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MERGERS & ACQUISITIONS AND INNOVATION PERFORMANCE IN THE TELECOMMUNICATIONS EQUIPMENT INDUSTRY

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Mergers & Acquisitions and Innovation Performance in the Telecommunications Equipment Industry*

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ABSTRACT

The telecommunications in the 1990s witnessed an enormous worldwide round of Mergers & Acquisitions (M&A). This paper examines the innovation determinants of M&A activity and the consequences of M&A transactions on the technological potential and the innovation performance. We examine the telecommunications equipment industry over the period 1988-2002 using a newly constructed data set with firm-level data describing M&A and innovation activity as well as financial characteristics. Based on a matching propensity score procedure, the study provides evidence that M&A realize significantly positive changes to the firm's post-merger innovation performance.

Keywords: Mergers & Acquisitions, Innovation Performance, Telecommunications Equipment Industry

JEL Classifications: L63, O30, L10

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1 INTRODUCTION

The telecommunications industry is moving fast both on the technology front and in terms of structure. A recent surge of Mergers and Acquisitions (M&A) in the telecommunications industry is a reflection of the drastically changing environment of the market.[1] Deregulation and liberalization, technological innovation and digital convergence and the evolving requirements of the capital markets have driven dramatic changes in the telecommunications industry as a whole. The industry in turn has sparked fundamental changes in the economic landscape worldwide. As the telecommunications firms face increasing exposure to international competition, the industry has undergone a radical transformation creating exciting new opportunities and new challenges for infrastructure and service providers (Li and Whalley, 2002). Market winners are in most cases also technology leaders or highly capable of turning a base technology into a superior product that meets the customer needs (Brodt and Knoll, 2004).

The rapid technological change, growing technological complexity and the shortening of product life cycles add new dimensions to an already complex scenario and increasingly force firms to source technologies externally. Firms will often prefer M&A to other cooperative approaches of R&D network building, e.g., R&D joint ventures, because M&A provide an immediate controlling presence in the new, fast expanding market, rather than having to gradually build a new business or negotiate with a partner about developing a cooperation (Caves, 1982; Capron and Mitchell, 1997). While several analyses have stressed that the telecommunications industry has undergone major restructuring in the 1990s through intense M&A activity (e.g., Jamison, 1998; Kim, 2005; Rosenberg, 1998, Warf, 2003), we are not aware of any study which investigates the linkage between recent rises both in M&A and innovation activity. The goal of this paper is to uncover the keen reliance of the telecommunications firms on M&A as a technology sourcing strategy.

We aim at providing answers to the following questions: Why do firms in the telecommunications industry increasingly use M&A as a technology source? Does M&A affect the innovation performance of firms involved as their proponents expect? Before attempting to determine this task, however, a more basic question needs to be addressed, namely: Does the innovation activity of firms depict a significant predictor of entering the M&A market? Admittedly, technological reasons do not motivate all M&A. M&A can be motivated, for instance, by the desire to obtain financial synergies or market power, to obtain access to distribution channels, and/or to gain entry into new markets.[2] Such M&A may not be able to be directly expected to improve the firms' innovation performance. However, in high technology

[1] Between 1996 and 2001, more than twenty M&A deals worth over $20 billion took place in the telecom sector, 14 of which were in the US. Telecom mergers amount for seven of the largest operations announced in 2000, and eight out of the ten largest of all times (Le Blanc and Shelanski, 2002).

[2] For extensive review, see Shimizu et al. (2004)

industries where innovation is the key to competitive advantage, firms will incorporate the impact of M&A on technological performance even when the transaction is not innovation-driven, thus choosing the most appropriate innovation and financial strategies. Moreover, to the extent that access to technology and know-how become increasingly important to succeed in the market, factors such as the firm's size, history and equity become less and less critical requirements. This allows new challengers to realize tremendous growth rates. Furthermore, it spurs the quest for external knowledge sourcing both at the established and new firms in the market. As innovation is becoming indispensable for strategic competitiveness in the high technology industry, we ask: How do firms that choose M&A and firms that stay outside of the M&A market differ with respect to their innovation performance? The follow up question is then, what are the effects of M&A on the innovative performance of firms if we control for the differences in innovation performance prior to M&A activities?

In order to explore the link between the effects of a merger and the reasons and expectations behind the transaction, we use a treatment effect estimation approach using a matching propensity score technique, thereby estimating the causal impact of merger on performance outcomes. We find that the telecommunications equipment firms undertake M&A in order to strengthen their success in innovation, and thereby, their market position. While the equipment manufacturers, which experienced low research productivity from ongoing exploitation of R&D efforts in the past, are forced to explore potential future innovation trajectories in new business units by acquisitions, those firms with a declining inventive portfolio are involved in pooling mergers to offer comprehensive and integrated equipment solutions. Finally, equipment firms in telecommunications outsource R&D through M&A as a means of revitalizing a firm by enhancing and supplementing its knowledge base effectively.

The article proceeds as follows: Section 2 discusses the theoretical underpinnings of our research questions. Data description is provided in Section 3, while empirical methodology is presented in Section 4. We report empirical results and analyze their sensitivity with respect to unobserved heterogeneity in Section 5. Section 6 concludes with discussion of our findings.

2 THEORETICAL BACKGROUND

Technological change influences the ability of firms to integrate, build and reconfigure internal and external competencies in order to address altering competitive and technological challenges. Dosi (1988) describes the technological changes to be continuous or incremental because they reflect a path dependent and cumulative development as a technological paradigm or pattern of inquiry. Incremental change tends to reinforce the market power of incumbent firms because it utilizes existing competencies in development and can be deployed through an established set of sales and marketing resources (Teece, 1996). Accumulated prior knowledge and heuristics constitute the learning capabilities that permit incumbents to acquire related problem-solving knowledge. Thereby, learning capabilities involve the development of the capacity to assimilate existing knowledge, while problem-solving skills represent a capacity to create new knowledge.

However, to the extent that the innovation embodies new skills or knowledge, incumbents can be hindered in responding as they may have little or no relevant development history to draw upon (Dosi, 1988). Cohen and Levinthal (1989) elucidated the two faces of R&D activity. That is, R&D activity does not only stimulate innovation, but it also enhances the firms' ability to assimilate outside knowledge. The second face of R&D is called the absorptive capacity, and it is considered to be crucial particularly for assessing the effective contribution by spillovers from others. Defined as a set of knowledge and competencies, the firm's knowledge base remains a preliminary condition in the assimilation of spillovers from R&D efforts of environment. For Rosenberg (1990), fundamental research inside the firm has strong complementarities with external R&D. All in all, both Cohen & Levinthal and Rosenberg insist on potential synergies between the firm's own knowledge base and external flows of scientific and technical knowledge. In order to fulfill technological challenges, firms must absorb the environmental information on innovation and eventually be able to exploit it through new products or processes in the market. Thus, the responsiveness of R&D activity to exploit external knowledge flows is an indication of the importance of absorptive capacity. In industries like telecommunications, this response must be quick due to highly competitive conditions caused by short product lifecycles, new technologies, frequent entry by unexpected outsiders, repositioning of incumbents and radical redefinitions of market boundaries as ICT industries converge. Highly reactive firms with highly absorptive capacities will not wait for failure to spur development. By contributing R&D to the firms' absorptive capacity, however, it should be noted that technological performance does not necessarily depend on past or referential performance, but rather on absorptive capacity generated in the past. In other words, firms with high absorptive capacity will exploit new ideas regardless of their past performance.

