THE IMPACT OF MERGERS ON R&D: AN EMPIRICAL ANALYSIS

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ABSTRACT

In this paper we examine the effects of horizontal mergers on the R&D activity of merging firms. We claim that such effects are modulated by several factors relating to the characteristics of the merger and the role of merging firms (i.e. acquirer or target). In the empirical analysis we consider a sample composed of 31 mergers with 62 firms involved. In contrast to most previous work, we study changes triggered by individual mergers in the R&D inputs, outputs, performance and mission of merging firms. For this purpose, we use data on R&D provided by informed top managers of acquiring firms during face-to-face interviews. The results of the estimates of several OLS models support the view that the effects of mergers on R&D are contingent on modulating factors.

January 2004

(*)In this paper we use data collected within the project "Mergers and Acquisitions and Science and Technology Policy" financed by the European Commission, DG Research (Contract No. ERBHPV2 -CT-1999-13). The study was carried out by an international team of researchers from different universities: Catholic University of Leuven, Politecnico di Milano, IESE Business School (Barcelona), Universitat Pompeu Fabra (Barcelona), Politecnico di Torino, Reading University, INSEAD and IDEA Consult. The results of the analysis can be found in the final report, which is published by the commission (DG Research). We are grateful to Mario Calderini, John Cantwell, Laurence Capron, Bruno Cassiman, Lucia Piscitello, Geert Steurs, Leo Sleuwaegen, Masako Ueda and Reinhilde Veugelers for comments and suggestions on this and related work. Responsibility for any errors lies solely with the authors. This paper does not reflect the views of the European Commission.

INTRODUCTION

The aim of this paper is to examine the impact of horizontal mergers[1], that is mergers between firms that operate in the same industry, on firms' research and development (R&D) activity.

A conspicuous body of research in management, industrial organization, and finance has analyzed the effects of mergers on the economic and financial performances of both acquiring and acquired companies (see for instance Jensen and Ruback, 1983; Lubatkin, 1983; 1987; Singh and Montgomery, 1987; Seth, 1990a; 1990b). A smaller number of studies has considered the effects of mergers on R&D (for a survey, see, among others, Calderini and Garrone, 2003; Cassiman, Colombo, Garrone and Veugelers, 2003). Empirical findings of pioneering works relating to this latter issue are rather mixed and to some extent controversial. For instance, a negative effect of mergers on R&D inputs was highlighted by Ravenscraft and Scherer (1987). Hall (1990) examine changes in R&D intensity of acquiring firms in the years immediately following a merger. Using a large panel of US manufacturing firms observed during the 1970s and 1980s, she finds no evidence of significant declines relative to the R&D intensity of the industry; this especially holds true after controlling for firms' own lagged R&D intensity[2]. On the contrary, she does find strong evidence of declines in R&D intensity following a substantial increase of leverage, be it determined by a merger or by other events.

In accordance with this latter result, several studies have contended that the effects of mergers on R&D are contingent on *modulating factors*. For instance, Hitt, Hoskisson, Ireland and Harrison (1991) consider the R&D intensity and patenting intensity of acquiring and acquired firms in the pre-acquisition period and those of the combined firms after the acquisition. They show that in general, mergers negatively affect relative R&D intensity, but not relative patenting intensity. However, diversifying acquisitions (i.e. acquisitions in a different two-

[1] In the following we will use the terms "merger" and "acquisition" as synonyms.

[2] See also Hall (1988) and (1994). In a later work (Hall 1999), it is suggested that in the US, R&D may indeed have slightly declined after mergers that occurred in the 1990s. However, statistical evidence is far from robust.

digit industry as the one of the acquirer) have substantial negative effects on both indicators. Hitt, Hoskisson, Johnson and Moesel (1996) show that firms engaging in acquisitions (and divestitures) often replace strategic controls with financial controls; in turn, this negatively affects internal innovation (measured by R&D and new product intensity). Ahuha and Katila (2001) relate the characteristics of the acquisitions conducted by US chemical firms to subsequent changes in patenting activity. Their econometric results indicate that the (absolute and relative) size of the knowledge base of target firms and the relatedness of the knowledge bases of acquirers and targets figure prominently in explaining the effects of mergers. Cassiman et al. (2003) suggest that the impact of mergers on the R&D process depends on both technology and product/market relatedness.

In this paper we conform to the above mentioned literature in that we consider several modulating factors that may influence the relation between mergers and R&D. Nonetheless, in contrast to most previous works we try to highlight the effects of *individual mergers* on the R&D activity of both merging entities relative to the situation before the merger. Actually, with a few exceptions (for instance Cassiman et al. 2003), previous studies consider annual firm level data relating to R&D inputs (i.e. R&D expenses) or outputs (i.e. patents). This makes it very difficult to disentangle the effects of individual mergers. In fact, large firms often make several acquisitions in a single year. In addition, firms often acquire only a portion of the assets of a company and after an acquisition, part of the acquired assets may be divested. If one relies exclusively on published firm-level data, when these events occur it is almost impossible to compare post-deal data relating to the combined firm with those of the acquiring and acquired companies before the deal. Lastly, a long time period may elapse before the effects of a particular merger become evident in firm level R&D output data.

In order to deal with such methodological problems, we examine a sample composed of 31 individual mergers with 62 firms involved. We rely on a large set of measures describing the changes in R&D inputs, outputs, performance, and mission in both acquiring and acquired companies that are triggered by a particular merger. Such measures are based on qualitative and perceptual data that were provided by informed top managers of acquiring companies during face-to-face interviews. These data are then synthesized through principal component analyses in a smaller set of indicators which are regressed against several characteristics of individual mergers. In particular, we consider the complementary or overlapping nature of the R&D operations of merging firms, whether merging firms competed in the same product markets before the merger, whether they had established prior collaborative relations with each other, the cross-border or domestic nature of the merger, and the extent to which it was motivated by technology-related considerations. We also distinguish between acquiring and acquired companies. The econometric results strongly support the view that the effects of mergers on R&D depend on (some of) the above mentioned modulating factors.

The paper proceeds as follows. In next section, we illustrate the theoretical background and the research hypotheses. Then we present the methodology of the empirical analysis, we describe the dependent variables of the econometric models, and we illustrate the explanatory variables and their predicted effects in the various models. The subsequent section is devoted to the results of the econometric estimates. A discussion of the evidence provided by the paper and of its implications for both practitioners and researchers concludes the paper.

THEORETICAL BACKGROUND AND RESEARCH HYPOTHESES

As far as R&D is concerned, horizontal mergers involve both benefits and costs for merging firms; their relative extent depends on several factors. In the following, we will consider the impact of mergers on the R&D inputs, outputs, performance, and mission of the combining entities and we will draw attention to the influence exerted by some *modulating factors*. They will be grouped into three categories, namely[3]:

[3] As was mentioned in the introductory section, several studies have focused on changes in financial structure after a merger, highlighting the negative effects on R&D of leveraged deals (see for instance Hall 1990). In this paper we will not address this issue because of lack of pertinent data.

- factors leading to greater R&D efficiency, due to economies of scale and scope in R&D, and combination and redeployment of firms' technological resources and capabilities[4];
- factors connected with greater market power in product and technology markets;
- factors that influence the post-deal organization of merging firms.

R&D Efficiency

Since the seminal work by Schumpeter (1942), the relationship between firm structure and innovation has been a quite controversial issue[5]. In principle, if R&D scale and/or scope economies are at work, an horizontal merger combining the R&D operations of two firms that operate in the same or in closely related technological fields, should lead to greater efficiency in the R&D process. In fact, in comparison with the pre-deal situation of individual merging firms, the combined entity will be able to produce the same R&D outputs with less inputs or more outputs with the same inputs.

