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Does Technology and Innovation Management Improve Market Position? Empirical Evidence from Innovating Firms in South Africa

Leon Oerlemans, Gerrit Rooks, and Tinus Pretorius

There is a growing recognition of the central role of technology and knowledge management for market success of organizations. Little is empirically know, however, about this relationship. Drawing on the South African Innovation Survey, a unique dataset on innovative behavior of South African firms in manufacturing and services, this paper investigates the question to what extent and in which ways do technology and innovation management activities affect firms' market position. Findings show that conducting technology strategy activities pays out. Moreover, especially a combination of internal and external technology audits seems to be beneficial for organizational performance.

Introduction

For a variety of reasons, for instance increasing global competition, there is a growing recognition of the central role of technology and knowledge in determining market success. As a result, organizations increasingly adopt and implement advanced technologies and, also, introduce technologically sophisticated knowledge-intensive products and services. These changing practices have alerted companies to the need for developing technology and innovation management as a part of their business strategies. Many firms understand that poor technology choices may affect firm performance and survival. To strengthen competitive position in a given market one of the most important organizational capabilities that a firm must develop is the ability to constantly evaluate and assess the development of relevant technologies inside *and* outside the organization. Based on the view that technol-

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ogy and innovation management addresses not only a firm's product technologies but also its process technologies and that both affect an organization's value chain, more integrative approaches have emerged that consider management of technology and innovation beyond the research and development areas and in a more strategic context (Burgelman and Rosenbloom, 1989; Zahra et al., 1993).

Most strategy theorists would agree that a systematic technology and innovation management approach, at a minimum, encompasses a firm's plans and activities to effectively develop, acquire and deploy technological resources and knowledge in a way to ensure better firm performance (Zahra, 1996). Ideally, technology and innovation management strengthens the successful deployment of an organization's technological capabilities and resources in pursuit of the goals of the organization. Effective deployment of technological resources helps to build a sustainable competitive advantage that enhances a company's financial performance (Porter, 1985a). However, despite the wide recognition of the importance of technology and innovation management for firm performance, this relationship has not been well documented empirically in the literature (see also: Zahra and Covin, 1993: 451). As Wilbon (1999: 148) argues: "Several streams of research exists which link bits of technology to pieces of strategy or performance, but too little effort has been given to integrating such works". More fundamentally, there seems to be a lack of agreement on the content of technology management policies, which makes it hard to assess their contribution as a source of competitive advantage. Moreover, the vast majority of the literature in this area is conceptual and prescriptive in nature (see for example: Brockhoff, 1996; Bone and Saxon, 2000; Da Silveira, 2002).

As a reaction to these existing deficiencies in the literature, a few empirical studies have been published that investigate the association between technology strategy and firm performance (McGee and Dowling, 1994; Zahra, 1996; Deeds et al., 1997, Lefebvre et al., 1997; Sharma, 2003). Wilbon (1999: 148) states that: 'nevertheless, more studies are needed to understand the dynamics of the technology strategy-performance relationship'. We agree with this statement, and want to contribute to the emerging scientific field of technology management in four ways by answering the following exploratory research question: to what extent and in which ways do technology and innovation management activities affect firms' market position? First, this paper provides additional empirical insights in the technology strategy-performance relationship. Second, to measure a technology strategy we take an activity approach as opposed to many studies that taken an outcome approach. Several studies argue that R&D effort and (the level of) automation is a major component of technology policy and strategy at the firm level (Zahra and Covin, 1983; Sharma, 2003). The measurement of, for example, the number of flexible manufacturing systems is regarded as a reflection of the technology strategy of a firm. Although we agree that these types of indicators measure the *outcomes* of technology strategies, we take a different angle, that is, we take an activity-based perspective. The number of technology and innovation management activities performed by innovating firms is regarded as the expression of activities taking place during the technology strategy development process (Turvani, 2001). To our knowledge, this approach is relatively new to the empirical field. Third, to test our hypotheses, a unique dataset is used, which was gathered within the framework of the First South African Innovation Survey research project. Therefore, in our paper we report on aspects of innovative behavior of South African companies on which hardly any recent empirical knowledge exists. Fourth, the results of this paper may be beneficial to practitioners in the field of technology management since insights are provided on how combinations of the use of technology and innovation management activities impact on firm's competitive position.

This paper is structured as follows. In the next section, a theoretical framework is developed leading to the formulation of a number of hypotheses. The subsequent section describes the research methodologies applied, whereas the following section presents the results of the data analyses. A discussion of the results, limitations, and research and policy implications are provided in the last section.