Firms, especially those with high technological content, strive to overcome constraints aligned with cost, appropriation, absorptive capacity and time regarding R&D performance. Thus, firms are faced with the associated objectives of developing a response to an innovation and doing so in a timely fashion. Therefore, there is a crucial strategic choice to be made for firms that decide to conduct R&D activities. Most theories of economic organization which rely on a comparison of costs or benefits per transaction to explain the organization of economic activity have typically ignored the possibility of multiple innovation sources. The theoretical literature, drawing on transaction costs economics (Coase, 1937; Williamson, 1981) and property rights theory (Hart and Moore, 1986), considers the choice between external sourcing and internal development as substitutes, i.e., the classical make-or-buy decision. Technological know-how is often tacit and can, therefore, not be easily transmitted from one firm to another (Larsson et al., 1998). In order to avoid high transaction costs, firms may be induced to engage in internal R&D to solve problems related to the transmission of tacit knowledge (Bresman et al., 1999). At the same time, internal developments may be perceived by firms because of the high risk due to the low probability of the innovation success and the length of required time for the innovations to provide adequate returns (Hundley et al., 1996). Thus, firms prefer to invest fewer resources in internal R&D when faced with resource constraints or attractive external innovation sources exist. It is argued that the mergers of firms with an innovative portfolio of interest often represent more certainty and lower risk of exploiting knowledge assets than new ventures do (Chakrabarti et al., 1994). Engaging in mergers, firms, however, may trade off payment of debt and debt costs for investment in R&D. That is, as the innovation developments embed assets that are largely non-redeployable, firms are likely to prefer the use of debt to fund acquisitions rather than to support innovation activities (Hitt et al., 1990). However, due to the fact that the financial and innovation strategies of future-oriented firms are jointly decided, a financial lack is imperative for firms pursuing a competitive strategy premised on innovation. Hence, the mutually exclusive choice between these innovation strategies is too restrictive. Moreover, R&D strategy adopted by a firm depends on its environment and on differences in the abilities of the firms to conduct R&D activities. The studies inspired by the resource- and knowledge-based approaches argue that a firm can rely on a combination of different strategies to engage in innovation. To justify the desideratum of the external technology source, it is essential to attend to the increasing evidence that a firm’s size and position within the industry affects the nature and the type of innovation in which it is engaged (Hart and Ramanantsoa, 1992; Christensen, 1997). On the one hand, pursuing to develop the knowledge and to create a new one internally, firms might be particularly blocked from adjusting from environment by their prior success in developing competencies. The former competencies may become rigidities or barriers to performance for radical or significant developments rather than for minor or incremental innovations since the latter are technological changes that are close to the current expertise. This is distinctive to established firms in the market or market leaders, mostly large firms, which tend to innovate in order to reinforce their positions or to enhance their core competencies. The ongoing exploitation of the existing knowledge and capabilities hinders the creation of new knowledge and eventually leads to a technological exhaustion after a certain point (March, 1991; Vermeulen and Barkema, 2001). These self-reinforcing capacities can also create competency-destroying technological change. Thus, a disruption in the innovation activity of firms may force them to turn outward to external technology source.

On the other hand, new firms or market challengers, mostly small firms, are more entrepreneurial and can respond more quickly to unexpected opportunities. By creating new fields of technology or new skills where the market leader does not have an expertise or an established position, they are looking for opportunities to upset the leader's position and to radically change the competitive situation, thus eliminating or diminishing the leader' market dominance. While they are more likely to fail, they are more willing or able to venture into completely new directions because they have less of a vested interest in the current technology and are not tied to sunk investments in obsolete technologies. At the same time, small challengers have fewer resources to spend on R&D and because there is a lack of strong enterprise channels, they are less likely to have the resources to bring an invention to the marketplace. This lack of manufacturing and distributing activity can be filled by large firms which possess a greater ability to finance a large amount of R&D as well.

Though occurrence of mergers[3] has grown dramatically in the last years, academic research on the relationship between innovation and mergers has not kept pace with the changes. In spite of the vast and rapidly growing body of literature on mergers,[4] empirical evidence which has explored this relationship is rather limited and often inconclusive.[5] The literature on the technological effects of mergers shows contradictory implications. On the one hand, mergers may build up competencies and foster innovation for a number of reasons. Mergers can reduce high transaction costs related to the transmission of knowledge between firms (Bresman et al., 1999). Furthermore, in fast moving markets with abbreviated product life cycles, firms may perceive that they do not have the time to develop the required skills and knowledge internally, and therefore, turn outward to mergers. In this sense, mergers may offer a quick access to knowledge assets (Warner et al., 2006). Moreover, mergers may extend the technological base of firms involved allowing them to achieve greater economies of scale and scope through more efficient deployment of knowledge resources. Also, mergers may enlarge the overall R&D budget of firms engaged, which then enables them to tackle larger R&D projects and, thereby, this spreads the risk of innovation. In addition, the integration of complementary knowledge may also increase innovation through mergers leading to more advanced technologies being developed (Gerpott, 1995). Finally, by exchanging the best practices on innovation management within the combined entity, firms may employ efficient technology integration.

On the other hand, innovation-driven mergers encompass the difficulties associated with innovation as well as the obstacles faced in mergers. First of all, differences in corporate culture, processes and knowledge base may impede a smooth transition of knowledge (Lane and Lubatkin, 1998; Very, 1997). Furthermore, mergers integration process is time consuming and costly. This may divert management attention away from innovation (Hitt et al., 1996). Also, trade off payment of debt and debt costs for investment in R&D can occur due to mergers (Hitt et al., 1990). In addition, a disadvantage of mergers is that it involves entire firms whereas the advantages for knowledge exchange may be limited to

[3] We employ, hereafter, the term "merger" to define both merger and acquisition if not otherwise indicated.
[4] For review see Roeller et al. (2001) and Shimizu et al. (2004)
[5] For review see Veugelers (2005)

only a small part of the firms involved. In mergers, knowledge beyond that required is also acquired. This may cause indigestibility: a firm may acquire more knowledge than it can use in a meaningful way (Hennart and Reddy, 1997). Finally, as the literature has shown, technologically motivated and intensive acquisitions are highly vulnerable to failure (Chakrabarti et al., 1994). One of the main reasons for this value destruction lies in the miscarried and inappropriate integration of the technology-based firm after the acquisition (Duysters and Hagedoorn, 2000). Even when the merger is successful in terms of the integration of R&D departments, in other business areas the merger may not be a success, thereby influencing a disintegration of the entire firm.

One of the main reasons for the contradictions and inconclusiveness of previous studies might be due to cross-industry investigations. Consequently, this study provides empirical evidence on our research questions by examining the mergers that took place between telecommunications equipment firms during the 1988 to 2002 period. This period witnessed an enormous wave of mergers that dramatically reconfigured the market structure of global telecommunications equipment as a result of international competition stemming from the liberalization of its market and pace of technological evolution (see figure 1 in annex). Lying at the core of the telecommunications industry, the telecommunications equipment industry takes a central role in the technological transformation of the entire industry. As the trade and regulatory liberalization primarily has globalized the demand for telecommunications equipment, technological change in the industry has had upstream effects on R&D (see figure 2 in annex). Moreover, the growth in the patenting has been tremendous - from 1988 to 1998 the number of communication equipment patents applied by the UPSTO increased by more than four times (see figure 3 in annex).[6]

3 DATA DESCRIPTION

In order to examine the interaction between merger and innovation activity, a new firm-level database is constructed which covers all firms in the telecommunications equipment industry that operated in any year over the 18 years period, 1987 to 2004 (including lagged periods). This database is created by complex matching process of information from initially four separate data sets. The first two datasets

[6] The abrupt fall in the patent applications after 1998 in figure 3 is primarily caused by the truncation of the patent data sample. We have patents which were granted by 2002. Thus, we end our analysis on patents in 2000 because, in the subsequent years, a truncation due to the grant lag appears to be more visible.

include firms' financial characteristics and the additional two data sets describe the firms' merger and innovation activities, respectively.

