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THE IMPACT OF M&A ON THE R&D PROCESS. AN EMPIRICAL ANALYSIS OF THE ROLE OF TECHNOLOGICAL AND MARKET RELATEDNESS

Bruno Cassiman*
Massimo Colombo**
Paola Garrone**
Reinhilde Veugelers***

* Professor of General Management, IESE
** Politecnico di Milano
*** Catholic University of Leuven

IESE Business School - University of Navarra
Av. Pearson, 21 - 08034 Barcelona, Spain. Tel.: +34 93 253 42 00 Fax: +34 93 253 43 43
Camino del Cerro del Águila, 3 (Ctra. de Castilla, km. 5,180) - 28023 Madrid, Spain. Tel.: +34 91 357 08 09 Fax: +34 91 357 29 13

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Abstract

While the impact of M&A on R&D and innovation examined at the aggregate level left inconclusive evidence, we find that at the level of the R&D process both the technological and the market relatedness between the target and the acquirer are helpful dimensions to identify effects. Using information on 31 in-depth cases of individual M&A deals we show that technological relatedness between M&A partners directly affects the inputs and organizational structure of the R&D process. M&A partners that operate in the same technological fields tend to reduce their R&D effort and rationalize the R&D process after the M&A compared to firms active in complementary technological fields that merge. These firms will furthermore face less technological competition in the technology market, but risk creating a more bureaucratic R&D process with a less motivated workforce. Market relatedness between partners, while having comparable aggregate effects on the R&D process, operates on different dimensions of the R&D process. Former rivals that engage in a M&A are significantly less likely to expand into new R&D fields or leverage their technological competences across the products and markets of the new entity. Non-rival firms that join forces, in contrast, significantly increase R&D output and productivity through these activities.

JEL classification: D21, O31, O32

Keywords: M&A, R&D, scale and scope, market relatedness, technological relatedness

THE IMPACT OF M&A ON THE R&D PROCESS. AN EMPIRICAL ANALYSIS OF THE ROLE OF TECHNOLOGICAL AND MARKET RELATEDNESS (1)

Introduction

Firms have been using M&As intensively as instruments for firm growth for many years. Concurrent with the heavy M&A activities, innovation has become increasingly important as a way for companies and nations to achieve and maintain a competitive advantage. With both M&A and innovation a centerpiece of today's competitive strategy development, a debate has arisen among policymakers, academics and the public about the consequences of M&A transactions on the potential for innovation. Unfortunately, most of the existing studies on the effects of M&As are limited to shareholder value or short-run firm performance (e.g. Mueller (1980), Jensen & Ruback (1983)). But even if there are positive short-run effects, this does not necessarily clarify the impact on firms' innovative potential and hence their long-run viability or capacity to create long-run shareholder value.

Despite its importance, the link between M&A and R&D has been less well examined in the literature, at least directly. Views on how firms' technological activities are affected by mergers and acquisitions are often conflicting. For instance, R&D inputs can either increase or decrease. On the one hand, R&D will decrease after M&A due to elimination of duplicated R&D. On the other hand, M&As may lead to scale and/or scope economies in R&D and therefore merged firms may have a bigger incentive to perform R&D than before their M&A. Also, economic thinking has yet to reach consensus on the relationship between market power, concentration and innovation (a.o. Cohen & Levin (1989)).

The empirical literature has tried to test which theoretical hypotheses fit the data best. Here too, however, the results are mixed (a.o. Hall (1999), Hitt et al. (1991),

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Ravenscraft & Scherer (1987)). Only a limited number of empirical studies really focus on the consequences of M&As on companies' technological activities, at least directly. Most of these empirical studies were carried out in the US and tend to find on average negative effects on R&D inputs, although all show a high variance in results and hence fail to find any robust results.

The contribution of this paper is twofold. First, we advance the discussion by arguing that the impact of a M&A on R&D and innovation depends on the relatedness between the target and the acquirer. We contend that both technological relatedness and market relatedness affect –in different ways– the impact of a M&A. The impact of a merger between firms active in the same technological fields is expected to bring about an important rationalization of the R&D process, while firms active in more complementary technological fields are more likely to realize synergies and economies of scope in the R&D process. Relatedness on the output market is another important dimension. M&A activity through the aggregation of markets could lead to economies of scale in output and/or distribution. This will feed back into the innovation process. Similarly, economies of scope in product markets –or product diversification– leads to efficiencies in the R&D process and hence indirectly stimulates R&D. Finally, increasing market power in the output market will have an impact on innovation, although there is no consensus in economic thinking as to whether it will lead to more or less R&D activity.

A second contribution of this paper is empirical. Using a new dataset which was collected by directly interviewing key personnel of high and medium-tech firms that have been involved in M&A, we measure the effects of a M&A at the R&D process level rather than at the firm level as in previous studies. As a consequence, we are able to accurately link a particular M&A deal with associated changes in R&D. Although the sample is rather small (31 deals and 62 companies), the depth of the data is exceptional. In particular, we have collected not only traditional R&D indicators such as R&D expenditures, R&D personnel, patent counts, but also in-depth measures such as change in R&D portfolios and the degree of R&D reorganization. As a result of these in-depth measures, we can study not only to what extent M&As have an impact on R&D but also how, by scrutinizing the dynamic reorganization process of firms that have undergone M&As. The data furthermore allow to construct fine grid indicators for technology & market relatedness, which make it possible to test the impact of relatedness in more depth than in previous studies.

Our results can be summarized as follows. First, when merged entities are technologically complementary, they become more active R&D performers after the M&A. In sharp contrast, when merged entities are technologically substitutive, they significantly decrease their R&D level after the M&A. Second, R&D efficiency increases more markedly when merged entities are technologically complementary than when they are substitutive. These two findings –on R&D level and performance– support the scope economy effect of M&A, on the one hand, and reject the scale economy effect of M&A, on the other. Third, if we focus on the cases in which merged entities are technologically substitutive, the reduction of R&D is more pronounced and the R&D efficiency gain is smaller if merged entities were rivals in the product market prior to their merger than if they were non-rival. This suggests that rival firms reap few technology gains from mergers.

Finally, we also dig into the sources from which changes in R&D activities originate. We find that when merged firms are technologically substitutive, key employees tend to leave more often, the R&D portfolio becomes more focused, the R&D horizon becomes shorter, and internal funds available for R&D decrease.

The paper is organized as follows. Section 2 surveys the existing literature on the impact of M&A on R&D. We draw from both the economics and the technology management literature. Section 3 summarizes the most important effects M&A is thought to have on the R&D process according to the existing literature. In addition, we discuss the consequences of these effects for our measures of R&D input, output, performance and organization. Section 4 describes the data and Section 5 reports the results of our statistical analysis. The section concludes with a discussion of how relatedness between partners in the M&A conditions these discussed effects. Conclusions are presented in Section 6.

2. Literature Overview

Despite its importance, the link between M&A and R&D has not been well examined, at least directly. The scarcity of "know-how" on this issue contrasts with the extensive theoretical literature that exists on motives for M&A and most empirical studies of M&A which focus on the link with shareholder value and economic performance. In section 2.1 we will review the mainstream theoretical and empirical M&A literature, using their main findings as a prelude to get a fuller understanding on the innovation-related issues, tackled in the following sections.

2.1 Theories & evidence on why M&A occur

The frequency with which M&A activities are observed suggests that there are strong reasons why it makes sense for two (or more) firms to consolidate into one, or for one firm to purchase another. Typical motives identified in the theoretical *Industrial Organisatio*n literature are the desire to achieve or strengthen market power and the search for efficiency gains by exploiting economies of scale & scope (e.g. Caves (1989), Röller et al. (2001)). The *financial economics* (market for corporate control) literature suggests that M&As are used to correct for internal inefficiencies, agency problems and capital market imperfections (e.g. Manne (1965), Jensen & Ruback(1983)).

Nevertheless, despite the many advantages M&As could offer, the statistical evidence supporting the hypothesis that profitability and efficiency increase following M&A is at best weak, while there is considerable variation from the central tendencies. (see e.g. Mueller (1980), Ravenscraft & Scherer (1987), Lichtenberg (1992), Jensen & Ruback (1983), Berkovitch & Narayanan (1993)). The problem with most existing studies is, as Caves (1989) argues, that they disregard the issue of how value is created through acquisition and hence fail to identify the conditions that should hold to create value through M&As.

2.2. M&A and R&D

In sharp contrast with the extensive literature that exists on the impact of M&As on the financial and economic performance of companies, only a limited number of studies really focus directly on the consequences of M&As on companies' technological activities. Furthermore, only empirical studies exist, while the theoretical literature remains silent on this issue. Nevertheless, the theoretical literature on M&A indirectly provides several predictions about the relationship between M&A and R&D.

The *financial economics* literature indicates that the increased financial leverage from M&A activities affects the financing of R&D activities by increasing the opportunity cost of funds allocated to R&D, leading to elimination of R&D projects and/or a higher risk-aversion in R&D project selection. Similarly, managerial time and effort spent on managing M&As ex post may imply reduced attention to R&D projects. A crisis mentality in the management of the acquisition can lead to only residual energies being devoted to day-to-day operations even in the technological core of the company (Hitt et al., 1996).