Theory and Hypotheses

The goal of implementing business strategy is to gain sustainable competitive advantage (Porter, 1990). Likewise, the aim of employing a technology strategy is to gain or maintain a sustainable technological advantage that accommodates a competitive edge (Khalil, 2000). This implies that a high level of interrelatedness and integration between business and technology strategies is paramount. To achieve a high level of interrelatedness and integration, extensive deliberations about an organization's distinguishing technological competences, the goods and services it can produce, its potential users, and the position in which the company wants to be, is required. Hence, an organization's technological competences, capabilities, and technologies must be exploited, protected and developed on the basis of a well-designed plan. Linking business and technology strategies successfully is the bases of effective technology management (see also Porter, 1985a).

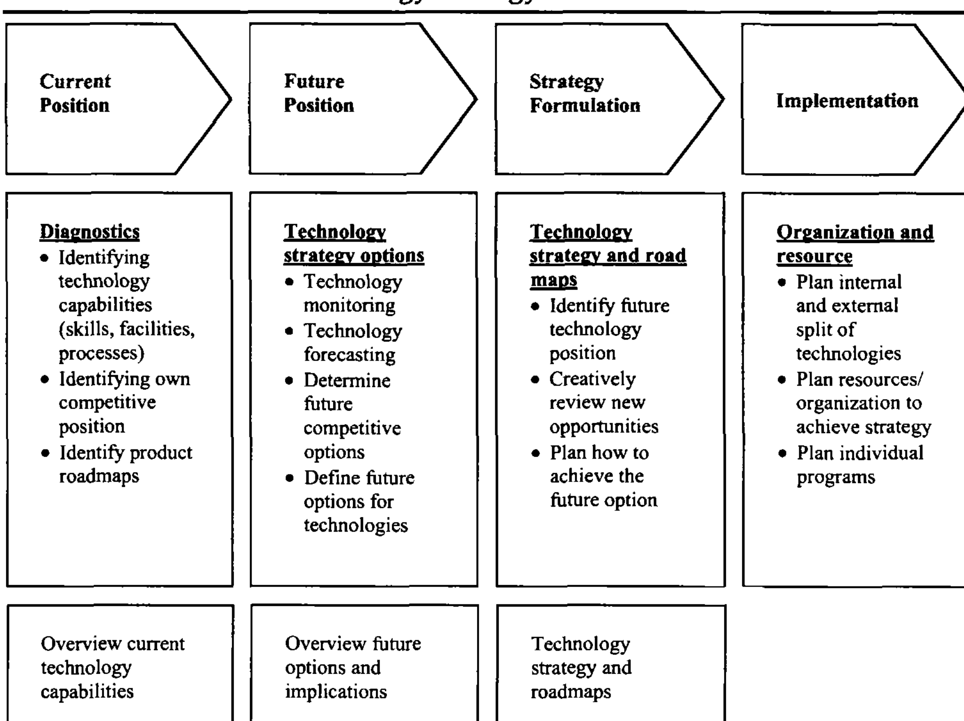
Ford (1988) stated that technology strategy is concerned with exploiting, developing, and maintaining the complete set of knowledge resources and abilities of an organization. Notice that Ford's description uses verbs to stress that technology strategy is an activity-based effort directed at the knowledge base and its development of an organization. Bone and Saxon (2000) took the same approach by maintaining that technology strategy is both an analytical and creative process, again pointing at the activity-based features of the concept.

Several scholars (Twiss and Goodridge, 1989; Dussauge et al., 1992; Stillman, 1997; Bone and Saxon, 2000) stress the benefits of implementing a technology strategy process in an organization. Examples of such benefits are an increased ability to react faster and more effectively to changes in the organizational environment; a clearer focus on main technological competences and knowledge, which could lead to better quality products, earlier product launches, and increased revenue and profit; an increased protection from sudden technological leaps and discontinuities; better focus investment, lower costs and new value creation. One of the most important benefits of a technology strategy process is a well-defined future pathway for research & development and engineering that can be communicated, understood and agreed to by all organizational stakeholders. In the end, these benefits will translate into competitive advantages, which could improve the relative market position of firms.

However, designing and implementing a technology strategy successfully is a far from unproblematic process. In the literature (see for example: Burgelman et al., 1995; Carayannis, 2000) several essential conditions have been identified for successful strategy implementation. To name a few: key players in the organization are identified and their needs and expectations understood; the process is explicit and transparent; top management is involved in a systematic way; the development of the strategy is a continuous process, which is clearly mapped and communicated throughout the organization; the strategy is well-linked to organizational culture. Moreover, it is found that well-tried and tested approaches have to be adapted and modified to suit the needs of the particular organization, and the use of 'off the shelf' prescriptive tools and techniques should be avoided.

