Technology Alliance Portfolios and Financial Performance: Value-Enhancing and Cost-Increasing Effects of Open Innovation

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ABSTRACT

The purpose of this study is to develop and test a conceptual framework that disentangles both the value-enhancing *and* cost-increasing effects of technology alliances on financial performance. To test our model, we rely on a sample of 305 Belgian manufacturing firms. Our data provide empirical confirmation for the assumption of existing research that technology alliance portfolio diversity has an indirect positive impact on financial performance via increased product innovation performance. However, we also observe a direct cost-increasing effect of technology alliance portfolio diversity on financial performance. Moreover, our structural equation analyses suggest that, in the short term, the direct cost-increasing effect of technology alliance portfolio diversity exceeds the indirect value-generating effect of technology alliances. These findings have important implications for the open innovation model.

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Firms increasingly adopt an open innovation model (Chesbrough, 2003) in which they rely on technology alliances or ‘formal arrangements between otherwise independent firms that pool together technological resources’ to complement and supplement their internal innovation efforts (Deeds & Rothaermel, 2003; Dittrich & Duysters, 2007; Hagedoorn, 2002; Poot, Faems & Vanhaverbeke, 2009). In addition, consistent evidence is present that firms, which engage in technology alliances, outperform firms that do not initiate such collaborative efforts in terms of innovation performance (for an overview of this research, see De Man & Duysters, 2005). Some scholars (Baum, Calabrese & Silverman, 2000; Faems, Van Looy & Debackere, 2005; Nieto & Santamaria, 2007), for instance, show that greater diversity of the technology alliance portfolio or ‘the amount of different alliance partners (i.e. suppliers, customers, competitors, universities) with whom a firm simultaneously collaborates’ increases the innovation performance of the focal firm.

Although these previous studies have provided in-depth insight into the impact of technology alliances on the innovation performance, they remain relatively silent on how technology alliances eventually influence the financial performance of the firm. Actually, these studies seem to assume a positive indirect relationship between technology alliances and financial performance, via increased innovation performance. In this paper, we do not want to question this positive indirect relationship between technology alliances and firm productivity. However, we argue that the simultaneous adoption of a wide variety of technology alliances also triggers costs that might negatively influence the financial performance of the firm. Numerous alliance governance scholars (e.g. Faems, Van Looy, Madhok & Janssens, 2008; Gerwin, 2004; Gulati & Singh, 1998), for instance, stress that technology alliances ask for substantial monitoring and control efforts. In addition, it is argued that, as the diversity of alliances partners increases, firms increasingly need dedicated alliance functions in order to manage potential synergies and conflicts between the different alliances (Hoffman, 2007; Kale, Dyer & Singh, 2002; Parise & Casher, 2003). Based on these arguments, we hypothesize the existence of a direct negative relationship between the diversity of the technology alliance portfolio and financial performance, reflecting the costs of simultaneously collaborating with different kinds of partners.

The purpose of this study is to develop and test a conceptual framework that disentangles both the value-enhancing and cost-increasing effects of technology alliances on financial performance. To test our model, we rely on a sample of 323 Belgian manufacturing firms. For these firms, we managed to collect data on their collaborative strategies and innovation performance via the Fourth Community and Innovation Survey and their financial performance via the Belfirst database. Our structural equation analyses generate several important findings. We observe an indirect relationship between the diversity of the technology alliance portfolio and product innovation performance via internal R&D intensity. We also find empirical confirmation for the assumption of existing research that technology alliances have an indirect positive impact on financial performance. However, we also observe a direct cost-increasing effect of technology alliance portfolio diversity on financial performance. Moreover, our analyses suggest that, within the observed time frame, the direct cost-increasing effect of technology alliances is larger than the indirect value-generating effect of technology alliances, resulting in an aggregated negative effect of diversity of technology alliance portfolios on financial performance.

These findings contribute to the current research on open innovation in two important ways. On the one hand, our results support the open innovation model by illuminating the interconnectedness between internal and external innovation strategies. On the other hand, they complement the focus of existing open innovation research on the value-generating properties of technology alliances, directing our attention to the cost-increasing effects of such collaborative strategies.