Nevertheless, the empirical evidence supporting the view that mergers have a positive effect on R&D due to economies of scale is weak. For instance, Henderson (2000) highlights that in the drug industry most R&D projects already have the necessary critical mass and mergers are motivated by scale economies in activities other than R&D, like marketing and distribution. In addition, in order to reap scale economies, the new entity arising from a merger generally needs to restructure its R&D operations. Accordingly, anecdotal evidence from different industries indicates that horizontal mergers are frequently accompanied by cut of overlapping research programs and other measures aimed at rationalizing R&D.[6] This may have

[4] Resource and capability redeployment relates to the use by a merging firm of the other merging firm's resources and capabilities; this may involve transfer of assets and personnel from and to the previously separated units after completion of the deal or shared use of such resources and capabilities without physical transfer (see Capron, Dussauge and Mitchell, 1998, p. 631).

[5] For a survey of the theoretical and empirical literature on the relationship between firm size (and other firm characteristics) and R&D, see for instance Kamien and Schwartz (1982), Cohen and Levin (1989).

[6] These peculiar scale economies are termed "efficiency without synergies" by Farrel and Shapiro (2001). Examples in utilities and telecommunications are presented in "R&D in a world of M&A", Utility Business,

unexpected negative effects on the productivity of R&D departments due to the worsening organizational climate and ineffective motivations of research personnel (e.g. Bommer and Jalias, 1999), as will be discussed in greater detail in the last part of this section.

In this regard, the combination of diverse research programs so as to capture scope economies in R&D is more likely to engender beneficial effects. The econometric analysis of pharmaceutical firms by Henderson and Cockburn (1996) shows that larger R&D departments are more productive due to scope economies that arise from "internal knowledge spillovers" flowing between different yet related research activities, and from the sharing of basic knowledge between different projects.

In addition, studies inspired by the resource- and knowledge-based traditions (see for instance Wernelfelt, 1984; Winter, 1987; Conner and Prahalad, 1996; Grant, 1996; Kogut and Zander, 1996) argue that mergers are often motivated by the desire of firms to create novel combinations of idiosyncratic assets. Such argument especially applies to technological resources and capabilities (Granstrand and Sjölander, 1990; Capron *et al.*, 1998; Capron, 1999; Vermeulen and Barkema, 2001). Nonetheless, the beneficial effects of such recombination will depend on the *relatedness* of the knowledge bases of merging firms (Lane and Lubatkin, 1998. See also Nooteboom, 1992). From one side, if merging firms have very similar knowledge bases, the novelty value of their combination will be limited, as there will not be much to learn from each other. From the other side, if knowledge bases are very distant, absence of shared languages and similar cognitive structures will inhibit communication and knowledge transfer; under such circumstances, mutual learning will be difficult due to lack of adequate "absorptive capacity" (Cohen and Levinthal, 1990). In this vein, Ahuja and Katila (2001) track acquisition activity in the chemical industry in the period 1980-1991; they focus on the impact of mergers on the innovation outputs of acquiring firms, as measured by patenting frequency. They show that after controlling for R&D expenses, the

May 1999, issue 4. Evidence on the drug industry is illustrated in "Drug company mergers cut R&D", Drug relatedness of the knowledge bases of the acquiring and acquired companies has an inverted U-shaped relation with the subsequent innovation output of the acquiring company.[7]

In the present work, we consider whether the R&D activities of merging companies focus on the same or on complementary technological fields. The former situation allows to reap the alleged benefits of R&D scale economies, while the latter one is conducive to R&D scope economies and to synergistic effects that arise from combination and redeployment of merging firms' technological resources and capabilities. We then derive the following hypotheses.

Hypothesis 1a. If R&D scale economies are at work, mergers between firms with overlapping R&D activities will lead to greater R&D productivity, due to either a reduction of R&D inputs with similar R&D outputs, or to an increase of R&D outputs with similar R&D inputs.

Hypothesis 1b. If R&D scope economies and other synergistic effects are at work, mergers between firms with complementary R&D activities will lead to greater R&D productivity, due to either a reduction of R&D inputs with similar R&D outputs, or to an increase of R&D outputs with similar R&D inputs.

Market Power in Product and Technology Markets

A long-time tradition contrasts the market power effects of horizontal mergers to the efficiency effects.[8] A reduction in product market competition is likely to affect innovation in a fairly complex way (see for instance Aghion, Bloom, Blundell, Griffith and Howitt, 2002. For a survey of empirical evidence, see again Kamien and Schwartz, 1982; Cohen and Levin, 1989). On the one hand, since the seminal work by Arrow (1962), the industrial organization

Topics, June 19, 2000.

[7] Ahuja and Katila (2001) also examine the effect on the innovation output of the acquiring company of the size of the knowledge base of the target company. In particular, they show that if the acquiring and target companies' knowledge bases are similar in size, the intra-organizational learning process is likely to be difficult, resulting in a deterioration of R&D performances. We will come back to this issue later on in this section.

[8] See, among others, the recent international comparison by Gugler, Müller, Burcin Yurtoglu and Zulehner (2003). See also the discussion of antitrust practices by Farrel and Shapiro (2001).

literature has argued that with greater product market competition, R&D expenditures are encouraged precisely because they allow innovative firms to escape competition. On the other hand, the schumpeterian tradition claims that more competition reduces the monopoly rent that rewards successful innovation, thus reducing the incentives to invest in R&D (see for instance Dasgupta and Stiglitz, 1980). In addition, the desire to preserve a monopoly rent in the face of the threat of entry of new innovative competitors may induce firms that enjoy such rent to invest more in R&D (see Gilbert and Newbery, 1982).

In addition to the effects on R&D engendered by the concentration of product markets, markets for technologies are likely to be directly affected by horizontal mergers that result in greater concentration of R&D activities. Nevertheless, the net effect again is uncertain, as opposed forces are likely to be at work (see for instance De Bondt, 1996). On the one hand, the race for technological innovations may slowdown after the integration of two formerly competing firms; in fact, coordination of R&D may result in reduced R&D investments, elimination of competing technologies, or control of standardization committees. On the other hand, if the appropriability regime is weak due to the existence of substantial technological spillovers that render imitation easier, firms have low incentives to invest in R&D; acquisition of a technological rival may allow a firm to internalize technological spillovers, thus favoring R&D investments.

In conclusion, our expectations as to the potentially anti-competitive effects of horizontal mergers and their implications for R&D are ambiguous. We then derive the following hypotheses.

> *Hypothesis 2a*. If merging firms are rivals in product or technology markets, a merger will result in a decrease of R&D inputs, outputs, and productivity, and in a slowdown of technological competition.
>
> *Hypothesis 2b*. If merging firms are rivals in product or technology markets, a merger will result in an increase of R&D inputs, outputs, and productivity.

Post-Deal Organization of Merging Firms

Change in control mechanisms. Growth through acquisitions leads to greater organizational complexity, as the number and the variety of the units the top management team must oversee increase. In order to cope with greater span of control, top managers may adopt a multi-divisional organization and replace strategic controls with financial controls (Hitt *et al.*, 1996).[9] In turn, greater reliance on financial controls is likely to produce greater risk-aversion and short-termism in managerial ranks. As compensation and career prospects of middle managers are directly linked to the achievement of short-term financial objectives, long-term R&D investments will be reduced or postponed (Hoskisson and Hitt, 1988; Hoskisson, Hill and Hill, 1991).

Previous studies claim that the above argument especially applies to diversifying acquisitions (Hitt *et al.*, 1996). In accordance with such view, Hitt *et al.* (1991) show that diversifying acquisitions have more negative effects on the patenting intensity of firms than other acquisitions. In a similar vein, we expect cross-border acquisitions to lead to greater organizational complexity, favor adoption of a multi-divisional organization, and induce merging companies to rely to a greater extent on financial controls, with potentially noxious effects on R&D activity. Note also that the corporate cultures of firms located in different countries may significantly differ (Kogut and Singh, 1988). This reinforces the stimuli to abandon use of strategic controls in favor of financial controls. It also renders the post-deal integration process more difficult, thus further hampering R&D (see infra).[10] Hence, we derive the following hypothesis.