Bone and Saxon (2000) provided a framework for the development of a technology strategy, which is suitable for our purposes for two reasons. First, it is an activity-based framework encompassing the major activities to be conducted to develop a technology strategy. Second, it stresses that the strategy development process comprises of a set of interrelated stages and activities that are aimed at the present and future evaluation of available and needed knowledge and competences, which could impact on the competitive position of the organization. An adapted version of this framework is presented in Figure 1. Since we are interested in the empirical relationship between technology management activities and market position, the focus will be on the first two activity stages as defined by Bone and Saxon.

Figure 1
Technology Strategy Framework



Source: Adapted from Bone and Saxon (2000).

Internal Technology Audit

The first stage in the technology strategy process is to diagnose, that is, to determine and evaluate the current technological core competences and capabilities of the organization. In other words, a part of the first stage is conducting an internal technology audit. As argued by Khalil (2000), core competence is a fundamental concept in the formulation of a technology strategy since it reflects the inner strength upon which a strategy is built. Prahalad and Hamel (1990) maintained that the core competences of an organization are "the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies", whereas capabilities are "a set of business processes strategically understood" (Stalk et al., 1992: 66). Therefore, competences and capabilities are distinct, but complementary concepts.

Auditing the internal technological competences and capabilities denotes defining the organization's current technical skills (e.g., a special method of software design, a specific chemical synthesis procedure, or a unique way of establishing large-scale system integration), quality of facilities available (plant, equipment, test facilities, and laboratories), and organizational structures and business processes (e.g., product and process development, technology transfer). Typical activities applied are technology audits, core competence assessments, and intellectual property audits.

A technology audit is an analysis conducted to identify the strengths and weaknesses of the technological assets of an organization. Its main aim is to evaluate an organization's position in technology relative to its competitors and the current state of the art. It encompasses not only assessments of product and process technologies, but also of service and marketing technologies. Core competence assessment is the measurement and evaluation of the organization's abilities to coordinate a diverse set of production skills and integrate different flows of technologies. An intellectual property audit provides an evaluation of the intangible assets of an organization. It helps to quantify the value of these assets to the extent that such value depends on the legal rights to these assets. The audit investigates and assesses the strengths and weaknesses in the procedures used to protect each intangible asset and secure appropriate intellectual property rights. Where appropriate, the audit furnishes tools to put additional processes in place, make improvements to existing processes, and take correcting steps to help ensure appropriation of future intellectual property rights.

The application of these internal auditing activities boils down to an evaluation of internal strength and weaknesses of the tangible and intangible technological assets (see also: Fallah, 1997; Takei, 1985). Organizations performing these activities are more aware of the strengths of their own technological knowledge bases, which enable them to formulate a more focused technology strategy, which could improve their success in the market. Therefore, our first hypothesis reads:

H1: Conducting an internal technology audit is positively associated with the improvement of the relative market position of organizations.

Competitive Position Analysis

A second set of activities performed in the diagnostic stage relates to the identification of the current competitive position of the organization. After all, the technological competences and capabilities currently available in the organization are converted to core products or processes, which in turn may be embodied in one ore more end products or services. These end products and services link the organization to its customers. Therefore, an important activity in this stage is market analysis. Under the assumption that for this analysis a market is defined from an (end) user perspective, that is, competing products or services are those products or services, which perform comparable functions and utilities for buyers regardless in which sectors these products or services are produced, an investigation of the criteria that influence user purchase behavior is of importance. Examples of the criteria to be analyzed are cost, price, color, convenience, ingredients, quality, and speed of delivery, service backup, or a large product portfolio. Additional topics to be researched in a market analyses are current market size, market segmentation, market trends, and demographics and economic developments impacting on purchase behavior.

Complementary to market analysis is competitor analysis, which can be defined as the process that involves collecting, analyzing and acting on information and knowledge about competitors and the competitive environment (Khalil, 2000). Since, seen from a producer perspective, competitors are those firms that sell substitutes on a same market, this analysis produces not only information on the overall market structure, but also on the position of an organization relative to other actors active in the market. Industry analysis refers to an investigation in the position of an organization in the value chain. As Porter (1980, 1985b) convincingly has argued, this position is an important determinant of a firm's competitive position since it reflects the level of control an organization has over the technologies (product, production, marketing, and disposal technologies) that contribute to producing and marketing a product or service. By evaluating the strength and weaknesses of its current position in the value chain, an organization can determine to what extent the bargaining power of suppliers and distributors is affecting its competitive advantage.

