Do technology strategies matter? A comparison of two electrical engineering corporations, 1988-1998

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Abstract

In order to reap competitive advantage of innovation, a firm's technology activities should square with its technology strategy. But how do technology strategies relate to activities and financial performance in relevant business areas? This paper investigates this question by means of a comparison between two leading firms in the electrical engineering industry: ABB and General Electric. We show that substantial performance differences between these companies in the Power Generation field are related to differences in their espoused technology strategies (as indicated by statements in annual reports) and technology activities (as indicated by patenting) and the degree of alignment between these.

1. Introduction

Technological innovation, it has been argued, is a paramount source of competitive advantage of firms (Carl Pegels and Thirumurthy 1996; Zahra, Nash, and Bickford 1994). However, as shown by Schoenecker and Swanson (2002), sheer scale in firms' technological activities does not equate superior performance. A company's technological activities should square with its technology strategy in order to reap competitive advantages (Porter 1985). But how do technology strategies relate to actual activities and economic outcomes? For instance, do publicly articulated intentions and strategies have any links with actual technology activities, and is there any relationship between these pronouncements and activities and observable financial performance in relevant business areas?

This paper purports to investigate these questions by means of a detailed comparative study of two leading firms in the technology-based electrical engineering industry: Asea Brown Boveri (ABB) and General Electric (GE). In particular, we study one of their core business segments: Power Generation. Here the two giants were competing neck to neck in the 1990s. But at the end of the decade GE emerged as the undisputed leader, whereas ABB after increasing financial and technical problems chose to exit by selling off its entire power generation segment to French competitor Alstom. Can this dramatically different outcome be related to differences in the technology strategies and technology activities of these well-known companies with regard to their power generation business?

ABB and GE are examples of a particular type of technology-based firms that are active in a number of different technological fields and, hence, in the literature have been categorized as multi-technology corporations (Granstrand and Oskarsson 1994; Granstrand, Patel, and Pavitt 1997; Granstrand and Sjölander 1990; von Tunzelmann 1998). In such corporations, technological diversity is seen as a source of competitive advantage. In order to manufacture complex systems, such as power generation equipment, technological breadth, depth and systems integration are necessary ingredients (Magnusson, Tell, and Watson 2005; Prencipe 2000; Tell 2003; Wang and von Tunzelmann 2000). These features imply challenging questions regarding the technology strategies and technology activities of multi-technology corporations. For instance, when (if ever) does technological leadership pay off? What is an appropriate level of technological diversity on a segment level?

When investigating espoused technology strategies in ABB and GE, we study the rationale provided by top management in corporate annual reports for investments in activities directed towards future products and technologies. The actual technology activities of the two firms are measured by using patent data. In this study, technology strategies and technology activities in conjunction are conceived as the technological capabilities of these firms.

In the next section, previous research and our research questions are discussed in more detail, followed by a section on the selected methods for data collection. The fourth section presents our empirical data on financial performance, espoused technology strategies and the patenting patterns of the two companies from 1988 to 1998 (this year ABB started to retreat from the Power Generation segment). Section 5 provides a comparative analysis of technology strategies and activities. In the concluding section, we return to the key question – do technology strategies matter –discussing implications for strategic management of multi-technology corporations.

2. Theoretical framework and research questions

Technological capabilities: strategies and activities

The literature on resource-based theories of the firm singles out firms' capabilities as a determinant of business performance and competitive advantage (Fai 2003; Helfat 2000). The concept of organizational capability refers to the ability of firms to do or make things, "to have a reliable capacity to bring that thing about as intended action" (Dosi, Nelson, and Winter 2000, 2). Technological capabilities, which may considered as a subset of firm capabilities (Davies and Brady 2000; Tell 2000), are particularly important, as they are assets that are hard to copy for competitors and may be associated with rapid transformation of technological knowledge into new products which give rise to first-mover advantages.

As pointed out in recent research, capabilities are constituted both by top-management's strategic intentions and by operational activities (Dosi, Nelson, and Winter 2000; Fransman 1994; Witt 1998; Zollo and Winter 2002). While the latter are highly embedded in the day-to-day operations of the firm, strategic intent can be more public and deliberate as top management tries to communicate its intentions to both internal and external stakeholders. Technological capabilities may, thus, be considered to have two components: technology strategies and technology activities.

Technology strategies involve corporate intentions regarding what technological resources to employ and how these resources should be utilized in the market (Collins, Hull, and Hage 1996). They can be related to generic competitive strategies such as cost leadership or differentiation (Vernet and Arasti 1999; Zahra, Sisodia, and Matherne 1999), and may include issues such as magnitude of commitment to R&D, choice of technology leadership or followership, choice of technologies to develop, technological scope, and attitudes towards licensing (Cooper and Schendel 1976; Granstrand and Sjölander 1990; Maidique and Patch 1982; Porter 1985; Zahra, Nash, and Bickford 1994). Our analysis includes the following strategic dimensions:

- *Cost leadership* refers to the ambition of a company to compete based on a low cost structure, resulting either in lower prices or higher profit margins than those of the competitors (cf. Porter 1980; Vernet and Arasti 1999; Zahra, Sisodia, and Matherne 1999). (Differentiation is difficult to assess in an industry such as this where products are tailor-made to customer specifications.)
- *Technology leadership* refers to the ambition of a company to be – or at least be perceived to be – on the technological forefront (cf. Bierly and Chakrabarti 1996; Brockhoff and Chakrabarti 1988; Porter 1985; Song and Dyer 1995). This may imply having the most advanced technology, being first to market with new products and product generations etc.
- *Technology scope* refers to the degree of diversification in selecting target technologies (Maidique and Patch 1982). Referring to multi-technology firms producing complex products, technology scope captures how firms position themselves with regard to depth and breadth (Prencipe 2000; Tell 2003; Wang and von Tunzelmann 2000). Technology scope thus is compatible with concepts such as technological diversification (Fai 2003; Granstrand 1998) and corporate coherence (Piscitello 2000, 2004; Teece et al. 1994).

