p. 693).