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The Restructuring of Technological Capabilities through Corporate Expansion

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Abstract:
This paper analyses the restructuring of technological capabilities following M&A-based growth in large industrial firms with a substantial technological knowledge base. In particular, we focus on the restructuring of those technological capabilities that are of a general purpose kind (namely ICT) or related to the core capabilities of a firm. We develop and test a conceptual framework grounded on a co-evolutionary view, that relates the motivations and environment for corporate expansion to the firm-specific pattern of restructuring in the composition of corporate technological capabilities. We find that distinct patterns of technological capability restructuring are associated with each combination of the motivations and environment for firm growth. In particular, inter-industry contexts reduce technological relatedness in market motivated expansions, while relatedness has also declined in more recent technology-motivated growth in general. The acquisition of ICT is common as well to both technology-motivated inter-industry deals and more recent market-motivated deals. However, we speculate that any similarities in the outcomes of these alternative motives for firm growth arise for quite different purposes.

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1. Introduction

This paper investigates the patterns of transformation in the technological capabilities of firms at times of major new departures in their technological competence base. In tune with the recognition that external corporate expansion can be a short cut to acquire key new competences (Zollo and Winter 2002; Helfat *et al*. 2007), we contend that substantial technological restructuring is often associated with merger and acquisition (M&A) deals that are important enough to achieve a more rapid transition to new areas of capabilities. These we term technology-based M&As .

Studies in the dynamic capabilities tradition (Teece *et al*. 1997; Teece 2007) have investigated the acquisition of technological capabilities through external corporate expansion, when that is technology-motivated (Ahuja and Katila 2001; Cloodt *et al*. 2006; Cassiman *et al*. 2005). Empirical research on the topic has provided inconclusive evidence by documenting both positive (Ahuja and Katila 2001; Cassiman *et al*. 2005) and negative (Cloodt *et al*. 2006) effects of technology-motivated external corporate expansions on technological capability accumulation. It has also been shown that if the extent of knowledge relatedness between partner firms is either too close or too distant, this may hamper the acquisition of technological capabilities and innovation performance in strategic technological partnerships (Nooteboom *et al*., 2007) and M&A deals (Ahuja and Katila 2001; Cloodt *et al*. 2006).

Our study addresses two shortcomings in the extant literature. First of all, non-technology motivated growth may still coincidentally affect the restructuring of technological capabilities. The accumulation of new areas of corporate technological capabilities may occur either as the intended result of a direct strategy for

technological diversification in the firm (Granstand and Sjölander 1990; Granstrand *et al*. 1997), or as the indirect and sometimes unintended outcome of a strategy for market diversification or consolidation in the product range of firms (Nerkar and Roberts 2004). The product diversification of firms is closely related to the achievement of stronger economies of scale and joint production (Chandler, 1990; Caves 1989; Röller *et al*. 2001), which may coincidently entail the development or acquisition of new lines of technological capabilities. Yet market-motivated corporate expansion may be less concerned with an appropriate matching of related technological capabilities than in the case of technology-motivated expansion. Within this context, we distinguish here between two routes for corporate expansion through diversification. In particular, firms may move 1) from established capabilities into technologically related or otherwise allied areas of capabilities and/or 2) from some established product markets into related markets, or areas in which joint production and distribution are more efficient. When these diversification strategies are pursued through M&A deals we can say that these deals are respectively either technology-motivated (Graebner 2004) or market-motivated (Vermeulen and Barkema 2001), according to whether the M&As are motivated mainly by the first kind of diversification or the second (or occasionally by both).

The second shortcoming this study speaks to concerns the consideration that the restructuring of technological capabilities in the immediate aftermath of major M&A deals between firms with already substantial technological assets may involve various different potential paths for new capability accumulation. This raises the issue of the likely direction of change in the composition of restructured technological profiles. We might ordinarily expect that since technological search tends to be localized and path-dependent, corporate strategies for the restructuring of corporate

technological capabilities often take the form of the acquisition of related technological expertise (Nelson and Winter 1982; Teece *et al*. 1994; Nerkar and Paruchuri 2005). However, other recent research has also suggested that more substantial forms of corporate restructuring that involve the spanning of technological and organizational boundaries may lead to some change in what is perceived to be related, and therefore may move a firm away from its traditionally received areas of established technological relatedness (Ahuja and Katila 2004; Ahuja and Lampert 2001; Fleming and Sorenson 2004; Karim and Mitchell 2000; Rosenkopf and Almeida 2003; Rosenkopf and Nerkar 2001). Another allied new feature of corporate technological trajectories that has been commonly observed in recent times is the increasing acquisition of capabilities in the fastest growing and most pervasive general purpose technologies that are relevant in many industries (and most notably information and communication technologies, ICT) (Gambardella and Torrisi 1998).

The central question we ask is whether, when firms are accumulating major new technological capabilities, the restructuring of ICT and related technological competences is different in technology-motivated, as opposed to market-motivated types of external expansion.

2. Conceptual framework and hypotheses

In building our conceptual framework, we subscribe to a co-evolutionary view of the progress of the firm and its changing environment, as developed in the fields of evolutionary economics (e.g. Nelson 2007; Ramlogan and Metcalfe 2006) and management (e.g. DiMaggio and Powell 1983; Aldrich and Ruef 2006). In this perspective, the paths followed by organizations are understood as the outcomes of the co-evolution of actors and their environment. Accordingly, our conceptual

framework, as summarized in Figure 1, holds that alternative outcomes for the restructuring of related, and of ICT capabilities, can be explained in terms of the co-evolution of the actor's subjective motivations of external corporate expansion and the changing influences on firm external expansion provided by the environment. In tune with prior strategy studies (Ahuja and Katila 2001; Cloodt *et al*. 2006), with respect to the actor's motivations we contend that external corporate expansions may be motivated by the acquisition of resources that confer technological relatedness (reinforcing existing complementarities or creating new areas of technological proximity) or product market relatedness (market proximity), which we have labeled as technology- and market-motivated respectively, in the columns of Figure 1.