We define the telecommunications equipment firms as those which have primary activity in the communications equipment Standard International Codes (SIC) 3661, 3663, or 3669. The population of firms and their financial information including R&D expenditures were drawn from Compustat and Global Vantage databases. After eliminating firms with missing financial information, we could identify a sample of 638 telecommunications equipment firms for those data on R&D expenditures, total assets, market value, cash flow, long term debt were available.

Our patent statistics for the telecommunications equipment industry are based on the database which is compiled by the National Bureau of Economic Research (NBER, Hall et al., 2001). This database comprises detailed information on all US patents granted between 1963 and 2002 and all patent citations made between 1975 and 2002. The patent and citations data were procured originally from the US Patent Office and from Derwent Information Services, respectively. Although this US data could imply a bias in favor of US firms and against non-US firms, the group of non-US firms in this sample represents a group of innovative and rather large firms that are known to patent worldwide. Our database includes information on the patent number, the application and grant dates, the detailed technology field(s) of the innovation, the name(s) of the inventors, the city and state from which the patent was filed and citations of prior patents on which the current work builds. Following the classification in Hall et al. (2001), we include the patents for which firms applied in twelve main classes of the International Patent Classification (IPC) 178, 333, 340, 342, 343, 358, 367, 370, 375, 379, 385 or 455 - in the category communication equipment. As the distribution of the value of patented innovations is extremely skewed, we also consider the number of forward citations as an indicator of the importance or the value of innovations for each patent, thereby overcoming the limitations of simple counts (Brouwer and Kleinknecht, 1999; Griliches, 1990). During the observed period, 251 firms from our sample have applied for a total of 11,226 patents in communication equipment (including multiple applications by the same firm in the same year and for the whole period); this produces a total of 86,442 citations.[7]

M&A transaction data were obtained from the Thomson One Banker-Deals database. Updated daily, the database offers detailed information on merger transactions including target and acquirer profiles, deal terms, financial and legal advisor assignments, deal value and deal status. This database includes alliances with a deal value of more than 1 million USD, thus ensuring that the overwhelming majority of mergers are covered. Our initial sample on merger transactions contains information on 364 completed deals (including multiple deals by the same firm in the same year and during the observed period) carried out by 178 firms and announced during the period from 1988 to 2002. Using information from the data source, we distinguished between the role that a firm played in a M&A transaction and classified the firms in our sample in generally as an acquirer, the firm which purchased the stock or other equity interests of another entity or acquired all or a substantial portion of its assets; a target, the firm which sold a significant amount or all of itself to another firm; or a partner in a pooling merger, the firm which pooled its assets with another firm or merged with another firm of approximately equal size. Out of 364 M&A transactions, we could identify 217 acquirer, 25 targets and 122 partners in pooling mergers.[8] Furthermore, 59.6% of all of the mergers involve innovative firms, i.e., firms that applied for at least one patent during the observed period. While 84.8% of the merger firms took part up to three times in a merger, we can observe that the merger activity of the telecommunications equipment industry is characterized by the transactions of certain firms.[9] For our econometric analysis, we restrict the multiple transactions carried out by one firm in the same year to the largest transaction only.[10] Finally, the estimation sample consists of total 300 M&A transactions, which involve 186 acquirer, 22 targets and 94 partners in pooling mergers.

The databases were matched on the basis of firm names, CUSIP numbers[11] and address information provided by each database. The firms that are lacking information or have inadequate data on the matching procedure were cross-checked and completed with information reported in the Dun & Bradstreet's "Who owns whom" annual issues.

4 ECONOMETRIC METHODOLOGY

[7] The data set is truncated, which might cause a downward bias in the citation counts of recent patents.

[8] We lack financial data on the target firms for transactions that involve the acquisitions mostly of a privately held and/or relatively small firms that are not operated in the US and not listed in Global Vantage.

[9] For instance, the large-scale firms such as Ericsson, Siemens, ADC Telecommunications, Motorola and Alcatel carried out 17.86% of the total merger transactions.

[10] The frequency of merger transactions carried out by one firm in the same year is as follows: 294 firms with one deal, 44 firms with two deals, six firms with three deals, and three firms with four deals in a given year during the sample period.

[11] CUSIP stands for Committee on Uniform Securities Identification Procedures.

4.1 Estimation of the Propensity to Merge

We start our analysis by exploring the determinants of mergers and by investigating the attractiveness of telecommunications equipment firms as merger candidates. Employing a random utility model, we consider the firm i's decision of whether to acquire, to be acquired, to have involvement in a pooling merger or to stay outside the merger market. The utilities associated with each of these choices k are modeled as a function of the firm's characteristics X_i which affect the utilities differently:

$$U_{ik} = X_i \beta_k + e_{ik} \tag{1}$$

While the level of utility is not observable, we can, however, infer from the firms' choices how they rank each of these alternatives. If we assume that the e_{ij} are distributed Weibull, the differences in the disturbances are distributed logistic and a multinomial logit can be used to estimate the differences in the parameters β_k.

The propensity of engaging in a merger is modeled as a function of the firm's characteristics. We base the analysis on a panel that consists of innovation-related and financial variables on both merged and non-merged firms for which data were available during the 1988 to 2002 period. The probability that firm i chooses alternative k is specified

$$Pr(\,i\ chooses\ k\,) = \frac{exp\left(\beta_k' X_i\right)}{\sum_l^m exp\left(\beta_l' X_i\right)} = \frac{1}{\sum_l^m exp\left[\left(\beta_l - \beta_k\right)' X_i\right]} \tag{2}$$

where $\beta_1,...,\beta_m$ are m vectors of unknown regression parameters.

An important property of the multinomial logit model is that relative probabilities are independent from each other, which is the so-called independence of irrelevant alternatives (IIA) property. In order to obtain robust standard errors of estimated coefficients, appropriate tests were conducted, which are discussed in Section 5.1.

In the following, we explain the determinants of a merger captured by our analysis and assess the appropriateness and plausibility of the merger choice. Summary statistics of the variables are shown in table 1.[12]

The innovation performance of a firm is examined with respect to its R&D input, R&D output, the stock of accumulated knowledge generated by past R&D efforts, and the research productivity. R&D

[12] We checked that there exists no multicollinearity among selected variables.

input and R&D output of firms are measured by their R&D expenditure[13] and the number of patent applications that are actually granted, respectively. As a strong relationship exists between the size of the firm and its R&D expenditure and total number of patents, as suggested by common innovation studies, we took the ratios of the R&D expenditures and the patent counts to the total assets; we then defined them as R&D intensity and patent intensity, respectively.

INSERT TABLE 1 ABOUT HERE

In order to account not only for the quantity but also the quality of the patented inventions, we measured the patent-based characteristics of a firm using the number of forward citations of patents. The number of citations received by any given patent is truncated in time because we only know about the citations received thus far. In other words, the number of forward citations a patent received depends on the year of the application. We, therefore, normalize the citation counts by their average value calculated over all patents belonging to the same technological sub-class whose application was filed in the same year.[14] We then weight each patent of a firm by the number of normalized citations that it subsequently received (Trajtenberg, 1990).