Technology activities refer to what kind of operations the firm performs with regard to the exploration and exploitation of technology (cf. Granstrand and Sjölander 1990; Tell 2000). In particular we are here interested in search-oriented (exploration) activities, i.e. technological activities undertaken by the firm in order to obtain new technological knowledge. Formulated like this, technological activities may, for instance, refer to the day-to-day activities of engineers in research labs or production engineers involved in making a new product ready for manufacture. Hence we refer to technological activities as the documented operational routines (Nelson and Winter 1982) performed by employees in a firm, for example in – but not restricted to – research and development (R&D). Our analysis of activities includes the technology leadership and technology scope dimensions.

(Multi)-technological capabilities and firm performance

Empirical findings regarding the relationship between technological capabilities and firm performance are somewhat mixed. For instance, Franko (1989) shows that, in a global context, technological capabilities emanating from R&D activities (measured as R&D intensity) of firms are an important determinant of corporate performance relative to competition in a wide range of industries. Carl Pegels and Thirumurthy (1996), using patent data, argue that technological capabilities measured as technological cycle time and technological strength play an important role in determining firm performance. In their empirical test on 49 firms in several industries, 45% of the variation in firm performance, measured as operating profits, could be explained with reference to their model. In addition, in a study of the U.S. pharmaceutical industry Bierly and Chakrabarti (1996) found that the two most active strategic groups “innovators” and “explorers”, outperformed “exploiters” and “loners”, which indicates that a technology leadership strategy is related to higher performance.

On the other hand, Schoenecker and Swanson (2002), using a sample of 89 American firms in three industries, demonstrate the difficulties involved in verifying the relationship between firm technological capabilities and economic performance. They show that technological capability indicators, such as patent counts, average R&D spending and new product introductions, are positively correlated with each other, but do not explain firm performance in their study. These inconclusive results are highly unsatisfactory. There is a need for developing more precise methods for assessing technological capabilities (strategies and activities) and their impact on firm performance.

A particular case of technological capabilities and firm performance related to the present study concerns so called multi-technology corporations (Granstrand and Oskarsson 1994; Granstrand, Patel, and Pavitt 1997; Granstrand and Sjölander 1990; von Tunzelmann 1998). Both ABB and GE generally fit the description of such firms. The literature on multi-technology firms has argued that an essential determinant of the sustainability of technological capabilities and performance in such firms is technological diversity. Technological diversity, it is argued, is necessary in order to reap opportunities associated with increasingly complex products and rapidly changing markets. This leads technology-based corporations to have “distributed” rather than “distinctive” core competencies (Granstrand, Patel, and Pavitt 1997), and to acquire technological knowledge that is dispersed over a wider range of sectors than their production activities, that is, “to know more than they make” (Brusoni, Prencipe, and

Pavitt 2001). The implication for technology strategy is that increased technological diversity is essentially good, as long as it is coupled with systems integration. Similar to the literature on technological capabilities and performance, the empirical basis for these claims primarily stems from surveys, in this case patenting patterns among the world's largest firms (Granstrand, Patel, and Pavitt 1997; Piscitello, 2000, 2004; von Tunzelmann, 1998). An exception is the comparative case study of aircraft control systems presented in Brusoni, Prencipe, and Pavitt (2001). However, as pointed out by Piscitello (2004), this literature has in general neglected (financial) performance, instead focusing on effects on technological diversification and growth. There is thus a need for more detailed studies on the relationship between technological capabilities and performance in multi-technology firms.

Finally, with regards to the relationship between cost leadership and performance, the results are, again, mixed. On the one hand, relative direct cost position and cost efficiency have been found to be significant determinants of business performance in several different business areas (cf. Phillips, Chang, and Buzzell 1983; Berman et al. 1999). On the other hand, the success of cost leadership seems to be dependent on the business environment: A cost leadership strategy seems to be most successful in predictable and stable environments without much complexity or need for product innovation that may "thwart" efficiency (Miller 1988). However, focus on cost-efficiency is not necessarily a determinant of performance, but may also be a short-term strategic response to deteriorating performance (Bowman 1997).

Whereas the broad studies referred to above tend to equate (or at least measure) capabilities with either activities or strategies, our approach of combining activities and espoused strategies means that we add direction to activity – technological efforts in what field, focused on what, and in relation to what ambitions? – but also activity to direction. However, it is beyond the realm of the study to investigate possible causal relationships between strategy and activity, i.e. if activity follows strategy or if activities precede strategy by forming the basis for emergent strategies. The issues at stake here is whether there is a distinct relationship between strategic intents and revealed activities, resulting in distinct strategic technology profiles, and if these profiles matter for financial performance.

