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The impact of M&As on company innovation: evidence from the US medical device industry

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Abstract The acquisition of new technologies represents a vitally important and fundamental goal of many corporate managers, particularly those within the medical device industry. We collect data on ten medical device companies as our sample in this study, covering the period from 1990 to 2006; this sample is drawn from the top 20 companies in the US, on the basis of international sales performance. We also collect details on all of the acquisitions undertaken by these companies, along with their patenting performance. The empirical results of this study suggest that technological acquisitions are only likely to be of help to the acquiring firms, in terms of improving their innovative performance, if they set out to acquire those companies that are in similar proximity, in terms of their technological field. There is also a clear need for such acquiring firms to ensure their continuing commitment to internal R&D investment in order to maintain their own versatility.

Keywords US medical device industry · M&A · Patent stock · Patent diversity

Introduction

One of the major impacts of the current international trend, a trend proclaiming the growing demand for synergy between globalization and localization, is that companies within the high-technology industries are increasingly finding themselves faced with changing demand for strategies involving synergies that are capable of helping them to meet the global and local challenges to their product designs and the preferences of their

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customers. Such challenges arising from these rapid changes have direct impacts on the newly-developing global markets and the new technologies demanded for the 21st century. Within the biotechnology industry in particular, one of the most rapidly-developing branches is the medical device industry, an industry of increasing importance within which many firms are at the forefront of these new challenges.

Like their counterparts in many of the other sub-sectors of the biotechnology industry, these globally-based medical device companies currently find themselves locked in competition with one another, either directly or indirectly, in terms of both their product markets and their level of technology. The core competences of such firms are usually derived from the build-up of essential technologies, along with continuing in-house innovation, which thereby provide them with further access to important new technologies that can ultimately enable them to enter new, and potentially lucrative, international markets.

Within this overall process, patenting represents a strong driving force for resource deployment, whilst also serving as a potential source of entry barriers. In order to accelerate the generation of innovative output, whilst also strengthening the intensity of their patenting, corporate strategies begin to focus not only on the major reallocation of resources from factor inputs to R&D activities, but also on the adoption of more aggressive methods, aimed essentially at securing their current competitive advantage within those markets where their core competencies lie. Those companies that have already achieved this stage are also starting to diversify their risks in time- and capital-consuming R&D investment in order to avoid being locked into any less profitable product markets in which they has planned to knock on in the future.

Over the past two decades in particular, strategic alliances have emerged as one of the most widely used means of engaging in competition, with the motivation for the adoption of such alliances lying in the two major categories of technology acquisition and market expansion. The category of 'technology-oriented strategic alliances' appears to have a much more intensive role to play within the high-technology sectors, since R&D within these sectors is no longer considered to be the sole domain of larger companies with more abundant resources; it is instead considered to be a process involving a network, invariably of allied companies, with each of these playing their own specific and complementary roles (Arora and Gambardella 1990).

Thus, the strategic alliances adopted within the high-tech industries, such as the medical device industry, are invariably characterized by a very deliberate design strategy, essentially because R&D activities are considered to be vital to these industries. The financing of such R&D activities is regarded as very capital consuming, and it is extremely difficult to come up with any precise evaluation of the return on such investment until after the final outcome of the investment becomes obvious, in terms of whether the project is a success or a failure. Thus, it is important to allocate the control rights of these crucial resources and activities so as to maximize efficiency and efficacy with regard to the conduct of everyday business (Lerner and Merges 1998).

Amongst the various types of strategic alliances, the most direct strategy is one involving mergers and acquisitions (M&As), which are often characterized by the primary objective of gaining dominance and control over various subsidiaries; and yet the actual effects of such M&A on technology acquisition are amongst the most complex to analyze and evaluate.

The prior literature focusing on this particular area of research includes: (i) the assessment of the impact of a dual-market structure on strategic alliances within the biotechnology industries of North America and Europe (Roijakkers and Hagedoorn 2006); (ii) the empirical analysis of a variety of M&A strategies within high-tech firms, including studies on firms within the bio-pharmaceutical sector, those on market relatedness and the impact of such strategies on the overall process of corporate R&D (Cloodt et al. 2006); and (iii) a study of the motivational framework for M&As in the high-tech industry (Cassiman et al. 2005), as well as the impact of M&As on company learning derived from the prior patenting and citation records of the firms being acquired (Hall and Bagchi-Sen 2007). There has, however, been very little research concentrating on the in-depth construction of metrics and models that may be utilized to evaluate the true effects of M&A strategies on corporate innovative activities.