Positive effects of M&A on R&D are predicted by the *Industrial Organisation* literature. If there exist scale and scope advantages in R&D, ex post R&D efficiency will be higher after the merger (Cohen & Levin (1989), Röller et al. (2001)). In addition, M&As may eliminate R&D competition. The possibility of coordinating R&D investment levels will typically lead to lower R&D investment levels. Nevertheless, a technology regime characterized by low appropriability because of the presence of involuntary technology spillovers may change this impact on R&D investment levels and hence the incentives to coordinate. A robust finding in the Industrial Organisation literature is that if technology spillovers are high enough, higher levels of coordination –making it possible to internalize these spillovers– will lead to higher R&D investments. But w hen technology spillovers are not important, the usual negative effect on R&D investments arises (Kamien & Schwartz, 1992; De Bondt, 1997).

Like the theoretical literature, empirical studies linking M&A and R&D are not abundant. The empirical studies in the corporate control tradition provide statistical analysis on large samples. Most studies rely on publicly available information sources for M&A activities, R&D investment levels, and patents at the industry or firm level, mostly for the US (Hall (1990) (1999), Ravenscraft & Scherer (1987), Hitt et al. (1991) (1996)), Blonigen & Taylor (2000)). They have generally found that acquisitions have a negative impact on the post-acquisition R&D input and output of acquiring firms. There is also consistent evidence for the negative implications of debt levels induced by M&A activities on the level and nature of R&D activities. But the evidence is rather weak and seldom strong enough to allow robust conclusions (2).

Economies of scale and scope in R&D are important in determining whether the larger scale induced by the M&A will lead to more or less R&D. Unfortunately, the empirical results assessing whether economies of scale and scope in R&D exist are most accurately described as fragile. Most studies in the Industrial Organisation tradition (see Cohen & Levin (1989) for a review) tend to find insignificant or small positive effects of size and diversification on R&D (intensity). In large, diversified firms, there is more technical personnel (Gort, 1962), and R&D productivity –measured by patents– is high (Grabowski, 1968; Teece, 1980 and Jovanovic, 1993).

There is a wide body of literature in Industrial Organisation that tries to empirically assess the extent to which market size and market power, both possibly achieved through M&As, indirectly affect R&D. But again the empirical evidence on the effect of *market power* and concentration in the output market on R&D intensity is weak and depends upon other industry-level variables capturing technological opportunity and appropriation conditions (see Cohen & Levin, 1989).

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(2) The empirical finance literature provides some results on the relationship between M&A and investments in general. To the extent that R&D can be seen as a particular case of investments, the results from these studies can be extrapolated to R&D. They all confirm the negative impact of M&As (Kaplan (1989), Bhagat, Schleifer & Vishny (1990).

2.3. M&A and the R&D process

Without zeroing in on the process through which a larger scale and scope may result in increased R&D efficiency, empirical research is bound to lead to inconclusive results. The *Technology Management* literature tries to dig deeper into the processes governing the impact of M&As on innovative output. Most emphasis is on the process of realising technological synergies through M&A.

Seth (1990) a.o. stresses the importance of understanding how synergies are realised. A first prerequisite is a pre-acquisition strategy, with a careful due diligence to assess ex ante the target's capabilities and their fit with the acquirer's (a.o. Chaudhuri & Tabrizi, 1999). A full symbiosis with two-way resource sharing and/or new resource creation does not always follow every M&A deal. It requires integrating business cultures, which depends upon post-acquisition integration strategies. Capron (1999) identifies resource redeployment as a main source of value creation in M&As, with an impact on efficiency and capability enhancement. If the post-integration process is badly managed, an acquisition can imply a potential disruption in the established routines of the merging firm and in its newly acquired component, and thereby even reduce R&D productivity. Key innovators and ideas may leave the company. This will seriously harm the ex post innovative capacity of the merged entity. This occurs a fortiori when the M&A results in subsequent divestiture (Jemison and Sitkin, 1986; Haspeslagh and Jemison, 1991). In addition to driving away key people, (the threat of) "post-restructuring" sell-offs are likely to have a negative effect on internal innovation, since they lead to a more conservative short-run view. The crucial role of this "people issue" is increasingly being recognised in the post acquisition management literature (Ernst & Vitt, 2000).

Empirical studies in this tradition are often based on small sample survey results (Capron (1999), Capron et al. (1998), Ahuja & Katila (2001), Chakrabarti et al. (1994), Grandstand & Sjölander (1990), Bresman et al. (1999), Ernst & Vitt (2000)). This literature predicts a more favorable impact of M&As on R&D, at least when: 1) firms are involved in M&As for technology sourcing purposes; 2) the M&A integration process is effectively managed; 3) firms are able to retain key people, and; 4) firms have a strong own internal know-how base, which allows to better evaluate potential targets and to realize synergies from combining know-how from the target and acquiring firm.

2.4. M&A, the R&D process and relatedness

An important factor driving the potential synergies that can be realised within the M&A is whether or not the merging entities "strategically fit". This is determined by their "relatedness". The Strategic Management field has explored this issue of relatedness and value creation in more depth (a.o. Rumelt (1974), Seth (1990)). Relatedness may have several dimensions. Businesses are related if they (a) serve similar markets and use similar distribution channels, (b) employ similar production technologies, or (c) exploit similar science-based research (Rumelt (1974)).

Similarity in research base facilitates the integration of the acquired and acquiring knowledge base from both technical and organisational perspectives (Kogut & Zander, 1992; Grant, 1996). Common skills, shared languages and similar cognitive structures enable technical communication and learning. When the knowledge bases are unrelated, assimilation or application of the new knowledge is likely to be difficult and resource consuming, if not counter-productive (Haspeslagh & Jemison, 1991). Although firms with larger knowledge bases stand to gain more from combining know-how through M&A, they are also more likely to witness fairly major changes in existing routines, when own and acquired knowledge is dissimilar (Ahuja & Katila, 2001).

Besides the knowledge relatedness, there is also the market relatedness, examined more often in the economics literature. Chatterjee (1986) tries to allocate the market relatedness of partners to a particular type of synergy. While *conglomerate mergers* create the potential for financial synergies, *related M&A* hold the additional potential for operational synergies. These are the classical economies of scale and scope discussed above. On top of these synergies, *horizontal M&A* have the advantage of collusive synergies, capitalising on gains in market power.

A number of empirical studies have tried to test the impact of relatedness. This became one of the hottest issues in the finance literature in conjunction with the so-called "diversification discount". That related M&A would create more value does not, however, show up as a stylised fact (Rajan, Servaes & Zingales (1998), Bodnor et al. (1997), Chevalier (2000)). A problem in these aggregate studies is the construction of an operational measure for relatedness. Using industry codes as a measure for market relatedness, Chevalier (2000), for instance, finds that the event responses are largely independent of measures of the extent to which the merger is related. She also finds that the market reacts positively to announcements of diversifying acquisitions. Market relatedness in itself does not seem to necessarily and automatically translate into efficiency gains. Hence the task is still to better understand the process of value creation through M&As.

When focusing on technology relatedness, the evidence is more favorable. Ahuja & Katila (2001), using a sample of 32 technology-motivated acquisitions in the chemicals industry, identify as an important success factor leading to higher innovative performance the relatedness of the knowledge base of acquirer and target, as measured by the number of common patents. However, there is significant evidence for non-linearity, where both too close and too distant a relationship need to be avoided, the former for lack of complementarity and the latter because of integration problems. In addition, they identify as success factor a higher absolute (but not relative) size of the acquirer's knowledge base.

Chakrabarti et al. (1994) investigate the R&D process as well as the technical and economic results of technology-driven M&As in 30 dyad interview cases. A first important finding is again the large variation in performance. Factors that seem to be important to explain technological failure are technological uncertainty, cultural differences, size asymmetries between target and acquirer, and production technology differences. Ernst & Vitt (2000), in a sample of 43 acquiring EU firms, trace the inventive performance of 61 key inventors, i.e. individuals with high patent activity and high quality patents. The greater the cultural differences between R&D departments and the technological distance, the more likely it was that the inventors who stayed would have reduced inventive performance. None of these studies, however, combine technology and market relatedness.

In summary, most empirical studies in the *corporate control* tradition have found that acquisitions have a negative impact on the post-acquisition R&D input and output of acquiring firms. Unfortunately, another consistent finding in these studies is the lack of strongly significant effects. This is not surprising, given the absence of an in-depth analysis of the conditions governing the relationship. The *technology management* literature tries to dig deeper in these processes governing the impact of M&As on innovative output. The evidence from these mostly small-scale survey studies is more favourable with respect to the impact of M&A on innovative performance. This is true at least for technology-motivated

M&As, when firms have a strong own internal know-how base, where partners are complementary, but not too dissimilar, in their (technological) know-how, and when the M&A integration process is effectively managed with a high retention of key people.

3. M&A and the R&D process: effects, consequences and relatedness

3.1. Research design

The major conclusion from the existing studies is that any results on the relation between M&A and the innovation process are weak and/or difficult to generalise. First, most data used to analyse these effects are standardized large sample data such as R&D expenditures, patent counts, and productivity. These data may reveal to what extent mergers and acquisitions have an impact on innovation but they do not tell us how. The importance of zeroing in on the acquisition management process implies, however, that "depth" is a necessary dimension in empirical studies, requiring information that is typically beyond publicly available data sources. The case study design employed for collecting our data allows us to uncover *how* M&A impacts innovation by interviewing key people and scrutinizing the dynamic reorganization process of the firms that undergo mergers and acquisitions. Second, most data previously used are aggregated at the firm level and are too noisy to analyse the impact of a single M&A deal on innovation because a firm often engages in more than one acquisition (sometimes more than ten per year). We performed our case study analysis at the deal-level, which is finer than most firm-level data previously used. Third, the *depth* of the analysis is substantially increased compared to the existing literature because we analyse the impact not only at the firm level but also at the business unit level. Also the *breadth* of this study is unprecedented because we explore different effects of M&A on R&D and innovation simultaneously, as opposed to the existing literature.