One problem in the general literature on technological capabilities and performance seems to be that these variables is studied on an aggregate level, where it is difficult to establish relations between specific technological activities and strategies on one hand and performance on the other. In particular, there is a gap between R&D efforts, patenting and technology strategies on an industry or corporate level and product and market outcomes on the business segment level, where product competition takes place. Moreover, in a multi-technology firm the positive effects of strong technological performance in one area may be obscured by sub par financial performance in another. There is, thus, a lack of studies of technological strategies and activities on a detailed, yet comparative, level. Against this background, we have chosen to focus our study to one key business segment of the two companies, power generation. This should make it easier to link capabilities to actual performance.

Research questions

In Section 4 below we present findings on differences between ABB and GE in the power generation business, relating to performance, to espoused technology strategies, and to technology activities. Based on these findings two research questions are addressed:

RQ 1: Are the espoused strategies and actual technology activities in the power generation segment of these two firms related in a systematic way, implying distinctly different technological capabilities? This question will be addressed in Section 5.

RQ 2: If so, is it possible to link these differences in technological capabilities to the differential economic performance of the power generation segment in the two firms in a plausible way? This question will be addressed in Section 6.

Alternative explanations of firm performance

In this study, two aspects of technological capability – strategies and technological activities – have been singled out. It could be argued that *managerial capability* is a third important component of technological capability (Granstrand 1998; Maidique and Patch1982), for example the organizational capability to manage complex high-technology product development projects successfully. In our case, the top managers of both GE and ABB were highly admired by their contemporaries in the 1990s, and received a number of awards. But on the business segment level there is very little public information on management styles and capabilities. This would require another type of analysis, involving a close comparative study, not on business level, but on project level and access to a number of company-internal data sources. This is outside the scope of this paper, but remains an important area for further studies.

It could also been argued that Jack Welch's famous statement that GE should be #1 or #2 in all its industries or ABB's problems in developing its new generation of gas turbines could explain the varying success of the companies. However, such explanation tell us nothing about *how* a company becomes number one or two in a particular business segment or succeeds in developing new products in an R&D-intensive technologically and commercially turbulent environment. The basic purpose of this paper is to show that it is reasonable to relate GE's success and ABB's failure to the nature of their respective technological capabilities.

As a third alternative explanation, it may seem as if GE enjoyed an advantage over ABB in its access to a large domestic market. However, this advantage was less pronounced in the power generation segment than could perhaps be expected. In a key growth technology such as advanced gas turbines, for example, GE competed on the international market for the majority of its orders almost every year until the U.S. turbine boom in 1999 – 2001 (after our measurement period).

3. Methodology

This paper uses a new data set to compare the Power Generation segments of ABB and GE 1988-1998, and relates (a) the financial performance of these segments to (b) technology strategies, as espoused in annual reports, and (c) technology activities, as measured by patent counts. These three components of our data set are described in more detail in the following.

Financial performance

The economic performance of the two business segments was measured using financial indicators provided by corporate annual reports. Optimally, these data would have been compared with other data in order to confirm their validity, but unfortunately there is very little data available on a business segment level, especially considering the 11-year time frame of the study. Market value (based on share prices) is used in other studies, but is not accessible to us since we operate on segment level. Data on product market shares are problematic in this case, since the studied power generation segment contains a multitude of different products sold on different markets.

We use operating income and annual revenue growth as performance measures (Schoenecker and Swanson 2002). Using operating rather than net income avoids distortion caused by mandated or deliberate adjustments (Carl Pegels and Thirumurthy1996). Despite changing accounting standards and some difficulties in comparing an American and a European firm, such an approach provides reasonably robust data seen over a longer time period.

Various external factors may influence comparisons between firms across countries, however, e.g. the size and demand characteristics of the home markets, or changes in exchange rates. With respect to differences in domestic markets, GE's advantage was, as previously described, not so pronounced in the power generation segment, at least not until *after* our measurement period.

Exchange rate variations may of course unduly influence any comparison of the financial performance of companies operating in different currencies and different parts of the world. To check for this, we have calculated the relative strength of ABB's main European currencies – the Swiss franc, the German mark and the Swedish krona – against the US dollar (GE's main currency) in the studied period, and constructed an index for ABB where each currency – including the US dollar since ABB had significant operations in North America during the entire period – is weighted according to the relative number of employees in the corresponding country. (Relative number of employees at the corporate level is used as a proxy for the production value in each country, since there unfortunately are no available data on segment level.) When the value of the index increases, ABB is enjoying an advantage of weaker currencies in its international operation structure, and vice versa.

The starting year of our measurement period, 1988, is used as reference year with a value of 100 (meaning that if there had been no exchange rate variation and no variation in relative production levels across countries the index would have stayed at 100 for the entire period). We can see that ABB enjoyed the most unfavourable currency configuration in the mid-1990s (see Table 1), at a time when it was most competitive compared to GE (see Figure 1 in Section 4). At the end of the period, the European currencies (especially the Swedish krona) fell against the US dollar but this did not save ABB, where revenues and profits collapsed. As a whole, this gives an indication that the fluctuations of ABB's main European currencies did not influence the reported segment profit in a substantial way.