With regard to variations across firms in the influence of the environment, we contend that external corporate expansions are characterized by their sector-spanning and time period-specific contexts. That is, they may occur between or within industries and in more recent time periods as compared to earlier ones, as illustrated in the rows of Figure 1. Consideration of the sectoral context is called for since the increasingly multi-technology nature of the firm has made cross-industry expansion more common as a means of accessing new areas of capabilities, as suggested by the evolutionary economics literature (Dosi *et al*. 2000; Patel and Pavitt 2000). Similarly, research in the management field has shifted away from a general evaluation of post-acquisition performance to an evaluation of different forms of deals such as horizontal, vertical and unrelated M&As (Hitt *et al*. 1998, Kusewitt 1985; Capron 1999). Consideration of the time dimension is due to the recognition that M&As occur in waves. In particular, the managerial literature investigating the M&A waves of the 1960s-1970s and the 1980s has documented that the pursuit of

corporate expansion led to the rise of big conglomerates in the earlier period, but to a refocusing of corporate activity upon greater innovation in or around the core product areas in the later period (Shleifer and Vishny 1991; Chandler 1992). As a result the nature of the impact upon the composition of corporate technological capabilities is likely to differ in different historical phases of expansion.

We can illustrate the alternative outcomes of different restructuring strategies with reference to shifts into or out of related or ICT technological capabilities, compared to the core fields of capabilities that are associated with a firm's primary industry. In the case of previously related technological capabilities, technology-motivated expansion may have increasingly begun to experimentally depart from what had been traditional areas of technological relatedness (Cell 2), while market-motivated expansion may often require a rationalization of technological relatedness as the outcome of more distant cross-industry integration (Cell 3). In the case of acquiring new ICT capabilities, in technology-motivated corporate expansion the objective is to further extend the range of corporate technological relatedness in cross-industry integration (Cell 1), while in the case of market-motivated expansion the objective is more generally to increase over time the efficiency of joint production and of systems for the distribution of combinations of related products (Cell 4). In the next sub-section, we further develop these contentions, and formulate empirically testable hypotheses that correspond to the arguments associated with each of the four cells of Figure 1.

Development of hypotheses

Following the conceptual structure summarized in Figure 1, we develop four hypotheses on the effects of technology- and market-motivated expansions respectively across sectors (as opposite to within industries) and in more recent time periods (as opposed to thirty years ago) on the restructuring of corporate technological capability profiles. The specific details of these four hypotheses are set out in Figure 2.

Drawing on Penrose (1959), we argue that the identification of opportunities from within existing capabilities can lead to the growth of the firm and diversification into what have the potential to become related areas of technological specialization. In particular, research in evolutionary economics (Nelson and Winter 1982) and strategic management (Rosenkopf and Nerkar 2001; Rosenkopf and Almeida 2003) has documented that technological search tends to be localized, although to different extents. One way of thinking about this would be to distinguish between capabilities that are core to a firm's industry and those that lie outside the core but are related to it (Patel and Pavitt 1998). Thus, highly localized search occurs when moving between one field and another within the core fields of the relevant industry. Less localized search typically takes the form of moving between one field of capabilities within the core and another that is related but outside the core areas of the industry (Nerkar and Roberts 2004; Stuart and Podolny 1996; Tripsas and Gavetti 2000). While search within a firm's primary industry will typically be of the first kind, search into other lines of business is more likely to involve the second. When establishing new links with related fields outside the core as opposed to between fields within the core, investments in ICT capabilities are especially likely to be effective. ICT is akin to a branch of technology that is pervasive across industries (Kodama 1992;

Gambardella and Torrisi 1998), and is selectively establishing new areas of technological convergence between industries (Arora and Gambardella 1990; Bresnahan and Gambardella 1998). Thus, ICT capabilities provide a means for combining formerly separate areas of technological endeavor (Kodama 1992) to achieve dynamic economies of scale (Granstrand 1998). In the case of technology-motivated deals occurring across industries, the restructuring in the composition of firm's capabilities is more likely to be associated with the acquisition of ICT capabilities which, due to their general purpose nature, help to fuse together capabilities that are most closely related between the industries in question (Figure 2, Cell 1).

H1: In technology-motivated inter-industry deals, there is more likely to be an acquisition of ICT technological capabilities.

The transformation of capabilities is recognized to be a time-dependent historical process, in which firms must adapt to better conform to the needs of each era of development as the requirements of the environment shift (DiMaggio and Powell 1983; Zollo and Winter 2002; Aldrich and Ruef 2006). Over the past thirty years, the patterns of what constitute (or do not constitute) related technological capabilities have been in the process of change with the rise of a more knowledge-driven economy. In response, firms have moved away from historically received patterns of technology relatedness to attempt to establish newly emerging areas of relatedness. Thus, for example, chemical and pharmaceutical businesses were frequently combined in the past, whereas now in the era of biotechnology they are more often conducted separately. This again implies that over time firms have been increasingly experimenting with new combinations of their core capabilities with potentially related capabilities. In more recent times, technological search has thus become less strictly

localized and more likely to range beyond the most commonly traditionally received combinations of activities. In order to achieve suitable new combinations, firms have tended to become more reliant on accessing capabilities through a more open structure for innovation development (Arora *et al*. 2001; Chesbrough *et al*. 2006; Laursen and Salter 2006; Cassiman and Veugelers 2006). External knowledge acquisition can 'fill holes' in a firm's existing profile (Rosenkopf and Almeida 2003). Non-localized search may be most effective for capability development even within a firm's traditional domain where it combines technological and organizational boundary spanning (Rosenkopf and Nerkar 2001), and science may asist in finding otherwise unpredictable areas of newly emergent relatedness (Fleming and Sorenson 2004).

In addition, the growth of the more externally networked multi-technology corporation can be attributed to the increasingly systemic and complex character of innovation (Fleming and Sorenson 2001; Patel and Pavitt 1997). Thus, technology-motivated deals occurring in more recent time periods have been increasingly inspired by the prospects for a greater technological convergence across formerly separate areas of activity, leading to a rising experimentation with potential new combinations, and to a growing recognition of the wider scope and more systemic character of technological development in a more recent times (Figure 2, Cell 2). Under various conditions that may be associated with more open environments new technological search paths may be triggered (Ahuja and Katila 2004), and experimenting with combinations that lay beyond a firm's traditional domain of relatedness increases the likelihood of achieving breakthrough inventions (Ahuja and Lampert 2001).