The stock of accumulated knowledge of a firm is measured using citation-based patents and calculated by applying the perpetual inventory method by assuming a depreciation rate of 15% per annum (Hall, 1990). Hence, the individual patents in the firm's knowledge base provide the basis for comparing the firm's own knowledge base with that of other firms. R&D productivity, defined as the ratio of citation-weighted patent to R&D expenditure, accounts for the firm's research productivity. Research productivity may be interpreted as the efficiency with which R&D brings forth new and useful knowledge.

Since financial profiles of firms are likely to influence both their innovative and merger activity, we also include the firms' financial characteristics. To express all monetary values in real terms, we employ the U.S. industry-based Producer Price Index with basis year 1999. All covariates in the regressions have been lagged by one year in order to avoid potential endogeneity problems as well as possible biases arising from different merger accounting methods and financial statement consolidation.

Firm size is proxied by the book value of the total assets. Some empirical evidence has shown that the purchase of larger companies is positively related to post-merger performance, as larger targets

[13] R&D expenditures involve both current and capital expenditures, where the current expenditures are composed of labor costs and other current costs, and the capital expenditures are the annual gross expenditures on fixed assets used in the R&D projects of firms.

[14] This is the *fixed-effects* approach proposed in Hall et al. (2001)

can benefit the buyer in terms of economies of scale, a larger resource base and a larger customer base (Seth, 1990; Loderer and Martin, 1992; Clark and Ofek, 1994; Ahuja and Katila, 2001). However, other studies have claimed that these potential benefits might not be realized if the integration of larger acquired organizations creates greater coordination problems and needs resources to be devoted to solve this at the expense of business operations, thus leading to a negative impact of a merger (Lubatkin 1983; Kusewitt 1985; Ahuja and Katila, 2001).

The economic performance of a firm is proxied by firm growth and Tobin's *q*. Firm growth is measured by the annual growth rate of the market value. Firms with growing market value may appear as likely acquisition targets for mature firms looking to absorb growth opportunities. We approximate Tobin's *q* by calculating the ratio of the market value to the book value of a firm's assets, where the former is the sum of the book value of long-term debt and the market value of common equity (Danzon et al., 2004). According to the *q*-theory of investment, capital should flow from low-*q* to high-*q* firms. Indeed, by knowledge flows, technology shocks cause a large variation in the firms' Tobin's *q* (Jovanovic and Rousseau, 2004). The interpretation of the effect of Tobin's *q* should be treated with some caution, because, apart from being a forward looking indicator - a firm's growth opportunities (Gugler et al., 2004), Tobin's *q* is also likely to reflect stock undervaluation (Mork et al., 1990), or managerial performance (Powell, 1997).

The cash flow ratio is defined as the ratio of cash flow to the total assets, and it represents the financial capabilities of the firms. The cash-flow ratio amounts for funds available to a firm for operations, investments and acquisitions. Given the argument that R&D is primarily financed by internally generated resources, the cash-flow ratio might be an important determinant of the (inclusively) choice between internal R&D or external know-how of innovative firms.

We include a dummy variable which indicates missing R&D values and equals one when R&D is missing and zero otherwise (Hall, 1999). For the firm-years observations with missing R&D intensity, we then set the R&D intensity equal to zero. Moreover, to capture the difference between firms with no R&D output, we employ similarly a dummy for firms with zero (citation-weighted) patent intensity.

Table 2 depicts the *t*-statistics of the differences in means of the firms' characteristics separately for merged and non-merged firms. Firms that actually merged are characterized by a greater knowledge stock expressed in accumulated intellectual property rights than firms that did not merge. In terms of total assets, there is a significant size difference between merged and non-merged firms, thus showing that larger firms are more likely to merge.

INSERT TABLE 2 ABOUT HERE

The merged firms had, on average, a larger Tobin's *q* and cash-flow ratio, and they were less likely to have missing R&D values and zero (citation-weighted) patent intensity. The firms in our sample do not differ significantly in their R&D and (citation-weighted) patent intensity as well as research productivity prior to a merger.

1.

4.1 Estimation of the Impact of M&A on Innovation

Our analysis of the effects of mergers controls for endogeneity and ex-ante observable firm characteristics using a propensity score method (Dehejia and Wahba, 2002).

For each firm i in the sample, let M_i be a merger indicator that equals one when the firm engages in a merger and zero otherwise. We denote Y_{i1} as the innovation performance of merging and Y_{i0} as the innovation performance of non-merging firms and observe M_i and hence $Y_i = M_i \cdot Y_{i1} + (1 - M_i) \cdot Y_{i0}$. Accordingly, let $E\left[Y_{i1} \middle| M_i = 1\right]$ and $E\left[Y_{i0} \middle| M_i = 0\right]$ denote average outcomes of the technological performances of merged and non-merged firms, respectively. The effect we are interested in is that of merger on the technological performance of the merged firms, or the difference between the expected innovative performances of the merged firms and the firms that would have experienced if they did not merge:

$$\tau\big|_{M_i=1} = E\left[Y_{i1} \middle| M_i = 1\right] - E\left[Y_{i0} \middle| M_i = 1\right] \qquad (3)$$

This denotes the expected treatment effect on the treated. Since we do not have the counterfactual evidence of what would have happened if a firm had not engaged in a merger, $E\left[Y_{i0} \middle| M_i = 1\right]$ is unobservable. However, it can be estimated by $E\left[Y_{i0} \middle| M_i = 0\right]$ and the effect can be then given by the difference in the average outcome between the merged and non-merged innovative performances:

$$\tau^e = E\left[Y_{i1} \middle| M_i = 1\right] - E\left[Y_{i0} \middle| M_i = 0\right] \qquad (4)$$

In fact, we have observations on the firms which did not engage in a merger, but if the merged and the non-merged firms systematically differ in their firm characteristics, (4) will be a biased estimator of (3) (Hirano et al., 2002).[15]

Rubin (1997), Rosenbaum and Rubin (1983, 1984) showed that a propensity score analysis of observational data can be used to create groups of treated and control units that have similar characteristics, whereby comparisons can be made within these matched groups. In these groups, there are firms that have been merged and firms that have not been merged; hence, the allocation of the merger can be considered to be random inside the groups of firms.

The merger propensity score is defined as the conditional probability of engaging in a merger given a set of observed covariates X_i:

$$p\left(M_i\right)=\Pr\left(M_i=1\middle|X_i\right)=E\left[M_i\middle|X_i\right] \tag{5}$$

The treatment effect of a merger is then estimated as the expectation of the conditional effects over the distribution of the propensity score in the merged sample:

$$\tau\Big|_{M_i=1}=E_{p(M_i)}\left\{E\left[Y_{i1}\middle|p\left(M_i\right),M_i=1\right]-E\left[Y_{i0}\middle|p\left(M_i\right),M_i=0\right]\middle|M_i=1\right\} \tag{6}$$

The propensity score matching relies on two key assumptions (Rosenbaum and Rubin, 1983; 1984). The first, conditional independence assumption (CIA) requires that conditional on the propensity score potential outcomes are independent of treatment assignment. The CIA assumes that selection into treatment occurs only on observable characteristics. Hence, unbiased treatment effect estimates are obtained when we have controlled for all relevant covariates. The second assumption is the common support or overlap condition, meaning that firms must have a positive probability of being either merger or non-merger rather than just having same covariate values. In sum, the propensity score matching relies on the “strong ignorability” assumption, which implies that for common values of covariates, the choice of treatment is not based on the benefits of alternative treatments.