TABLE 1 IN HERE

Espoused technology strategies

The espoused strategies of the two companies were operationalized using the non-financial sections of the companies' annual reports. One of the main benefits of annual reports as a data source is that they were written in the time period of interest, which reduces the risk of post-rationalization. Previous research has also shown that annual reports provide a fairly comparable set of data for a broad sample of corporations, and can be a rich source of information concerning company strategies (Bettman and Weitz 1983; Bowman 1978). For example, Bowman (1978) used annual reports to compare the strategies of companies in the large mainframe industry in terms of, e.g., vertical integration, customer orientation and growth strategies. Moreover, there exist few other comparable sources on the strategic intentions of companies, especially over time.

Annual reports contain a somewhat arbitrary mix of items – efforts and ‘successes’ – corporate management wants to highlight, e.g. business results and key orders received during the reported year; technological investments and product launches in important areas; assessment of market trends for regions and/or technologies; and explicit strategies defining the positioning of the company. As a consequence, a comparison of two companies for one year often yields a confusing picture, but when similar business areas are compared over an extended period, a systematic pattern emerges.

In compiling data from the annual reports we made use of our comparative approach to generate conceptual categories related to the technology strategies of the two firms regarding e.g., products, technologies and general strategies (Glaser and Strauss 1967). We took our starting point in a grounded theory methodology (Dougherty 2002; Strauss and Corbin 1990). As a second step, we added iterations between theory and empirical findings; we searched our records for statements concerning the strategic variables identified in literature, but also used the records to qualify the variables. In particular this aided us in developing Tables 2-5, where we identify significant differences (but also similarities) in several conceptual categories between the two firms with regard to their espoused technology strategies.

The data were collected and coded in three steps. First, two researchers analyzed one company each. Second, each researcher also analyzed a sample of reports from the other company to ascertain intercoder reliability (Whittington, Mayer, and Curto 1999). Third, two master students made an independent coding of the reports, which was compared with the coding made by the first two researchers. The intercoder reliability between these analyses was on average 75 percent.

In line with the main focus of the paper, we were primarily concerned with statements related to the segment denoted Power Generation or similar. However, since there were very few statements on cost leadership on a segment level, we decided to search for corporate level statements as well for this variable. These statements are clearly separated from the others in our analysis below and should only be seen as a complement to the segment level statements.

The analysis and documentation of the annual reports were done independently from the patent analysis, to avoid "contamination". Only when these two empirical studies were completed, the results were compared and the analytical section of the paper developed.

Technology activities

This analysis focuses on two of the capability dimensions discussed above: technology leadership and scope, whereas cost leadership on an activity level was not possible to ascertain on a comparative basis in this paper.

As an indicator of the technological activities of the two companies in these dimensions, we used patent data. An alternative approach would have been to use R&D resource commitments (cf. Carl Pegels and Thirumurthy 1996; Maidique and Patch1982), but from a capability perspective the advantage of using patents data is that they (in addition to being a standard descriptive device) also shed light on how productive firms are in executing their technology activities (in terms of knowledge production rather than commercial success). Furthermore, patent data are not confined to the output of R&D departments, but may be related to many different parts of a company. It should be noted that we are not concerned with the economic value of patents, but merely view them as an indicator of technological activities within a company.

The patent data for the relevant 11 years were compiled by us from information supplied via the official website of the United States Patent and Trademark Office (USPTO). We used the following measures for each capability dimension:

- *Technology leadership* was measured in absolute and relative volumes of patents, both for total patenting in relevant fields and, perhaps more importantly, for selected technologies (patent classes).
- *Technology scope*, in terms of the degree of specialization and diversification of technology activities, was measured by using an entropy measure. We also made comparisons between each firm's total pool of power generation patents and between selected classes of patents of each firm.

The general advantages and disadvantages of patent data have been discussed extensively elsewhere (see, e.g., Hagedoorn and Cloodt 2003; Holmén and Jacobsson 1997; Le Bas and Sierra 2002; Patel and Pavitt 1991). Here, we will focus on the two largest patent-related methodological problems of this study.

The first problem concerns the well-known variation in the propensity to patent between firms, especially between firms with different countries of origin. Some caution is, thus, warranted when interpreting differences between two firms in absolute terms. In addition, the use of US patent data may result in an over-estimation of GE's patenting activities in comparison with ABB.

To a large extent we rely on relative measurements, such as relative shares and changes over time, where propensity to patent should not be an issue. However, we also think that significant differences in numbers do relate to real differences in technical competence and priorities. For such absolute measures, the potential “home country bias” of GE is a relevant problem to discuss. In order to estimate the magnitude of this problem, we calculated the “GE-to-ABB ratio” of our sample and compared it to ratios derived from searches on company names in the European Patent Office (EPO) database, Patent abstracts Japan, and the entire USPTO database in 1988-1998. We found that our ratio was lower than in the general USPTO database and in Patent abstracts Japan and, in fact, showed the closest correspondence to the EPO ratio, where we would expect an ABB bias. This gives an indication, albeit rough, that the US bias is not so strong in our database. From interviews with patent managers at ABB we also know that ABB has had an explicit strategy to patent extensively in the US, due to the importance of the US market.

In addition, US patent data have been used in a large number of earlier studies and is usually considered to be a quite reliable measure. In spite of e.g. variations in the propensity to patent in different countries, Patel and Pavitt (1991, 6) show that, ”… the international distribution of the sources of US patenting show statistically highly significant similarities to the international distribution of business enterprise R&D expenditure”.