Conducting market, competitor, and industry analysis increases the knowledge and awareness of an organization on its current competitive position. Packed with this knowledge and awareness, an organization is able to better position itself relative to other actors in its business environment, and to decide more informed on how to manage its control over relevant technologies, for example by means of forward, backward, or horizontal (dis)integration (Khalil, 2000). An improved market position could be the result of applying the results of competitive position analysis (see for example: Molina et al., 2004; Leavy, 2003; Coburn et al., 2002). Therefore, the second hypothesis reads:

H2: Conducting a competitive position analysis is positively associated with the improvement of the relative market position of organizations.

External Technology Audit

Besides determining the current technological position of an organization, a necessary input for the technology strategy process is an overview and understanding of future technological options and their implications, that is, to perform an external technology audit. Such overviews can be used to gain a better understanding of the threats and opportunities that have a probability to impact on established technologies, products and markets, and, as a result, of the nature and magnitude of changes needed. Since technology is causing major changes in society and organizations, determining future technology strategy options is vital to top management, since it will provide information on the size of an organization's technology gap, that is, the difference between an organization's current technology position and where it should or could be in the future. Organizations can conduct several activities to investigate future technology strategy options. The literature (Burgelman et al., 1996; Khalil, 2000; Phillips, 2001) suggests several activities aimed at creating images of the technological future such as technology monitoring and scanning, technology forecasting and foresighting, and competitive (technological) intelligence.

Typically, technology monitoring and scanning is an activity aimed at observing the development of already existing and emerging technologies, which are new to the organization. It includes search, evaluation of alternative possibilities and their impacts, and a conclusion grounded on an assessment of progress and its implications over time. This activity has been applied for raising diversifying industrial opportunities (Vicente and Palop, 1996), identifying the possibilities of research on laser holographic lenses conducted by an university for the automotive sector (Anonymous, 2000), monitoring technological developments in the energy sector (Ashton et al., 1991), and investigating the advances in speech recognition and artificial intelligence (Halal, 2004). Technological forecasting can be defined as "the description or predication of a foreseeable technological innovation, specific scientific refinement, or likely scientific discovery, that promises to serve some useful function, with some indication of the most probable time of occurrence" (Prehoda, 1967).

Therefore, technological forecasting is about sensing trends, pressures and emerging capabilities, interpret these in terms of organizational need, indicating the likely of internal financial support for R&D programs, and predicting the form of possible innovations and their probable time scale. Typical techniques used are amongst others, trend extrapolation, Delphi forecasts and, scenario methods. Whereas technological forecasting deals with predicting probable paths of technological development, technological foresighting takes a (very) long-term perspective and tries to anticipate significant changes in society, the environment, the economy, and technology trends, with the aim to identify most likely development paths. Consequently, the accuracy of the latter activity is far lower. As argued by Lemos and Porto (1998), technological forecasting techniques are often applied in combination with (technological) competitive intelligence activities. Competitive intelligence is basically a future oriented extension of competitor analysis (Wright et al., 2002). Activities performed are aimed at the collection of information on how competitors deal with customers and their (future) needs and perceptions. Adding the adjective 'technological' implies that the information collection also deals with the technologies that competitors use to anticipate these (future) customer needs and perceptions. The results of both type of intelligence are used as an input to the technology strategy decision-making process (Taskin et al., 2004).

Conducting activities as described above results in an overview of relevant technological options, which can assist in (Burgelman et al., 1996) strategic decision-making on major reorientations of company policy (e.g., business and R&D strategy) and the improvement of operational decision-making, especially with regard to the R&D portfolio ands its direction of development, R&D project selection, and resource allocation between technologies. In sum, it allows an organization to get better informed about possible developments in the technological future, which could guide it to a more favorable market position. The above line of reasoning leads to Hypothesis 3:

H3: Conducting an external technology audit is positively associated with the improvement of the relative market position of organizations.

Interaction between Internal and External Technology Audits

The interrelated nature of the activities put forward in the technology strategy framework, which was depicted in Figure 1, suggests that interaction effects are plausible. Especially, innovating firms combining internal and external technology audits possibly outperform organizations that only apply one of both (Haley, 2000; Gregory, 1996; Ford, 1998). The argument runs as follows. Firms conducting either internal technology audits or external technology audits are well informed about their current technological positions or about their future technology options, respectively. Although innovating firms conducting one of both audits have clear knowledge and information advantages over firms not performing one of these activities, the actual combination of both audits could lead to stronger competitive advantages that translate in improved market positions. After all, firms possessing knowledge and information about their current technology position and their future technology options have a clear view on the magnitude of their technology gap. This awareness enables them to formulate a well-informed and goal-directed technology strategy that will help them to bridge the existing gap. Hence, Hypothesis 4 reads:

H4: Conducting both an internal and an external technology audit is positively associated with the improvement of the relative market position of organizations.