Using the stratification matching, we estimate the effects of a merger on innovation performance by taking the weighted average (by number of merged firms) of the within-strata average differences in performance outcomes between merged and non-merged firms. This is the average treatment effect on the treated referred to in the causal inference literature.

[15] Descriptive data in Table 2 show that merged and non-merged firms in our sample suggest significant differences in the observed characteristics.

5 Empirical Results

5.1 Technological Determinants of a Merger

In this section, we examine the merger decision of the telecommunications equipment firms in a multivariate analysis. Given that both merging and non-merging firms are included in the sample, we can attempt to distinguish between the characteristics of merging firms in transaction events and the firms outside of the merger market. We estimate equation (2) using a multinomial logit model with four outcomes: to be an acquirer, to be acquired, to be a pooling merger, or to be not involved in a merger. There are substantial drawbacks associated with the use of the multinomial logit estimation because it assumes that the disturbances are independent across alternatives. This assumption suggests that if a firm was choosing between the four alternatives, then there is no relationship between a firm's disturbances for being an acquirer, a target, a partner in a pooling merger or no involvement in a merger. In the context of this analysis, it is likely that merger behavior will not fulfill this requirement. The test of the maintained assumption of independence of irrelevant alternatives (IIA) will indicate whether the ratio of the choice probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternatives. In order to examine how the estimation results are affected by this property, four Hausman tests were conducted. The results from multinomial logit are compared with those from a binomial logits between the non-merged firms sample and each of the samples of acquiring, acquired and pooling merged firms as well as between acquirer and pooling merger samples. The *p*-values associated with the resulting test statistics were .88, .93, .76, and .67, respectively. Therefore, the null hypotheses are not rejected each, which implies that the IIA assumption is not violated. Furthermore, the results of the binomial logit regressions were almost identical to those of multinomial logit model. This also substantiates that the independence assumption is not a concern in our analysis, and that we can utilize robust estimates of the variance of coefficients.

Table 3 presents the marginal effects for the multinomial logit regressions. The statistics for the joint hypothesis and likelihood ratio tests are also reported. All estimated models are highly significant as indicated by the likelihood ratio tests of the null hypothesis that the slope coefficients are jointly zero, which are rejected at the 1 percent level using the chi-square test statistic.

INSERT TABLE 3 ABOUT HERE

Merging firms as a whole seem to have, on average, a significantly different innovative profile compared to that of non-merging firms. Larger firms, as measured by the book value of total assets, are more likely to engage in merger activity. This suggests that large firms are more willing to make use of their large and more stable internal funds to finance external R&D projects. A 100 percent increase in a firm's total assets is associated with a .0026 and .0005 percentage point increase in the likelihood of acquiring another firm and being involved in a pooling merger, respectively, which is a .37 and a 1.67 percent increase in each probability.

The significantly positive effect of the cash flow ratio on the likelihood to acquire another firm suggests that acquiring firms have considerable cash to run a larger firm and agency controls are imperfect. This is in accordance with the evidence that possessing the ability to finance a merger tends to precipitate acquisitions. Firms with a relatively low cash flow ratio tend not to engage in a merger due to their financial constraints. Thus, either imperfect agency concerns or availability of financing are significant constraints on acquisitions.

In the current sample, we do not find any statistically significant relationship between the variables confirming the growth opportunities of firms, which are growth in market value and Tobin's q, and the probability that a firm is engaged in a merger.

When we take the proposed determinants on innovative performance of the firms into account, then, at first, the merging firms are more likely to have a large accumulated citation-based patent stock. This evidence seems to be in accordance with the theoretical argument that a large stock of accumulated knowledge is essential if the acquirer (or one partner in a pooling merger) is to have the necessary absorptive capacity to identify the appropriate target (or another partner in a pooling merger). The fact that firms with a rather low accumulated knowledge stock are less likely to engage in a merger supports this evidence.

Next, firms with greater R&D and citation-based patent intensities have a greater propensity to undertake acquisitions. These results seem to mutually support the hypothesis that higher levels of relative absorptive capacity and the strengthening of its creation on the part of research-focused firms are necessary for those firms to incorporate and exploit new research into their R&D programs effectively. We also obtain a significantly negative coefficient of the dummy for acquiring firms when R&D expenditure is not reported, which are expected to have zero or low R&D intensity. Therefore, the acquirer are more likely to have non zero R&D input in the year before the merger. At the same time, the non-merging firms tend to have more frequent zero R&D intensity than merging firms.

After controlling for R&D and citation-based patent intensities, we find that the likelihood of becoming an acquirer is higher with a lower R&D productivity of firms. Although the acquiring firms experienced higher input and output in R&D, they seem to carry either a low number of patents and/or a relatively low-valued patents yield of R&D dollars before acquisitions. As mentioned above, large firms are often argued to have a lower R&D productivity than that of their somewhat smaller rivals because research conducted in most large laboratories is found to generate predominantly minor improvement inventions rather than new major inventions. This result suggests that an enhanced desire to acquire new technology and innovation-related assets driven by declining returns from the exploitation of the firms' existing knowledge base exists. At this step of the analysis, we are yet cautious about this indication, since the target probability regression provides insignificant results on marginal effects. The lack of preciseness in the target estimation may due to the fact that the probability of being acquired greatly varies among the small sample of target firms. We will come back to this point as some predications regarding the target firms' pre-merger performance can be derived from the next step of our analysis.

An interesting result is that firms with a poor accumulated citation-weighted patent stock and, at the same time, presenting higher R&D productivity tend not to engage in mergers. We ascribe these firms to be relatively young and with significantly new know-how. The negative effect of firm size on the propensity to stay outside of the merger activity also seems to point toward that direction. Moreover, the coefficient estimates of the multinomial logit model, which are not reported here, indicate that acquisition targets possessed a significantly large accumulated knowledge stock than the non-merged firms.

Finally, firms that experienced a low R&D output are more likely to be involved in a pooling, suggesting that the lack of innovation is an important driving force behind the merger activity. There is no significant relationship between R&D productivity and the propensity to go through a pooling merger that would further confirm this evidence.

5.2 Post-Merger Innovation Performance

Implementing the matching requires choosing a set of variables that satisfy the plausibility of the CIA. This implies that only variables that simultaneously influence the merger decision and the outcome variable(s) should be included. The outcomes of the firms' innovation performance are defined as the annual growth rates of the innovation determinants, e.g., we analyze the post-merger annual percentage changes of innovation input and output, knowledge stock and research productivity. In order to derive the merger propensity score, we estimated the multinomial logit model of equation (2) with annual percentage changes of the innovation and financials covariates used in our first step of analysis as well as their interaction terms.

In order to check the common support region, we compare the maximum and minimum propensity scores in the merged and non-merged groups. That is, we discard all observations whose propensity score is smaller than minimum and larger than maximum in the opposite group. As a consequence, any observations lying outside the region of common support given by [0.0072,0.6101] are excluded. Almost 42.6 percent of non-merged firms have a propensity score below 0.1, while 7.3 percent of merged firms have the same low propensity scores.[16] Since the number of treated firms lost due to common support requirement amounts up to 3 percent of the treated group and there are still comparable control firms to remaining treated firms, there is a good overlap in the estimated propensities scores for merged and non-merged firms in the sample.