In summary, the information gathered through the case studies helps to find evidence corroborating or refuting existing hypotheses about the relation between M&A and innovative inputs, outputs and performance by uncovering how they are linked at a *more accurate* level (Yin, 1994). The price we pay for this depth and breadth of the study is a smaller sample size. We had to limit ourselves to studying 31 mergers or acquisitions, which has implications for our analysis, as discussed below.

The main hypothesis developed in this paper is that the *relatedness* between partners will condition the effect that a merger or acquisition has on the R&D process. Failing to control for this important segmenting variable may lead to weak or inconclusive results, as is mostly the case in existing empirical studies on the effect of M&A on innovation. From the literature review we extract six potential processes through which M&A will have an impact on the R&D process. Although hypotheses exist about the consequences of M&A for R&D inputs, R&D outputs, R&D performance, R&D organization and R&D mission at the level of each of these processes, separating these consequences for each process empirically is difficult. Typically, the joint effect will be measured. However, by segmenting the M&As according to relatedness between partners, we are able to characterize some effects unambiguously. Because we identify various measures of R&D inputs, R&D outputs, R&D performance, the organisation and management of R&D, and R&D mission, the data allow us to test our hypothesis on the relation between relatedness of the target and acquirer and the consequences of the M&A for the R&D process in more depth and breadth than the existing literature. We expect that the impact of different types of relatedness will manifest itself in different effects. First, there exists a *direct effect* of M&A on the R&D process whenever the

R&D processes of the partners are related. We capture this relatedness of the R&D processes by defining the technology relatedness of the partners. Second, there potentially exists an *indirect* effect of the M&A on the R&D process. Most M&As are not driven by innovation-related motives, but will nevertheless indirectly impact the R&D process through the reorganizations that take place in the output markets and production processes. The *market* relatedness of the partners in the M&A is intended to capture this indirect effect that works through the output market and production process and reinforces the different direct effects on the R&D process.

We start out by describing the six potential processes and their consequences on R&D (section 3.2). After that we discuss how the relatedness between M&A partners triggers a specific combination of processes (section 3.3).

3.2. M&A and the R&D process: effects and consequences

a) Indivisibilities/Specialization, i.e. spreading fixed costs of R&D over more R&D output

A first important factor derived from the economics literature is the existence of economies of scale in R&D. Economies of scale due to specialization are realized through both the spreading of fixed costs over more output and the elimination of common inputs for the production of the same output. In order to disentangle the consequences of M&A on the R&D process, it is helpful to distinguish between these two effects. While elimination of common inputs is discussed below, the possibility of spreading fixed costs over more output increases the incentive to invest in R&D. One should expect an expansion of R&D activities due to the economies of scale in this activity. M&As where this effect is important are therefore unlikely to cut R&D in the form of personnel, labs and equipment, or to terminate R&D programs; rather, they may be expected to increase the scale of typical R&D projects. Furthermore, the new entity will attempt to reorganize the R&D process by centralizing knowledge, reorganizing R&D teams and specializing in R&D tasks, while setting up parallel projects. These changes should lead to higher R&D output, measured through the speed at which knowledge is developed and new products and processes are introduced, and to higher R&D performance, including more productive R&D personnel and R&D management. M&As based on economies of scale in R&D will tend to focus the organization on specific technological fields.

b) Indivisibilities/Specialization: spreading fixed costs of R&D over different types of R&D output

A second important factor derived from the economics literature is the existence of economies of scope in R&D. Economies of scope arise whenever the total cost of producing two goods jointly is lower than producing the two goods separately. Combining different R&D programs within the same organization can create economies of scope in R&D, leveraging R&D investments across different R&D projects. A similar logic as in the case of economies of scale is applicable. Again, the new organization is unlikely to cut R&D in the form of personnel, labs and equipment, or to terminate R&D programs; rather, it may be expected to increase the scale of typical R&D projects to achieve critical mass. Furthermore, the new entity will attempt to reorganize the R&D process by redeploying resources such as technical personnel and equipment, and by creating joint research teams. These changes should lead to higher R&D output, as measured by the speed at which knowledge is developed, especially new technological competencies. R&D performance may also be expected to increase. M&As based on economies of scope in R&D will tend to broaden the mission of the firm's R&D process.

c) Elimination of common R&D inputs

Economies of scale & scope are realized not only through the spreading of fixed costs over more, and more diverse, outputs, but also through the elimination of common inputs. An obvious effect of M&A activity on the R&D/innovation process is the elimination of duplicate R&D inputs: firing of personnel, closure of R&D labs, termination of R&D programs. Restructuring the R&D organization, by reorganizing R&D teams and replacing R&D management and by making cutbacks, should positively affect R&D performance. Frequently, the cost-cutting restructuring is associated with a shortening of the time horizon and drives the R&D process more towards development as opposed to research.

d) Synergies, i.e. combining different R&D/knowledge inputs (3)

M&As combine different R&D inputs and potentially realize new outputs or achieve efficiencies that could not be achieved previously or only at prohibitive costs. Combining resources and capabilities of the acquirer and the target might create knowledge and capabilities that did not exist before. This is discussed in the economics literature, but more in depth in the technology management literature. After the M&A, projects that were not feasible before become feasible thanks to the transfer and fusion of existing knowledge and technology, which reduces the cost of operation across R&D projects and increases the incentive to invest in R&D. M&A would, therefore, affect the R&D organization through the transfer of knowledge, the (re)organization of joint teams, specialization of R&D tasks and the sharing of R&D resources. These activities allow the new entity to attain critical mass in a broader portfolio of technologies and results in increased R&D output and improved R&D performance. The M&A will typically also broaden the scope of R&D that is performed.

e) Technology Market Power and Appropriation

M&As can increase market power both in the output market and in the technology market. This latter effect has recently received more scrutiny from antitrust authorities as M&As can clearly affect competition in technology. However, whether the merged entity is able to secure more technology market power will depend on whether the M&A creates barriers to entry in technology, or whether the threat of potential future technological entry remains intact. Furthermore, the effects of increased market power on the inputs, the outputs and the performance of the R&D process are ambiguous, as indicated in Section 2. The increase in market power might lead to less innovation, on the one hand, and longer-term R&D projects and more basic research, on the other. Nevertheless, we expect the effect on the returns to the R&D process to be positive. Firms attempting to take advantage of technology market power will organize R&D by centralizing knowledge and focusing on specific technological fields by terminating concurrent R&D programs.

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(3) Note that this is not equivalent to economies of scope. Economies of scope are measured across different outputs, while here we consider the input level.

f) Bureaucracy and Internal R&D Organization

M&As affect the internal organization and bureaucracy of a company's R&D management. This may clearly also influence companies' innovative behaviour through its effect on the organization of R&D. The effect of M&A on the organization of R&D is an aspect of the R&D process that has tended to receive little attention in the economics literature, but more in the technology management literature. We expect this effect to be significant whenever the objective of the M&A is not directly innovation-related. In these cases, the primary effect of the M&A will be related to the output market and the production process, while there will be a significant (negative) indirect effect of the M&A on the R&D process. Instead of economies in R&D, diseconomies may surface. This effect should be contrasted with the effects related to economies of scale and scope. The effect on the R&D process will be to reduce R&D inputs, outputs and performance. The lack of skills in order to learn from the target, high internal resistance to the M&A and slower decision making could further damage the M&A's innovation potential. In addition, agency problems resulting from the M&A will affect the motivation of researchers at the new entity, in turn affecting R&D inputs and performance. The loss of key researchers and the lack of motivation of researchers would indicate motivational problems after the merger. Typically, there will be pressures to shorten the time horizon of research projects and focus on development rather than on more basic research, with severe cutbacks in the launch of new projects.

3.3. M&A and the R&D process: effects, consequences and relatedness

We can now examine how the relatedness between M&A partners will trigger a specific combination of forces. We discuss both technology and market relatedness. Within the technology relatedness between acquirer and target we make a distinction between firms active *in the same technology fields* (STF) and firms active in complementary technology fields (CTF). If the target and acquirer are active in the same technological fields (STF) we expect economies of scale –in particular the elimination of common inputs and the acquisition of market power in the technology market– to be the dominant forces, while some diseconomies in the R&D process might surface as the organization grows larger. If the target and the acquirer are active in *complementary technological fields* (CTF), economies of scope together with the generation of synergies should dominate the effects on R&D inputs, R&D outputs and performance, while the elimination of common R&D inputs is likely to be observed insofar as there is duplication. Comparing M&As between same technology (STF) firms with M&As between complementary technology (CTF) firms, we would expect the STFs to dominate in reducing R&D inputs and in R&D rationalization. The CTFs, in contrast, should be more active in resource redeployment to achieve critical mass in different technological fields and better exploit technological competencies while accessing new R&D fields. Furthermore, M&As between STFs are more likely to be affected by bureaucratic and internal organizational problems, leading to problems in the R&D organization, such as less motivated R&D personnel and reduced R&D performance. Finally, an M&A between STFs will be more likely lead to a focusing of the R&D mission, with a shortening of the time horizon and an emphasis on development as opposed to research.