This paper is structured in four sections. First we introduce our conceptual framework, hypothesizing on the value-enhancing and cost-increasing effects of technology alliance portfolio diversity on financial performance. Subsequently, we discuss our methodology. Next, the results of our analyses are presented. Finally, we point to the main theoretical and managerial implications of our findings, discuss the study's main limitations, and suggest interesting avenues for future research.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

The purpose of this paper is to disentangle the value-enhancing and cost-increasing effects of technology alliances on financial performance. In order to do so, we developed a conceptual framework that is presented in Figure 1. This framework provides particular hypotheses on the connections between technology alliance portfolio diversity, internal innovation efforts, product innovation performance, personnel costs in value added and the profit margin of firms.

----- Insert Figure 1 about here -----

Value-Enhancing Impact of Technology Alliances on Innovation Performance

Over the past decades, we have witnessed a shift from a closed innovation model, where firms generate, develop and commercialize their own ideas, toward an open innovation model, where firms commercialize both their own ideas as well as innovations from other firms and seek ways to bring their in-house ideas to the market by deploying pathways outside their current businesses (Chesbrough, 2003). Technology alliances have been recognized as an important strategy to support such a paradigm shift (Neyens, Faems & Sels, In Press; Vanhaverbeke, 2006). Several scholars (e.g. Baum et al., 2000; Faems et al., 2005; Nieto & Santamaria, 2007), for instance, point to the positive impact of collaborating with a large variety of different kinds of alliance partners (i.e. suppliers, customers, competitors, universities, research institutes) on innovation performance. In particular, they provide evidence that increasing the diversity of partners in the technology alliance portfolio has a significant positive impact on the ability of a firm to be the first one to launch new or significantly improved products onto the market. These findings support the resource based argument that, as firms simultaneously collaborate with different types of partners, they are more likely to access a wide variety of technological capabilities, which in-turn improves a firm's innovation capabilities (Eisenhardt & Schoonhoven, 1996). In line with these previous findings, we hypothesize that:

> *Hypothesis 1: Technology alliance portfolio diversity has a positive direct effect on product innovation performance of the focal firm.*

Value-Enhancing Impact of Technology Alliances on Personnel Costs in Value Added

Most alliance scholars seem to implicitly assume that increased diversity of the technology alliance portfolio will lead to increased financial performance via increased product innovation performance. In our conceptual framework, we make this assumption more explicit though hypothesizing an indirect relationship between the diversity of technology alliances and one particular financial performance indicator (i.e. share of personnel costs in added value). When a firm is able to be the first one to launch a new or strongly improved product on the market, it is likely to gain market share in that particular market. Moreover, firms can realize larger margins on such highly innovative products. In our conceptual framework, we rely on value added to reflect these positive effects of product innovation on financial performance. Value added is the difference between total operating results and the costs of the goods and services, which are necessary to achieve results (Sels et al., 2006). Based on the above arguments, we expect that increased product innovation performance implies that more value added can be generated with the same amount of employees, representing a lower share of personnel costs in value added. We therefore hypothesize:

> *Hypothesis 2: Technology alliance portfolio diversity – through its positive impact on product innovation performance – decreases the share of personnel costs in value added.*

Cost-Increasing Impact of Technology Alliances on Personnel Costs in Value Added

Whereas previous research has emphasized the value-enhancing effects of diverse technology alliance portfolios, it has remained relatively silent on the cost implications of simultaneously collaborating with different kinds of alliance partners. However, in the alliance portfolio literature, first indications can be found that technology alliance portfolio diversity introduces significant costs as well.

Several alliance scholars (Dyer, Kale & Singh, 2001; Hoffmann, 2005; Kale, Dyer & Singh, 2001) emphasize that, as the complexity of a firm's alliance portfolio increases, the firm needs to introduce a dedicated alliance function at the corporate level of the organization. Such a dedicated alliance function holds responsibility for the management of the whole alliance portfolio. In particular, it keeps an overview on the various divisions and configures, coordinates, evaluates and promotes the alliance portfolio (Dyer et al., 2001; Kale and Singh, 2009; Kale et al., 2001). Other scholars (Barnes, Pashby & Gibbons, 2002; Faems, Janssens, Bouwen & Van Looy, 2006) provide first indications that alliances with downstream partners (e.g. research institutes and universities) require a different management approach than alliances with upstream partners (e.g. suppliers and customers). The adoption of a diverse technology alliance portfolio therefore requires a wide variety of alliance management skills that often are not present within the company.