The data in the region of propensity score overlap were sub-classified into five blocks defined by the quintiles of the propensity scores for merged firms. [17] To check for the adequacy of the propensity score model, we then used a two-way ANOVA to assess whether the propensity score balances each covariate between the merged and non-merged groups of firms. Each covariate is regressed on the merger and the propensity score stratum indicator and their interaction as factors. The insignificant effects of mergers and insignificant effects of the interaction between propensity score stratum and merger indicators determine that the distributions of the covariates within the sub-classes are the same for merged and non-merged firms.[18] The results of T-tests on the differences in outcome means in both groups after the stratification matching are shown in Table 4. The balance in covariates of merged and non-merged firms assures an unbiased estimate of the effect of a merger on the innovation performance (Dehejia and Wahba, 1990).

INSERT TABLE 4 ABOUT HERE

Since the full impact of mergers on the innovation performance takes time and results may not be evident immediately, we examine the impact of a merger in year *t* on the change in outcomes from

[16] Rosenbaum (1984) argues that low propensity score below than 0.1 percent is not uncommon in distributions of propensity score estimates, even for treatment observations.
[17] Five sub-classes (quintiles) constructed from the propensity scores will often suffice to remove over 90% of the selection bias due to each of the covariates (Rosenbaum and Rubin, 1984).
[18] Before sub-classification, we found using one-way ANOVA significant effects of mergers on more covariates.

$t+1$ to $t+2$, $t+2$ to $t+3$ and $t+3$ to $t+4$, in order to capture the long-run post-merger performance .[19]

Table 5 reports our findings on the effects of mergers on innovation performance. The impact of mergers appears to be more concentrated in the first year following a merger. Herein, stronger result are obtained for our main variables which more strictly explain the firm's innovation performance.

INSERT TABLE 5 ABOUT HERE

First, the percentage change in R&D intensity displays a significantly positive sign in all three years following a merger. Hence, according to our previous result from the first stage of the analysis, this indicates that the strong R&D intensity of acquiring firms positively influences the assimilation of the external knowledge by supplementing in-house R&D effort. Moreover, it suggests that the firms engaged in the mergers did not depreciate their investments in R&D on behalf of financing the transaction. Next, we find that mergers are followed by an improvement in the accumulated citation-based patent stock. In addition to the partners in a pooling merger, who possessed a large accumulated knowledge stock prior a merger, the targets also tend to be firms with highly valued patent stock. This result is in accordance with our prediction that accumulated knowledge stock confers an ability to recognize the new knowledge in environment and this ability seem to enhance the technological strengths even further.

The merged firms experience a significantly positive impact on the (citation-based) patent intensity compared to those outcomes that these firms would have reached if they did not merge. Due to the fact that the acquiring firms had a higher citation-based patent intensity prior acquisitions, this effect suggests that an intensification of high-valued patents creation relative to the firm's assets base prior an acquisition generates a significantly high innovation output of the merged entity. Additionally, the pooling partners which faced some absence of innovation efficiency in terms of the innovation output seem to grow following a merger, potentially because the merger provided access to technological resources which the firms previously lacked.

Furthermore, the insignificant result on the post-merger research productivity suggests that the marginal returns from R&D investments do not change with respect to the innovation output. At the same time, merged and non-merged firms do not significantly differ in their financial characteristics such as cash flow ratio and Tobin's *q*, at least for the observation period.

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[19] We cannot compare pre- and post-merger performance of merged firms with the matched sample of non-merging firms over the same time period because we lack pre-merger accounting data for one component of the merged entity for a significant fraction of our mergers.

Finally, we find a significant increase in the following variables reflecting the firms' economic performance. Firstly, there is a firm's size growth effect with respect to the annual percentage changes in the total assets as typically expected. Secondly, the positively significant increase in the annual growth of the market value on average confirms that, in the first year following the mergers, overall returns for shareholders are above those of the non-merged firms with similar characteristics.

5.3 Sensitivity Analysis

CIA assumes that the effects of casual merger are not influenced by any correlation between unobserved factors and a firm's selection into casual merger. Hence, the treatment effect estimators are not robust against "hidden bias" if unobserved factors like managerial skills and technological shocks that affect the merger are also correlated with the outcomes. After the adjusting for selection bias due to non-overlapping support and discrepancies in the distribution between merged and non-merged firms, the purpose of sensitivity analysis is to determine whether or not inference about treatment effects may be altered by unobservable variables in order to undermine our conclusions of matching analysis. While it is not possible to estimate the magnitude of selection bias with non-experimental data, the bounding approach proposed by Rosenbaum (2002) does provide a way of judging how strongly an unmeasured confounding variable must affect the selection process.

If we let u_i be an unmeasured covariate that affects the probability p_i of a firm *i* of selecting into the treatment and x_i are the observed covariates that determine treatment and outcome variable, then treatment assignment can be described by log odds as

$$log\left(\frac{p_i}{1-p_i}\right)=k\left(x_i\right)+\gamma u_i \tag{7}$$

where $0 \leq u_i \leq 1$.

Rosenbaum (2002) shows that this relationship implies the following bounds on the odds ratio between treated *i* and control j units which are matched on the propensity score *P(x)*

$$\frac{1}{\Gamma} \leq \frac{p_i\left(1-p_j\right)}{p_j\left(1-p_i\right)} \leq \Gamma \tag{8}$$

where $\Gamma = exp\left(\gamma\left(u_i - u_j\right)\right)$.

Because of the bounds on u, a given value of γ measures the degree of which the difference between selection probabilities can be a result of hidden bias. $\gamma = 1$ and accordingly $\Gamma = 1$ imply that both matched firms have the same probability of the engaging in a merger and thus hidden bias does not exist. Increasing values of Γ simulate an increasingly influence of unobservables on the selection decision. If a large value of Γ does alter inferences about the merger effect, the results are sensitive to potential selection bias.

We adopt Becker and Caliendo's (2007) procedure for bounding treatment effect estimates for binary outcomes and define new outcome variables which take the binary values according to the annual growth of performance outcomes.[20]

INSERT TABLE 6 ABOUT HERE

Table 6 contains the results of the sensitivity analysis for the significant effects of the mergers on the annual growth of the firms' innovation input and output, and knowledge stock in the first year following a merger. It displays the Mantel and Haenszel (MH,1959) test statistics for the averaged treatment effect on the treated while setting the level of hidden bias to a certain value Γ. The MH test statistics is used to test the null hypothesis of no merger effect and for each assumed Γ a hypothetical significance level "p-critical" is calculated, which represents the bound on the significance level of the treatment effect in the case of endogenous self-selection into treatment. Given the positive estimated treatment effects and thus looking at the bounds under the assumption that we have potentially overestimated the true treatment effects, the results indicate that the robustness with respect to hidden bias varies across the outcome variables.[21] Under the assumption of no hidden bias ($e^{\gamma} = 1$), the MH test statistics provide a similar results suggesting significant merger effects. The finding of a positive effect of mergers on the patent intensity is at least robust to the possible presence of selection bias. The critical

[20] Stata procedure *mhbounds* (Becker and Galiendo, 2007) has been applied, which is implemented for the case of binary outcome variables. We define an outcome variable taking the value 1 if a firm had a positive annual growth and 0 otherwise.
[21] The significance levels p^{+} calculated under assumption of overestimation treatment effect are presented.

value of e^{γ} is 1.20 indicating that firms with the same observable characteristics differ in their odds of treatment by 20 percent. Next, the critical value of e^{γ} at which we would have to question our conclusion of a positive effect on the R&D intensity is between 1.40 and 1.60. However, the Rosenbaum bounds are worst-case scenarios. Hence, a critical value of 1.40 does not mean that unobserved heterogeneity exist and there is no merger effect on the innovation input. This result means that the confidence interval for the R&D intensity effect would include zero if the odds ratio of treatment assignment differs between the merged and non-merged firms by 1.40 due to an unobserved variable. Furthermore, the effect on the knowledge stock remains significantly positive even in the presence of substantial unobserved bias by a factor of 2. This result imply that if an unobserved variable caused the odds ratio of merging to differ between the merged and non-merged firms by a factor of as much as 2, the 90 percent confidence interval would still exclude zero. Thus the positive estimated effects on the firms' innovation input and knowledge stock are robust to the unobserved heterogeneity, while the positive effect on the patenting intensity is less so.