H2: In more recent technology-motivated deals, there is more likely to be a decline in formerly related technological capabilities.

In market-motivated corporate expansion, it is known that diversification tends to be more successful where products are related to one another (Rumelt 1974, 1982; Teece 1980; Markides and Williamson 1996; Farjoun 1998). However, the technological capabilities required for related products may or may not be related in terms of their technological characteristics. Economies of scale are achieved through the combined use of facilities in common systems of production and distribution, such as in Singer's integrated production and distribution of sewing machines and sewing machine cabinets (Teece *et al*. 1994). In the case of inter-industry expansion (as opposed to a more focused expansion of the product range within a firm's own primary industry), it is likely that related technological capabilities will undergo rationalization (Hitt *et al*. 1991). Instead, firms will tend to place greater emphasis on investments in the joint production and distribution systems that facilitate the relevant new market combinations. Market-motivated M&A deals occurring across industries are thus likely to be associated with a rationalization of related technological capabilities in the context of joint production and distribution across formerly separate industries (Figure 2, Cell 3).

H3: In market-motivated inter-industry deals, there is more likely to be a decline in formerly related technological capabilities.

As market-motivated deals have evolved over time, just-in-time systems and similar organizational innovations have become increasingly important in conferring benefits from joint production and distribution of products formerly in different industries (Chandler 1977, 1990; Hennart 1991). Such deals have also been associated with some selected convergence of markets and of production and

distribution conditions. Inventory holding costs have fallen through larger and more effective systems for storage, transportation and distribution of related activities (Monteverde and Teece 1982; McCann 1998). Moreover, firms have developed an ability to better manage larger scale and more distant operating systems through the use of ICT (Langlois 2003; Feinberg and Keane 2006; Keane and Feinberg 2007). Accordingly, market-motivated types of expansions have evolved over time to become increasingly reliant upon complementary investments in ICT capabilities and in the capabilities for managing common production and distribution systems across related lines of business (Figure 2, Cell 4).

H4: In more recent market-motivated deals, there is more likely to be an acquisition of ICT capabilities.

3. Methodology

Corporate knowledge base

So far, we have advanced some propositions about the composition of the process of restructuring of the corporate knowledge base following a substantial M&A-associated corporate expansion. In testing our hypotheses a key issue is the measurement of the distribution of this corporate knowledge base. We argue that a firm's patent portfolio provides a suitable means to this end, at least for the largest industrial firms. This approach is consistent with that of others that have examined firms' technological capabilities (Stuart and Podolny 1996; Ahuja and Katila 2001; Rosenkopf and Nerkar 2001).

A patent represents a contribution towards new knowledge creation. A firm's patent portfolio reflects the accumulated knowledge developed by the firm over time (Jaffe 1984; Patel and Pavitt 1991). The patents owned by a firm measure its efforts

in knowledge creation and, accordingly, they provide an indirect input measure of the fields in which corporate technological capabilities are established in order to make such knowledge operational (Pavitt 1985). In line with the evolutionary approach to technological change (Nelson and Winter 1982), this interpretation emphasizes the significance of gradually assimilating newly acquired knowledge into tacit capabilities that are embodied in best practices in some given fields, and which areas of advantage for a given firm can then be sustained and reproduced over time through a localized firm-specific learning path of a cumulative and incremental kind.

Dataset Construction

We tested the hypotheses on a longitudinal data set derived from 25 of the world's largest firms operating in 8 industries and involved in major M&As in the period 1969-1995. The focus on the world's largest firms ensures the availability and reliability of data and is also consistent with prior research on M&As (Hitt *et al*. 1991, 1996). Although companies were selected partly on the grounds of their patenting size at the end of the period analyzed, the data confirms the leading position of the selected companies in patenting throughout the period in question. While the number of cases under analysis is rather small, our data provide in-depth information for the restructuring of corporate technological capabilities in differently motivated deals. Thus, we believe that our investigation should enable us to draw some general conclusions (with due qualifications) on the way in which different corporate strategies of capabilities restructuring emerge by relying in part on M&As to rapidly accumulate new technological capabilities during a phase of significant restructuring

The change in the composition of corporate profiles of technological capabilities was investigated through the use of US patent data. The use of US patent data for all selected firms, including foreign firms ensures consistency, reliability and

comparability as patenting systems across countries differ in their application of standards, granting systems and value of protection granted. Several studies have shown that US patents provide a good measure of foreign firms innovative activity (e.g. Soete and Wyatt 1983) and research on international samples have extensively adopted US patent data (e.g. Stuart and Podolny 1996; Patel and Pavitt 1997). The dataset construction has been designed to keep in mind the issues raised by the research problem addressed in this study, since births, deaths, mergers and acquisitions as well as the occasional movement of firms between industries (sometimes associated with an historical change in ownership) have been taken into account. Patents have been consolidated into corporate groups, initially on the basis of the structure of ownership of groups in 1982. Post-1982 mergers and acquisitions are mostly incorporated into the data through the practice in most groups of centralizing the patent application procedure in the parent company. In other important cases of mergers and acquisitions affecting the ultimate ownership of significant numbers of patents, the change in ownership structure is incorporated into the organization of the data, which involves in some cases the creation of a new corporate group and, in others, the expanded consolidation of groups with newly acquired subsidiaries.

For each of the 25 companies, annual patenting activity was considered from 1969 through 1995, and for each firm the periods of the sharpest increases in patenting were identified. Within each corporate patenting portfolio, for each substantial rise in patenting activity an 8-year period was identified, consisting of two sub-periods of 4 years each (before and after the patenting break under consideration). The selection of this time period for measuring a firm’s knowledge base before and after an external acquisition was also adopted in previous studies

(e.g. Ahuja and Katila 2001). A patent growth rate between the two 4-year sub-periods was then calculated. Therefore, in the econometric analysis, for each firm we considered the 8-year period that yielded the highest growth rate for that firm, provided the firm had at least 50 patents in each of the 4-year sub-periods. For each sharp structural patenting break it is possible to identify specific M&A deals that contributed to the observed breaks. This way of proceeding is consistent with our research aim, since we are not concerned with the impact of (all) M&As in general on corporate patenting activity. Rather, our interest lies in the analysis of M&As that were conducted in a specific context, namely that quite small subset of M&As which have been part of an observed strategy to significantly transform the structure of the acquiring firm, and that have been of sufficient importance to have produced noticeable effects on the technological profiles of the firms involved. M&As are surely only one part of the transformational activities undertaken at such times of structural change that contribute to structural breaks in patenting. Indeed, we have no way of establishing precisely how much those deals contributed relative to the other factors that may have been involved in each case — such as inter-firm alliances, purely internal transitions, and so forth, the significance of which will vary across our cases in ways we are unable to establish precisely (since an in depth case study approach lies beyond the scope of our analysis here). However, although M&As are only a part of a wider process, they are a *necessary* part, on the grounds that they are the only means of obtaining relatively sharp structural increases in activity and the addition of new lines of activities in a short period of time. M&As are here defined as the purchase of the majority of a company's capital by another company, although this very often involves deals to transfer some subsidiary or division of a larger corporate group and not just a change in the ownership of the group as a whole.