The above hypotheses relate to the direct effects of M&A on the R&D process. However, many M&A will also have indirect effects on the R&D process. We hypothesise that the *market relatedness* of firms indirectly affects the R&D process. Because of overlapping product lines and, hence, overlapping R&D processes, M&As between market related targets and acquirers –rivals before the M&A– are likely to benefit from significant economies of scale, through specialization and through elimination of duplication. The latter effect, in particular, should dominate whenever the motivation for the M&A is not innovation-related. As the effects on the R&D process are not central to the M&A decision, bureaucratic effects are more likely to surface. Both of these effects lead to a negative effect on R&D inputs and are likely to reduce R&D output, as R&D is not the main motivation for the M&A. In particular, it is unlikely that new R&D initiatives will be launched after this M&A. Whenever the M&A creates market power in the output market, which is more likely in the event of an M&A between firms in the same output market, we expect returns to R&D to improve. While the effect of market power on R&D inputs and outputs has been hotly debated since Schumpeter, R&D performance should improve. This might weaken the hypothesised negative effect on R&D performance due to the former effects on the creation of more bureaucracy for the R&D process.

Table 1 summarizes the different potential effects on the R&D process and our hypotheses about the interaction between the relatedness between target and acquirer, and the consequences of these effects: the effects on R&D inputs, R&D outputs, R&D performance, R&D organization, and R&D mission. A quick glance at the table immediately reveals why the previous literature has found mixed results of M&A on these different measures: the total effect of a M&A on R&D inputs, R&D outputs and R&D performance can increase or decrease depending on the forces that dominate the M&A. After classifying the M&As according to their technological and market relatedness, the effect of a M&A on the R&D process becomes more clear-cut. For CTF firms, M&As are predicted to lead to more R&D inputs, R&D output and a higher R&D performance. Relative to CTF firms, STF firms are more likely to cut R&D inputs. A positive effect on R&D output and performance is more likely in both cases. M&As between firms in the same market, however, are more likely to have a negative effect on R&D input and output compared to firms that are less related through the output market.

Table 1: Predicted Effects of M&A on the R&D process by Input-Relatedness

	R&D input	R&D output	R&D performance	R&D Organization	R&D Mission	Conditioning Factors: Firms Active in Same Technological Field (STF)	Conditioning Factors: Firms Active in Complementary Technology Fields (CTF)	Conditioning Factors: Firms Active in Same Markets
Effect 1: Indivisibilities/Specialization, i.e. spreading fixed costs of R&D over more R&D output	+	+	+	Centralizing knowledge, re-organizing R&D teams, specialization, parallel projects	Focus on specific technological fields	•		• (second order)
Effect 2: Indivisibilities/Specialization: spreading fixed costs of R&D over more and different types of R&D output	+		+	Resource redeployment, joint research teams	Broadening of scope of R&D		•	• (second order)
Effect 3: Elimination of common R&D inputs	–		+	Restructuring, i.e. reorganizing R&D teams, replacing top management of R&D	Shortening of time horizon, more development than research	•		•
Effect 4: Synergies: Combining different R&D/knowledge inputs	+	+	+	Knowledge transfers, joint research teams, mutual specialization of R&D tasks, reorganizing R&D teams, resource redeployment	Broadening of scope of R&D		•	
Effect 5: Technology Market Power and Appropriation			+	Centralizing knowledge	Focus on specific technological fields	•		• (second order)
Effect 6: Bureaucracy and Internal Organization	–	–	–	Reorganization of R&D teams, replacing top management of R&D	Shortening of time horizon, more development than research	• (second order)		•
						R&D input/ R&D output/ R&D performance	R&D input/ R&D output/ R&D performance	R&D input/ R&D output/ R&D performance
TOTAL EFFECT	?	?	?			? / + / +	+ / + / +	– / – / ?

4. Description of the Data

Our sample includes 31 merger or acquisition deals in medium- and high-tech industries concluded in the last 15 years, with 62 firms involved. This sample cannot be regarded as representative of the M&A population because the sample is not random. Interviewees chose the acquisition for which they would respond in the questionnaire. One would expect managers to select deals that they considered a success (4). Furthermore, the size of the sample is limited. However, due to our limited sample of M&As we are only able to do some univariate analysis and look at differences in means (5). Despite this, we do think that a statistical analysis of data from case studies, when properly designed, can shed new light on the issues at hand. In this sense, our work extends the available knowledge on M&As.

The case studies were based on a structured questionnaire that allowed to collect qualitative data in a standardised format suitable for statistical analysis. In the questionnaire we organised the information that needed to be gathered for each of the cases at two levels: the new post-M&A entity and the acquisition deal. In particular, we were able to compare the situation of each of the merging firms before and after the deal. The qualitative data were collected through interviews with at least one qualified contact person in each acquiring company. Typically this person was the vice-president for R&D or Strategy (or equivalent level). Before engaging in all of the case studies, we organized a number of "pilot" cases in order to further refine our questionnaire.

Table 2: Sample distribution

Dimensions	Types	No. of Observations	Frequency
Sector	Same business	25	80.6%
	Same product lines	11	35.5%
	Different product lines	14	45.2%
	Different business	6	19.4%
Market relatedness	Direct competitors	10	32.3%
Technology relatedness	Same technological fields[a]	17	54.8%
	Complementary technological fields[b]	14	45.2%
Nationality	Cross-border	22	71.0%
	Total sample	**31**	**100.0%**

Legend

[a] In 7 out of the 17 M&As classified in the "Same technological fields" category, merging firms also were in complementary technological fields before the deal.

[b] M&As are assigned to the "Complementary technological fields" category if before the deal: i) merging firms were in complementary technological fields; and ii) they were not in the same technological fields (i.e. they did not have overlapping technological capabilities)

(4) This bias is favourable for our analysis, as we examine the impact of M&A on the R&D process. Therefore, we would like to restrict attention to the impact of successful M&A. We are looking for characteristics of the deals that allow us to segment the effects on the R&D process.

(5) See our full report to the European Commission for many other interesting results such as the impact of the debt level, prior relationships, etc. Given our limited number of observations, a multivariate analysis is unfortunately not possible.

Table 2 summarises some characteristics of the sample and Table A.1 in the Appendix provides an overview of the different cases and their classification. First of all, note that all sample M&As are "horizontal": that is, before the deal, merging firms operated in the same sector (at the two digit NACE-CLIO classification). Therefore, the sample does not include vertical and conglomerate mergers. Nonetheless, horizontal deals comprise different M&A types: the two companies may operate in the same sector but in different businesses, or in the same sector and businesses but in different product lines. Properly speaking, horizontal deals are M&As between companies operating in the same product lines, to be defined at a finer level than the usual NACE-CLIO 2-digit classes; accordingly, while we follow the established convention by referring to deals in the same industry as "horizontal", we show how the sample distributes across types that have been more finely defined. Companies operating in the same business turn out to account for 25 out of the 31 deals (80.6%), with more than half of them specialised in different product lines (14 out of 25 deals). Initiatives taken by firms coming from different businesses make up the residual share (19.4%).

In this paper we focus on market and *technology* relatedness. Rather than having these dimensions determined exogenously by the researchers on the basis of aggregate production and patent classification schemes, we directly asked the respondents to assess the market and technology relatedness of the partners involved. This allows a more refined assessment of the relatedness dimension. As for market relatedness, M&As between direct competitors constitute almost the entire class of deals between companies who have the same product mix (10 out of 11). However, the majority of observed pairs of firms were not rivals before the merger (21 out of 31 deals), either because their businesses were different, or because they served different customers and geographical markets. In 9 out of the 10 cases direct competitors were active in the same technological fields.

As for technological relatedness, companies which had distinctive capabilities in the same technology fields as the partner account for a 54.8% share (17 out of 31 deals), while complementary technological strengths emerge in 21 out of 31 deals, that is, 67.7% of the total number of initiatives. In order to avoid double counting in the empirical analysis, 7 pairs of merging companies that had both similar and complementary technological capabilities were assigned to the "Same technological fields" (STF) category. Therefore, the "Complementary technological fields" (CTF) category comprises firms that a) had strengths in complementary technological fields, and b) had no overlapping technological strengths (6). Note also that 9 pairs of merging firms that were classified in the "STF" category were rivals before the deal, while the same holds true for only one pair of "CTF" firms. Table 3 classifies the cases according to the relatedness between partners.

In the questionnaire there was a section especially devoted to M&A motives (7). In general, a distinction can be made between *technology-related* motives and *market-related* ones. The former category includes motives such as scale and scope economies in R&D, R&D risk spreading, access to technological resources, and reduction of spillovers and of competition in technology markets. The latter category comprises traditional motivations of

(6) Actually, we checked the sensitivity of our results to the assignment of the 7 cases that had both overlapping and complementary technological capabilities. In particular, their deletion does not significantly alter the empirical findings that will be illustrated in Section 5.

(7) In principle, motives represent expectations and preliminary evaluations formulated by the parties before the completion of a deal. Note however that there is a possible shortcoming in the approach adopted in this work. In fact, firms' managers were interviewed after completion of the deal, even though they were asked to report about firm's motivations before the deal. Of course, such time lag may have influenced answers to the questionnaire. The effects and their consequences we discussed in the previous section attempt to measure the actual ex post realizations.