Amongst the few studies in which attempts are made to analyze the ways in which M&As can influence both the process and performance of innovation, an examination of 31 M&A firms with either a high-technology or medium-technology orientation was undertaken by Cassiman et al. (2005). They constructed variables which represented market- and technology-relatedness for companies on both sides of the merger and/or acquisition to explain the impact of such M&As on R&D inputs and outputs.

The discussion in their study centered on the identification of potential sources of economies of scale and scope, as well as the resultant synergies that would have potentially arisen from the pooling of the two firms' resources; their results concluded that if both the acquiring and acquired firms had complementary technologies, a merger/acquisition would tend to increase both the inputs and outputs of the acquiring firm's R&D activity, and that those cases of mergers or acquisitions that went ahead either with or without any technological motives could have equally important impacts on the overall process of R&D within the firms once the mergers/acquisitions had taken place.

The findings reported by Cassiman et al. (2005) are clearly of some interest; however, in defining technology relatedness, their approach was to regard the whole company as a single unit, ignoring the fact that nowadays, within the overall range of businesses in which they are involved, corporations have become quite versatile and diversified, and indeed, technological capabilities are now available even to medium-sized firms. Furthermore, the distortion that may have resulted from their use of simple self-reported information from a few selected cases of successful M&As could clearly lead to bias with regard to the areas in which the various synergies are developed. Clearly, therefore, further investigation into the learning effect is called for in order to identify the source of such synergy.

The research by Cloodt et al. (2006), which features publicly available data with a larger sample size, helps to shed some light on the learning effect on corporate innovation arising from technological acquisitions. They provide a much more thorough study, since it adopts a multivariable analysis approach to the examination of 2,429 cases of M&As, involving a total of 347 companies, with the sample encompassing four different high-tech sectors (aerospace and defense, computers and office machinery, pharmaceuticals, and electronics and communications). Cloodt and colleagues constructed a quantitative model to demonstrate the ways in which relative knowledge size and knowledge relatedness can have impacts on the integration of R&D resources, both during and after the merger/acquisition, as well as on the learning process and innovation performance thereafter. Nevertheless, their analysis failed to provide any qualitative comparisons of the knowledge on both sides, which might conceivably be one of the more decisive benefits that a company might gain from engaging in a merger/acquisition.

Focusing on corporate learning and technological acquisitions, the present study examines the innovative activities of medical device companies in an attempt to assess the ways in which the widely acknowledged innovative performance of these companies can be attributed to adopted M&A strategies. We place the greatest focus on the construction of a model with both quantitative and qualitative matrices that will allow us to evaluate the true influence of M&A on patenting activities of acquiring firms, taking into consideration the predominance of the dual market structure, particularly in the US biotechnology industry, and the enlightenment provided by the extant theories on factor inputs in the process of R&D, as well as the relationships that exist between company size and innovation. Our observations are based upon corporate learning, technological synergy through diversification and technological deployment from a resource-based perspective, all of which are aimed at achieving acquiring firm's sustainable competitive advantage.

One defining characteristic of the present study is that, as opposed to merely comparing quantitative factors, we also attempt to create three different planes within our approach to the analysis of the qualitative impact of purchased patents on the innovative performance of the acquiring firms. There three elements to our examination of the relevant qualitative considerations are: (i) the current position of the individual acquiring firms within the industry, in terms of their technological propensity and versatility; (ii) the overall degree of diversity in the acquired knowledge obtained each year; and (iii) the propensity, on the part of the acquiring firms, to acquire knowledge on technological deployment and market competition.

We use the US patent class (UPC) as the indicator of knowledge fields in our examination of the impacts of all of the above aspects, constructing measures for each element in the regression model based upon data obtained on ten US medical device companies covering the years 1990–2006. We anticipate gaining some insights into the technological interactions taking place between the acquiring and acquired firms, which we also anticipate will allow us to illustrate more accurately the relationship that exists between M&A efforts and technological change.