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[9] Strategic controls entail use of strategically relevant long-term criteria for the evaluation of the actions and performance of middle managers, while financial controls are based on objective standardized indicators such as return on investments, thus allowing top managers to save on information and communication costs.

[10] Nevertheless, cross-border acquisitions may be an efficient mechanism to access internationally dispersed knowledge, replacing market transactions. Hence, a trade-off between internal proximity (that is, proximity between headquarters and internationally dispersed laboratories) and external proximity (that is proximity of the multinational enterprise to foreign centers of excellence) may emerge, with mixed implications for the R&D process (Blanc and Sierra 1999). Accordingly, previous studies have shown that cross-border acquisitions have similar, and in some cases even better performances than domestic acquisitions (see Weber, Shenkar and Raveh,1996; Very, Lubatkin, Calori and Vega, 1997. See also Gugler et al., 2003).

Hypothesis 3. Cross-border mergers are more likely to engender organizational problems, to result in a decrease of R&D inputs, outputs and productivity, and to lead to greater focus on short-term R&D objectives than domestic mergers.

Post-deal integration. Acquisitions generally involve substantial transaction costs for selection of targets, negotiation, bidding, and above all post-deal integration (Barney, 1988). Before completion of a deal, merging firms may not be able to accurately identify efficiencies arising from the combination of their assets with those of the other firm because of lack of relevant information; potential sources of conflicts may also be neglected. It follows that the integration of the previously separated units is likely to absorb top managers' attention and energy, and to divert them from other activities (Jemison and Sitkin, 1986; Haspelagh and Jemison, 1991; Hitt *et al.*, 1996). As R&D investments generally have long-term pay-offs, R&D activity will be among those that suffer most, with basic R&D and projects aimed at developing generic technologies being especially at risk. In fact, the reduction of top management's commitment to innovation may damage the "championing process" (Burgelman 1986), as the incentives of R&D project managers to struggle to identify and pursue new promising areas for innovation are hampered.

In addition, the integration process may involve disruption of merging firms' organizational routines (Singh and Zollo, 1998. See also Jemison and Sitkin, 1986; Haspelagh and Jemison, 1991). In order to combine the two previously independent entities, organizational structures, chains of command, channels of communications, and spheres of responsibility of managers, all need to be redefined. Such reorganization may deeply affect the functioning of R&D departments and the motivations of R&D personnel. Accordingly, Gerpott (1995) shows that in mergers between German firms, management interventions that were designed to promote learning opportunities and reduce uncertainty for acquired employees played a key role in assuring effective integration of the R&D departments of merging firms. On the contrary, restructuring and downsizing negatively affect the willingness of R&D personnel to take risks and make suggestions (Bommer and Jalajas, 1999); they may also induce key innovators to reduce their performances or even leave the firms (Ernst and Witt, 2000). This in turn has negative implications for firms' innovation rates.

The above remarks are especially pertinent for acquisitions that are not driven by technological motivations, such as those aimed at increasing market share or entering into a new market. On the contrary, if merging firms have experience of prior collaborations with each other, information asymmetries and the associated transaction costs are reduced. Furthermore, if merging firms have complementary rather than overlapping R&D activities, we expect organizational problems to be less severe as there is less room for integration and rationalization. Lastly, motivational problems are likely to be more acute for the target than for the acquirer. In fact, the available empirical evidence suggests that following a merger, the extent of the reorganization is greater in the R&D departments of target firms than in those of acquirers (see Capron et al., 1998). Furthermore, the difficulty of interpreting signals given by the management of the acquiring firm creates substantial uncertainty in target firms' managerial ranks (Hitt et al., 1996). This in turn may damage the motivations of key research personnel. Therefore, we derive the following hypotheses.

> *Hypothesis 4*. If mergers are driven by non-technological motivations, they are more likely to engender organizational problems, to result in a decrease of R&D inputs, outputs and productivity, and to lead to greater focus on short-term R&D objectives.
>
> *Hypothesis 5*. If merging firms have prior experience of collaborative relations with each other, mergers are less likely to engender organizational problems, to result in a decrease of R&D inputs, outputs and productivity, and to lead to greater focus on short-term R&D objectives.

Hypothesis 6. If merging firms have complementary rather than overlapping R&D activities, mergers are less likely to engender organizational problems, to result in a decrease of R&D inputs, outputs and productivity, and to lead to greater focus on short-term R&D objectives.

Hypothesis 7. Mergers are more likely to engender organizational problems, to result in a decrease of R&D inputs, outputs and productivity, and to lead to greater focus on short-term R&D objectives in the target company than in the acquiring company.

METHODS AND VARIABLES

The Sample

Most previous studies that examined the effects of mergers on R&D through the estimates of econometric models used either published yearly statistics (e.g. R&D expenses, patents) or survey-based firm-level data. Such level of analysis is too aggregate in that it does not permit to unambiguously relate the detected changes in R&D inputs and/or outputs to the characteristics of individual mergers. In fact, firms often make several acquisitions in a given year. Moreover, the acquired assets may be only a portion of target firm's assets, and acquisitions are sometimes followed by partial divestitures of acquired assets. Lastly, a quite long time period usually elapses before the effects of a merger become apparent in firm-level R&D output data.

The present study departs from previous literature in that we aim to detect the effects of individual mergers. Accordingly, our sample consists of 31 horizontal mergers in medium- and high-tech industries concluded in the last 15 years with 62 firms involved. The key characteristics of the mergers included in the sample are illustrated in Table A1 in the Appendix. As will be apparent in next sections, the sample is quite heterogeneous in spite of its small size (see also Cassiman et al., 2003). In the empirical analysis, we compare the pre-deal and post-deal situations of the 62 merging firms. More precisely, we relate changes in the R&D inputs, outputs, performance, and mission of merging firms to the characteristics of mergers; we also distinguish between target and acquiring companies. For this purpose, we rely on qualitative data and perceptual measures based on judgements of firms' informed top managers. In fact, information relating to changes in firms' R&D activities engendered by an individual merger was provided by top managers of acquiring firms (typically, the vice-president for strategy and/or the chief technology officer) during in-depth face-to-face interviews. The interviews were at least two hours long (actually, in several cases we had several meetings with firm managers) and were primarily aimed at the realization of case studies. In the interviews we used a structured questionnaire that allowed to collect data in a standardized format suitable for statistical and econometric analysis. Data collected during the interviews were then cross-checked with firms' published documents; if necessary, they were subsequently rediscussed with the interviewed managers so as to be sure that questions were unambiguously interpreted by them. Therefore, in spite of their qualitative nature, the data used in this study can be regarded as quite accurate and reliable.

It is fair to acknowledge that our sample of mergers suffers from some limitations. First and foremost, the sample is not random and so it cannot be regarded as representative of the merger population in the period under scrutiny. While in selecting acquiring firms we took care of assuring heterogeneity across industries and countries, the individual acquisitions were selected by firm managers. As interviews were quite demanding in terms of absorption of managers' time, this procedure was necessary to assure their collaboration; of course, it may be a source of bias. Managers generally chose large deals that they deemed as successful. On the contrary, no hostile takeover is included in the sample. Leveraged deals also are rare. Therefore, the organizational problems related to post-deal integration that were highlighted by previous studies might be underestimated in our sample of mergers. Furthermore, the size of the sample is relatively small; this may limit the statistical significance of the econometric results. This notwithstanding, we think that an econometric analysis of the data collected from the case studies can shed new light on the effects of mergers on R&D and considerably extend the available knowledge on this issue.