M&As such as increase of market share, rationalisation, or entry into new businesses and geographic markets. More precisely, technology-related motives are captured by 9 different items, while technology-unrelated ones add up to 10 items (8). Each item was assessed by the interviewees on a five-point Likert scale (from 0, "not important at all", to 4 "very important"). Accordingly, we define a deal as "technology-motivated" if one or more of the technology-related items were assigned a score equal to or greater than 3. Due to poor sample stratification, the empirical distribution of motives is not to be assumed as representative of the universe of M&As. With this caveat in mind, it is noteworthy that interviewees described the set of non technology-related motives as prevailing in the merger decision. In fact, in 15 cases out of 31 (i.e. 48% of sample cases), technology-related motives were reported to have been of negligible importance. In other words, technology-unrelated motives seem to be the main drivers of M&As even in medium- to high-tech industries. This is already suggestive of the importance of what we have labelled as the indirect effets of M&A on R&D running through product market effects.

5. Empirical Results on the impact of technology & market relatedness

This section discusses the empirical results relating to the effects of M&As on the R&D process. In particular, we are interested in assessing the role played by technology and market relatedness of the combining firms. We proceed in two steps in order to convince the reader both of the relevance of these dimensions and of the need to analyze the effect of the M&A at the R&D process level directly.

First, we will consider a limited selection of traditional indicators. They capture changes in R&D inputs (i.e. R&D personnel and lab equipment) and performance (i.e. returns to R&D expenditures) that were experienced by merging firms after the deal and that according to the interviewed managers, were directly attributable to the completion of the deal. Answers in the questionnaire concerning such aspects were codified as ordered categorical variables and so can be used in statistical analyses. Use of such traditional indicators makes it easier to compare our results with those of previous studies.

Second, as was mentioned earlier, the questionnaire comprises a large number of specific questions relating to changes in R&D inputs, outputs, productivity, organisation, and mission that were engendered by the specific deal under consideration. We will rely on such information to build a series of (quantitative) synthetic indicators through principal component analyses of five independent groups of individual answers concerning each of the above mentioned aspects. As we will show, these indicators are much more informative and comprehensive than those that have been used so far to study the impact of M&As on R&D.

(8) The following technology related motives were considered: R&D risk spreading, economies of scale in R&D, economies of scope in R&D, restructuring of R&D, access to target's technological resources, access to technological resources embedded in the target's environment, get competing technologies under control, reduce the risk of being imitated, and set a common standard. Technology unrelated motives were classified as follows: rationalisation of production, spread fixed costs of production over larger output, rationalisation of marketing and sales, access to specialised assets and capabilities in production, access to specialised assets and capabilities in commercial activities, access to non technological resources embedded in target's environment, increase market share, broaden product mix, entry into a new geographic market, and entry into a new business.

Table 3: Classification of M&A Deals (number of cases)

	Rivals	Non-Rivals	
Same Technological Fields (STF)	9	8	17
Complementary Technological Fields (CTF)	1	13	14
	10	21	31

Then, we will relate the values taken by both types of indicators to the technology and market relatedness of merging firms. Table 3 classifies M&A deals according to both market and technology relatedness. A full split into 4 types is not possible. Not surprisingly we have only 1 case of firms that are rivals and in a CTF. To distinguish the effects of technology relatedness from market relatedness as much as possible, we compare the rival (R) and non rival (NR) firms within the STF category. This allows to discuss the impact of market relatedness, controlling for technology relatedness (i.c. STF). To discuss the effect of technology relatedness for a given market relatedness (i.c. NR), we compare the "STF" and "CTF" categories for Non-Rival firms.

As a final remark, we are aware that the empirical results that will be presented below suffer from the limited size of our sample and sample selection, as previously illustrated. Nonetheless, we believe that these results are interesting in their own right; in fact, they considerably extend our understanding of the relationships between M&As and R&D by pointing out the conditioning role played by technology and market relatedness. More importantly, they suggest guidelines with respect to data collection for further analyses based on larger, more representative samples.

5.1. R&D inputs and performance

We will first analyse the information directly provided by the case study questionnaires on the effects of M&As on the R&D efforts and the returns to R&D expenditures of the merging firms. For this purpose, we consider answers to individual questions that will not be used in the subsequent principal component analyses.

Interviewees described changes in the amount of physical R&D facilities and in the number of R&D personnel that occurred in both merging companies as a consequence of completion of the deal on a scale ranging from "100% decrease" to "increase greater than 100%". Furthermore, interviewees described changes in the returns to R&D expenses as ranging from "substantial decrease" to "substantial increase". Answers were codified through three discrete variables, ordered along, respectively, ten- and nine-point Likert scales. For each variable, we computed the mean value in the pertinent M&A categories and assessed differences across M&A categories through t-tests. The results are illustrated in Tables 4 and 5.

First of all, Table 4, focusing on non-rival firms only, shows that technology relatedness matters. In fact, the impact of a deal upon merging firms' R&D effort differs considerably depending on the merging firms' technological characteristics. If firms were in the same technological fields (STF) before the deal, changes in R&D effort were considerably more negative and less positive, respectively, than if firms were in complementary technological fields (CTF). In the former category, changes relating to both R&D facilities turned out to be negative, while they were positive in the latter category. The difference between the two categories is statistically significant at conventional levels. In addition, the mean value of the "Changes in R&D performance" variable is smaller in the "STF" category than in the "CTF" one, but, in line with most existing studies, these results are not significant.

Table 4: The effects of M&As on R&D inputs and performance in non rival firms: the role of input relatedness

	Non rival firms		
Variables	**Same technological fields[a]**	**Complementary technological fields[a]**	**Confidence level[b]**
Changes of physical R&D facilities[c]	–0.188 (1.642)	0.808 (1.625)	*
Changes of R&D personnel[c]	–0.375 (1.544)	0.423 (1.629)	
Changes of R&D performance[d]	1.750 (1.438)	2.385 (1.472)	

Legend
[a] Mean values; standard errors in parentheses.
[b] t-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.
[c] Answers codified through a ten-point Likert scale, ranging from -5 (100% decrease) to +4 (increase greater than 100%). 0 means no change.
[d] Answers codified through a nine-point Likert scale, ranging from -4 (substantial decrease) to +4 (substantial increase). 0 means no change.

In Table 5 attention is focused on firms with similar technological strengths (STF). We examine differences as to changes in R&D inputs and performance according to whether the merging firms competed directly with each other before the deal or not. In general, rival firms exhibit a larger decrease of R&D effort and lower returns to R&D expenses than non-rival firms. However, only the difference relating to the latter variable turned out to be statistically significant at conventional levels.

Table 5. The effects of M&As on R&D inputs and performance: the role of market relatedness

	Same technological fields		
Variables	**Rival firms[a]**	**Non-rival firms[a]**	**Confidence level[b]**
Changes of physical R&D facilities[c]	–0.556 (0.856)	–0.188 (1.642)	
Changes of R&D personnel[c]	–0.833 (1.150)	–0.375 (1.544)	
Changes of R&D performance[d]	0.556 (1.947)	1.750 (1.438)	**

Legend
[a] Mean values; standard errors in parentheses.
[b] t-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.
[c] Answers codified through a ten-point Likert scale, ranging from -5 (100% decrease) to +4 (increase greater than 100%). 0 means no change.
[d] Answers codified through a nine-point Likert scale, ranging from -4 (substantial decrease) to +4 (substantial increase). 0 means no change.

At face value these results indicate that relatedness between partners –irrespective of whether it is market or technological relatedness– has a negative impact on R&D inputs and performance. However, to really understand what is driving these aggregate results of M&A on R&D, we need to delve deeper into the R&D process itself, a task we perform next.

5.2 Synthetic indicators of consequences of M&A on R&D process

In addition to the three individual questions considered in section 5.1, another fifty questions in the case study questionnaire concern R&D activities. Such a richness of descriptive elements was necessary to cope with the variety of the observed impact of M&As on R&D and the complexity and multi-dimensional nature of the R&D process. We decided to extract principal components from the original questions to provide a more parsimonious description of the phenomena at hand. Answers from the questionnaires were codified through binary or discrete ordered variables. In order to obtain meaningful indicators, we subdivided the whole set of questions into five groups relating to R&D inputs, outputs, productivity, organisation, and mission respectively, and ran a principal component analysis for each group. The results of these principal component analyses are summarized in Table 6. The first column indicates the name of the principal component while the second column groups the individual questions that loaded onto this principal component with the load factor for the score between brackets.

Table 6. Principal Components and Individual Questions

Principal Component	**Questions (load factor)**
R&D Inputs	
A1: Increase of R&D effort	Hiring of R&D personnel (0.809) Increase of R&D expenditures (0.841) More funds internally available to finance R&D projects (0.618)
A2: Decrease of R&D effort	Cut of R&D personnel (0.875) Closure of R&D laboratories (0.742) Less funds internally available to finance R&D projects (0.557) Decrease of R&D expenditures (0.549)
A3: R&D rationalisation	Termination of non-concurrent R&D programs (0.797) Termination of concurrent R&D programs (0.744) Loss of key researchers (voluntary abandonment) (0.558)
A4: New R&D fields and sources	Launch of new R&D programs in technological fields new to the company (0.800) Increase of the use of external R&D sources (0.732) Launch of new R&D programs in technological fields already covered by the company (0.554)
A5: Critical mass in R&D	Achievement of critical mass in technological fields that were new to the company (0.565) Achievement of critical mass in technological fields already covered by the company (0.540) Decrease of the use of external R&D sources (0.533) Opening of new R&D laboratories (0.499) Increase of the scale of the typical R&D project (0.468) Decrease of the scale of the typical R&D project (-0.399)