Our major finding is that those firms which maintain their versatility whilst continuing to acquire firms with patents with close associations to their own technological field appear to be the ones which gain the greatest benefits from their M&A strategies, as reflected in their subsequent innovative performance. In terms of corporate learning, we find that a more appropriate approach to the acquisition of technology would be to acquire patents of smaller quantity, which are nevertheless relevant to the know-how already possessed by the acquiring firms. In short, there is no real need for the overall diversity of the acquired technology to be particularly strong; indeed, the acquiring firm must continue with its own internal R&D activities in order to create a more flexible and diversified knowledge base, thereby providing a better cradle for the technology know-how which it obtains from the market.

The remainder of this paper is organized as follows. Section Methodology describes the sampling and the modeling featured in this study, along with a discussion of the variables; this is followed in Sect. Empirical results by a discussion of the empirical results. Finally, the conclusions drawn from this study and suggestions for future research are provided in the closing section.

Methodology

Sampling and data collection

In order to evaluate the impact of M&As on learning and technological innovation within companies in the medical device industry, this study uses sampling data collected from ten US medical device companies, selected on the basis of three specific criteria: (i) all of the firms are required to have at least one major product segment, if not the whole company, competing in the medical device industry; (ii) all of the firms must be registered in the US; and (iii) the sales revenue ranking of the firms must have been in the top 20 amongst their

Table 1 Acquiring firms selected in the regression sample

Global sales ranking	Company name[a]	Location of headquarters	2005 Revenue (US$ million)	Total number of acquisitions (1990–2006)
1	**Johnson & Johnson**	US	18,347.00	25
3	Medtronic Inc.	US	10,389.90	21
4	Baxter International Corp.	US	9,880.00	7
5	**Cardinal Health Corp.**	US	9,824.00	20
10	Boston Scientific Corp.	US	6,317.00	13
11	Beckton Dickinson Corp.	US	5,288.45	4
12	Stryker Corp.	US	4,605.30	5
15	Guidant Corp.	US	3,820.00	6
16	**Abbott Laboratories**	US	3,616.00	12
17	Zimmer Holdings	US	3,177.30	2

[a] The names of companies appearing in bold text are those that are recognized as having a higher degree of technological diversification

international medical device competitors.[1] The ten sampled firms are identified in Table 1, which shows that, the aggregate revenue of these ten firms accounted for more than 40% of the total revenue within the global biotechnology industry (Ernst & Young 2007).

According to information obtained from the Compustat database along with the annual reports of the US Security Exchange Commission (SEC), in terms of being the group of companies with the best sales performance, there is considerable diversity between these firms in terms of firm age, firm size and their range of businesses, as well as in their major product markets and technological fields. Half of the firms have been in business for more than 70 years, whilst the remainder have been in existence for less than 20 years. Four of the firms have a workforce of more than 50,000 employees, whereas the rest employ 20,000 or less.

Furthermore, three of the firms in the sample are found to be more diversified than the rest, essentially in terms of their products not initially being in any way related to the high-tech industry, whilst the other seven companies each have much greater concentration in the high-technology industry, as well as in the category of disease control. With regard to this particular characteristic of the sample, the ten firms are grouped into just two categories, as shown in Table 1. Category 1 includes Johnson & Johnson, Cardinal Health Corporation and Abbott Laboratory, as the more diversified companies, with the remainder representing category 0.

We can determine from the official websites of these ten companies, that their M&As were carried out between 1990 and 2006; this is also verified by the information contained in their annual reports. In the 115 cases of mergers/acquisitions included in this study, the acquired firms in our sample are characterized as: (i) those firms whose main lines of business are associated with the bio-pharmaceutical industry; (ii) those firms which had filed patent applications from 1990 onwards with the US Patents and Trademark Office (USPTO); and (iii) those firms which, prior to the M&A deal, had been complete companies, and not just a division or a product line of another company. The acquired firms cover a wide range of businesses, with both vertical and horizontal heterogeneity in the

[1] The sales revenues are ranked according to the statistics provided by MD&DI's Industry Yearbook (2005).

medical device industry. There is also unequal distribution across the individual acquiring firms, with the annual takeovers per acquiring firm ranging between 4 and 26 cases.

Modeling

There are a huge number of studies within the literature on corporate innovation which identify a range of factors that may have attributed to the company's innovative performance[2]; these factors include (among many others) company R&D intensity, firm size, market structure, accumulated experience in innovation and technology variety as important sources of innovation.