As was mentioned above, interviewed managers generally selected successful mergers. Of course, this also influences changes engendered by the sample mergers in merging firms' R&D activities, as is apparent from the mean value of the detected changes (see Table A2 in the Appendix). For instance, according to managers' opinions, sample mergers resulted in a moderate increase of returns to R&D expenditures (1.6 in a 9 point Likert scale ranging from -4 to +4). This was mainly the outcome of better management of the R&D process, greater speed in innovative activities, and improvements and enlargement of firms' technological capabilities. Nonetheless, reported increases in patenting activity after the merger were surprisingly modest (1.0 in a 4 point Likert scale). In addition, mergers resulted in extensive reshuffling and rationalization of R&D operations. From one side, in almost half of merging firms overlapping R&D projects were eliminated after the merger, while non concurrent R&D projects were cut by 27% of firms. From the other side, new R&D projects were launched by 40% of firms. It is noteworthy that on average, there was a slight reduction of firms' R&D personnel after the deal (-0.18 in a 10 point Likert scale ranging from -5 to +4). Furthermore, as was expected, post-deal integration and motivational problems were assigned quite low scores, even though loss of key researchers due to voluntary abandonment was mentioned by 16% of merging firms. Lastly, in 61% of firms R&D operations were refocused on specific technological fields; on average, greater emphasis was placed on development as opposed to research, with a shortening of the time horizon of the typical R&D project.

The Dependent Variables

In the survey questionnaire there are several questions concerning changes in R&D inputs, outputs, performance, and mission that were directly attributable to the specific merger under consideration. This reflects the complexity and multi-dimensional nature of the R&D process. However, synthetic indicators are needed to provide a more parsimonious description of the phenomena at hand. Therefore, we subdivided the whole set of variables related to R&D into four groups (see Table A2 in the Appendix): i) R&D inputs; ii) R&D outputs; iii) R&D performance; and iv) R&D mission. Then, we run a principal component analysis for each group of variables. The results are displayed in Tables 1-4, which show the values of the factor loadings for each component. The eight synthetic indicators we obtain, coinciding with the n components of each principal component analysis for which the associated eigenvalues are greater than 1, have an obvious economic interpretation which is mirrored by the name of the indicator. In addition, they explain a substantial amount of the total variance of the data. Lastly, all values of the Kaiser-Meyer-Olkin measure exceed 0.5, with only one exception (relating to R&D performance; in this case, the value is 0.498); so they support the adequacy of use of such indicators (see Kaiser, 1958 and 1960).

The Explanatory Variables

In order to test the theoretical hypotheses, we considered a set of variables modulating the impact of mergers on the R&D inputs, outputs, performance, and mission indicators. Definitions of explanatory variables are given in Table 5, while in Table 6 we illustrate the predicted sign of their coefficients in the various econometric models; the columns refer to the synthetic indicators presented in the previous section.

First of all, we considered the distribution of merging firms' R&D activities across technological fields. We defined two firms as having complementary R&D activities if they had R&D operations in the same broadly defined technology class but not in the same specific technological fields: in this case COMPLTECH equals 1[11]. As a preliminary remark, it is worth noting that in our sample of mergers all merging firms had R&D operations either

[11] A description of the main R&D activities of all merging firms is provided in TableA1 in the Appendix. Some examples help clarify the definitions adopted in this work. In merger n. 2, the R&D operations of both merging firms focused on cardiovascular instruments; hence for this merger COMPLTECH equals zero. On the contrary, in merger n. 22, while both merging firms were in biotechnology, their R&D projects targeted different therapeutic fields; so COMPLTECH=1. Lastly, in merger n. 14 merging firms were in the same technological area (advanced materials) and had both overlapping and complementary R&D operations (while both firms had capabilities in coating technologies, firm A was also in metal forming technologies). In order to avoid double counting, in this case again COMPLTECH was equal to zero.

in the same or in complementary technological fields (or in both). In other words, there were no deals between firms that had developed technological capabilities in unrelated technological fields; this is hardly surprising as our sample includes only horizontal mergers. It follows that when COMPLTECH equals zero, merging firms have overlapping R&D operations. The predicted effect of COMPLTECH in the various models is rather complex (see Table 6).

Let us firstly consider Hypotheses 1a and 1b. A positive coefficient of COMPLTECH in the "Increase of R&D productivity" model may signal that R&D scope economies and other synergistic effects arising from combination and redeployment of merging firms' complementary technological assets prevail over R&D scale economies. Under such circumstances, we also expect a negative coefficient in the "Increase of R&D effort" model and/or a positive one in the "Increase of R&D output" model. On the contrary, should R&D scale economies prevail, the predicted signs of the coefficients of COMPLTECH in the three models would be reversed.[12] However, a relatively more beneficial effect of mergers on firms' R&D productivity when merging firms are in closely related technological fields but have no overlapping R&D operations (and so COMPLTECH equals 1) may also be determined by avoidance of the negative consequences on firms' organization of extensive restructuring and rationalization of R&D departments (see Hypothesis 6). In this latter case, COMPLTECH should also exhibit a positive coefficient in both the "Increase of R&D effort" and "Increase of R&D output" models, and a negative one in the "R&D rationalization", "Organizational and motivational problems in R&D" and "Focusing of R&D mission" models. Alternatively, when firms are in the same technological fields (and COMPLTECH equals zero), a merger results in greater concentration of R&D activities. Therefore, a positive

[12] As was mentioned above, all merging firms in our sample of mergers had either overlapping or complementary R&D operations. In the former case, COMPLTECH=0, while in the latter one COMPLTECH=1. Therefore, if both R&D economies of scale and scope were at work, we might not be able to detect any significant effects of COMPLTECH on the indicators of R&D inputs, outputs, and productivity. We acknowledge this as a limit of the present study.

coefficient of COMPLTECH in the “Increase of R&D effort”, “Increase of R&D output” and “Increase of R&D productivity” models may also indicate that greater market power in technology markets negatively affects R&D. Under such circumstances, a negative coefficient should show up in the “Decrease of technological competition” model.

Second, RIVAL equals 1 if merging firms were rival before the deal. We define two firms as rivals if the following conditions are both met: i) they are in the same product lines (i.e. they have an overlapping product mix), and ii) they are in the same geographical markets or have the same customer base. As is highlighted by Hypotheses 2a and 2b, the fact that merging firms competed in the same product market before the merger may have positive or negative effects on R&D inputs, outputs, and performance. So, the sign of the coefficients of this variable in the “Increase of R&D effort”, “Increase of R&D output” and “Increase of R&D productivity” models is uncertain. On the contrary, a positive coefficient in the “Decrease of technological competition” model would unambiguously signal a reduction of technological competition after a merger that combines rival firms.

Third, CROSSBORDER is coded 1 for firms that merged with a firm located in a different country. This variable allows to examine the effects on R&D of cross-border acquisitions as opposed to domestic ones. Relying on Hypothesis 3, we predict a negative effect of such variable on measures of R&D inputs, outputs, and productivity, and a positive effect on the indicators that reflect the focusing of the R&D mission and the extent of the organizational problems engendered by a merger. In fact, following a cross-border acquisition, replacement of strategic controls with financial controls is more likely than after a domestic merger, as the variety and complexity of firms’ operations increase. In addition, integration of internationally dispersed activities is more difficult and will likely absorb greater managerial energies. Nonetheless, as was reminded in footnote 10, cross-border deals may be motivated by the need to access an internationally dispersed knowledge base, assuring more efficient coordination in comparison with market transactions. If this latter effect prevails, the sign of the coefficients of this variable in the “R&D effort”, “R&D output” and “R&D productivity” models may be reversed.

The extent to which a merger was driven by technology-related motivations is captured by TECHMOTIV. In the questionnaire, the following technological 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 technological resources and capabilities possessed by the other firm, access to technological resources and capabilities embedded in the environment of the other firm, get competing technologies under control, reduce the risk of being imitated, and set a common standard. For each motive, interviewed managers were asked to assign a score using a 5 point Likert scale (from 0=unimportant to 4=of crucial importance). TECHMOTIV equals the maximum score.[13] In accordance with Hypothesis 4, we claim that if mergers are not driven by technological motivations, they are more likely to crowd out investments in R&D and have other negative organizational implications for R&D activities. Therefore, we predict for TECHMOTIV a positive coefficient in the “Increase of R&D effort”, “Increase of R&D output”, “Increase of R&D productivity” models, and a negative one in the “Organizational and motivational problems in R&D” and “Focusing of R&D mission” models.