Hiring dedicated alliance managers and expanding the alliance management skills is likely to change the internal cost structure of the firm (Kale & Singh, 2009). Ceteris paribus, the share of personnel costs in the added value will rise due to this change in internal cost structure. We therefore hypothesize:

Hypothesis 3: Technology alliance portfolio diversity directly increases the share of personnel costs in value added.

The Overall Impact of Technology Alliances on Financial Performance

The final purpose of this paper is to compare the value-enhancing and cost-increasing effects of technology alliance portfolio diversity. In order to do so, we incorporated profit margin as the final outcome variable in our conceptual framework. Profit margin measures the profitability of a firm. In particular, it reflects the net profit (after taxes) as a percentage of the revenues. If the total effect of technology alliance portfolio diversity on profit margin turns out to be positive (negative), we can conclude that the value-enhancing effect of technology alliance portfolio diversity is stronger (weaker) than the cost-increasing effect of it.

The Impact of Internal Innovation Efforts on Financial Performance

Not only external innovation efforts (i.e. technology alliances), but also internal innovation efforts might affect the financial performance of firms. Therefore, we also included internal innovation efforts in our conceptual model. In line with existing product innovation research (e.g. Ahuja, Lampert & Tandon, 2008; Schumpeter, 1939), we expect that, as firms increase their investment in internal innovation efforts, the probability of generating products that are new to the market significantly increases:

Hypothesis 4: Internal innovation efforts have a positive direct effect on product innovation performance of the focal firm.

In line with hypothesis 2, we also expect that, via increased product innovation performance, internal innovation efforts will decrease the share of personnel cost in the added value. At the same time, we hypothesize a significant direct relationship between internal innovation efforts and share of personnel cost in the added value. The existing new product development literature (e.g. Cooper, Edgett & Kleinschmidt, 2004; Griffin, 1997), for instance, seems to argue that, as the intensity of internal innovation efforts increases, companies need R&D portfolio managers in order to coordinate and manage potential synergies and conflicts between the different internal innovation projects. Recruiting such R&D portfolio managers implies additional personnel costs. We therefore hypothesize:

Hypothesis 5: Internal innovation efforts directly increase the share of personnel cost in the added value.

METHODOLOGY

Sample

In order to test our conceptual framework, we needed data on the collaborative activities, innovation performance and financial performance of firms. We therefore merged two different databases: the Belgian CIS IV database and the BELFIRST database.

In 2005, the Community Innovation Survey (CIS IV) was conducted in several Member States of the European Union. The survey sought to develop insights into the innovative behavior of private organizations. For the Belgian part of the CIS IV survey, a representative sample of 2075 Belgian manufacturing firms was selected and a 20-page questionnaire was sent out to them. The response rate was 42.8 % (888 firms). Only the firms that had introduced at least one product or process innovation between 2002 and 2004 or that had initiated innovation activities[1] between 2002 and 2004 needed to fill out questions on innovation performance and collaborative activities in the CIS IV survey. In this study, the analysis is therefore restricted to the 526 manufacturing firms of the

[1] In the CIS survey, innovation activities are defined as all activities that are oriented toward the development and/or implementation of product –or process innovations.

sample that introduced at least one product or process innovation between 2002 and 2004 or that were engaged in innovation activities between 2002 and 2004.

Each year, the majority of Belgian firms are legally bound to file their annual accounts at the Central Balance Sheet Office in order to provide third parties with reliable information on their financial health, employment and development (Sels et al., 2006). Subsequently, these data are added to the BELFIRST database, an electronic database containing financial information on Belgian companies and businesses. As a result, this database provides detailed information on the financial performance of Belgian firms.

After merging the Belgian CIS IV database and the BELFIRST database, we obtained a sample of 515 firms. Because of missing values on the variables that we constructed, the size of our sample was further restricted. In total, the sample of this study consists of 305 firms.