A strategy of mergers and acquisitions aimed at boosting a firm's strength, in terms of both the quantity of its patenting and the quality of the acquired technology base, has also been identified as a way of enhancing the subsequent development of technology by the acquiring firms. However, when setting out to measure the innovative output of firms, there has been a general tendency within the prior studies to adopt either R&D inputs or the number of patents issued (or successfully applied for) as the numerical metric.[3] Here, we use the number of patent applications filed with the USPTO as our measure of innovative capacity.

For our analysis of the factors influencing the innovative performance of firms, and more importantly, to confirm and reveal in greater detail the ways in which M&As can have an impact on corporate innovation, this study uses pooled time-series data and cross-sectional information obtained directly from the medical device industry. Given the discrete nature of patent stock data, we estimate the equation for the dependent variable using the maximum likelihood method, with an embedded negative binomial model, as follows:

$$Patent\_Stock_{i,t} = \exp\begin{pmatrix} \alpha + \beta\, Buy\text{-}in\_Patent\_Stock_{j,t-2} + \gamma\, Buy\text{-}in\_Patent\_Diversity_{j,t-2} \\ +\delta\, Technology\_Proximity_{i,j,t-2} + \varepsilon_1 Internal\_Diversity_{i,t-2} \\ + \varepsilon_2 Age_{i,t-2} + \varepsilon_3\, Size_{i,t-2} + \varepsilon_4\, R\&D\_Stock_{i,t-2} \end{pmatrix}, \quad (1)$$

where $Patent\_Stock_{i,t}$ represents the non-negative integer-valued dependent variable for the innovative performance of an acquiring firm i, measured by the number of patent applications filed by the acquiring firm i, accumulated to the current year t, since the year $t-3$.

The fact that the technology development cycle within the medical device industry is only about three to five years is considered to be quite a distinguishing characteristic, given that it is about ten years or longer in other bio-technology industries such as pharmaceuticals. Therefore, in this study we create all of the stock variables for the firm, *Patent_Stock* and *Buy-in_Patent_Stock*, based upon a four-year accumulation period. $Buy\text{-}in\_Patent\_Stock_{j,t-2}$, $Buy\text{-}in\_Patent\_Diversity_{j,t-2}$ and $Technology\_Proximity_{i,j,t}$ are independent variables with i denoting the acquiring firm, and j denoting the acquired firm. The remaining explanatory variables, $Internal\_Diversity_{i,t-2}$, $Age_{i,t-2}$, $Size_{i,t-2}$, and $R\&D\_Stock_{i,t-2}$, are control variables β, γ, δ and ε_1–ε_4 are the respective estimated coefficients for these independent and control variables; and α is a constant intercept to the y-axis. With regard to the point in time at which learning starts to significantly affect a firm, all of our independent variables are based upon a two-year lag period, i.e. $t-2$.

[2] Examples include: Acs and Audretsch (1991), Hall and Ziedonis (2001) and Nesta and Saviotti (2004).

[3] See Hall et al. (1986) and Patel and Pavitt (1997).

It should be noted that we do not include other potential explanatory variables in this study, such as the Herfindahl-Hirschman Index (HHI) or CR4, as the means of reporting market structure and competition; this is essentially for the following three specific reasons: (i) one major characteristic of the firms within the medical device industry is that they do not usually compete directly with each other; indeed, they rarely sell products which provide the same function as that of other companies, since there are usually technological barriers which are attributable to their core patent deployment; (ii) it is actually quite difficult to calculate market structure indices, such as the CR4, where different companies are engaged in the sale of quite diverse ranges of products with various levels of global market penetration; and (iii) the return on equity for these sampled firms tends to be very steady, with very little fluctuation over time; we assume that this is can be attributed to the fact that over the 17 year-period under examination in this study, there appear to have been only minor changes in the market structure of this particular industry.

Variables

Patent_Stock is the dependent variable reporting the innovative performance of the acquiring firms in the post-M&A period. Innovative performance is defined in this study as the number of patent applications filed by the acquiring firms, using a four-year period from $t - 3$ to the current year, t, based upon 15% depreciation. The patent application data are obtained from the online database of the USPTO.