6 CONCLUSION

This paper delivers insights into the desirability of M&A for the innovation performance of firms by analyzing the mergers that took place in the international telecommunications equipment industry from the late 1980s until the early 2000s. The conclusion that arises from the analysis is that, on average, mergers realize significantly positive changes to the innovation performance of firms following a merger. The post-merger changes are in turn driven by both the success in R&D activity and the weakness in internal technological capabilities at acquiring firms prior to a merger.

The findings about the innovation-related characteristics of the merging firms have interesting implications for the propositions about the rationale of mergers set out in our theoretical section. According to the absorptive capacity view, firms with a greater R&D intensity and a larger stock of accumulated knowledge have a greater propensity to engage in the technological-related mergers, and these underlying higher levels of absorptive capacity convincingly indicate the necessity for the identification, the assimilation and the exploitation of the targets' technological knowledge.

We find that larger firms with strong internal funds to finance R&D are more likely to acquire and to engage in a pooling merger, whereas the firms which lack these characteristics are more likely to pursue technology internally. Solely relying on in-house R&D, non-merged firms are appear to be rather young and small market challengers, which are striving to rival the market establisher with a significantly new and/or advanced technology on their own. Contrary to these firms, the acquired firms seem to be experienced entrepreneurs that have succeeded in the past at generating larger and high-valued inventions.

The analysis reveals that mergers are, on average, a positive experience for shareholders, at least for a short-time span. Moreover, the finding that mergers even in the long-run increase their R&D spending suggests that post-merger R&D effort is not affected by financial resource constraints induced by the transaction and integration processes. Indeed, efficiency gains from mergers in terms of R&D productivity are not evident in this industry.

With respect to the average effects of mergers, the analyses clearly indicate that the merged firms face heterogeneous outcomes regarding the post-merger innovation performance. One potential explanation of this heterogeneity in the performances might be due to different financing of the mergers transactions. How and to what extend the merger financing choice affects firms' post-merger innovation deserves further investigations in future research.

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Table 1. Sample Statistics (n = 9,570 firm-years)

Variables	Mean	Standard Deviation
R&D Intensity	0.115	0.336
Patent Intensity	0.019	0.097
Patent Stock (Ln)	1.441	1.504
R&D Productivity	0.237	1.194
Total Assets (Ln)	4.001	2.120
Annual Growth of Market Value (Ln)	1.519	3.236
Tobin's *Q*	2.091	3.259
Cash-Flow Ratio	-0.162	1.460
Indicator for Missing R&D Expenses	0.171	0.376
Indicator for Zero Patent Intensity	0.512	0.500

Notes: The figures refer to the sample used for the estimation of the multinomial logit model (Table 3).

Table 2. Merged versus Non-Merged Firms before Matching

	Mean (Standard Error)		t-statistic for difference in means
	Merged Firms	Non-Merged Firms	
R&D Intensity	0.105 (0.005)	0.115 (0.005)	0.48
Patent Intensity	0.014 (0.003)	0.020 (0.001)	0.85
Patent Stock (Ln)	2.327 (0.152)	1.378 (0.029)	-8.00***
R&D Productivity	0.214 (0.067)	0.238 (0.024)	0.27
Total Assets (Ln)	5.344 (0.153)	3.914 (0.031)	-10.89***
Annual Growth of Market Value (Ln)	1.410 (0.081)	1.611 (0.06)	0.52
Tobin's *Q*	2.476	2.037	

	(0.158)	(0.057)	-2.01**
Cash-Flow Ratio	0.019	-0.174	
	(0.016)	(0.023)	-2.10**
Indicator for Missing R&D Expenses	0.100	0.175	
	(0.018)	(0.005)	3.20***
Indicator for Zero Patent Intensity	0.455	0.515	
	(0.030)	(0.007)	1.90*

Notes: Standard errors are given in parentheses. ***, ** and * indicate that the difference in sample means is significantly different from zero at the 1%, 5% and 10% statistical level, respectively.

Table 3. Marginal Effects of the Propensity of Involvement in M&A Activity

	Acquirer	Target	Pooling Merger	No M&A
R&D Intensity	0.34e-02***	-0.62e-05	-0.20e-02	-0.13e-02
	(0.11e-02)	(0.34e-04)	(0.13e-02)	(0.17e-02)
Patent Intensity	0.76e-05***	-0.45e-07	-0.39e-05**	-0.37e-05
	(0.28e-05)	(0.17e-06)	(0.21e-05)	(0.35e-05)
Patent Stock (Ln)	0.34e-05**	0.20e-07	0.35e-05***	-0.70e-05***
	(0.16e-05)	(0.72e-07)	(0.11e-05)	(0.20e-05)
R&D Productivity	-0.79e-05***	0.67e-07	0.15e-05	0.62e-05*
	(0.27e-05)	(0.23e-06)	(0.19e-05)	(0.34e-05)
Total Assets (Ln)	0.26e-02***	-0.54e-05	0.48e-03**	-0.31e-02***
	(0.41e-03)	(0.15e-04)	(0.19e-03)	(0.45e-03)
Annual Growth of Market Value (Ln)	-0.78e-06	-0.64e-08	0.88e-06	-0.89e-07
	(0.17e-05)	(0.28e-07)	(0.10e-05)	(0.20e-05)
Tobin's *Q*	0.36e-05	0.15e-06	0.82e-06	-0.46e-05
	(0.25e-05)	(0.58e-06)	(0.14e-05)	(0.30e-05)
Cash-Flow Ratio	0.17e-04***	0.53e-05	0.34e-05	-0.26e-04*
	(0.76e-05)	(0.14e-04)	(0.27e-05)	(0.16e-04)
Indicator for Missing R&D expenses	-0.44e-02***	0.16e-04	0.37e-03	0.40e-02**
	(0.17e-02)	(0.59e-04)	(0.11e-02)	(0.21e-02)
Indicator for Zero Patent Intensity	-0.17e-02	-0.10e-04	0.12e-02	0.51e-03
	(0.14e-02)	(0.36e-04)	(0.84e-03)	(0.17e-02)
Mean of Dependent Variable (Percentage Points)	0.70	0.00	0.30	99.00
Observations	217	25	122	9,206
Log Likelihood	-1,350.60			
Restricted Log Likelihood	-1,590.54			
Prob > ChiSqd	0.00			

Notes: The marginal effects provide percentage point changes in the probability of an outcome. Marginal effects are computed at means of explanatory variables. Standard errors are given in parentheses. ***, ** and * indicate a significance level of 1%, 5% and 10%, respectively.