Technology Manager

Bone and Saxon (2000) argue that the presence of an employee responsible for the management of technology is an important precondition for successful technology strategy processes. Such an employee or employees (i.e., a technology management team) may perform several functions. First, technology managers can get sign-on. Second, they are able to generate and stimulate internal implementation champions. Third, they are able to create a process that is lasting. Fourth, they can act as a recognizable focal point for all relevant stakeholders. Since the presence of a technology manager in an organization probably will lead to a more well structured technology strategy process and a more clearly directed technology strategy, an innovation firm will have a competitive advantage over innovating organizations lacking such an official (see also: Randall, 2004; Jones, Herschel and Moesel, 2003; Hauschildt and Schewe, 2000). Therefore, Hypothesis 5 runs as follows:

H5: The presence of a specific person for the management of technology in organizations is positively associated with the improvement of the relative market position of organizations.

Control Variables

The estimates that will be presented in one of the next sections will contain two control variables. The first control variable is organizational size. Size could perform two functions in our theoretical framework. On the one hand, conducting internal and external technology audits and competitive position analysis may be dependent on size, that is, larger firms may have a higher propensity to perform these type of activities. Hence, the effects of the technology strategy process indicators are corrected for firm size. On the other hand, larger firms have as compared to smaller firm more resources at their disposal, which they could spend on for example marketing activities. Thus, larger firms are better equipped to improve their relative market position.

An organization's market position could be improved simply because it recently bought another firm, which could lead to an autonomous increase of sales and market share, that is to its (financial) performance (DeLong, 2003; Ramaswamy & Waegelein, 2003; Ramaswamy, 1997). Models have to be controlled for such an event.

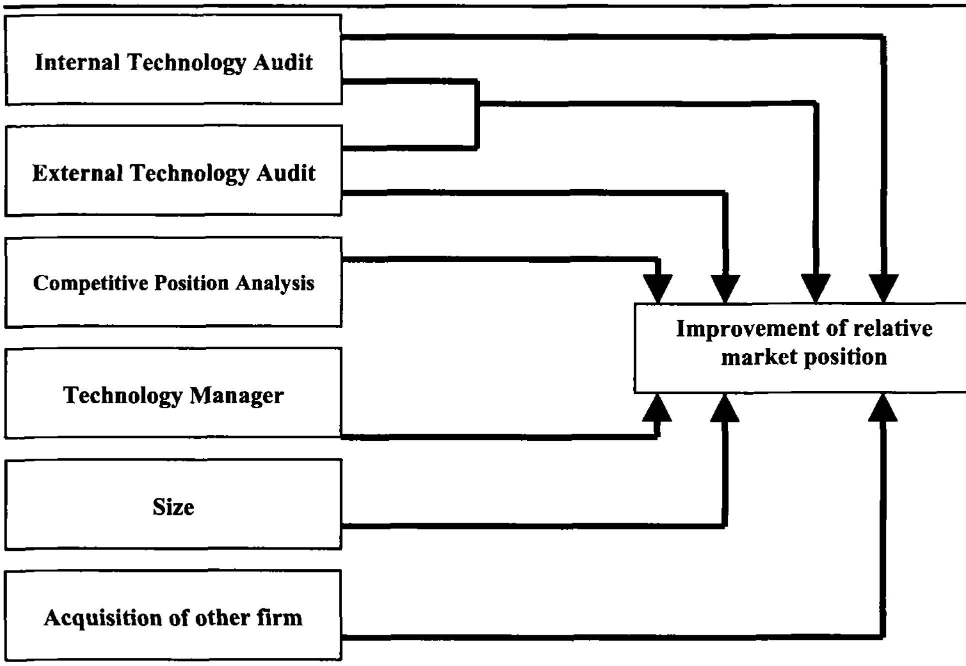
The above lines of reasoning can be summarized in a research model, which is presented in Figure 2.

Research Method

To test our hypotheses empirically we make use of the South African Innovation Survey 2001 (SAIS2001). The SAIS2001 questionnaire was based on the European Community Innovation Survey but adapted to the South African context. Alterations concerned a stronger focus on engineering activities as a form of innovative behavior and more attention for non-innovating organizations. The population of firms in the survey consisted of all South African firms in manufacturing and services with 10 or more employees that conducted economic activities in the period 1998–2000. As a sampling frame the Reedbase Kompass database (August 2000 version) was used. This database contains 16,931 South African firms with a known number of employees.