Buy-in_Patent_Stock is an independent variable selected as the means of evaluating the quantity effect of the acquisition of technological learning through M&A strategies. This variable is defined as the average number of patent stock obtained relative to the acquiring firm's annual number of M&A deals. In order to specify the timing of M&As (i.e., the point at which technology learning and synergy takes place), all of the patents applied for by each acquired firm prior to the deal are collated separately, and then included into the data for the year in which they were subsumed by the acquiring firm. This flow dataset is then computed into a four-year stock period from the year $t - 5$ to $t - 2$, with the accumulated number of patents obtained via M&As subsequently being counted. The *Buy-in_Patent_Stock* variable is thus compiled by dividing the count by the accumulated number of firms acquired since 1990 for each current year.

Buy-in_Patent_Diversity, which is defined as the heterogeneity of buy-in patent stock at time $t - 2$, is an independent variable designed to analyze the impact on the quality of the acquiring firm's technological learning through M&As. This variable is measured by $1-HHI_{t-2}$, where HHI_{t-2} represents the technology concentration of the patents in terms of patent class at year $t - 2$, and is specified as follows:

$$HHI_{t-2} = \sum \left(\frac{n_{i,t-2}}{N_{t-2}} \right)^2, \qquad (2)$$

where $n_{i,t-2}$ represents the total number of UPC patents of firm i in year $t - 2$, and N_{t-2} represents the grand total of the four-year stock of patents in year $t - 2$.

Technology_Proximity is an independent variable which is used to measure the technological proximity between each of the acquiring firms and their acquisitions. This variable represents the impact of the technological proximity of obtained patents on innovative learning within a firm by comparing the major technological fields associated with each of the acquiring firms with their overall buy-in patents. Here we define major technological fields as those patent classes that make up more than 25% of, or located in the top three of the numerous patent classes of, the four-year patent stock between the years $t-5$ and $t-2$. This variable takes a value of 1 where the purchased four-year stock belongs to the identical major field of technology as that of the acquiring firms, otherwise 0.

Internal_Diversity, which is defined as the heterogeneity of the acquiring firm's patent stock at time $t-2$, is an independent variable designed to distinguish between the indigenous diversity for the full range of technologies in the acquiring firm; this can generally be inferred as a way of explaining the divergence in corporate innovation, and is measured by $1-HHI_{t-2}$, where HHI_{t-2} represents the technological concentration of the acquiring firm's patents, in terms of patent classes, in year $t-2$.

The *Age* variable measures the total length of time that the acquiring firms have remained in operation since their initial start-up. This control variable is expected to explain whether the age of a company can indicate its level of experience, in terms of learning, which might conceivably have some impact on the acquiring company's current capacity for learning and innovativeness. The *Size* variable, which is defined by the logarithmic value of the total number of employees within the acquiring firm at year $t-2$, is a control variable indicating the impact on innovative ability attributable to the scale of the company. Finally, *R&D_Stock* is a control variable which reports the acquiring firm's four-year stock of R&D expenditures, from the year $t-5$ to $t-2$. Following several of the prior studies on the relationship between R&D stock and innovative performance,[4] this study also considers the time effect of deterioration, by including the diminishing significance of R&D expenditures on innovation through the application of a 15% depreciation rate.

Empirical results

A summary of the data is provided in Table 2, along with brief definitions of the variables used in this study. Since there is little correlation between the regressors, the table for the correlations among independent variables is not listed. The estimation results of the negative binomial regression model constructed in this study are reported in Table 3, which shows that with the exceptions of the *Age* and *Buy-in_Patent_Diversity* variables, all of the estimated coefficients of the explanatory variables are significant.

As regards the variables relating to the acquired firms, Cloodt et al. (2006) found that in those cases where the absolute size of buy-in technology base was substantial, this was likely to have a negative impact on corporate patenting. They concluded that the purchase and integration of knowledge into an existing organization was quite a resource-consuming process which could temporarily compromise the innovative ability of a firm. Since the medical device industry is highly demanding, in terms of technological know-how, and since R&D expenditure also tends to consume a disproportionately large share of corporate resources, in this study, we expect to find that, from a resource-based perspective, our *Buy-in_Patent_Stock* variable will also have a negative impact on the patenting activities of the acquiring firms.

As Table 3 shows, our quantitative estimation of technology M&As seems to coincide with that of Cloodt et al. (2006), since the coefficient of *Buy-in_Patent_Stock* is highly significant, with a value of –0.0367. This value indicates that, *ceteris paribus*, a single unit increase in *Buy-in_Patent_Stock* could reduce the patenting intensity of the acquiring firms by 3.67%.