Moreover, the dummy variable PREVIOUSLINK is equal to 1 if merging firms had established prior collaborative relations with each other before the deal (i.e. joint ventures and other equity and non-equity collaborations, either of technological or of other nature) or were engaged in customer-supplier relations. In accordance with Hypothesis 5, if firms have acquaintance of each other before the merger, information asymmetries are reduced and the integration process is likely to be less demanding of managers’ time and energy. Disruption

[13] We also investigated the importance of technology unrelated motives of mergers. They were classified as follows: rationalization of production, spread fixed costs of production over larger output, rationalization of marketing and sales, access to specialized assets and capabilities in production, access to specialized 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. Among technology-related motives, access to technological assets possessed by the other firm was assigned the highest average score, while increase of market share was by far the most important technology unrelated motive (see European Commission-DG Research, 2002).

of firms' organizational routines and demoralization of technical personnel also are less likely. So we predict for this variable the same coefficients as for TECHMOTIV.

Lastly, in order to investigate the different impact of mergers on the post-deal R&D activities of the acquiring and acquired companies, we considered the dummy variable TARGET. It equals 1 for firms that could unequivocally be identified as acquired companies. For this purpose, we relied on both the opinions of interviewed managers and information provided by secondary sources. Organizational and motivational problems that hamper post-deal R&D activity are likely to be more severe in target than in acquiring companies. Therefore, in accordance with Hypothesis 7, the sign of the coefficient of TARGET should be opposite to the one of PREVIOUSLINK. In accordance with the results of previous empirical studies, we also expect TARGET to exhibit a positive coefficient in the "R&D rationalization" model.

Descriptive statistics of the explanatory variables and the correlation matrix are presented in Table 7. In our sample there are only two "mergers between equals"; in the remaining mergers we were able to identify the acquired and acquiring companies. In 13 out of 31 cases merging firms have non overlapping, complementary R&D operations. In the sample there are 10 mergers between rival firms. In 9 out of such 10 mergers, merging firms were in the same technological fields; this explains the negative correlation between COMPLTECH and RIVAL. Cross-border deals make up the majority of the sample (71%). In slightly more than half of mergers, merging firms had established collaborative relations with each other prior to the deal. Lastly, in most cases interviewed managers described the set of technology-unrelated motives as more important than technology-related ones in the merger decision. In fact in 15 cases out of 31, all technology-related motives were assigned a score equal to zero.

THE RESULTS OF THE ECONOMETRIC ESTIMATES

The results of the estimates of the OLS models are illustrated in Table 8. Due to the small number of observations, we present the estimates of restricted models (the estimates of the unrestricted models are in Table A3 in the Appendix). For each model we report the value of the coefficients of explanatory variables, standard errors, adjusted R squared, and F test.

Hypotheses 1a and 1b relate to the efficiency effects of mergers in the R&D sphere. As to this aspect, empirical results are weak, possibly as a consequence of absence in the sample of dyads of merging firms with R&D operations in unrelated technological fields (i.e. firms with neither overlapping nor complementary R&D operations). COMPLTECH has positive, though insignificant coefficients in the "Increase of R&D effort", "Increase of R&D outputs" and "Increase of R&D productivity" models (see the unrestricted models in Table A3 in the Appendix). So we are not able to accept either Hypothesis 1a or Hypothesis 1b.

On the contrary, in accordance with Hypothesis 2a, when merging firms are rival in technology and/or product markets, mergers have negative implications for R&D. First, COMPLTECH has a negative coefficient significant at 99% in the "Decrease of technological competition" model. Second, RIVAL exhibits negative coefficients statistically significant at conventional confidence levels in the "Increase of R&D effort", "Increase of R&D output" and "Increase of R&D productivity" models.

The results of the estimates also indicate that quite unsurprisingly, when merging firms have overlapping R&D operations, the extent of the reorganization of R&D departments after completion of the merger is substantially greater than with mergers between firms that have R&D activities in complementary technological fields; in fact, the coefficient of COMPLTECH in the "R&D rationalization" model is negative and significant at 99%.[14] In accordance with Hypothesis 6, R&D rationalization leads to organizational problems, demoralization of R&D personnel, and increased focus on short term R&D objectives. In fact, COMPLTECH exhibits large negative coefficients, significant at conventional confidence

[14] As to this aspect, termination of concurrent and non concurrent R&D projects after completion of the merger was mentioned by 61.1% and 38.9% of merging firms with overlapping R&D operations (COMPLTECH = 0), respectively; such moves were quite rare if merging firms had no R&D activities in the same technological fields (they were mentioned only by 30.7% and 11.5% of merging firms, respectively). Cuts of R&D personnel also were infrequent in this latter category of mergers (they occurred only in 4 out of 26 firms).

levels, in the “Organizational and motivational problems in R&D” and “Focusing of R&D mission” models.

On the contrary, our findings do not support Hypothesis 3; there is no evidence in our data that the implications for R&D of cross-border mergers are more negative than those of domestic mergers. The reason may be that when merging firms are located in different countries, R&D departments conserve greater autonomy after completion of the deal. In fact, as is apparent from the negative, significant at 99% coefficient of CROSSBORDER in the “R&D rationalization” model, firms’ managers may have lower propensity to restructure international R&D operations. In turn, this has positive organizational implications which may overwhelm the difficulties arising from combination of firms with different cultures; accordingly, CROSSBORDER has a negative though insignificant effect in the “Organizational and motivational problems in R&D” model.

Hypotheses 4 and 5 are partially confirmed by our findings. The coefficients of TECHMOTIV which captures the importance of the technological motivations of mergers, are positive and statistically significant at conventional confidence levels in the “Increase of R&D effort” and “Increase of R&D output” models; however, such variable has no significant effects in the remaining models. Furthermore, the establishment of alliances between merging firms prior to a deal positively affects R&D effort, outputs, and productivity: in the corresponding models the coefficients of PREVOUSLINK are positive and the latter two are significant at 95%. However, again the expected negative impact of such variable in the “Organizational and motivational problems in R&D” and “Focusing of R&D mission” models does not show up.

Lastly, we failed to detect any difference between acquiring and acquired companies in the impact of mergers on R&D. The coefficients of TARGET are never significant at conventional confidence levels. This may well be a consequence of the sample selection bias that was mentioned in previous sections and, in particular, of absence in the sample of hostile takeovers.

DISCUSSION AND CONCLUSION

The aim of this paper was to assess the effects of horizontal mergers on the R&D activity of merging firms. Contrary to most previous studies, we have tried to identify the impact of individual mergers and to relate it to several modulating factors. For this purpose, we have considered a sample composed of 31 mergers concluded in the last 15 years involving 62 firms. First, we have collected very detailed qualitative data on changes in merging firms' R&D inputs, outputs, performance, and mission engendered by a particular merger through face-to-face interviews with firms' top managers. Then, we have built synthetic indicators of changes in R&D through principal component analyses. Lastly, we have regressed such indicators against a set of explanatory variables that reflect the characteristics of mergers and also discriminate between target and acquiring companies.