The empirical context of our research is the South African economy. To get an impression of the business landscape of the country, we briefly describe some features of its economy. South Africa's GDP in 2004 is estimated at about 175,300

Figure 2:
Research Model



million Rand (GDP in constant 1995 market prices). Compared to comparable 1994 figures, the South African economy experienced a 30% growth of GDP. Official employment in South African dropped from 5,3 million in 1994 to about 4,6 million in 2002. Between 1970 and 1990, the industrial structure of the country changed considerably. In 1970, about 30% of all jobs could be found in agriculture, 30% in manufacturing, and 39% in the service sector. In 1990, the figures were: 14% (agriculture); 32% (manufacturing); 54% (services) respectively, signaling a development to a service economy.

In SAIS 2001 *stratified sampling* was used as the sampling technique (see Oerlemans, Pretorius & Buys (2001) for a detailed description of the sampling procedures). The population of South African firms was divided into three different *size classes*. Taking the number of employees as an indication of the size of a firm, the following three strata were distinguished:

Stratum 1: firms with 11 to 20 employees; Stratum 2: 21–50 employees, and; Stratum 3: more than 50 employees.

Data collection process started in December 2001, when about 7,000 questionnaires were mailed to sampled South African firms in manufacturing and services. The questionnaire was sent, including a letter of recommendation by the South African Minister of Arts, Culture, Science and Technology, to the managing directors of the sampled firms. Firms were given the option to complete a web-based electronic version of the questionnaire or to fill in the paper version of questionnaire and send it back by postal mail to the research team. In May 2002, the research team decided to change the data collection strategy because too few completed questionnaires came in. Therefore, the postal surveying process was ended and a strategy of direct surveying by telephonic interview and e-mail was implemented.

A total of 617 firms of the 7,339 in the sample filled in and returned the questionnaire. The percentage of firms that responded was thus 8.4%. This is a rather low figure, even when we consider that response figures in organizational research often are rather low (see for example Kallebergh, 1996). We therefore decided to survey the non-response group to determine whether this group differed from the response group. A telephonic interview of 462 firms was conducted. Some questions were asked about specific reasons not to respond and about some firm characteristics, like for example R&D activity. The response to the non-response survey was very high (90%). Non-responding firms indicated that their reasons for not participating in the survey fell into two categories. Either they stated that their organization did not receive a copy of the questionnaire (52%), or a lack of time resulted in non-participation (33%). Amongst others, non-responding firms were asked whether they had technological innovations in the period 1998–2000 and to what extent their R&D activities were of a continuous nature. Of course, the same questions were asked to the responding organizations. A comparison of the response and the non-response group revealed no significant differences.

In this study, we focus on a subset of the response group, namely firms with technological innovations, that is, organizations that had process, product or service innovations in the period 1998–2000. In the response group 319 of the 617 firms (51.7%) indicated that they had technological innovations in this period.

Measures

Our dependent variable, improved relative market position, was measured by making use of the following question in the questionnaire: "Compared to the market leader in your firm's line of business, how have the innovations reported in questions 2a–2c affected *your* firm's relative market position in the period 1998 — 2000?". Respondents could indicate on a five point scale how their firm's position changed: 'worsened substantially' (1.2%), 'worsened to a small extent' (6.1%), 'no change' (17.5%), 'improved to a small extent' (37.2%), and 'improved substantially' (38%). Since the categories 'worsened' and 'improved to a small extent' are close to the category 'no change', we decided to construct a dummy variable IMPROVE (1 = substantially improved relative market position (38%), 0 = no improvement of relative market position (62%)).

The questionnaire contained a list of questions about technology and innovation management activities. Table 1 presents these activities and the frequency in which innovating firms perform them.

Each of the three theoretical variables 'external technology audit', 'competitive position analysis' and 'internal technology audit' is measured as a dummy variable, successively EXTAUDIT, COMPOS, and INTAUDIT. If one or more of the technology management activities indicating the theoretical variable was conducted (see Table 1) then the dummy variable takes on the value 1, otherwise it takes the

Table 1
The Proportion of Firm Conducting Technology and Innovation Management Activities

Theoretical variable	TIM activity	Proportion of innovating firms conducting activity
External technology audit	Technology monitoring and scanning	55%
	Technology forecasting and fore-sighting	35%
	Competitive technological intelligence	49%
Competitive position analysis	Competitor analysis	72%
	Industry analysis	78%
	Market analysis	85%
Internal technology audit	Technology/innovation audit of own organization	37%
	Core competence assessment of own organization	62%
	Intellectual property audit of own organization	36%

value 0. Additionally an interaction variable, EXT_INT, representing the interaction between external technology audit and internal technology audit was constructed. This interaction variable is computed as the product of EXTAUDIT and INTAUDIT.