Measures

Diversity of Technology Alliance Portfolio

In the CIS IV survey, organizations indicated whether they engaged in inter-organizational agreements involving innovation between the beginning of 2002 and the end of 2004. Respondents specified whether they participated in R&D or other innovation-related projects with (1) Suppliers; (2) Customers; (3) Competitors; (4) Consultants; (5) Universities; and (6) Research institutes. In line with previous research (Faems et al., 2005; Nieto & Santamaria, 2007), we used this information to construct the variable *diversity of technology alliance portfolio,* representing the extent to which an organization collaborates with different kinds of partners.

Internal Innovation Efforts

In our conceptual framework, we also incorporated internal innovation efforts as a factor that influences innovation and financial performance. In the CIS IV survey, each respondent had to report the total number of R&D employees in 2004. Based on the Belfirst database, we also possessed information on total number of employees in 2004. As a result, we were able to construct the variable *internal innovation efforts*, representing the share of R&D employees in the total number of employees in 2004. According to previous research (Faems et al., 2005; Neyens et al., In Press), this variable is an adequate proxy to measure the internal R&D intensity of firms.

Product Innovation Performance

In line with previous research (Belderbos, Carree & Lokshin, 2004; Faems et al., 2005; Nieto & Santamaria, 2007), we measure product innovation performance as the proportion of turnover in 2004 attributed to new or strongly improved products that the company introduced between 2002 and 2004 and that were new to the market[2]. The analyses do not incorporate the proportion of turnover attributed to new products itself but instead the natural logarithm of 1+ the proportion of turnover attributed to new products in order to obtain a normal distribution.

Financial Performance

In order to assess the financial performance implications of technology alliances, we rely on two financial performance measures: personnel costs in value added and profit margin. *Personnel costs in value added* represent all costs of the work-force employed on a temporary or permanent basis divided by value added in 2004. Personnel costs encompass wages, social security taxes and benefits. Value added is measured by firm

[2] In the CIS IV survey, 'new to the market' means that the company was the first one to introduce this new or strongly improved product in its markets.

revenues minus the sum of subsidies, costs of commodities, raw materials and auxiliary materials and costs of services and diverse goods. We chose value added instead of sales because value added is a better indicator of value creation, which is a central construct in our hypotheses (Cooke, 1994; Sels et al., 2006). *Profit margin* is the final outcome variable in our conceptual framework and is measured by calculating the net profit after taxes as a percentage of the revenues in 2004.

Control variables

Several variables have been introduced in order to control for possible confounding effects: industry, firm size, whether the organization is part of a divisional entity, and past financial performance.

Because of potential industry differences in terms of likelihood to engage in technology alliances, internal innovation efforts, value added and personnel costs we controlled for them by introducing ***industry*** dummies. Relying on the NACE codes, we made a distinction between 11 industries. The food sector was used as our reference category in our analyses. Table 1 provides an overview of the frequencies of the different industries.

----- Insert Table 1 about here -----

Since the seminal writings of Schumpeter (1939), the relation between size and performance of firms has been much debated (Ahuja, Lampert & Tandon, 2008; Cohen, 1995). Within the framework of our analyses, the variable ***size***, measured by natural logarithm of the number of employees in 2002, has therefore been included within the different models as a control variable.

With R&D remaining a centralized function within numerous firms, the R&D strategy of subsidiary companies may be seriously affected by the parent company. (Veugelers & Vanden Houte, 1990). Deeds and Hill (1996), for instance, found evidence that firms listed as a subsidiary of another firm, performed significantly better in terms of bringing new products to the market than non-subsidiary firms. To test the differential behavior of subsidiaries, a dummy, labeled '***subsidiary***', has been included in the analyses.

Finally, we introduced past financial performance (i.e. profit margin in 2001) in our model. This will control for any residual unobserved heterogeneity across firms leading to systematic differences in financial performance. In addition, it allows assessing whether past financial performance has an impact on the technology alliance portfolio decisions of managers.