Three main types of data sources were used to identify the M&As that contributed to the observed breaks in patenting and to collect information on these deals: international business press, technical publications and specialized databases. Possible drawbacks and limitations of this method of information gathering have been addressed by adopting meticulous cross-checking procedures. In collecting this information, the location of the corporate unit acquired or sold (rather than the nationality of the parent company from which it might have been acquired) was compared with the main country of origin of the post-M&A increase in patenting.

The two key M&As motives identified are operationalized by classifying M&As as *market*-motivated and/or *technology*-motivated. The two motives are classified independently from one another so to allow that corporate expansion may sometimes combine these two elements rather than regarding them as strictly alternative to one another. This distinction of motives is intended to capture corporate strategies that draw upon *product*-related diversification and *technology*-related diversification, respectively. To identify technology-motivated (T-motivated) M&As, we drew on the methodology of Ahuja and Katila (2001). We adapted the Ahuja and Katila (2001) criteria for technology-based M&A deals, which included as technological acquisitions all deals in which technology was reported as a motive in news stories, or in which the acquired firm had been granted any US patent in the five years prior to the acquisition. However, their purpose was to identify, among a large sample of many M&As, any deals in which the acquired company had some significant technological assets. Instead, we are examining alternative paths of corporate technological development in circumstances in which there was an important acquisition of a company that had some significant prior technological capabilities. Therefore, we were more concerned with the motives of the acquiring

company than with the presence or absence of technological assets in the acquired firm, since such assets were always present in our case. Thus, we restricted ourselves to the first of the two criteria, namely where there was mention of a technology-based motive in news stories about each deal. In addition, we could not rely on patent data to identify technology-motivated M&As, since patent measures of an acquired unit cannot be computed if only a division of a firm is acquired rather than the complete entity, and this applies to most of the acquisitions that we are considering. To identify market-motivated (M-motivated) deals we examined the information provided by our data sources to establish if the acquiring and acquired firms operate in the same or in a complementary market, or not. T-motivated deals account for 16 out of the 25 deals, consisting of those that were intended to support technological diversification to enable firms to create new innovative combinations, generating higher rates of innovation, and thus yield *dynamic economies of scope*. M-motivated M&As account for 13 out of the 25 deals, in which M&As substantially increased the product economies of scope of the acquiring or merging firms involved. Four out of the 25 deals are classified as both market- and technology-motivated. These overlapping cases involve three intra-industry deals and a deal between firms operating in closely related industries. In these four cases, acquiring firms were targeting firms operating in the same or complementary markets, and technology-based motives were also reported in news stories.

For each of the 25 deals, Table A1 reports the focal firms and their industry of output, the target firm identified, and distinguishes between T- and M-motivated M&As, some selected characteristics of the deals as well as the exact year of the structural break in the number of patents, the year of the deal, the rate of growth of

patents and the number of patents of the acquiring firm in the first 4-year sub-period considered.[i]

Variables

The composition of corporate profiles of technological capabilities is proxied by a measure of technological specialization across technological fields. In particular, our dependent variable measures changes in corporate technological specialization in any given technological field through the use of patent data. The detailed cross-field structural information offered by patents provide us with insights suited to our research purpose. In the context of our study, the major drawback of using patents as a proxy for technological capabilities lies in the different propensity to patent across industries (Scherer 1983). This problem can be addressed through the construction of a relative measure, such as the (adjusted) revealed technological advantage (RTA) index introduced by Soete (1987).

Thus, technological specialization was proxied by the RTA index of each of the 25 focal firms calculated across 56 technological fields, relative to other large firms in the equivalent industry. Hence, for each of the 25 focal firms the index is defined as follows:

$$RTA_{ij} = (P_{ij} / \sum_i P_{ij}) / (\sum_j P_{ij} / \sum_{ij} P_{ij}) \quad (1)$$

where P_{ij} is the number of patents attributed to firm *i* in the technological field *j*. Thus the index shows the specialization of firm *i* in field *j* relative to other firms in the same industry, the denominator being summed over all the largest firms in the relevant industry, and not just the 25 focal firms that are here the subject of particular investigation.[ii] For each of those 25 firms, the index was calculated for each 4-year sub-period (representing respectively the phases before [RTA_{ijt-1}] and after [RTA_{ijt}] the sharp structural break in patenting related to a specific M&A deal). In order to

normalize the index (which would otherwise vary between 0 and $+\infty$ and so have a lower but no upper bound), for each of the two sub-periods we calculated an adjusted RTA (*adjRTA*) index as follows:

$$adjRTA_{ij} = (RTA_{ij} - 1)/(RTA_{ij} + 1) \quad (2)$$

This adjusted index varies between –1 and +1. Positive (negative) values denote a comparative technological advantage (disadvantage) of the firm in the field in question relative to the other largest firms in the equivalent industry. Our dependent variable was then specified as follows

$$\Delta TECHSPEC_{ij} = 1 + (adjRTA_{ijt}/(adjRTA_{ijt-1} + \Delta adjRTA_{ijt-1}))$$

$$= (adjRTA_{ijt} + \Delta adjRTA_{ijt-1})/(adjRTA_{ijt-1} + \Delta adjRTA_{ijt-1}) \quad (3)$$

which serves as a proxy for the change in corporate technological specialization of firm *i* in field *j* between the 4 years before (*t*-1) and the 4 years after (*t*) the structural break in patenting considered. To avoid division by zero, the mean value ($\Delta adjRTA_{ijt-1}$) is added to *adjRTA* to obtain the expression denoting the change in *adjRTA.* Since the mean value is roughly 0.2, $adjRTA_{ijt-1} + \Delta adjRTA_{ijt-1}$ ranges from 0.2 to 2.2.