The second methodological problem concerns the categorization of patent classes, which proved to be a difficult task. Patent class titles are difficult to interpret and, above all, are not related to actual products or business areas, which makes it hard to relate patenting activities to economic performance. Therefore, we sought the help of industry specialists, who aided us in the identification of patent classes related to the power generation sector. We provided the specialists with descriptions of patent classes and patent data (including the development over time of patent classes, geographical dispersion of patents within each class and inventor names) and then together discussed which classes were most relevant for the power generation area. The patent classes included in our sample are listed in Appendix A.

There are two concerns with regards to the categorizations. First, many technologies can be used in several different applications. This implies that within each patent class, individual patents may be more or less relevant for a particular product area and there is a risk that not all patents in an identified class is relevant to power generation, even though some of them are according to the specialists. Second, due to technological interrelatedness there may be indirect relationships between patent classes and product areas. In a company such as GE, with operations in many different sectors, one sector could benefit from investments in other sectors, without any activity being recorded in the patent classes usually associated with the first sector. Linkages may, for example, exist between the aircraft engine field (in which GE is strong) and the power generation sub-field of gas turbines. Thus, there is a risk that GE's power generation related activities are under-estimated in comparison to ABB when we only consider the patent classes directly related to power generation.

4. Performance and technology strategy at ABB and GE

Power Generation: Financial Performance

In the 1980s, after nearly a century of development along national lines with comprehensive R&D facilities and broad product portfolios, the entire electrical engineering industry entered a period of restructuring (Tell 2000). Out of this turbulent time, General Electric (GE) emerged as the undisputed American leader. In Europe, Asea Brown Boveri (ABB), the result of a cross-border Swiss-Swedish merger, was heralded as a trendsetter in globalization with its far-flung transnational network of manufacturing and R&D facilities (Belanger et al. 1999).

Around 1990, ABB's total revenues amounted to about two-thirds of GE's, excluding the financial segments of the two firms. During the first half of the 1990s, ABB displayed stronger growth, whereas GE pleased its owners with a more robust profitability. A comparison of Power Generation, the most similar segment in the two diversified enterprises, yields the same picture, on average roughly equal in size, stronger ABB growth in revenues (see Figure 1a), but superior GE operating profit margins (see Figure 1b).

In the middle of the decade, however, the picture changed. Whereas GE's Power Generation segment grew in terms of revenues, ABB went from growth to contraction (see Figure 1a). GE also managed to keep up its profit margins, whereas ABB started to have problems in this respect (see Figure 1b).

FIGURE 1 IN HERE

These trends continued after the period studied here: In the early 2000s, GE gained momentum and showed tremendous growth, whereas ABB sold off of the entire Power Generation segment to the European competitor Alstom in 1999-2000.

Espoused technology strategies

As explained in the previous section, annual reports for 1988-1998 have been compared focusing on the power generation segments. As is seen in Tables 2-6 below, this 11-year period yields an interesting pattern of similarities and differences. In the tables, the two companies are compared in terms of cost leadership, technology leadership, broad technology scope and emphasis on specific technologies.

With regards to *cost leadership* (see Table 2), ABB espoused an ambition to be the industry's low cost producer a number of times on a business segment level, whereas GE hardly ever mentioned costs. However, compared to the other dimensions there were relatively few statements regarding costs on a segment level, perhaps because cost reduction measures often address several segments in a corporation. As mentioned in Section 3, we therefore searched for corporate level statements as well for this variable. This further strengthened the impression of substantial differences between the companies: With the corporate level included, ABB referred to cost leadership almost every year, whereas GE still only mentioned it at a couple of occasions.

TABLE 2 IN HERE

With respect to *technology leadership*, the findings are less clear-cut (see Table 3). On the one hand, GE constantly and explicitly referred to technology leadership as a key aspect of its strategy (especially in advanced gas turbine technology), in contrast to ABB that made few direct references to this strategy. On the other hand, ABB made repeated – albeit sometimes vague – statements about its leading technologies and technological breakthroughs, which may very well be interpreted as an ambition for technology leadership.

TABLE 3 IN HERE

The two firms' statements regarding *broad technology scope* reveal some clearer differences (see Table 4). ABB again and again emphasized its broad scope, both directly and indirectly in terms of provision of a wide assortment of products and technologies relating to power plants (turbines, coal combustion, nuclear, hydro, etc.). In contrast, GE maintained a narrow focus. As reflected in the annual reports, its Power Systems segment concentrated on a few (3-4) technologies, among which gas turbines and to some extent nuclear technologies were the most prominent, never portraying itself as having the ambition to offer a wide scope of technologies.

TABLE 4 IN HERE

Finally, with regards to *emphasis on specific technologies*, both companies early on identified advanced gas turbines and CCGT, combined cycle gas turbine-applications, as important growth areas and both proclaimed themselves as leaders (see Table 5). ABB did so in rather general (market) terms, while GE did so in specific technological terms. In addition, GE's specificity when presenting technological advances and performance in the turbine area is particularly interesting to note. The successive development and testing of first the new F turbines and then the next generation H technologies can be followed through consecutive annual reports, including major customer problems (rotor issues reported in 1995). This leads to the impression that systematic development and marketing of gas turbines as a key technology (or cluster of technologies) played a more prominent role at GE.