R&D Outputs	
B1: Increase of R&D output	Greater speed in developing technological knowledge (0.756) Greater speed in introducing new production processes (0.737) More patents granted (0.739) Improvement of existing technological competencies (0.725) Greater speed in introducing new products (0.675) Development of new technological competencies (0.668)
B2: Better exploitation of technological competencies	Application of the target's existing technological competencies in the acquiring firm's product markets (0.941) Application of the acquirer's existing technological competencies in the target firm's product markets (0.910)
B3: Less technological competition	Decreased danger of being imitated (0.846) Elimination of competing product standard (0.837)
R&D Performance	
C1: Increase of R&D productivity	More productive R&D personnel (0.909) Increase of returns to R&D expenditures (0.780) Improved management of the R&D process (0.609)
C2: Organisational problems in R&D	Greater complexity, less focus and/or slower decision making in R&D (0.862) Less motivated R&D personnel (0.795) Decrease of returns to R&D expenditures (0.498)
R&D Organization and Management	
D1: R&D specialisation and knowledge transfer	Getting knowledge (patents, methods, other blueprints) from the other company (0.847) Creation of joint teams (0.793) Mutual specialisation of the R&D tasks (0.643)
D2: R&D restructuring	Re-organization of R&D teams (0.829) Top management of the R&D function replaced (0.715) R&D projects run in parallel by independent R&D teams (0.464)
D3: R&D resource redeployment	Transfer of R&D technical personnel from the other company (0.805) Transfer of R&D physical equipment from the other company (0.817)
R&D Mission	
E1: Broadening of R&D mission	Greater emphasis on research as opposed to development (0.719) Extension of the typical time horizon of R&D projects (0.655) Broadening of the scope of R&D (0.601)
E2: Focussing of R&D mission	Shortening of the typical time horizon of R&D projects (0.778) Focussing of R&D on specific technological fields (0.760) Greater emphasis on development as opposed to research (0.641)

5.3 Results from the synthetic indicators

In section 5.1 we showed that the effects of M&As on R&D inputs and the returns to R&D expenditures depend on merging companies' technology and market relatedness. In this section, we tackle the effects in a broader perspective, taking advantage of the quite complete representation of R&D activities yielded by the synthetic indicators that were illustrated in the previous section.

Again, we follow a similar methodology to the one adopted in section 5.1. First, merging firms are subdivided into mutually exclusive categories. In particular, we compare a) the "STF" and "CTF" categories for non-rival firms, and b) within the "STF" category, rival ("STF-R") and non-rival ("STF-NR") firms. Then, mean values of the synthetic indicators are computed for each category and the differences between mean values are assessed through t-tests. In Table 7 we consider technological relatedness, while Table 8 presents the results for market relatedness.

5.3.1 Technological relatedness

The results of Table 7 confirm that firms in the "CTF" category increased R&D effort after completion of a merger or an acquisition to a larger extent than those in the "STF" category. But, as in Table 4, the difference is not significant. The "STF" category also exhibits poorer performance in terms of both R&D output and productivity, even though the results relating to the corresponding indicators (B1 and C1, respectively) are statistically insignificant at conventional levels. Analysis of the individual answers reveals that firms with overlapping technological strengths never opened a new research laboratory after the deal, an event that occurred for 11% of the firms with complementary technological specialisation. In addition, they more often decreased R&D expenditures (31% against 15%) and fired R&D personnel (19% against 11.5%) (9). In spite of their declaration of a better profit outlook after the deal, 12% of "STF" firms reported a decrease of the internal funds available for R&D financing; no firm in the "CTF" category mentioned such an occurrence.

(9) Tables A.2 to A.6 in the Appendix report the results for the individual questions of our questionnaire. As one can note, many of the differences in means on individual questions are not significant, which reinforces the need to aggregate the results into synthetic indicators. Nevertheless, by reporting the difference for individual questions the reader gets a feel for the depth and breadth of our data. Table 6 indicates which individual questions (and weighting) make up the different synthetic indicators.

Table 7. The effects of M&As on R&D synthetic indicators in non-rival firms: the role of input relatedness

	Non-rival firms		
Factors	**Same technological fields**[a]	**Complementary technological fields**[a]	**Confidence level**[b]
A1: Increase of R&D effort	0.199 (2.016)	0.332 (2.095)	
A2: Decrease of R&D effort	–0.145 (2.207)	–0.708 (1.357)	
A3: R&D rationalisation	0.762 (2.005)	–0.728 (1.121)	**
A4: New R&D fields and sources	0.406 (1.568)	0.219 (1.636)	
A5: Critical mass in R&D	–0.081 (0.706)	0.545 (1.949)	
B1: Increase of R&D output	0.623 (2.051)	0.600 (3.621)	
B2: Better exploitation of technological competencies	0.349 (2.054)	0.211 (1.412)	
B3: Less technological competition	0.600 (1.598)	–0.696 (1.306)	**
C1: Increase of R&D productivity	0.253 (1.686)	0.568 (1.889)	
C2: Organisational problems in R&D	0.476 (1.871)	–0.568 (0.763)	**
D1: R&D specialisation and knowledge transfer	0.589 (0.682)	–0.501 (2.009)	**
D2: R&D restructuring	0.355 (1.590)	–0.215 (1.486)	
D3: R&D resource redeployment	–0.158 (1.663)	0.331 (1.274)	
E1: Broadening of R&D mission	0.175 (1.210)	0.279 (1.615)	
E2: Focussing of R&D mission	0.717 (1.360)	–0.615 (1.324)	***

Legend

[a] t-test of the difference between mean values. *** confidence level > 99%; ** confidence level > 95%; * confidence level > 90%.
[b] Mean values; standard errors in parentheses.

The data of Table 7 also help to further explore why firms with overlapping technological strengths performed so poorly. As predicted, such firms turned out to rely on the rationalisation of R&D activity to a much larger extent than firms with complementary technology specialisation, as is highlighted by the larger mean value of the A3 indicator; the difference between the two categories of firms is statistically significant at 95%. In particular, termination of concurrent and non-concurrent R&D projects were mentioned by 50% and 56% of "STF" firms, respectively. Again these values are significantly larger than those of "CTF" firms (35% and 11%). In addition, firms with similar technological strengths seem to have been looking for faster returns to R&D expenses by focusing their R&D mission. In fact, the difference between the mean value of the E2 indicator in the "STF" and "CTF" categories is large and statistically significant at 99%. Consideration of the individual answers shows that 50% and 38% of firms with overlapping technological specialisation mentioned that the merger or the acquisition resulted in greater emphasis being placed on development as opposed to research and in the shortening of the typical time horizon of R&D projects. The corresponding values for firms with complementary technological strengths were 8% and 15%.

In turn, the rationalisation and the focusing of R&D often lead key researchers to voluntarily abandon the firm, an event that was mentioned by almost 31% of "STF" firms, while it was never mentioned by firms in the "CTF" category. In addition, organisational problems engendered by the merger or the acquisition, especially those associated with the motivation of R&D personnel, were found to be more serious for firms with similar rather than complementary technological capabilities; again the difference in the mean value of the C2 indicator between the “STF” and “CTF” categories is significant at 95%.

By contrast, M&As between firms with complementary technological specialisation were often a vehicle for the technological diversification of merging firms. Even though this aspect is not immediately apparent from the synthetic indicators, the individual answers reveal that the “achievement of critical mass in technological fields new to the firm” and the “development of new technological competencies” were assigned quite high importance scores by managers of “CTF” firms; the mean values in this category equal 2.62 and 2.69 on a four-point Likert scale and were found to be significantly greater than those reported by managers of firms with overlapping technological strengths (1.13 and 2.00 respectively).

The indicators on R&D organization indicate that firms in the same technological fields tend to specialize significantly more and transfer codified technology. Firms in complementary technological fields seem to rely rather on resource redeployments, although the effect is not significant. We would expect these resource redeployments to consist of transfers of non-codifiable technology. In line with the higher organizational problems, R&D restructuring (D2) is higher for same technology firms, but this effect is not significant.

Lastly, it is noteworthy that M&As between firms with overlapping technological knowledge more often resulted in a reduction of competition in technology markets than those between firms with complementary strengths. Note the large difference in the mean values of B3, which is statistically significant at 95% confidence level. In fact, the interviewed managers of “STF” firms, when asked about the technological implications of the deal, attributed quite high scores to the “elimination of a competing product standard” and the “decrease of the danger of being imitated” (the mean values are equal to 1.25 and 2.00, respectively). In contrast, the importance of such aspects was considered to be negligible by managers of “CTF” firms (average scores equal 0.69 and 0.62, respectively). These differences are again significant at 99%.

Overall, we find support for our hypotheses concerning the conditioning effect of technological relatedness on the effect of M&As on the R&D process. Firms active in STF are likely to have a more negative impact on R&D inputs. This is particularly apparent through the R&D rationalizations that occur as a result of this type of M&A. Furthermore, as conjectured, the mission of R&D is affected in opposite directions depending on the technological relatedness of combining firms. For both types of firms we expected R&D output and performance to increase. However, it is interesting to note that the process for generating these positive results is different. STF firms specialize their R&D process and reduce technological competition in addition to the prevalent rationalization. CTF firms redeploy resources across the new entity to create critical mass in technological fields new to the firm and develop new competencies.