The empirical results confirm the view that mergers with different characteristics have different effects on R&D. First of all, the combination of firms that have overlapping R&D operations and are in the same product markets is likely to negatively affect merging firms' R&D. From one side, in line with previous studies (see for instance Henderson and Cockburn, 1996), we found no evidence of greater efficiency due to economies of scale in R&D. Nor R&D rationalization seems to be beneficial to firms; on the contrary, it may be a source of organizational problems leading to organizational turmoil, demoralization of R&D personnel, and focalization on short-term R&D objectives (see also Jemison and Sitkin, 1996; Haspelagh and Jemison, 1991; Singh and Zollo, 1997; Bommer and Jalajas, 1999, Ernst and Witt, 2000). From the other side, when mergers combine companies with R&D in the same technological fields, the risk arises of a decrease of technological competition, due to elimination of a potential competitor, lower risk of imitation, and tighter control of standardization committees. The negative effects on R&D inputs, outputs, and productivity are exacerbated when merging firms also compete in the same product market before the deal. Altogether, such results indicate that in accordance with the seminal work by Arrows (1962), in oligopolistic industries dominated by a few players with large market shares an increase of market power through a horizontal merger is likely to adversely affect the incentives to and the efficiency of R&D expenses.

Second, whether mergers between companies that have complementary R&D operations lead to greater efficiency in R&D is not clear from our results. In fact, we were not able to provide compelling evidence in support of the argument proposed in the competence-based literature (see for instance Ahuja and Katila, 2001) that with all else equal, combination of firms with moderately dissimilar knowledge bases has positive effects on R&D outputs and performances.

Furthermore, according to our findings, horizontal mergers that are driven by technology-unrelated motives have negative effects on R&D inputs and outputs. On the contrary, cross-border mergers do not seem to differ from domestic ones as to the effects on R&D; this result is in line with those of the empirical literature that has examined the economic and financial performances of mergers (see for instance Conn and Connell, 1986; Harris and Ravenscraft, 1991; Morck and Yeung, 1992; Gugler et al., 2003). A possible explanation is that there are opposed forces at work. On the one hand, a cross-border merger may lead to replacement of strategic controls with financial controls as top managers struggle to deal with increasing information and communication costs; this may adversely affect R&D activities (see the discussion by Hitt et al., 1991, 1996 in a related empirical context). On the other hand, such effect may be offset by the benefits accruing from internalization of arm’s length transactions in international markets for new technologies (Blanc and Sierra, 1999). Alternatively, because of greater physical distance, firm managers may refrain from reshuffling R&D operations after a cross-border merger, thus avoiding the associated organizational and motivational problems.

As to this latter aspect, we do find evidence that post-deal integration is a source of serious problems for R&D activities. As was said above, such problems are more severe when merging firms try to rationalize overlapping R&D operations. On the contrary, when firms have experience of prior collaborations with each other, information asymmetries are reduced and trust may develop (see Gulati, 1995; Nooteboom, 1999). This makes integration of merging firms easier, limiting clashes of culture and unintentional disruption of firms' organizational routines. Consequently, the likelihood that integration negatively influences the functioning of R&D departments and the motivations of R&D personnel is reduced.

Implications for Managers

Our findings confirm that post-deal integration indeed is a difficult task that may have negative implications for R&D. Therefore, firms' top managers must take care that combination of previously separated operations does not divert their time and energy from R&D and other long-term investments. The risk of inadvertently creating organizational turmoil, damaging the "championing process" and inducing key R&D personnel to leave the firm appears to be quite concrete after a merger.

In this perspective, alliances may be an effective device to reduce information asymmetries between the two parties of a merger, thus alleviating the organizational burden and the motivational problems inherent in the merger. In the literature numerous studies have argued that alliances involve learning (see for instance Mody, 1993; Simonin, 1997). Trough the establishment of an alliance firms may obtain private information on the other party that may reduce the transaction costs of a subsequent merger; this is an important additional form of learning in alliances.

Implications for Anti-Trust Authorities

A well established tradition in anti-trust contends that mergers between firms that are rivals in product markets lead to greater market power, with negative implications for allocative efficiency (see Gugler et al., 2003. See also Jacquemin and Slade, 1989). Our results indicate that such mergers also have negative effects on R&D inputs, outputs, and productivity. Hence, a reduction of dynamic efficiency due to a decrease of innovation rates after a merger between competitors is an additional concern for anti-trust authorities.

Furthermore, we detected a reduction of technological competition following a merger between firms that were investing in the same technological fields, independently of whether they competed in the same product markets or not. Therefore, such mergers deserve a careful scrutiny by anti-trust authorities, because of the associated potentially negative implications for dynamic efficiency.

Implications for Research

In this study, we departed from most previous work (for an exception see Cassiman et al., 2003) in that we tried to detect changes in R&D activities of merging firms that are directly attributable to an individual merger. For this purpose, we relied on a large set of qualitative and perceptual measures based on judgements expressed by informed top managers. Such measures were used to build indicators suitable for statistical and econometric analysis. We think that this is an important step forward as it allows to overcome several methodological problems encountered by previous studies that related changes in firm-level annual data on R&D inputs and/or outputs to the aggregate merger activity of firms in a given year.

Of course, we are aware of the limits of the present study. The most important one is that the sample of mergers is small and is not random. This may possibly explain why some of the empirical results illustrated in the previous sections are weak. Even when the results are statistically robust, they should be regarded as preliminary and wait for further corroboration in other empirical settings. In addition, we were not able to consider other important modulating factors, such as the friendly or hostile nature of an acquisition and the type of financing that was used. Nonetheless, we think that the methodological approach adopted in this paper is very promising for future research. In particular, replication of this study with survey data relating to a large sample representative of the merger population may considerably extend our understanding of the effects of mergers on R&D.

TABLE 1

Principal Component Analysis of the Effects of Mergers on R&D Inputs

Questions	*R&D input factors*		
	Increase of R&D effort	*R&D rationalization*	*New R&D fields and sources*
Increase of physical R&D facilities	0.85	-0.18	–
Increase of R&D personnel	0.85	-0.30	–
More funds internally available to finance R&D projects	0.71	0.17	0.28
Launch of new R&D programs in technological fields already covered by the company	0.45	0.34	0.53
Increase of the scale of the typical R&D project	0.48	0.51	–
Termination of concurrent R&D programs	-0.25	0.75	–
Termination of other (non concurrent) R&D programs	–	0.82	–
Increase of the use of external R&D sources	–	–	0.83
Launch of new R&D programs in technological fields new to the company	–	–	0.81
Eigenvalues	*2.68*	*1.89*	*1.36*
Cumulative % of variance	*27.36*	*46.98*	*65.98*
Kaiser-Meyer-Olkin Measure of sampling adequacy		*0.58*	

Legend
The Varimax rotation has been applied and absolute values lower than 0.15 have been eliminated.

TABLE 2

Principal Component Analysis of the Effects of Mergers on R&D Outputs

Questions	*R&D output factors*	
	Increase of R&D output	*Decrease of technological competition*
Greater speed in introducing new products	0.76	0.21
Greater speed in introducing new production processes	0.75	–
More patents granted	0.74	–
Greater speed in developing technological knowledge	0.74	-0.39
Improvement of existing technological competencies	0.70	–
Development of new technological competencies	0.66	–
Better exploitation of the existing technological competencies	0.48	0.19
Decreased danger of being imitated	–	0.85
Elimination of competing product standards	–	0.82
Eigenvalues	*3.459*	*1.625*
Cumulative % of variance	*37.957*	*56.496*
Kaiser-Meyer-Olkin Measure of sampling adequacy	*0.62*	

Legend
The Varimax rotation has been applied and absolute values lower than 0.15 have been eliminated.

TABLE 3

Principal Component Analysis of the Effects of Mergers on R&D Performance

Questions	*R&D performance factors*	
	Increase of R&D productivity	*Organizational and motivational problems in R&D*
More productive R&D personnel	0.88	–
Improved management of the R&D process	0.66	–
Increase of returns to R&D expenditures	0.63	-0.39
Greater complexity, less focus and/or slower decision making in R&D	–	0.84
Less motivated R&D personnel	–	0.85
Loss of key researchers (voluntary abandonment)	–	0.55
Eigenvalues	*1.92*	*1.61*
Cumulative % of variance	*31.76*	*58.80*
Kaiser-Meyer-Olkin Measure of sampling adequacy	*0.50*	

Legend
The Varimax rotation has been applied and absolute values lower than 0.15 have been eliminated.