TABLE 5 IN HERE

With regards to other technologies, investments in nuclear energy technologies also figured repeatedly in the reports from both companies. Further, both companies frequently mentioned technologies for emissions and air control. With regards to combustion-related technologies, ABB highlighted its effort within coal-related technologies and steam power plants, whereas GE focused on its activities in steam turbines, which we interpret as a further indication of its emphasis on CCGT, where steam turbines are an integral part. Finally, ABB emphasized hydropower technology, especially in relation to its new Powerformer technology.

To sum up, the annual reports show several similarities: a common recognition of gas turbines and CCGT as a central growth area and investments in nuclear research and technologies for emissions control. The main impression, however, is one of substantial strategic differences, with ABB striving to provide a broad range of technologies at low cost, while simultaneously introducing breakthrough technology, and GE focusing on being the technology leader in a limited number of technologies, especially gas turbines and CCGT.

Technology activities

Figure 2 describes the patenting activity of ABB and GE in the power generation field (as defined above) in terms of the cumulative number of granted patents applied for in the period studied. GE's superiority in numbers over ABB is quite obvious on this overall level, which gives an indication of a *technological leadership* position. Given the general difference in US patenting levels between American and European firms, we should however be somewhat cautious to infer too much of this simple comparison, although, as concluded in Section 3, the U.S. bias does not seem to be that strong in our sample.

FIGURE 2 IN HERE

With respect to *technology scope*, the two companies differed in the diversification-specialization dimension. According to Zander (1999, 2002), diversification can be measured in terms of entropy. The entropy measure takes into account both the number of classes in which the company is active and the relative distribution of activities between classes:

$$\text{Entropy measure (E)} = \sum_{i=1}^{n} P_i \ln(1/P_i)$$

where P_i in the present context represents the share of patents accounted for by the *i*th patent class. The entropy measure ranges between zero and ln *n*, where *n* is the number of classes. A value of zero implies that all patents are located in one single class, whereas a value of ln *n* implies that patents are evenly distributed between all *n* classes. In the case of ABB and GE, $0 \leq E_{ABB} \leq 2.1$ and $0 \leq E_{GE} \leq 1.7$, calculated on all power generation patents applied for in 1988-1998 for each company. For the combined sample, $0 \leq E_{ABB\&GE} \leq 2.48$.

Thus, ABB’s entropy was higher than GE’s if we look at the total number of patents, and a similar difference was present in all years except one (1992). This difference indicates a difference in scope, which is also illustrated by Figure 3. This figure describes the relative shares of different patent classes of the total number of power generation related patents. Apparently, ABB both had patents in more patent classes and a more even distribution of patents between the classes than GE, which explains the difference in total entropy.

FIGURE 3 IN HERE

On a more detailed level, there are interesting differences in terms of the *emphasis on specific technologies*. If we first consider the patenting activity in absolute numbers, GE's much larger patent activity in classes 60 (Power plants), 376 (Induced nuclear reaction), 310 (Electrical generator or motor structure) 415 (Rotary kinetic fluid motors and pumps) and 416 (Fluid reaction surfaces) in comparison to ABB is particularly apparent (see Figure 4a). The shares of classes 310 and 416 of the total number of power generation related patents were also larger for GE than for ABB in the entire period studied. Figure 3 indicates that this was the case for class 415 as well. These three classes are, according to interviewed industry specialists, related to gas turbine technologies.

ABB had, on the other hand, more patents in classes 431 (Combustion), 110 (Furnaces), 122 (Liquid heaters and vaporizers), 165 (Heat exchange) and D23 (Environmental heating and cooling) (see Figure 4b), classes that also had larger shares of ABB's total patenting than of GE's (see Figure 3). Many of these patents are related to new coal-burning methods. The total number of patents in these classes was much smaller than that in GE's major classes, though (compare Figures 4a and 4b).

FIGURE 4 IN HERE

In sum, the patent analysis presents evidence both of GE's general technological superiority, which cannot be explained by its higher propensity to apply for US patents, and on differences in scope and specific areas of technological specialization.

5. Technology strategies and technology activities

Our first research question was if the espoused strategies and technology activities in the power generation segment of ABB and GE were related in a systematic way, implying distinctly different technological capabilities. A comparison of the statements in annual reports and the patenting patterns presented above suggests correspondence in several cases.

The first of these relates to the issue of *technology scope*. On a corporate level, GE has generally been regarded as a conglomerate, vastly more diversified than ABB, but our study shows that within the Power Generation segment, the opposite is true. Here the more narrow scope espoused by GE in its annual reports contrasts to ABB's ambition to cater for all needs in power generation. This difference is seen in the patent data as well. Based on the entropy measure and the analysis of relative shares of different patent classes, it was shown that ABB's patenting was spread more evenly over a larger number of patent classes than the activities of GE.

A second case of correspondence concerns the *emphasis on particular technologies*. Apart from the broad classes nuclear reactions and power plants, GE displayed a high concentration to a few specific areas related to gas turbine technologies. Patent classes related to gas turbine technologies (310, 415, and 416) had larger shares of GE patenting in the power generation field than of ABB's, and GE's activity in these classes was much higher than ABB's in absolute numbers. Thus, the impression from the annual reports that systematic development and marketing of gas turbines played a more prominent role at GE is consistent with the patent data.