[4] See for example, Griliches and Mairesse (1990) and Jang and Huang (2005).

Table 2 Variable definitions and summary statistics

Variable	Definition	Mean	SD	Maximum	Minimum
Patent Stock	Four-year stock of patent applications to the USPTO by the acquiring firms using a 15% annual depreciation rate	291	214	775	0
Buy-in_Patent_Stock	Four-year stock of patents acquired from the subsidiaries as a result of each merger/acquisition	11	10	42	0
Buy-in_Patent_Diversity	The value of 1-*HHI* for the patent stock of the acquired firms. The calculation of *HHI* is as in Eq. 2	0.6918	0. 2380	0.9949	0
Technological_ Proximity	The relevance and the closeness, in terms of technological fields, between the individual acquiring firm and the cumulative total of its acquisitions. The cumulative total of the acquired firms comprises only of its four-year stock, with the major technological fields being defined as UPC classes of patents as the three most numerous amongst all patent classes; a comparison is then made between the acquiring firm and its cumulative acquisitions. If the major fields of technology between the acquiring and acquired firms in the four-year period are the same, or very close, the variable for that year takes a value of 1; otherwise 0	0.4000	0. 4934	1	0
Age	The age of each acquiring firm at year $t-2$	74.0428	34.3424	118	7
Size	The number of employees hired by the acquiring firms each year (in logarithmic value)	1.5152	0.3307	2.0437	0 .8195
R&D_Stock	Four-year stock of R&D expenditure by the acquirer using a 15% annual depreciation rate	3.1539	0. 5318	4.1831	1.6901
Internal_Diversity	The value of 1-*HHI* for the patent stock of the acquiring firm. The calculation of *HHI* is as in Eq. 2	0.8299	0. 1210	0.9646	0.3200

Table 3 Regression results on the impact of M&As on innovation for firms in the medical device industry

Variables	Coefficient	SE
Constant	–3.5046	0.1766*
Acquired firm-related variables		
Buy-in_Patent_Stock	–0.0367	0.0089*
Buy-in_Patent_Diversity	0.0039	0.4414
Acquired and acquiring firm relationship		
Technology_Proximity	1.2298	0.2550*
Acquiring firm-related variables		
Age	–0.0014	0.0050
Size	–1.3693	0.5113*
R&D_Stock	0.8222	0.3023*
Internal_Diversity	10.1196	1.5752*
Number of observations	70	
Log likelihood	−439.3102	

* Indicates statistical significance at the 0.01 level

As regards the *Buy-in_Patent_Diversity* variable, we actually need to consider two contradictory forces coming into play. The first of these comes from a perspective of synergy, that a higher degree of bought-in technological versatility and diversity could lead to stronger innovation by the acquiring firms through a combination of experience and information from different technological fields, thereby potentially creating greater opportunities, as well as potential economies of scope in the overall process of R&D arising from the sharing of activities and facilities, such as legal and scientific personnel and laboratories. Nevertheless, the second force, which comes from a resource-based perspective, considers that over-diversification could distract a firm from real and potential market opportunities. Since these two forces always seem to come together, it is difficult to determine precisely under what conditions either of the two would prevail. As shown in Table 3, the estimated coefficient of *Buy-in_Patent_Diversity* has an insignificant result, which would appear to suggest that these two contradicting forces cancel each other out.

As for the relationship between the acquiring and acquired firms, the proximity of the technology fields between these firms is clearly of importance; however, this can also give rise to additional problems. Indeed, the complicated process involving the effects of knowledge integration through M&As and the various potential sources of synergy that can be traced down to different levels within the R&D process may pose a major obstacle which could well hinder the possibility of carrying out any valid process of evaluation.

The prior study by Cloodt et al. (2006) pointed to a U-shaped relationship for proximity, which suggests that the acquisition of knowledge at a certain distance, though not totally unrelated, can actually present a better chance of raising synergy within the overall process of R&D, an issue on which the findings of Cassiman et al. (2005) remained ambiguous. As regards our empirical findings on this issue, as we can see from Table 3, the estimated coefficient on *Technology_Proximity* does have statistical significance, with a value of around 1.23, which suggests that a single unit increase in the proximity of the field of technology between the two parties in the M&A deal would result in an average increase in the acquiring firm's innovative capacity, at a factor of 1.23.