TABLE 4

Principal Component Analysis of the Effects of Mergers on R&D Mission

Questions	*R&D mission factors*
	Focussing of R&D mission
Shorting of the typical time horizon of R&D projects	0.85
Focussing of R&D on specific technological fields	0.68
Greater emphasis on development	0.62
Eigenvalues	*1.57*
Cumulative % of variance	*52.38*
Kaiser-Meyer-Olkin Measure of sampling adequacy	*0.51*

Legend
The Varimax rotation has been applied.

TABLE 5

Definitions of Explanatory Variables

Variable	*Definition*
COMPLTECH	=1 if merging companies had distinctive technological strengths in complementary but not in similar technological fields[a]
RIVAL	=1 if merged companies a) were in the same business and b) were in the same geographic markets or competed for the same customer base
CROSSBORDER	=1 for cross-border deals
TECHMOTIV	Maximum score assigned by merging firms' managers to technology-related motives[b]
PREVIOUSLINK	=1 if merging companies were engaged in supply relations or had established collaborative relations with each other before the deal
TARGET	=1 for the acquired company

Legend

[a] In the sample there was no merger between companies that had R&D operations neither in complementary nor in similar technological fields.

[b] 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.

TABLE 6

Predicted Effects of the Explanatory Variables

	R&D Inputs		R&D Outputs		R&D Performance		R&D Mission
	Increase of R&D effort	*R&D rationalization*	*Increase of R&D output*	*Decrease of technological competition*	*Increase of R&D productivity*	*Organizational and motivational problems in R&D*	*Focussing of R&D mission*
COMPLTECH							
- Scale economies	+	n.s.	–	n.s.	–	n.s.	n.s.
- Scope economies	–	n.s.	+	n.s.	+	n.s.	n.s.
- Market power	+/–	n.s.	+/–	–	+/–	n.s.	n.s.
- Post-deal integration	+	–	+	n.s.	+	–	–
RIVAL	+/–	n.s.	+/–	+	+/–	n.s.	n.s.
CROSSBORDER	–	n.s.	–	n.s.	–	+	+
TECHMOTIV	+	n.s.	+	n.s.	+	–	–
PREVIOUSLINK	+	n.s.	+	n.s.	+	–	–
TARGET	–	+	–	n.s.	–	+	+

Legend
+: positive effect; –: negative effect; +/–: uncertain net effect; n.s.: no effect.

TABLE 7

Descriptive Statistics of the Explanatory Variables and Correlation Matrix

Variable	*Min.*	*Max.*	*Mean*	*Std. Dev.*	COMPLTECH	RIVAL	CROSS BORDER	TECHMOTIV	PREVIOUSLINK	TARGET
COMPLTECH	0	1	0.42	0.50	1					
RIVAL	0	1	0.32	0.47	-0.45	1				
CROSSBORDER	0	1	0.71	0.46	-0.03	0.14	1			
TECHMOTIV	0	4	1.93	1.91	0.27	-0.12	0.05	1		
PREVIOUSLINK	0	1	0.52	0.50	0.17	-0.16	-0.05	-0.07	1	
TARGET	0	1	0.47	0.50	-0.01	0.04	0.03	-0.07	0.00	1

TABLE 8

Results of the Econometric Estimates

Variable	R&D Inputs: *Increase of R&D effort*	R&D Inputs: *R&D rationalization*	R&D Outputs: *Increase of R&D output*	R&D Outputs: *Decrease of technological competition*	R&D Performance: *Increase of R&D productivity*	R&D Performance: *Organizational and motivational problems in R&D*	R&D Mission: *Focussing of R&D mission*
COMPLTECH		-0.97^{**} (0.35)		-1.02^{**} (0.34)		-1.29^{***} (0.37)	-0.93^{*} (0.37)
RIVAL	-1.45^{**} (0.50)		$-1.55^{\dagger}$ (0.90)		-1.26^{***} (0.35)		
CROSSBORDER		-1.28^{***} (0.38)			0.44 (0.41)	-0.60 (0.49)	
TECHMOTIV	0.63^{***} (0.13)		0.40^{*} (0.19)				
PREVIOUSLINK	0.69 (0.49)		1.95^{*} (0.78)	0.54 (0.34)	0.84^{*} (0.35)		
TARGET							
CONSTANT	-1.11^{*} (0.51)	1.32^{***} (0.32)	-1.29 (0.85)	0.15 (0.28)	-0.34 (0.41)	$0.97^{\dagger}$ (0.54)	0.39 (0.26)
Adjusted R^2	0.36	0.21	0.16	0.11	0.19	0.12	0.07
F	12.22^{***}	9.31^{***}	4.97^{**}	4.62^{**}	5.88^{***}	5.35^{**}	5.70^{*}

Legend
Heterogeneity robust estimation (White corrected covariance matrix used). Standard errors in parentheses.
† p<.10; * p<.05; ** p<.01; *** p<.001

APPENDIX

TABLE A.1

Overview of Mergers and Merging Firms Included in the Sample

Merger nr.	*Firm nr.*	*Industry*	*Country*	*Relevant technological fields*
1	1	Aerospace	UK	Aeronautic engineering (R&D: aircrafts and avionic platforms)
	2	Aerospace	UK	Avionics (R&D: avionic components)
2	3	Biomedical instruments	Italy	Biomedical engineering (R&D: Cardiovascular surgery and cardiac devices)
	4	Biomedical instruments	US	Biomedical engineering (R&D: Cardiovascular surgery and cardiac devices)
3	5	Chemicals	US	Chemistry and advanced materials (R&D: polyolefins, catalysts and catalysis process)
	6	Chemicals	UK	Chemistry (R&D: polymer chemistry)
4	7	Chemicals	Germany	Chemistry and chemical engineering (R&D: specialty chemical processes)
	8	Chemicals	Germany	Chemistry and chemical engineering (R&D: specialty chemical processes)
5	9	Chemicals	Spain	Chemical engineering (R&D: commodity chemicals)
	10	Chemicals	Spain	Chemical engineering (R&D: commodity chemicals and petrochemicals)
6	11	Electrical machinery	Switzerland	Control engineering (R&D: building control systems)
	12	Electrical machinery	Switzerland	Control engineering (R&D: building control systems)
7	13	Electrical machinery	France	Automation engineering (R&D: control systems for industrial processes
	14	Electrical machinery	France	Automation engineering (R&D: control systems for industrial processes
8	15	Electrical machinery	Belgium	Electric engineering (R&D: transformers)
	16	Electrical machinery	Canada	Electric engineering (R&D: large power transformers)
9	17	Electrical machinery	Italy	Automation engineering (R&D: automation systems for automotive)
	18	Electrical machinery	US	Automation engineering (R&D: automation systems for automotive)
10	19	Electronics	Belgium	Analog electronics (R&D: display techniques)
	20	Electronics	US	Digital electronics (R&D: graphical engines; display techniques)