ABB, on the other hand, was granted more patents in power generation classes such as 110 (Furnaces), 122 (Liquid heaters), 431 (Combustion) and 165 (Heat exchange), in spite of a general inferiority in numbers. Thus the patent data reflect references in ABB reports to other technology areas than turbines and nuclear energy, for example coal combustion and boilers. According to one industry specialist, for example, several of the patents in classes 110, 122 and 431 were associated to ABB's investments in PFBC (pressurized fluidized bed combustion), which was mentioned frequently in the annual reports. Another example is nuclear energy technologies, to which both companies repeatedly referred in their annual reports, and which was one of their largest patent classes (class 376) (although its importance decreased towards the end in terms of both patenting and annual reports for both companies).

In summary, ABB made explicit efforts to offer products in all power generation fields and also had a diversified portfolio of patents (including substantial patenting in new coal burning technologies such as PFBC), whereas GE patented in significantly fewer technological areas (most notably advanced gas turbines) and also refrained from depicting itself as providing a full assortment of power generation products in its annual reports.

With regards to technology leadership, our findings are a bit more ambiguous. On the one hand, GE's clearly espoused technology leadership strategy corresponds well to its high absolute level of patenting in power generation, especially with respect to gas turbines and CCGT. On the other hand, ABB's somewhat more vague statements of technological breakthrough and leading technology are not matched by a large patenting activity. It thus seems as if ABB's strategic statements are more an expression of ambition than GE's, which indicate actual technology leadership on an activity level. Our interpretation is, therefore, that there is a difference in technological capabilities between the firms in this dimension as well.

Some findings in annual reports and patent data, respectively, have no match at all in the other data set. Most notably, we have not been able to find any correspondence between statements in the annual reports on the importance of technologies for emissions control and actual patenting activities. Emissions control technologies are often sold as a package with power generation equipment and therefore jointly mentioned in annual reports of these segments. Technically they are not directly related to power generation, however, and thus not included in power generation patent classes.

Finally, as mentioned in Section 3 we were not able to find a suitable activity measure for cost leadership, but on a strategy level the two companies differed greatly in this dimension. Whereas ABB repeatedly mentioned its ambition to be the industry's cost leader, especially when we also considered the corporate level, GE hardly made any reference to this strategy.

In summary, our findings indicate that there is a correspondence between technology strategies and technology activities within the Power Generation segments of the two firms, implying different technological capabilities.

6. Technological capabilities and performance: Discussion and conclusions

Discussion

We will now return to our second research question: Is it possible to link the differences in technological capabilities to the differential economic performance of the power generation segment in the two firms in a plausible way?'

In the previous sections, we described how GE outperformed ABB in terms of revenues and profit margins towards the end of the studied period. In this context we are discussing dramatic and sustained differences in outcomes. Whereas GE Power Systems could book its best results ever at the turn of the millennium, ABB suffered a devastating decline from the mid 1990s and finally chose to exit power generation completely.

We also identified several differences in technology capabilities between the companies. GE's capabilities were focused and consistent: Its technological leadership was a consistently espoused strategy, backed up by a large pool of patent applications in a few targeted areas. ABB, in contrast, described its strategy in terms of a combination of broad technology scope, low cost and leading technology, which corresponded to a lower level of patenting, especially in technology areas where the two companies were competing head-on (for example in advanced gas turbines), and to a wider distribution of patents over a larger number of patent classes, including substantial patenting in new coal burning technologies (such as PFBC).

We, thus, may conclude that in this case the focused technological capabilities of GE were related to higher performance than ABB's broad technological capabilities. How does that square with the findings of previous research as referred to above?

With regards to *cost leadership*, the long-term nature of ABB's commitment to cost leadership gives evidence that its focus on cost-efficiency was not a response to its poor performance (cf. Bowman 1997), but preceded it. Our results, thus, seem to be broadly in line with the findings of previous research that cost leadership may not be viable strategy in dynamic fields, such as power generation, where product innovation rather than process innovation is in focus (cf. Miller 1988). On the other hand, since we have not measured cost leadership on an activity level we cannot say to what extent ABB actually followed this strategy through. It must, however, have been difficult for ABB to exploit the potential benefits of economies of scope (Porter 1985) with a broad portfolio of technologies that in some cases were not very clearly related. In addition, without strong complementarities the costs associated with marketing, transporting and commissioning their products would have been high, since power generation equipment tends to be complex and tailored to different customers (cf. Jones and Butler 1988).

With regards to *technology leadership*, our findings provide some support for the argument that this strategy is positively related to high performance (e.g. Bierly and Chakrabarti 1996; Carl Pegels and Thirumurthy 1996; Franko1989). However, activity seems to matter more than espoused strategy in this respect: Whereas both companies made statements related to technology leadership (although ABB's strategic statements on this matter were somewhat vaguer than GE's), the larger patenting activity of GE gives an indication of the identity of the "true" technology leader.

Finally, our findings on *technological scope* qualify some previous literature on the management of multi-technology firms (cf. Granstrand and Oskarsson 1994; Granstrand, Patel, and Pavitt 1997; Granstrand and Sjölander 1990). This literature generally praises the importance of technological diversity in multi-technology firms. Being active in different technologies is said to bring the potential of cross-fertilization (Granstrand and Oskarsson 1994), yielding new functionalities and increased product and/or process performance as technologies are combined. In our study it turns out, however, that within the Power Generation business segment GE – the higher-performing of the two companies – was decidedly more focused on a narrow range of technologies and products. It could be argued that keeping such a comparatively narrow technological scope may be successful in the short run, but lead to lock-in and capability traps in the long run. The history of GE and the heavy electrical manufacturing industry in general, however, seems to indicate a more complex pattern. Too diversified companies (as e.g. Westinghouse) have been driven out of the industry, and our reading of ABB's annual reports indicates similar problems of being unfocused. Thus, our findings indicate a limit to diversity and its positive implications for performance on a segment level.