5.3.2 Market relatedness

Table 8 focuses on the market relatedness dimension. Again remarkable differences emerge between rival and non-rival firms who share the same technologies. First, rival firms exhibit an even greater post-deal reduction of R&D effort than non rival ones. In the “STF-R” category the A1 and A2 indicators have smaller and greater mean values, respectively, than in the “STF-NR” category, even though the differences are not significant at conventional confidence levels. Turning to individual answers, we observe statistically significant differences between the two categories as to the frequency with which firms mentioned having closed R&D facilities (38.9% against 12.5%) and having fired R&D personnel (44.4% against 18.8%). In addition, M&As between direct competitors very rarely lead combining firms to explore new technological fields and benefit from new external technology sources; the mean value of the A4 indicator is negative for "STF-R" firms, but positive for "STF-NR" firms, with the difference significant at 90%. In particular, 81.3% of the STF-NR firms launched new R&D projects relating to the technological fields in which they had previously developed distinctive capabilities; the corresponding share of rival firms was as low as 27.8%, with the difference significant at 99%.

Table 8. The effects of M&As on R&D synthetic indicators: the role of market relatedness

	Same technological fields		
Factors	**Rival firms**[a]	**Non-rival firms**[a]	**Confidence level**[b]
A1: Increase of R&D effort	–0.493 (1.315)	0.199 (2.016)	
A2: Decrease of R&D effort	1.097 (2.485)	–0.145 (2.207)	
A3: R&D rationalisation	0.534 (1.510)	0.762 (2.005)	
A4: New R&D fields and sources	–0.592 (1.423)	0.406 (1.568)	*
A5: Critical mass in R&D	–0.515 (1.500)	–0.081 (0.706)	
B1: Increase of R&D output	–1.344 (3.120)	0.623 (2.051)	**
B2: Better exploitation of technological competencies	–0.792 (1.841)	0.349 (2.054)	*
B3: Less technological competition	0.421 (1.236)	0.600 (1.598)	
C1: Increase of R&D productivity	–0.701 (1.337)	0.253 (1.686)	*
C2: Organisational problems in R&D	0.517 (2.181)	0.476 (1.871)	
D1 R&D specialisation and knowledge transfer	0.092 (2.060)	0.589 (0.682)	
D2: R&D restructuring	–0.137 (1.276)	0.355 (1.590)	
D3: R&D resource redeployment	–0.146 (1.209)	–0.158 (1.663)	
E1: Broadening of R&D mission	–0.430 (1.018)	0.175 (1.210)	
E2: Focussing of R&D mission	0.380 (1.995)	0.717 (1.360)	

Legend
[a] t-test of the difference between mean values. *** confidence level > 99%; ** confidence level > 95%; * confidence level > 90%.
[b] Mean values; standard errors in parentheses.

Second, firms that directly competed with each other exhibit poorer performance in terms of both R&D output and productivity, as is witnessed by the lower mean values of the B1, B2 and C1 indicators, all statistically significant at conventional confidence levels. Individual answers highlight the significantly lower propensity to patent of rival firms, the lower speed in introducing new production processes and developing new technological knowledge, and the lower capacity to combine their own capabilities with those of the partner so as to obtain synergistic gains.

In contrast, there were no significant differences as to changes in R&D organisation and mission in the merged entity. More interestingly, the negative implications for technology competition of M&As between firms with overlapping technological capabilities seem not to depend on whether the firms were direct competitors or not. The B3 indicator takes a large positive mean value for both the "STF-R" and "STF-NR" sub-categories, and the difference is insignificant at conventional levels.

In conclusion, we confirm our hypotheses concerning the conditioning effect of firms' market relatedness on the effect of M&As on the R&D process. M&As between rival firms have a significant negative effect on both R&D inputs and R&D outputs. Furthermore, we find a strong negative effect on R&D performance. While this was not necessarily expected, a possible explanation is that these M&As take place for non-innovation related motives and that the indirect effect on the R&D process is quite pronounced in these cases.

6. Conclusions and Discussion

In high- and medium-tech industries, non-innovation related motives for M&As are generally much more important than innovation-related motives. In a considerable number of the deals under scrutiny, M&As are aimed mainly at increasing market share and broadening the firm's product mix. The pursuit of economies of scale in R&D turns out to be a minor motive for the deals included in the sample. This absence of innovation motive for a M&A does not, however, imply that the deal has little or no effect on R&D. Quite on the contrary, our results show that there are considerable differences in the nature, direction and size of the effects on R&D depending on the type of relatedness between partners.

First, we consider *technology relatedness*, when before the deal firms had technological capabilities in the same technological fields. After the merger such firms experience a larger decrease of R&D effort relating to both R&D facilities and personnel, due to more extensive rationalization of R&D activity, with the elimination of common inputs to the R&D process and termination of supposedly duplicate projects. They also exhibit a greater propensity to focus the scope of their R&D on particular fields, placing more emphasis on development rather than basic research, and shortening the time horizon of R&D projects. However, the results of such actions seem to be fairly modest; in fact, deals in this category show a poorer performance, in terms of increased R&D productivity and returns to R&D expenditures, than other deals in our sample. Also important to note is that M&As in this category are significantly more likely to lessen competition in technology markets by consolidating their technological position in the market through the M&A.

For firms that had *complementary technological capabilities* before the deal, different results emerge. For such firms, M&As turn out to be a crucial vehicle for external technology sourcing and entry into new technological areas. In particular, in the category that includes deals between firms with complementary technological capabilities, the wish to capture scope economies in R&D and to develop new knowledge by combining the technological capabilities of the merging firms is more often mentioned by the interviewed managers as a key motivation. Decreases of R&D personnel are less likely than for the other firms in the sample, because there is less rationalization and cutting of R&D costs. In addition, such deals are more likely to lead to an increase of R&D output, due to greater speed in introducing new products and processes, improvement and enlargement of the stock of technological capabilities, and/or more intense patenting activity after the merger. However, there is no compelling evidence in our data that this results in a significant increase in R&D productivity and performance.

Finally, market relatedness between partners, while having comparable aggregate effects on R&D inputs and performance, operates on different dimensions of the R&D process. Former rivals that engage in a M&A are significantly less likely to expand into new R&D fields or leverage their technological competences across the products and markets of the new entity. In contrast, non-rival firms that join forces significantly increase R&D output and productivity relative to former rivals that merge.

These results clearly confirm our hypothesis that the ex-ante relatedness between merger-partners matters, and that market and technological relatedness have important, separately identifiable consequences for the impact of an M&A on the new entity's R&D and innovation process. To uncover these different consequences one needs to examine the impact on the R&D process at a sufficiently disaggregate level.

When re-considering the theoretical effects and their consequences for the R&D process that we developed, it is worth stressing that in order to provide a robust empirical test of these hypotheses, a multivariate analysis based on a larger scale sample representative of the target population of M&As carried out by European firms is needed. Therefore, the results presented here are to be considered preliminary and await further corroboration. This notwithstanding, we contend that they already extend substantially our understanding of the M&A phenomenon, where we need to control for the ex-ante relatedness between partners when evaluating the impact of M&As on the R&D and innovation process. □

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Appendix 1

THE IMPACT OF M&A ON THE R&D PROCESS.
AN EMPIRICAL ANALYSIS OF THE ROLE OF TECHNOLOGICAL
AND MARKET RELATEDNESS

Table A.1. Attribution of cases to types of M&As

	Sector	Market relatedness	Technological relatedness – same technologies	Technological relatedness – complementary technologies	Technological Classification	Nationality
1	Diff. businesses	O.c.	O.c.	Compl. tech.	CTF	Cross-border
2	Diff. businesses	O.c.	O.c.	Compl. tech.	CTF	Cross-border
3	Same prod. lines	Direct compet.	Same tech.	Compl. tech.	STF	Cross-border
4	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	Cross-border
5	Diff. prod. lines	O.c.	Same tech.	Compl.tech.	STF	Cross-border
6	Same prod. lines	Direct compet.	Same tech.	Compl. tech.	STF	Cross-border
7	Diff. businesses	O.c.	O.c.	Compl. tech.	CTF	Cross-border
8	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	Cross-border
9	Diff. prod. lines	O.c.	Same tech.	O.c.	STF	Cross-border
10	Diff. prod. lines	O.c.	Same tech.	Compl. tech.	STF	O.c.
11	Diff. businesses	O.c.	O.c.	Compl. tech.	CTF	O.c.
12	Same prod. lines	Direct compet.	Same tech.	O.c.	STF	O.c.
13	Diff. businesses	O.c.	Same tech.	O.c.	STF	O.c.
14	Same prod. lines	Direct compet.	O.c.	Compl. tech.	CTF	Cross-border
15	Diff. prod. lines	O.c.	Same tech.	Compl. tech.	STF	Cross-border
16	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	O.c.
17	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	Cross-border
18	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	Cross-border
19	Diff. prod. lines	O.c.	Same tech.	O.c.	STF	O.c.
20	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	O.c.
21	Same prod. lines	Direct compet.	Same tech.	Compl. tech.	STF	Cross-border
22	Same prod. lines	Direct compet.	Same tech.	Compl. tech.	STF	Cross-border
23	Same prod. lines	Direct compet.	Same tech.	O.c.	STF	Cross-border
24	Diff. businesses	O.c.	O.c.	Compl. tech.	CTF	O.c.
25	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	Cross-border
26	Diff. prod. lines	O.c.	Same tech.	O.c.	STF	Cross-border
27	Same prod. lines	Direct compet.	Same tech.	O.c.	STF	Cross-border
28	Same prod. lines	Direct compet.	Same tech.	O.c.	STF	Cross-border
29	Same prod. lines	O.c.	Same tech.	O.c.	STF	Cross-border
30	Same prod. lines	Direct compet.	Same tech.	O.c.	STf	O.c.
31	Diff. prod. lines	O.c.	O.c.	Compl. tech.	CTF	Cross-border

Legend
O.c. Other cases.
STF: Same Technological Fields
CTF: Complementary Technological Field