Two control variables were employed in the analysis. Organizational size was measured as the number of employees in the year 2000. To adjust for the skewness of the distribution of the number of employees, the variable SIZE is constructed as the natural logarithm of the number of employees. The second control variable is whether or not the firm bought another firm in the period 1998–2000. The dummy variable BUY (1 = firm bought other firm, 0 = firm did not buy another firm) was based on a straightforward question whether the firm bought another firm in the period 1998–2000. The dummy variable MANAGER indicated whether there was a specific person in the firm responsible for the management of technology and innovation (1 = technology manager present in firm, 0 = no manager present in firm).

Table 2 presents the variables used in the analysis. A fraction of 38 percent of the respondents in our sample indicated that their firm improved their market position substantially. Both external and internal technology audits were quite often conducted by the firms: 72% and 74%, respectively. Market analysis was most often carried out (85%). On average, the firms in our sample employed 1,217 persons. In 2000, the largest firm in our sample employed 90,514 persons. A total of 18% of the firms in our sample bought another firm in the period 1998–2000. The innovating firms in our sample rather often employed technology managers (69%).

Table 2
Summary Statistics of the Variables Used in the Analysis

Variable	Number of observations	Mean	Standard Deviation	Minimum	Maximum
IMPROVE	235	0.38	0.49	0	1
EXTAUDIT	217	0.72	0.45	0	1
COMPOS	226	0.93	0.25	0	1
INTAUDIT	213	0.56	0.50	0	1
EXT_INT	206	0.56	0.50	0	1
SIZE	234	5.18	1.65	1.10	11.41
BUY	232	0.19	0.40	0	1
MANAGER	230	0.70	0.46	0	1

Results

Table 3 compares the intensity with which the different technology and innovation management activities are conducted with a number of firm characteristics.

It turns out that innovating organizations performing a higher number of these activities: (1) are larger organizations; (2) in 2000, exported a higher proportion of their sales; (3) had higher percentages of specialists in their workforce; (4) had higher percentages of higher educated employees. Interestingly, innovating firms that conducted a higher number of technology and innovation management activities are not the more R&D intensive organizations, since no statistically significant differences could be observed.

Since the dependent variable IMPROVE is a dichotomous variable, we make use of a multivariate logistic regression model. Table 4 presents the estimated logistic regression coefficients for two models. In these models, we controlled for the fact that firms are clustered within sectors. In Model 1 only the main effects are included, whereas in Model 2 the interaction effect is added to the main effects of Model 1. According to a likelihood ratio test both models fit the data well. After

Table 3
Some Characteristics of Firms Conducting Technology and Innovation Management Activities

Firm Characteristics (means)	Number of TIM-activities 0-3	4-6	7-9	ANOVA (Kruskal-Wallis H)
Number of employees 2000	261	1,600	1,325	23.890****
Export ratio 2000	12%	17%	31%	16.743****
R&D effort	4.2%	4.0%	6.3%	0.489
Growth employment	16%	4.8%	10.2%	1.204
Percentage of specialists	18%	19%	26%	4.780*
Percentage of higher educated employees	16%	20%	30%	12.486***

* = $p < 0.10$; ** = $p < 0.05$; *** = $p < 0.01$; **** = $p < 0.001$

Table 4
Logistic Regression Analyses of Improved Market Position (n = 203; standard errors adjusting for clustering of firms within sectors; listwise deletion of cases with missing values).

	MODEL 1			MODEL 2		
Variable	Logit Coefficient	Standard Error	p value	Logit Coefficient	Standard Error	p value
INTERCEPT	0.387	0.921	0.674	1.300	1.023	0.204
EXTAUDIT	-0.196	0.221	0.375	-1.867	0.708	0.008
COMPOS	0.401	0.517	0.439	0.594	0.476	0.211
INTAUDIT	0.278	0.230	0.226	-1.126	0.519	0.030
MANAGER	0.011	0.456	0.456	-0.061	0.435	0.887
EXT_INT				2.538	0.884	0.004
Control variables						
SIZE	-0.269	0.100	0.007	-0.329	0.103	0.001
BUY	0.305	0.381	0.423	0.344	0.385	0.372
Goodness of fit statistics						
Wald chi2	23.92 (6 degrees of freedom)			73.12 (7 degrees of freedom)		
prob > chi2	0.0005			0.0000		

fitting the model, we performed regression diagnostics. An inspection of the Pearson residuals and leverage values (Pregibon, 1981) revealed no problems in the model fit.

Table 4 presents the logit coefficients. To be able to interpret the coefficients we have to transform the coefficients to so-called odds ratios (Hosmer & Lemeshow, 2000: chapter 3). The odds of a positive outcome are defined as the probability of a positive outcome divided by one minus the probability of that positive outcome. The odds ratio is defined as the ratio of the odds for a positive outcome to the odds of a negative outcome. Odds ratios have found wide use as they approximate how much more likely (or unlikely) it is, under certain conditions, for the outcome to be present.