11	21	Energy production	UK	Nuclear engineering (R&D: fuel process and decommissioning)
	22	Energy production	US	Nuclear engineering (R&D: fuel process; energy systems)
12	23	Farm machinery	Italy	Mechanical engineering (R&D: design, engineering and testing of new products components and systems)
	24	Farm machinery	US	Mechanical engineering (R&D: design, engineering and testing of new products components and systems)
13	25	Household appliances	Italy	Mechanical and electronic engineering (product development: free-standing white goods)
	26	Household appliances	France	Mechanical and electronic engineering (product development: Built-in white goods)
14	27	Industrial materials	Belgium	Advanced materials (R&D: metal forming and coating technologies)
	28	Industrial materials	US	Advanced materials (development: specialty coating technologies)
15	29	Instruments	Belgium	Software engineering (R&D: software for testing systems)
	30	Instruments	Netherlands	Software and hardware engineering (R&D: data acquisition systems; image processing software)
16	31	Instruments	Italy	Instruments (R&D: transport signaling systems)
	32	Instruments	US	Instruments (R&D: transport signaling systems)
17	33	Micro-electronics	Italy	Microelectronics (R&D: semiconductors, power devices)
	34	Micro-electronics	France	Microelectronics (R&D: small signal devices)
18	35	Motor vehicles	Germany	Mechanical engineering (R&D: new drives; new concept vehicles)
	36	Motor vehicles	US	Mechanical engineering (development: new vehicle lines)
19	37	Non-ferrous metals	Belgium	Metallurgy and materials (R&D: cutting tool powders; zinc powders for batteries)
	38	Non-ferrous metals	Canada	Metallurgy and materials (research: cutting tool powders; nickel powders for batteries)
20	39	Pharmaceuticals	Switzerland	Pharmaceutical chemistry and biotechnology (R&D: cardiovascular and inflammatory diseases)
	40	Pharmaceuticals	Switzerland	Pharmaceutical chemistry and biotechnology (R&D: dermatics and transplantations)
21	41	Pharmaceuticals	US	Pharmaceutical chemistry and biotechnology (R&D: large biologics and small molecules for several therapeutic areas).
	42	Pharmaceuticals		Pharmaceutical chemistry and biotechnology (R&D: small molecules for several therapeutic areas; nutritional products)
22	43	Pharmaceuticals	Belgium	Pharmaceutical chemistry and biotechnology (R&D: allergies, central nervous system diseases, other diseases)
	44	Pharmaceuticals	US	Biotechnology (research: inflammatory diseases)
23	45	Plastics	Belgium	Plastics (R&D: vinyls)
	46	Plastics	Germany	Plastics (R&D: vinyls)
24	47	Rubber	Australia	(R&D: natural rubber)

	48	Rubber	US	(R&D: synthetic rubber)
25	49	Specialty chemicals	UK	Chemistry and chemical engineering (R&D: wide range of specialty chemicals)
	50	Specialty chemicals	Netherlands	Chemistry and chemical engineering (R&D: natural, polymer and synthetic chemistry)
26	51	Specialty chemicals	Netherlands	Chemistry and materials (R&D: chemical processes, materials,)
	52	Specialty chemicals	Netherlands	Chemistry and biotechnology (R&D: ferments and enzymes)
27	53	Specialty chemicals	Belgium	Chemical engineering (development: wide range of products and processes)
	54	Specialty chemicals	France	Chemistry and chemical engineering (R&D: high-performance compound materials)
28	55	Specialty Chemicals	Switzerland	Chemical engineering (product development)
	56	Specialty Chemicals	Germany	Chemical engineering and chemistry (R&D: materials; environment-friendly process)
29	57	Specialty Chemicals	Germany	Chemistry and chemical engineering (R&D: detergent and adhesives)
	58	Specialty Chemicals	Canada	Chemical engineering (development: chemical management services)
30	59	Steel	UK	Metallurgy (R&D: process control; environment-friendly technologies)
	60	Steel	Netherlands	Metallurgy (R&D: manufacturing processes;)
31	61	Textile machinery	Italy	Mechanical engineering (R&D: Computer aided manufacturing systems)
	62	Textile machinery	Italy	Mechanical engineering (R&D: Computer aided manufacturing systems)

TABLE A.2

The Impact of Mergers on R&D: Descriptive Statistics of Individual Answers

Questions	*Answer typology*	*Mean value*
R&D input factors		
Increase of physical R&D facilities	Discrete ordered variable (-5 to +4)	0.13
Increase of R&D personnel	Discrete ordered variable (-5 to +4)	-0.18
More funds internally available to finance R&D projects	Discrete ordered variable (-1 to +1)	0.39
Launch of new R&D programs in technological fields already covered by the company	Binary variable	0.40
Increased scale of the typical R&D project	Discrete ordered variable (-1 to +1)	0.45
Termination of concurrent R&D programs	Binary variable	0.48
Termination of other (non concurrent) R&D programs	Binary variable	0.27
Increased use of external R&D sources	Discrete ordered variable (-1 to +1)	0.08
Launch of new R&D programs in technological fields new to the company	Binary variable	0.40
R&D output factors		
Greater speed in introducing new products	Discrete ordered variable (0 to +4)	2.16
Greater speed in introducing new production processes	Discrete ordered variable (0 to +4)	2.10
More patents granted	Discrete ordered variable (0 to +4)	1.03
Greater speed in developing technological knowledge	Discrete ordered variable (0 to +4)	2.48
Improvement of existing technological competencies	Discrete ordered variable (0 to +4)	2.68
Development of new technological competencies	Discrete ordered variable (0 to +4)	2.23
Better exploitation of existing technological competencies	Discrete ordered variable (0 to +4)	1.89
Decreased danger of being imitated	Discrete ordered variable (0 to +4)	1.26
Elimination of competing product standards	Discrete ordered variable (0 to +4)	1.10
R&D performance factors		
More productive R&D personnel	Discrete ordered variable (0 to +4)	1.61
Improved management of the R&D process	Discrete ordered variable (0 to +4)	2.03
Increased returns to R&D expenditures	Discrete ordered variable (-4 to +4)	1.61
Greater complexity, less focus and/or slower decision making in R&D	Discrete ordered variable (0 to +4)	0.68
Less motivated R&D personnel	Discrete ordered variable (0 to +4)	0.52
Loss of key researchers (voluntary abandonment)	Binary variable	0.16
R&D mission factor		
Shorting of the typical time horizon of R&D projects	Discrete ordered variable (-1 to +1)	0.08
Focussing of R&D on specific technological fields	Binary variable	0.61
Greater emphasis on development	Discrete ordered variable (-1 to +1)	0.11

TABLE A.3

Results of the Unrestricted Econometric Estimates

Variable	R&D Inputs		R&D Outputs		R&D Performance		R&D Mission
	Increase of R&D effort	*R&D rationalization*	*Increase of R&D output*	*Decrease of technological competition*	*Increase of R&D productivity*	*Organizational and motivational problems in R&D*	*Focussing of R&D mission*
COMPLTECH	0.25	-1.06**	0.66	-0.85*	0.24	-1.44**	-0.99*
	(-0.50)	(-0.35)	(-0.73)	(-0.41)	(-0.45)	(-0.44)	(-0.42)
RIVAL	-1.34*	-0.08	-1.28	0.33	-1.22**	-0.08	0.03
	(-0.52)	(-0.35)	(-0.91)	(-0.37)	(-0.44)	(-0.56)	(-0.46)
CROSSBORDER	-0.05	-1.30***	0.19	-0.23	0.46	-0.60	0.08
	(-0.43)	(-0.38)	(-0.73)	(-0.41)	(-0.41)	(-0.49)	(-0.43)
TECHMOTIV	0.62***	0.07	0.36†	-0.03	-0.11	0.07	0.11
	(-0.12)	(-0.09)	(-0.20)	(-0.09)	(-0.10)	(-0.12)	(-0.10)
PREVIOUSLINK	0.66	-0.12	1.88*	0.54	0.78*	0.18	-0.23
	(-0.49)	(-0.32)	(-0.76)	(-0.32)	(-0.36)	(-0.42)	(-0.38)
TARGET	0.28	-0.08	-0.28	-0.13	0.05	0.05	0.01
	(-0.49)	(-0.33)	(-0.77)	(-0.33)	(-0.36)	(-0.39)	(-0.38)
CONSTANT	-1.31	1.35**	-1.53†	0.26	-0.25	0.79	0.25
	(0.57)*	(-0.40)	(-0.89)	(-0.56)	(-0.51)	(-0.77)	(-0.49)
Adjusted R^2	0.33	0.17	0.13	0.06	0.17	0.07	0.02

Legend
Heterogeneity robust estimation (White corrected covariance matrix used). Standard errors in parentheses.
† p<.10; * p<.05; ** p<.01; *** p<.001

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