To examine the restructuring in the technological capabilities of firms following differently motivated M&A-related corporate expansions, a series of covariates were included in the model. In order to construct these covariates, we firstly considered contingent characteristics of the M&A deals, and classified the US patents held by acquiring firms into 56 technological fields which represent groupings of related patent classes and sub-classes.

Following our co-evolutionary conceptual framework illustrated in Figure 1, we consider the varying influences on firm expansion provided by the contexts of sectoral scope and time period. In particular, two contingent characteristics of each

M&A deal associated with a major rise in patenting were taken into account: 1) whether the industries in which each of the prospective partners operated were different or the same (i.e. whether deals were inter- or intra-industry), and 2) the M&A wave in which the deal occurred (i.e. whether it was in the 1970s or 1980s). For each of the 25 firms, these characteristics were then translated into two binary (0-1) variables: *Inter-industry* and *Recenttimes* respectively.

For each of the 25 firms, the 56 technological fields were further aggregated into one of the following broader categories of technological capabilities: a) ICT (*ict*) technological capabilities, comprising capabilities in communications and computed related areas[iii]; b) *core* technological capabilities, being those most directly linked with the firm industry's *core* products (e.g. chemical capabilities for firms in the chemical industry); c) *related to core* technological capabilities of the firm's industry; and d) all other fields. The received grouping of formerly related fields was identified through a two step procedure. First, a technological relatedness measure was constructed following the procedure of Teece *et al*. (1994). More specifically, for each industry *I*, technological relatedness (R_{jc}) between each technological field *j* (excluding the *core* and the ICT fields)[iv] and each of the *c* technological fields *core* to the industry in question was calculated as follows:

$$R_{jc} = n_{jc} - \square / \square, \qquad \text{where } j \neq c \qquad (4)$$

where n_{jc} is the actual number of linkages defined in terms of the number of the world's largest industrial firms in industry *I* that were granted patents in both *j* and *c* (that is, the number of times *j* and *c* occur together across firms in industry *I*); □ is the expected number of linkages in industry *I*; and □ is the standard error of the expectation (for a more in-depth discussion see Cantwell and Noonan 2001). Second, for each field *j* we took the mean of the relatedness values across all *core*

fields *c* in that industry ($\square_{Rjc}$). The criterion adopted to identify the fields that occurred together with the *core* areas more frequently than if technological combinations occurred purely randomly required that $\square_{Rjc} > 0$ or $R_{jc} > 0$ for at least 50 % of the *core* fields across which the mean value was calculated.

In order to examine the dominant trends in the direction of change in patterns of technological specialization in either the T-motivated or M-motivated cases, each of the broader groups of technological capabilities just described was in turn interacted with the two M&A characteristics outlined earlier, and a series of explanatory variables was obtained through this procedure.

More specifically, to capture the effects of various aspects of T- and M-motivated M&As on the restructuring of technological capabilities across industries (i.e. over product space), the following independent variables were deployed: *Inter-industry_ICT*$_{ij}$ is set equal 1 if the deal involving the focal firm *i* occurred between firms operating in different industries and if *j* is an ICT field, 0 otherwise; *Inter-idustry_core*$_{ij}$ is set equal 1 if the deal involving the focal firm *i* occurred between firms operating in different industries and if *j* is a core field in the primary industry in which *i* operates, 0 otherwise; *Inter-industry_related*$_{ij}$ is set equal 1 if the deal involving the focal firm *i* occurred between firms operating in different industries and if *j* is a field related to the fields of the primary industry in which *i* operates, 0 otherwise. To capture the restructuring of technological capabilities in T- and M-motivated M&As in the more recent time period considered the following explanatory variables were included: *Recenttimes_ICT*$_{ij}$ is set equal 1 if the M&A involving the focal firm *i* occurred in the 1980s and if *j* is an ICT field, 0 otherwise; *Recenttimes_core*$_{ij}$ is set equal 1 if the M&A involving the focal firm *i* occurred in the 1980s and if *j* is a *core* field in the primary industry in which *i* operates, 0 otherwise;

Recenttimes_related$_{ij}$ is set equal 1 if the M&A involving the focal firm *i* occurred in the 1980s and if *j* is a field related to the *core* fields of the primary industry in which *i* operates, 0 otherwise.

In order to control for potential differences in the nationality of ownership of partners, we also took into account the geographical spread of the deal by including a variable (*Cross-border*) equal to 1 if the deal involving the focal firm *i* was a cross-border M&A, 0 otherwise. It has indeed been recognized that locational heterogeneity provides critical opportunities, which have increasingly became central to corporate business strategy (Ghemawat 2001; Ricart *et al*. 2004; Ghemawat and Ghadar 2006).

Depending upon the environmental context analyzed (with respect to sector or time period), a further control variable was included in the model. In each of the T- or M-motivated cases, 1) when examining the restructuring of technological capabilities across industries, we included *Recenttimes* to control for the time period effects on the entire firm's technological profile; and vice versa 2) when examining the restructuring of technological capabilities in the more recent time period, we included *Inter-industry* to control for the effects of inter-sectoral combinations on the entire firm's technological profile.

4. Results

For each of the technology- and market-motivated cases respectively descriptive statistics and correlation matrices are reported in Tables 1 and 2.

To test the pattern of restructuring of technological capabilities in T- and M-motivated M&As in different environmental contexts, we used a hierarchical OLS regression analysis of the change in a firm's technological specialization profile. In the first specification, we entered the main effects for the contexts of external

corporate expansion (i.e. *Inter-industry* and *Recenttime*) and for the groupings of technological fields under analysis (i.e. *ICT*, *core*, and *related*) as well as the control variables. In the second specification, we entered the relevant interaction terms. The parameter estimates of the regression models of both T- and M-motivated deals are provided in Tables 3, 4, 5 and 6. In these tables, model 1 presents the overall results considering the main effects and controls, while in model 2 we include the intersections between the relevant environmental context and the selected grouping of technological fields analysed. We observe that the insertion of these interactions effects improves the explanatory power as illustrated by the increased of the adjusted R^2 values. In all cases, the F statistics are significant, supporting the chosen model specification. We also test for omitted variables through the Ramsey RESET test and for additivity through the Tukey test (1949). Neither test yields statistically significant results, thus further supporting the chosen model. Moreover, the variance inflation factors in all models are insignificant.