We suggest that this limit can be formulated in terms of coherence in technological capabilities (Foss and Christensen 2001; Piscitello 2000; Teece et al. 1994). As argued by Foss and Christensen (2001), corporate coherence implies capabilities for both generating and exploiting technology diversity and complementarities. In a large number of technological fields, however, there is a tradeoff between exploitation and extensive exploration (von Tunzelmann 1998): A narrow technology focus may lead to competence traps (e.g. lock-in effects), whereas overt experimentation may lead to equally detrimental failure traps, where new technologies fail and are replaced by other new technologies that fail in turn (Levinthal and March 1993; March 1991).

In our case, GE's focused strategy of placing its bets on a few products and technologies (basically two: nuclear and advanced turbines, of which nuclear did not pay off) generated less diversity in terms of new products and may, thus, at a first glance seem more risky than ABB's strategy of making large investments in many areas. On the other hand, GE managed to exploit its capabilities in, e.g., gas turbine technology in a highly successful way through its focused strategy and activities, whereas ABB through the dilution of its technological capabilities caused by too broad a technology scope lacked the technical depth or other capabilities to follow through. For example, the investments in PFBC technologies (Watson 2004), resulted in a number of patents, but no market breakthrough, and never balanced GE's superiority in gas turbines. ABB was also unsuccessful in rectifying the difficult problems in its new generation of gas turbines (see Table 6). Here, it appears as ABB underestimated the development challenge involved and lacked the critical capabilities needed for the critical "after-launch" redevelopment efforts.

TABLE 6 IN HERE

Conclusions

In this study, we set out to investigate the relationship between technology strategies and technology activities in what we denoted technological capabilities and their relationship to firm performance: Do technology strategies matter? Do they matter for technological activities, and do they matter for financial outcomes?

Our analysis above suggests a clear relationship between the espoused technology strategies and technology activity in terms of overall patenting patterns for GE. For ABB, the relationship was blurred by the somewhat bold statements concerning technology leadership in comparison to its more modest patenting activity, but we were, nevertheless, able to conclude that technology strategies do matter for technological activities.

With regards to whether the two companies' technological capabilities were distinctively different and whether (or how) these differences mattered for the companies' performance in the selected segments, the discussion above indicates that technology strategies do matter for performance. In order to qualify this statement, however, we need to distinguish between the concepts of "strategy profile" and "capability profile".

Our study shows how a strategic profile aiming at technological leadership and focus on a narrow range of advanced technologies and products resulted in a mutually supportive combination, as it allowed for deep, rather than broad, learning. In a market demanding advanced solutions and high efficiency and reliability this approach was richly rewarded. The opposite strategy – to become a broad scope provider of leading technology as well as a low cost producer – could be seen as less risky. But in a technology-based competition it resulted in "over-stretch" and too thinly spread resources, where its carrier could not follow through on any of its major investments. In the Power Generation field, the focused technological leadership profile as typified by GE, with a focus on both technology and product level, was thus associated with sustained better performance and staying power than the "broad-scope" and low cost profile pursued by ABB.

Our study also shows, however, that performance is dependent on alignment within the technology capability profile as a whole, i.e. between technology strategies and technology activities. Here, we saw that GE was able to match its narrow technology scope with technology activities in relevant fields to deliver products that were well received in the market and solve the problems experienced by its customers. In contrast, ABB neither managed to combine its broad technology scope with deep enough technology activities to provide the market with products that worked and were in demand, nor to use its cost leadership strategy to make any big improvements in its profit margins.

These results imply that managers in multi-technology companies face two problems. The first is to choose a strategy profile suitable in a particular industry, i.e. to handle the trade-offs between broad technology scope, technology leadership and cost leadership. The second is to achieve alignment between technology strategies and technology activities in order to exploit its capabilities to the full. Our findings indicate, however, that these two problems are related – it seems reasonable to assume that it is more difficult to achieve alignment with diversified technology strategy profile, such as ABB's, which requires the coordination of several different technology strategies and their corresponding technology activities.

So, do technology strategies matter? Based on a two-company case study, our tentative answer to that question is yes. We have shown that substantial differences in performance between GE and ABB in the Power Generation field can be related to differences in the two companies' technological capability profiles, with respect to the espoused technology strategies (as indicated by statements in annual reports) and technology activities (as indicated by patenting) and the degree of alignment between these two technological capability components.

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Appendix A

Patent data classes defined as 'Power Generation'

PATENT CLASS	DESCRIPTION
60	Power plants
110	Furnaces
122	Liquid heaters and vaporizers
137	Fluid handling
165	Heat exchange
310	Electrical generator or motor structure
363	Electric power conversion systems
376	Induced nuclear reactions: processes, systems, and elements
415	Rotary kinetic fluid motors and pumps
416	Fluid reaction surfaces (i.e. impellers)
417	Pumps
431	Combustion
D23	Environmental heating and cooling: fluid handling and sanitary equipment

Biosketches

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