Furthermore, for the variables relating to the acquiring firm, following the traditional wisdom on the effect of factor inputs on productivity,[5] we anticipate that the higher the R&D stock at time year $t - 2$, the stronger the innovative performance of the company concerned in the current year. The test result reveals an apparent correlation between R&D inputs and outputs, given that the estimated coefficient on *R&D_Stock* is highly significant and positive, with a value of 0.8222.

As regards the *Age* variable, which represents the age of each acquiring firm, we would generally expect to find firm age reflecting accumulated corporate experience in its core business, particularly within knowledge-intensive industries. In other words, we would normally expect to see those firms with more experience demonstrating a stronger ability to utilize the available resources, as well as stronger corporate governance capabilities. However, the functional flexibility of firms that have grown to a certain size, can be drastically reduced as a result of the institutionalization of managers and employees. Under such circumstances a firm can actually lose functional competence in its everyday activities.

On the other hand, newcomers, for whom technological know-how is the key to successfully competing, will usually find an opportunity to enter the market; they can often foresee market potential which provides them with an opportunity to capture market value by bringing new technology which they possess into the existing market. Thus, in such situations, younger firms can often be found to be more innovative than experienced firms. As regards our estimation of the *Age* variable, despite its negative value, we find that the coefficient is insignificant.

Turning to the *Size* variable, which represents the numbers of employees in year $t - 2$, there are complex and contradictory standpoints on its actual function; on the one hand, employees are part of production factor inputs, and logically, despite the diminishing marginal production, more factor inputs would lead to higher levels of production. On the other hand, early Schumpeterian theory argues that smaller firms remain aggregately more flexible; thus, as compared to large firms, they can more rapidly capture the available market opportunities and be more innovative. Thus, the estimated sign of *Size* remains uncertain; and indeed, our *Size* variable estimation shows a negative effect, with a value of around –1.37, which could be interpreted as the tendency for greater innovativeness amongst the relatively smaller of these top 20 ranking firms. Given the development of the biotechnology industry as a whole over the past two decades, the capital markets of North America and Europe appear to have great enthusiasm and confidence in this particular business sector, which thereby tends to provide easier access to finance for smaller firms. Strategic alliances between large and small firms have also been in abundance during this period (Roijakkers, and Hagedoorn 2006), providing a background environment in which smaller firms have a better chance of making the most of their flexibility within the R&D process; thus early Schumpeterian theory seems to provide the better rationale in our case.

Since our concern lies in whether the pre-M&A innovative behavior patterns of acquiring firms can affect their post-M&A R&D performance, we set up our *Internal_Diversity* variable to demonstrate the degree of diversification in technological development amongst the different acquiring firms. With regard to the ways in which learning takes place and proceeds, we would expect more versatile firms with greater and more diversified knowledge bases to be better learners, since versatility indicates greater experience in learning, and more importantly, greater knowledge integration ability, which is vital to the medical device industry. However, technological know-how in life sciences

[5] See Hall and Ziedonis (2001) and Jang and Huang (2005).

is only one of the prerequisites; the ability to combine this with many other technological fields, such as electrical engineering or biomedical materials, is also necessary.

Conceptually, it may be inferred that over-diversification can lead to distraction in the allocation of corporate resources, thereby resulting in reduced levels of efficiency and poor performance; however, we do not expect this effect here. The sample firms in this study are amongst the top performers in the US, and the prosperity of this group of leading firms, and indeed the industry as a whole, appears to be on a continual rise; hence, there are no indications thus far of any trend towards over-diversification.

The estimation of the *Internal_Diversification* variable reveals a strong, positive coefficient and a very high level of significance, with a value of 10.12. This would therefore appear to indicate that, *ceteris paribus*, a ten-unit average improvement in acquiring firm's R&D yields could be achieved in year t as a result of a single-unit increase in its internal diversity in year $t - 2$.

Conclusions

Our primary objective in this study is to examine the ways in which the external acquisition of technology through M&A activity can affect the internal R&D processes and innovative outcomes of firms in the medical device industry. We find that whilst patent acquisitions do contribute in some ways to the post-M&A patenting activities of the acquiring firms, the positive effects tend to be more qualitative than quantitative. Yet, on this point, corporate strategy must deliberate on the selection and deployment of the firm's knowledge assets since it is neither 'the more you buy' nor 'buying a wider variety' which strengthens a firm's R&D capabilities.