In Model 1 the main effects of EXTAUDIT, COMPOS, INTAUDIT, and MANAGER are tested. None of the coefficients of those variables differs significantly from zero. Hence, Hypotheses 1 to 4 are not confirmed by our results. We find no evidence that an external technology audit, a competitive position analysis, an internal technology audit, or the presence of a technology manager has an effect on improving relative market position. The only statistically significant ($p = 0.007$) variable with a negative sign is SIZE, indicating that smaller firms tend to have a higher probability to improve relative market position.

In Model 2 the interaction effect between EXTAUDIT and INTAUDIT, EXT_INT, is added to the equation. The logit coefficient of this interaction effect is positive and highly significant ($p = 0.004$). Hence Hypothesis 5 is confirmed. To be able to interpret the coefficient, we first have to compute the sum of the coefficient of the main effect of EXTAUDIT and the interaction effect EXT_INT, which gives 0.671 as a result. After the exponentiation of this number we obtain the odds ratio, which is 1.96. This tells us that an external technology audit will be about twice as effective in improving relative market position if it is combined with an internal technology audit, then when it is not combined with an internal audit. In Model 2 the signs of the variables indicating separate internal and external technology audits are statistically significant and negative. These results can be interpreted as follows. In the presence of the interaction effect, which indicates that firms combine internal and external technology audits, conducting either only an internal or an external technology audit produces negative effects. Only knowing what the current organizational technology position is or only knowing which technology options are available in the future result in both cases in an ill-directed technology strategy that impacts negatively on the relative market position of innovation organizations. Moreover, these findings stress the importance of an integrated technology strategy process.

Firm size is a significant predictor of whether or not an innovating firm improves its relative market position. The odds ratio is 0.72, indicating that larger firms are less likely to improve their market position than smaller firms. This result can be explained by the fact that large firms often already posses a significant share of the market, and thus it is more difficult for them to enlarge this share of the market substantially. Our results do not indicate that buying of other firms, or the presence of technology managers has an effect on market position.

Conclusions and Discussion

The main aim of this paper was an empirical exploration of the technology strategy-performance relationship at the level of the innovating firm. In the paper, a theoretical framework was derived from the technology management and strategy literature in which technology strategy activities were related to firm performance. Several hypotheses were derived on the effects of conducting technology strategy and management activities on the improvement of the relative market positions of innovating firms.

Our results give rise to some interesting conclusions and discussions. The first three hypotheses assumed that conducting internal and external technology audits, and competitive position analysis separately would impact on the improvement of the relative market position of innovating firms. However, none of these hypotheses were empirically confirmed. The first model only produced a statistically significant size effect indicating that smaller firms had a higher probability of improving their relative market position. These results signal that conducting unrelated technology strategy activities produce incomplete knowledge inputs for an organization's technology strategy. Subsequently, firms are less able to technologically position themselves adequately and to formulate and implement well-directed strategies. Investigating either current technology positions or possible future technology options produces insufficient combinations of different types of knowledge to design a strategic technological development path for an organization.

The importance of combining specific technology strategy activities was stressed by the findings of our second model in which the interaction effect of conducting internal and external technology audits turned out to influence the improvement of an innovating firm's relative market position in a positive way. This result highlights that the technology strategy process is truly a process in which different activities have to be integrated in order to be beneficial.

On the basis of the above, three conclusions can be formulated. First, conducting technology strategy activities pays out. Second, our findings stress that the technology processes should be a well-structured process in which specific activities are conducted, a finding of importance to practitioners in the field of technology management. Third, it can be concluded that the combination of specific technology strategy activities, that is internal in combination with external technology audits, is relevant to firm performance. Practitioners can benefit from this finding since it will enable them to direct resources to these kinds of activities and not to others.

Lastly, we provide some suggestions for future research. The empirical models in this paper used relatively straightforward measures of technology strategy activities. These measures could be made more sophisticated by looking more in depth at the activities taking place within for instance technology monitoring or forecasting. Which techniques and tools are applied? How is the collected information processed? These and other questions could enrich our understanding of the technology strategy process. This paper focused primarily at the first two stages of the Bone and Saxon technology strategy framework. Future research could concentrate on the strategy formulation and the implementation process. Furthermore, Bone and Saxon's model is sequential. Hence, the model suggests that activities should be performed in a specific order. But do specific sequences of activities really matter and are other sequences detrimental for the outcomes of the technology strategy process? Answering these and related questions demands a longitudinal research design, which could be another interesting research avenue to explore. Combined with the findings presented and discussed in this paper, this would lead to an understanding of the technology strategy processes beneficial to researchers and practitioners.

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