For the T-motivated cases the estimates of the restructuring of technological capabilities following M&A deals across industries and in the more recent time period are reported in Tables 3 and 4, respectively. In T-motivated inter-industry deals firms acquire *ICT* technological capabilities. These results support Hypothesis 1. In T-motivated deals occurring in the more recent time period, firms rationalize technological capabilities *related to the core* capabilities of the firm's industry. This supports Hypothesis 2.

For the M-motivated cases, the equivalent estimates are reported in Tables 5 and 6. In M-motivated inter-industry deals, firms rationalize technological capabilities fields that are *related to the core* capabilities for the firm's industry. This support Hypothesis 3. It can also be noted that in these inter-industry M-motivated deals

firms have tended to rationalize technological capabilities *core* to the firm's industry . This may be because in M-motivated corporate expansions investments to combine product-related business may be made at the expense of core technological capabilities. When considering M-motivated deals occurring in the more recent time period, firms acquire ICT capabilities. This supports hypothesis 4.

As far as controls are concerned, firms acquire new technological capabilities overall in inter-industry deals when investigating the restructuring of selected technological capabilities in T-motivated M&As occurring in the more recent time periods. This may be read along the lines of a greater effort and ability of firms to explore new technological synergies across industries recently (Capron 1999; Vermeulen and Barkema 2001). Similarly, in these T-motivated deals occurring in the more recent time period cross-border acquisitions lead to the acquisition of new technological capabilities overall. This result is consistent with research on international acquisitions, which finds that cross-border acquisitions lead to superior post-acquisition performance (Weber *et al*. 1996; Very *et al*.. 1997). No statistically significant results are gathered for the controls in the other estimations.

5. Conclusions and Implications

This paper analyses the restructuring of technological capabilities following M&A-based corporate expansion.

In the case of the firms we have examined, all are large industrial enterprises with substantial technological knowledge bases as measured by patents. In particular, we focused on the restructuring of general purpose (ICT) capabilities and those that had been most related to core fields in the relevant acquiring industry. We develop and test a conceptual framework grounded in a co-evolutionary view, that

relates different firm's motivations and contexts for corporate expansion to a specific restructuring in the composition of corporate technological capabilities. We find that distinct patterns of technological capability restructuring are associated with each combination of the motivations and environment for corporate expansion. In particular, inter-industry environments reduce technological relatedness in M-motivated expansions, while relatedness has also declined in more recent T-motivated growth in general. The acquisition of ICT is common to both T-motivated inter-industry deals and more recent M-motivated deals, although, we speculate, for different purposes.

Implications for theory

Our analysis may help to qualify the nature of an inverted U-shaped relationship between firms' technological relatedness and innovation performance in collaborative or coordinated ventures (Barlett 1993; Nooteboom ***et al***. 2007) by providing an explanation for the finding of Ahuja and Katila (2001) of such a curvilinear relationship in the case of innovation performance in the aftermath of M&A deals. In their study, they showed that technology-based M&A deals (broadly defined) are associated with better innovation performance than are non technology-based M&A deals. It should again be noted that their definition of technology-based M&As distinguished between cases in which acquired firms have significant technological assets, as opposed to those in which they do not. Our study has been concerned to examine, within the set of such technology-based expansions broadly defined in this way, those that were motivated by technology-motivated objectives and those that had instead market-motivated objectives. Hence, the Ahuja and Katila (2001) measure of technology-based acquisition used the technology status of the

target firm in an acquisition, while our definition of technology-motivated expansion is concerned with the motivation of a company acquiring external technological capabilities. Ahuja and Katila (2001) reason that their finding that if technological relatedness is either too close or too distant it leads to no subsequent innovation performance benefits, may be due to managers making mistakes in terms of a failure to recognize the desirability of more optimally related combinations. Our approach suggests an alternative interpretation of their findings, namely that such overly far away technological combinations may instead simply be the outcome of product market-motivated expansions that are not focused on technological relatedness at all, but that are mainly geared to the achievement of product relatedness. When they are market-motivated, more distant inter-industry amalgamations may have a disruptive effect on a range of innovation activities (Hitt *et al*. 1996; Cloodt *et al*. 2006), by actually further reducing technological relatedness.

A further contribution of our study lies in a more detailed account of post-acquisition innovation outcomes. In the literature on the impact of M&As on post-acquisition innovation performance, most studies have considered only aggregate outcomes, whether measured by levels of patenting (Ahuja and Katila 2001), R&D expenditures or employment (Hall 1988; Hitt *et al*. 1991). By drawing on the detailed disaggregation of US patent technological fields, we have shown instead that there are important differences in the paths of post-acquisition development of related or ICT capabilities, depending upon whether expansion is either technology- or market-motivated. In particular, we have found two sets of conditions under which the kinds of non-localized technological search that have been discussed in some recent research (Ahuja and Katila 2004; Rosenkopf and Almeida 2003) may be especially relevant. A disturbance to structures of corporate technological relatedness may

occur in market-motivated cross-industry expansion, but also increasingly over time in technology-motivated expansion. While in the former case this is a largely unintended side effect of product market strategies, in the latter case we contend that it may reflect a gradual evolution in the character of purposive technological search strategies.

Implications for managers

We have just suggested that managers following market-motivated expansions may not be making mistakes when failing to consider in some cases the extent of technological relatedness of business combinations. However, in these cases in which acquired businesses have substantial technological capabilities even though these are not the primary target, it is clear from our investigation that major issues of technological restructuring will still require to be addressed by management. In this context it may also be useful for managers to be able to appreciate that new ICT capabilities may have different roles. For technology-motivated expansions, investments in ICT are important in bridging technological capabilities in inter-industry combinations, while in market-motivated expansions they have recently become important in the restructuring of systems of production and distribution.