Appendix 1 (continued)

Table A.2. Individual questions. The effects of M&As on the structure of the R&D function: the role of market and input relatedness

Variables [c]	Same technological fields			Non-rival firms		
	Rival firms[a]	Non-rival firms[a]	Confidence level[b]	Same technological fields[a]	Complementary technological fields[a]	Confidence level[b]
Closure of R&D laboratories	0.389 (0.502)	0.125 (0.342)		0.125 (0.342)	0.154 (0.368)	
Opening of new R&D laboratories	0.000 (0.000)	0.000 (0.000)		0.000 (0.000)	0.115 (0.326)	
Cut of R&D personnel	0.444 (0.511)	0.188 (0.403)		0.188 (0.403)	0.115 (0.326)	
Hiring of R&D personnel	0.056 (0.236)	0.188 (0.403)		0.188 (0.403)	0.269 (0.452)	
Loss of key researchers (voluntary abandonment)	0.278 (0.461)	0.313 (0.479)		0.313 (0.479)	0.000 (0.000)	
Termination of concurrent R&D programs	0.722 (0.461)	0.500 (0.516)		0.500 (0.516)	0.346 (0.485)	
Termination of other (non-concurrent) R&D programs	0.278 (0.461)	0.563 (0.512)		0.563 (0.512)	0.115 (0.326)	
Launch of new R&D programs in technological fields:						
(a) new to the company	0.333 (0.485)	0.438 (0.512)		0.438 (0.512)	0.462 (0.508)	
(b) already covered by the company	0.278 (0.461)	0.813 (0.403)		0.813 (0.403)	0.577 (0.504)	
Scale of the typical R&D project:						
(a) decreased	0.056 (0.236)	0.000 (0.000)		0.000 (0.000)	0.000 (0.000)	
(b) increased	0.500 (0.514)	0.500 (0.516)		0.500 (0.516)	0.462 (0.508)	
Dependence on external R&D sources:						
(a) decreased	0.056 (0.236)	0.188 (0.403)		0.188 (0.403)	0.154 (0.368)	
(b) increased	0.111 (0.323)	0.250 (0.447)		0.250 (0.447)	0.269 (0.452)	

Legend

[a] Mean values; standard deviations in parentheses.

[b] χ^2-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.

[c] Answers codified through binary variables. 0 means no change.

Appendix 1 (continued)

Table A.3. Individual questions. The effects of M&As on the R&D mission and objectives: the role of market and input relatedness

	Same technological fields			Non-rival firms		
Variables [c]	**Rival firms**[a]	**Non-rival firms**[a]	**Confidence level**[b]	**Same technological fields**[a]	**Complementary technological fields**[a]	**Confidence level**[b]
Greater emphasis on:						
(a) research as opposed to development	0.111 (0.323)	0.125 (0.342)		0.125 (0.342)	0.231 (0.430)	
(b) development as opposed to research	0.333 (0.485)	0.500 (0.516)		0.500 (0.516)	0.077 (0.272)	
The typical time horizon of R&D projects has been:						
(a) extended	0.111 (0.323)	0.313 (0.479)		0.313 (0.479)	0.308 (0.471)	
(b) shortened	0.556 (0.511)	0.375 (0.500)		0.375 (0.500)	0.154 (0.368)	
Focussing of R&D on specific technological fields	0.556 (0.511)	0.813 (0.403)		0.813 (0.403)	0.577 (0.504)	
Broadening of the scope of R&D	0.278 (0.461)	0.500 (0.516)		0.500 (0.516)	0.423 (0.504)	

Legend

[a] Mean values; standard deviations in parentheses.

[b] χ^2-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.

[c] Answers codified through binary variables. 0 means no change.

Appendix 1 (continued)

Table A.4. Individual questions. The effects of M&As on the R&D organisation and management: the role of market and input relatedness

	Same technological fields			Non-rival firms		
Variables [c]	**Rival firms**[a]	**Non-rival firms**[a]	**Confidence level**[b]	**Same technological fields**[a]	**Complementary technological fields**[a]	**Confidence level**[b]
Top management of the R&D function replaced	0.222 (0.428)	0.563 (0.512)		0.563 (0.512)	0.308 (0.471)	
Re-organisation of R&D teams	0.667 (0.485)	0.688 (0.479)		0.688 (0.479)	0.615 (0.496)	
R&D projects in the same technological fields run in parallel by independent R&D teams	0.167 (0.383)	0.125 (0.342)		0.125 (0.342)	0.077 (0.272)	
Mutual specialisation of the R&D tasks	0.778 (0.428)	0.750 (0.447)		0.750 (0.447)	0.769 (0.430)	
Creation of joint R&D teams	0.889 (0.323)	1.000 (0.000)		1.000 (0.000)	0.769 (0.430)	
Transfer of R&D physical equipment from the other company	0.278 (0.461)	0.438 (0.512)		0.438 (0.512)	0.462 (0.508)	
Transfer of R&D technical personnel from the other company	0.667 (0.485)	0.500 (0.516)		0.500 (0.516)	0.769 (0.430)	
Getting knowledge (e.g. patents, methods, other blueprints) from the other company	0.889 (0.323)	1.000 (0.000)		1.000 (0.000)	0.769 (0.430)	

Legend
[a] Mean values; standard deviations in parentheses.
[b] χ^2-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.
c Answers codified through binary variables. 0 means no change.

Appendix 1 (continued)

Table A.5. Individual questions. The effects of M&As on the R&D efforts and financing: the role of market and input relatedness

	Same technological fields			Non-rival firms		
Variables [c]	**Rival firms**[a]	**Non-rival firms**[a]	**Confidence level**[b]	**Same technological fields**[a]	**Complementary technological fields**[a]	**Confidence level**[b]
R&D expenditures:						
(a) increased	0.278 (0.461)	0.313 (0.479)		0.313 (0.479)	0.308 (0.471)	
(b) decreased	0.556 (0.511)	0.313 (0.479)		0.313 (0.479)	0.154 (0.368)	
Funds internally available to finance R&D projects:						
(a) less	0.111 (0.323)	0.125 (0.342)		0.125 (0.342)	0.000 (0.000)	
(b) more	0.278 (0.461)	0.563 (0.512)		0.563 (0.512)	0.538 (0.508)	

Legend

[a] Mean values; standard deviations in parentheses.

[b] χ^2-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.

[c] Answers codified through binary variables. 0 means no change.

Appendix 1 (continued)

Table A.6. Individual questions. The effects of M&As on technological performances: the role of market and input relatedness

Variables [c]	Same technological fields			Non-rival firms		
	Rival firms[a]	Non-rival firms[a]	Confidence level[b]	Same technological fields[a]	Complementary technological fields[a]	Confidence level[b]
More patents granted	0.556 (0.705)	1.125 (0.806)	**	1.125 (0.806)	1.385 (1.577)	
Decreased danger of being imitated	1.333 (0.840)	2.000 (1.461)		2.000 (1.461)	0.615 (1.023)	***
Elimination of competing product standard	1.667 (1.372)	1.250 (1.238)		1.250 (1.238)	0.692 (1.158)	
Achievement of critical mass in technological fields:						
(a) new to the company	0.778 (1.353)	1.125 (1.310)		1.125 (1.310)	2.615 (1.813)	***
(b) already covered by the company	3.111 (0.900)	3.000 (0.516)		3.000 (0.516)	2.923 (1.412)	
Improvement of existing technological competencies	2.556 (0.856)	2.625 (0.719)		2.625 (0.719)	2.846 (1.047)	
Development of new technological competencies	1.667 (1.283)	2.000 (1.265)		2.000 (1.265)	2.692 (1.289)	*
Application of the acquirer's existing technological competencies in the target firm's product markets	1.333 (1.283)	2.250 (1.438)	*	2.250 (1.438)	1.846 (0.967)	
Application of the target's existing technological competencies in the acquiring firm's product markets	1.333 (1.283)	2.000 (1.461)		2.000 (1.461)	2.231 (1.275)	
Greater speed in:						
(a) introducing new products	2.000 (1.609)	2.500 (1.366)		2.500 (1.366)	1.923 (1.719)	
(b) introducing new production processes	1.778 (1.592)	2.875 (1.088)	**	2.875 (1.088)	2.000 (1.697)	**
(c) developing technological knowledge	1.667 (1.455)	2.875 (0.957)	***	2.875 (0.957)	2.769 (1.336)	
Improved management of the R&D process	1.667 (0.970)	2.000 (0.730)		2.000 (0.730)	2.462 (1.303)	
More productive R&D personnel	1.444 (1.199)	2.000 (1.033)		2.000 (1.033)	1.615 (1.525)	
Greater complexity, less focus and/or slower decision making in R&D	0.889 (1.323)	0.750 (1.125)		0.750 (1.125)	0.538 (0.859)	
Less motivated R&D personnel	0.667 (0.970)	1.125 (1.310)		1.125 (1.310)	0.077 (0.272)	***
Returns to R&D expenditures:						
(a) increased	1.000 (1.085)	1.750 (1.438)		1.750 (1.438)	2.385 (1.472)	
(b) decreased	0.444 (1.294)	0.000 (0.000)		0.000 (0.000)	0.000 (0.000)	

Legend
[a] Mean values; standard deviations in parentheses.
[b] t-test of the difference between mean values. *** confidence level > 99%, ** confidence level > 95%, * confidence level > 90%.
[c] Answers codified through a five-point Likert scale, ranging from 0 (Not important at all) to 4 (Very important).