By examining the technological domains of each acquiring firm in the US medical device industry, including those obtained externally, we find that those firms which maintain their versatility and continue to acquire other firms with patents in closer proximity to their own technology field, appear to be the ones which really benefit from M&A strategies, as reflected in their subsequent innovative performance.

In terms of corporate learning, we also find that knowledge accumulation, as well as the effects of synergies generated from learning, do not necessarily result in firms continuing to acquire their patents externally whilst maintaining their internal R&D investment. According to our findings, what might be considered to be more appropriate conduct in the adoption of any strategy of technology acquisition would be to acquire patents of smaller quantity, but which are, nevertheless, more related to the know-how currently possessed by the acquiring firms. We find that whilst the overall diversity of the acquired technology does not necessarily have to be so strong, it is clear that firms must continue to pursue their internal R&D activities in order to create a more flexible and diversified knowledge base, thereby providing the firm with a better cradle for the technological know-how obtained from the market.

Future research in this area should consider empirical analyses with larger sample sizes; the inclusion of M&As between firms outside of the US would also be helpful in terms of testing the transferability of our findings. Other factors, such as differences in international corporate outlook, which may also have impacts on the M&A behavior and patenting activities of such firms, could be included into the model to facilitate further exploration. Finally, since there are also many common features shared by firms in the high-tech industries, such as IC and pharmaceuticals, future studies could also consider the construction of a multi-sector model.

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References

Acs, Z. J., & Audretsch, D. B. (1991). Innovation and size at the firm level. *Southern Economic Journal, 57*(3), 739–744.

Arora, A., & Gambardella, A. (1990). Complementarity and external linkages: The strategies of the large firms in biotechnology. *The Journal of Industrial Economics, 38*(4), 361–379.

Cassiman, B., Colombo, M. G., Garrone, P., & Veugelers, R. (2005). The impact of M&A on the R&D process: An empirical analysis of the role of technological- and market-relatedness. *Research Policy, 34*, 195–220.

Cloodt, M., Hagedoorn, J., & Van Kranenburg, H. (2006). Mergers and acqusitions: Their effect on the innovative performance of companies in high-tech industries. *Research Policy, 35*, 642–654.

Ernst & Young (2007). Ernst & Young's global biotechnology report.

Griliches, Z., & Mairesse, J. (1990). R&D and productivity growth: Comparing Japanese and U. S. manufacturing firms. In C. Hulten (ed.), *Productivity growth in Japan and the United States Vol. 53 of NBER Studies in Income and Wealth* (pp. 317–348). Chicago: University of Chicago Press.

Hall, L., & Bagchi-Sen, S. (2007). An analysis of firm-level innovation strategies in the U.S. biotechnology industry. *Technovation, 27*, 4–14.

Hall, B. H., Griliches, Z., & Hausman, J. A. (1986). Patent and R and D: Is there a lag? *International Economic Review, 27*(2), 265–283.

Hall, B. H., & Ziedonis, R. H. (2001). The patent paradox revisited: An empirical study of patenting in the US semiconductor industry, 1979–1995. *Rand Journal, 32*(1), 101–128.

Jang, S. L., & Huang, G. G. (2005). Public R&D and industrial innovations at the project levels: An exploration of Taiwan's public research projects. *Contemporary Economic Policy, 23*(4), 636–646.

Lerner, J., & Merges, R. P. (1998). The control of technology alliances: An empirical analysis of the biotechnology industry. *The Journal of Industrial Economics, 46*(2), 125–156.

MD&DI's Industry Yearbook. (2005). The Biotech Communications Group, Inc.

Nesta, L. & Saviotti P. (2004). Coherence of the knowledge base and firm innovative performance: Evidence from the U.S. pharmaceutical industry. SPRU Working Paper, 113.

Patel, P., & Pavitt, K. (1997). The technological competencies of the world's largest firms: Complex and path-dependent, but not much variety. *Research Policy, 26*, 141–156.

Roijakkers, N., & Hagedoorn, J. (2006). Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: Trends, patterns and networks. *Research Policy, 35*(3), 431–446.