1.1 Table 4. Merged versus Non-Merged Firms after Matching

Group		Firm-years	R&D Intensity		Patent Intensity		Patent Stock		R&D Productivity	
			mean	t-statistic	mean	t-statistic	mean	t-statistic	mean	t-statistic
1	Merged	64	0.069		0.001		1.280		0.002	
	Non-merged	1622	0.116	0.51	0.012	0.50	0.877	-1.19	0.077	0.67
2	Merged	60	0.0776		0.015		2.293		0.168	
	Non-merged	1339	0.0862	0.15	0.015	-0.02	2.000	-0.78	0.161	-0.03
3	Merged	48	0.108		0.002		1.355		0.001	
	Non-merged	1109	0.142	0.62	0.010	0.71	0.921	-1.24	0.162	0.59
4	Merged	59	0.12		0.006		1.560		0.010	
	Non-merged	765	0.13	0.23	0.013	1.37	1.045	-1.40	0.170	1.26
5	Merged	60	0.135		0.032		3.528		0.384	
	Non-merged	514	0.114	-1.38	0.014	1.45	2.446	*-5.12*	0.222	1.16

Notes: The number of the observations are smaller than those in the tables 1 and 2 due to the region of common support requirement.

Table 5. Effects of M&A (Average Treatment Effects on the Treated)

	First year *(t+1 to t+2)*	*Second year* *(t+2 to t+3)*	*Third year* *(t+3 to t+4)*
R&D Intensity	0.139*** (0.045)	0.193*** (0.052)	0.228*** (0.039)
Patent Intensity	0.083*** (0.004)	-0.113 (0.152)	-0.051 (0.436)
Patent Stock (Ln)	0.0046*** (0.017)	0.004 (0.024)	0.018 (0.025)
R&D Productivity	0.816 (0.626)	-0.006 (0.589)	0.238 (0.315)
Total Assets (Ln)	0.052** (0.026)	0.041 (0.026)	0.040 (0.028)
Annual Growth of Market Value (Ln)	0.338*** (0.103)	-0.027 (0.197)	0.124 (0.146)
Tobin's *Q*	2.500 (2.920)	2.076 (2.053)	1.694 (1.642)
Cash-Flow Ratio	-0.031 (0.874)	1.002 (3.016)	-1.052 (2.096)

Notes: Reported are means. Standard errors are given in parentheses. ***, ** and * indicate a significance level of 1%, 5% and 10%, respectively.

1.1.1.1.1.1.1.1 Table 6. Rosenbaum Bounds for Effects of M&A

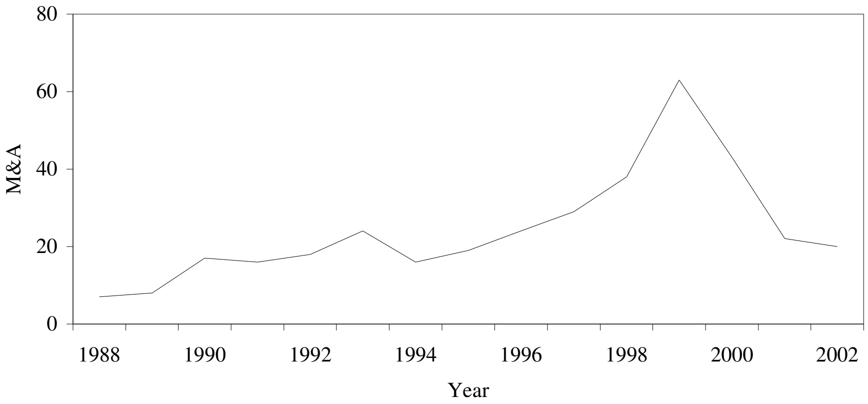
Gamma	R&D intensity		Patent Intensity		Patent Stock	
	[Q^+-MH; Q^--MH]	p-critical	[Q^+-MH; Q^--MH]	p-critical	[Q^+-MH; Q^--MH]	p-critical
1.00	[1.9775; 1.9775]	0.0002	[1.6774; 1.6774]	0.0334	[1.1254; 1.1254]	0.0000
1.20	[1.7896; 2.5660]	0.0113	[1.4226; 2.2627]	0.0843	[1.0452; 1.8044]	0.0003
1.40	[1.5221; 2.9142]	0.0401	[1.2476; 2.5704]	0.2910	[1.5905; 2.0123]	0.0051

1.60	[1.3764; 3.2422]	0.1211	[1.1898; 2.8621]	0.3200	[0.0864; 2.3213]	0.0124
1.80	[1.1644; 3.5521]	0.2523	[1.1342; 3.1394]	0.5171	[0.0657; 2.7868]	0.0594
2.00	[1.0897; 3.8461]	0.2973	[1.0698; 3.4764]	0.5940	[0.0266; 2.9612]	0.0821

Notes: Q^+-MH and Q^--MH are Mantel-Haenszel test statistics under assumptions of overestimated and underestimated treatment effects. Significance levels are under assumption of overestimation of treatment effects.

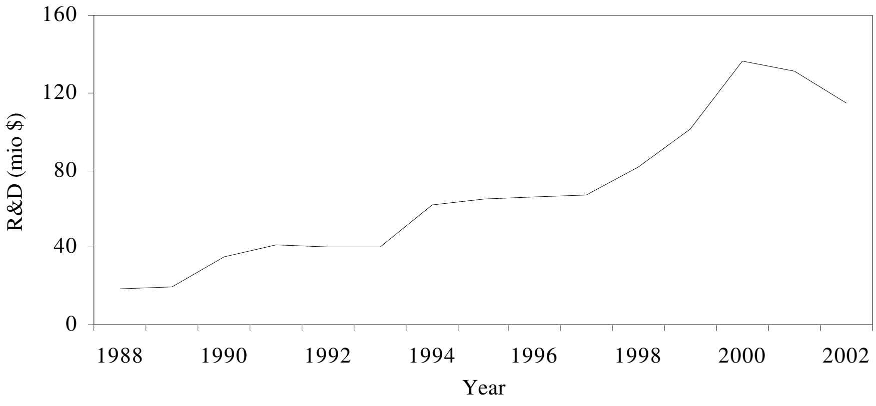
1.1.1.1.2 Annex

Figure 1. M&A in the Telecommunications Equipment Industry, 1988-2002



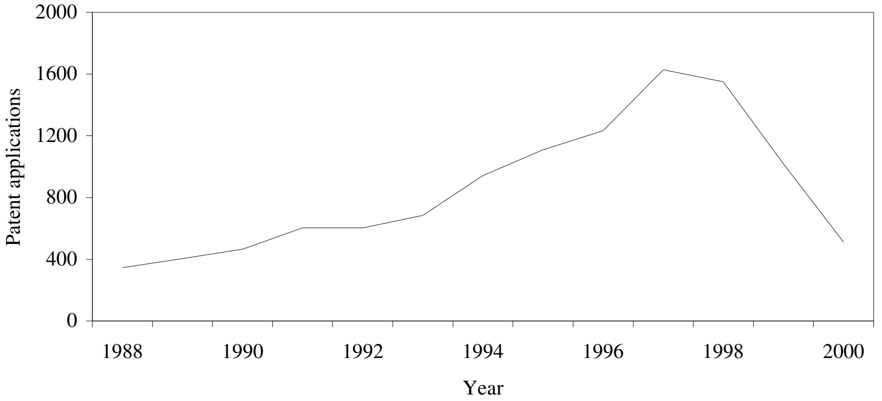
Source: Authors' calculations from Thomson One Banker-Deals

Figure 2. Average R&D expenditures in the Telecommunications Equipment Industry, 1988-2002



Source: Authors' calculations from Compustat and Global Vantage databases

Figure 3. Patenting in the Telecommunications Equipment Industry, 1988-2000



Source: Authors' calculations from NBER Patent Database