Limitations and further research

Several limitations of this study should be acknowledged. Our analysis is concerned with a relatively small number of cases. It would be desirable to enlarge the number of cases so to have a random sample in order to be clearer on the robustness of our results. Similarly, a larger number of firms in each industry would allow us to examine the effects of firm heterogeneity within industries. While we have measured technological relatedness, we do not adopt any measure of product relatedness. This is not a major constraint in this study, since we focus on outcomes in terms of

technology relatedness, but it would be useful to extend the argument to explicitly account for the extent of the product-relatedness of business combinations.

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Figure 1 – The areas of corporate technological capability restructuring promoted under different motivations and environmental contexts for external corporate expansions

		Motivations for external corporate expansion	
		Technology-motivated	*Market-motivated*
Environmental contexts for external corporate expansion	*Sector (across versus within industries)*	Building technological relatedness through ICT - 1 -	Building product market relatedness through a rationalization of technological relatedness - 3 -
	Time period (recent versus earlier time periods)	Increasing strategic experimentation - 2 -	Increasing efficiency of related product market combinations through ICT - 4 -

Figure 2 – Derivation of the hypotheses on the areas of corporate technological capability restructuring

		Motivations for external corporate expansion	
		Technology-motivated	*Market-motivated*
Environmental contexts for external corporate expansion	*Sector (across versus within industries)*	Acquisition of ICT technological capabilities: *technology fusion* (H1) - 1 -	Decline of related technological capabilities: *joint production and distribution to combine product-related businesses with no necessary relationships in their technologies* (H3) - 3 -
	Time period (recent versus earlier time periods)	Decline of formerly related technological capabilities: *greater experimentation over time* (H2) - 2 -	Acquisition of ICT capabilities: *reduction in joint inventory holding costs through information-based systems that combine storage, transportation and distribution across related lines of business* (H4) - 4 -

Table 1 - Descriptive statistics and correlation matrix for the T-motivated cases (896 obs.)

	Mean	Std. Dev.	□*TECHSPEC*	*Inter-industry*	*Recenttimes*	*ICT*	*core*	*related*	*Cross-border*
□*TECHSPEC*	1.340	1.551	1						
Inter-industry	0.750	0.433	0.043	1					
Recenttimes	0.688	0.464	0.008	-0.078	1				
ICT	0.107	0.309	0.057	0.000	0.000	1			
core	0.138	0.346	-0.033	0.008	0.096	0.112	1		
related	0.537	0.499	0.014	-0.035	-0.047	-0.373	-0.432	1	
Cross-border	0.750	0.433	-0.010	0.000	-0.078	0.000	0.045	0.038	1

Table 2 - Descriptive statistics and correlation matrix for the M-motivated cases (728 obs.)

	Mean	Std. Dev.	□*TECHSPEC*	*Inter-industry*	*Recenttimes*	*ICT*	*core*	*related*	*Cross-border*
□*TECHSPEC*	1.266	1.380	1						
Inter-industry	0.692	0.462	-0.011	1					
Recenttimes	0.769	0.422	0.012	0.030	1				
ICT	0.107	0.310	-0.013	0.000	0.000	1			
core	0.089	0.285	-0.031	-0.094	0.103	0.078	1		
related	0.571	0.495	-0.011	-0.066	-0.059	-0.400	-0.362	1	
Cross-border	0.615	0.487	-0.005	-0.527	-0.058	0.000	0.050	-0.057	1

Table 3 - Estimations for the T-motivated cases across industries

	Model 1				*Model 2*			
	Coef.	*Robust Std. Err.*	*t*		*Coef.*	*Robust Std. Err.*	*t*	
(Constant)	1.136	0.139	8.17	***	1.121	0.149	7.54	***
Inter-Industry	0.162	0.103	1.57		0.195	0.192	1.01	
ICT	0.359	0.206	1.74	*	-0.141	0.130	-1.08	
core	-0.130	0.139	-0.93		0.176	0.172	1.02	
related	0.096	0.118	0.81		0.177	0.196	0.9	
Inter-Industry_ICT					0.633	0.298	2.12	**
Inter-Industry_core					-0.343	0.243	-1.41	
Inter-Industry_related					-0.098	0.245	-0.4	
Controls								
Recenttimes	0.050	0.106	0.47		0.038	0.106	0.36	
Cross-border	-0.031	0.126	-0.25		-0.044	0.128	-0.34	
N. obs. 896								
R-squared	0.008				R-squared	0.011		
F(6, 889)	1.050				F(9, 886)	1.680	*	
					Ramsey RESET test F(3, 883)	0.12		
					Tukey's one-degree-of-freedom test for non-additivity	-0.069		

**** p < 0.01; ** p < 0.05; * p < 0.10*

Table 4 - Estimations for the T-motivated cases occurring in more recent time periods

	Model 1				*Model 2*			
	Coef.	*Robust Std. Err.*	*t*		*Coef.*	*Robust Std. Err.*	*t*	
Rcenttimes	0.392	0.105	3.73	***	0.869	0.172	5.06	***
ICT	0.635	0.197	3.21	***	0.951	0.348	2.73	***
core	0.088	0.138	0.64		0.265	0.241	1.1	
related	0.432	0.109	3.98	***	0.877	0.155	5.65	***
Recetitimes_ICT					-0.621	0.442	-1.4	
Recetitimes_core					-0.432	0.301	-1.44	
Recetitimes_related					-0.833	0.228	-3.65	***
Controls								
Inter-industry	0.560	0.102	5.49	***	0.402	0.104	3.88	***
Cross-border	0.332	0.113	2.93	***	0.214	0.119	1.80	*
N. obs. 896								
R-squared	0.408				R-squared	0.416		
F(6, 890)	106.89	***			F(9, 887)	76.95	***	
					Tukey's one-degree-of-freedom test for non-additivity	0.111		

**** p < 0.01; * p < 0.10.*

Table 5 - Estimations for the M-motivated cases across industries

	Model 1				*Model 2*			
	Coef.	*Robust Std. Err.*	*t*		*Coef.*	*Robust Std. Err.*	*t*	
(Constant)	1.419	0.170	8.35	**	1.196	0.199	6.02	***
Inter-Industry	-0.085	0.128	-0.66		0.239	0.239	1	
ICT	-0.113	0.167	-0.68		-0.228	0.152	-1.5	
core	-0.226	0.115	-1.96	*	0.173	0.182	0.95	
related	-0.113	0.129	-0.88		0.223	0.222	1.01	
Inter-Industry_ICT					0.102	0.281	0.36	
Inter-Industry_core					-0.564	0.234	-2.41	**
Inter-Industry_related					-0.467	0.274	-1.70	*
Controls								
Recenttimes	0.047	0.127	0.37		0.037	0.127	0.29	
Cross-border	-0.055	0.117	-0.46		-0.072	0.116	-0.62	
N. obs. 728								
R-squared	0.003				R-squared	0.008		
F(6, 721)	0.800				F(9, 718)	1.990	**	
					Ramsey RESET test F(3, 715)	0.880		
					Tukey's one-degree-of-freedom test for non-additivity	-1.150		

**** p < 0.01; ** p < 0.05; * p < 0.10.*

Table 6 - Estimations for the M-motivated cases in the more recent time periods

	Coef.	*Robust Std. Err.*	*t*		*Coef.*	*Robust Std. Err.*	*t*	
(Constant)	1.419	0.170	8.350	***	1.524	0.276	5.520	***
Rcenttimes	0.047	0.127	0.370		-0.072	0.298	-0.240	
ICT	-0.113	0.167	-0.680		-0.591	0.278	-2.120	**
core	-0.226	0.115	-1.960	*	-0.574	0.283	-2.030	**
related	-0.113	0.129	-0.880		-0.174	0.310	-0.560	
Recetitimes_ICT					0.604	0.348	1.730	*
Recetitimes_core					0.365	0.315	1.160	
Recetitimes_related					0.064	0.346	0.190	
Controls								
Inter-industry	-0.085	0.128	-0.660		-0.085	0.128	-0.660	
Cross-border	-0.055	0.117	-0.460		-0.059	0.117	-0.500	
N. obs. 728								
R-squared	0.003				R-squared	0.006		
F(6, 721)	0.800				F(9, 718)	3.69	***	
					Ramsey RESET test F(3, 715)	1.29		
					Tukey's one-degree-of-freedom test for non-additivity	-0.465		

**** p < 0.01; ** p < 0.05; * p < 0.10.*

Table A1- Firms under analysis, by industry, target, motive and period of the deal, and patenting information

Focal Firm	Industry	Target*	M&A motive		M&A year	patenting structural break year	Patenting growth rate**	N. of patents in t-1 **
			M-motivated	T-motivated				
BASF	Chemicals	Brabrand	x		1982	1985-1986	25.53%	1234
DSM	Chemicals	Unichema/Scado	x		1984	1985-1986	7.63%	118
ICI	Chemicals	Societé Europeenne des Semences (SES)		x	1987	1985-1986	16.28%	608
Bayer	Chemicals	Herman C. Starck Berlin GmbH & Co.		x	1986	1985-1986	12.59%	2144
Ciba-Geigy	Chemicals	Spectra-Physics		x	1987	1985-1986	18.92%	1348
Rhône-Poulenc	Chemicals	silicon division of ICI	x	x	1988	1985-1986	32.75%	400
Solvay	Chemicals	Reid-Rowell		x	1986	1985-1986	31.36%	118
SKB	Chemicals	Krautkramer GmbH		x	1972	1973-1974	41.22%	444
Degussa	Chemicals	Asta-Werke AG		x	1983	1981-1982	13.19%	288
Upjohn	Pharmaceuticals	Admiral Maschinenfabrik GmbH	x		1978	1976-1977	45.81%	716
Beecham Group	Pharmaceuticals	Scott & Bowne Ltd.		x	1978	1974-1975	112.79%	86
Glaxo	Pharmaceuticals	Bonomelli	x		1988	1987-1988	110.29%	68
Wellcome Foundation	Pharmaceuticals	International Minerals & Chemicals Corporation	x		1989	1986-1987	111.27%	71
Schering	Pharmaceuticals	The Cooper Companies		x	1988	1987-1988	29.65%	199
Shell	Oil	Gasunie	x		1988	1986-1987	46.75%	845
BP	Oil	Kennecott	x		1981	1978-1979	43.96%	414
British Aerospace	Aerospace	Rover Group	x	x	1987	1986-1987	137.31%	67
Daimler Benz	Motor Vehicles	transport application division of AEG	x		1986	1985-1986	39.22%	306
Bosch	Motor Vehicles	American Microsystems Inc. (AMI)		x	1979	1976-1977	14.39%	820
Schneider	Mechanical	Sodif		x	1986	1985-1986	86.54%	52
Siemens	Electrical equipment	G.D. Searle & Co.		x	1980	1978-1979	4.73%	1943
Brown Boveri	Electrical equipment	Studebaker-Worthington Inc.		x	1977	1978-1979	24.32%	333
Thomson-Brandt	Electrical equipment	consumer electronic division of AEG Telefunken	x	x	1984	1983-1984	20.57%	661
LM Ericsson	Electrical equipment	Ericsson (joint venture with Atlantic Richfield)	x	x	1987	1985-1986	36.92%	130
Metalgesellschaft	Metals	Swiss division of Reichhold Chemie AG	x		1974	1973-1974	21.76%	170

* This is the only M&A of those identified that matches the year of the structural break in firms' patenting activity and the associated structural shift in the geographical pattern of the location of the inventions.

** This information refers to the focal firm.

[i] Although in some cases the year of the deal follows the beginning of the structural break in corporate patenting activity, strategic delays in the announcement of a deal should be taken into account. Alternatively, a major new M&A may be the means of implementing more effectively a strategic change in the focus of production and technological effort that has already been decided upon, in which case the initial break represents a period of experimentation prior to the fuller commitment associated with the M&A deal.

[ii] *De facto*, the denominator of the *RTA* index accounts for all companies operating in the relevant industries to which US patents were granted in the period 1969-95, and which belong to the world's largest firms (i.e. listed in the Fortune 500 for US firms, or the global Fortune 500 for non-US firms, or having been assigned over 1,000 US patents since 1969).

[iii] The ICT technological fields are Telecommunications, Other Electrical Communication Systems, Special Radio Systems, Image and Sound Equipment, Semiconductors, Office Equipment and Data Processing Systems.

[iv] In the special case of electric firms, the core and ICT categories are the same.