RESULTS

Descriptive Statistics

Table 2 gives an overview of the most important descriptive statistics. The means for the variable Product Innovation Performance is 0.06. Taking into account this study's use of logarithmic transformations for this variable, the implication is that on average the respondents attributed 8.25% of their turnover to new or strongly improved products that the company introduced between 2002 and 2004 and that were new to the market. From Table 2 it becomes apparent that the diversity of the technology alliance portfolio was rather limited. On average, the innovating firms used 1.89 of the six collaborative partners that were included in the survey.

----- Insert Table 2 about here -----

To test the hypotheses, we used structural equation modeling (SEM) with manifest variables. Compared to ordinary linear regression models, this technique has two advantages (Sels et al., 2006). First, the method enables to define and test hypothesized relationships between variables. The output indicates whether the model is supported by the data as a whole and gives a significance test for the various individual relationships. Second, a variable in a SEM model can either be dependent or independent. This allows testing the indirect influence, if any, of certain variables.

The goodness-of-fit overview (see Table 3) indicates that the theoretical model is not adequately supported by the data. In order to optimize the model, we added a path between technology alliance portfolio diversity and internal innovation efforts. This relationship can be accounted for theoretically and, as will be discussed later on, enriches our understanding of the link between technology alliance portfolio and product innovation performance. The resulting model is presented in Figure 3.

----- Insert Table 3 about here -----

----- Insert Figure 2 about here -----

The goodness-of-fit measures (Table 3) indicate that the optimized model is effectively supported by the data. Below we interpret and explain the effects. First, we look at the effects of technology alliance portfolio diversity on product innovation performance. Second we assess the indirect impact of technology alliance portfolio diversity on the share of personnel costs in value added. Third, we evaluate the direct effect of technology alliance portfolio diversity and internal innovation efforts on the share of personnel costs in value added. Fourth, we discuss how the combination of these relationships leads up to overall financial performance. The standardized path coefficients are listed in Table 4. The results of the test of the optimized model are also represented in Figure 2. The control variables have been omitted in this graphical representation in order not to overload the figure.

----- Insert Table 4 about here -----

The Impact of Technology Alliances on Product Innovation Performance

Based on previous studies (e.g., Baum et al., 2000; Faems et al., 2005; Nieto & Santamaria, 2007), we hypothesized a positive impact of technology alliance portfolio diversity on product innovation performance. However, Table 4 indicates that technology alliance portfolio diversity has no significant impact on product innovation performance in our optimized model. At the same time, we observe that technology alliance portfolio diversity has a significant ($p<0.05$) positive impact on internal innovation efforts.

As stated in hypothesis 4, we expected firms that increase their internal innovation efforts generate significantly more turnover from products that are new to the market. This hypothesis is supported by our data as internal innovation efforts have a positive significant ($p<0.001$) direct effect on product innovation performance.

In sum, although we did not find a direct impact of technology alliance portfolio diversity on product innovation performance, our data illuminate the presence of a positive indirect relationship between technology portfolio diversity and product innovation performance via internal innovation efforts.

The Indirect effect of Technology Alliances on Personnel Costs in Value Added

We expected that increased product innovation performance significantly lowers the share of personnel costs in value added. The data indeed show a positive and significant ($p<0.05$) impact of product innovation performance on personnel costs in value added.

Taking into account the indirect impact of technology alliance portfolio diversity on product innovation performance, hypothesis 2 can be confirmed.

The Direct of Technology Alliances on Personnel Costs in Value Added

As expected in hypothesis 3, we also find that technology alliance portfolio diversity has a significant ($p<0.001$) direct positive effect on the share of personnel costs in value added. These findings seem to confirm that increasing diversity in a firm's alliance portfolio is likely to trigger additional control and monitoring costs, which in-turn increase the personnel costs in the added value.

We also hypothesized a direct positive effect of internal innovation efforts on personnel costs in the value added. However, in contrast to our expectations, our data show a marginally negative relationship between these two variables ($p<0.10$). These results suggest that increased internal innovation efforts do not only increase value added via product innovation performance, but also have a direct positive impact on value added. Moreover, it indicates that this latter positive direct effect of internal innovation efforts on value added compensates for the additional personnel costs that increased internal innovation efforts are likely to bring along. This positive direct effect of internal innovation efforts on value added might be explained by the fact that internal innovation efforts do not only contribute to the emergence of product innovations, but can also trigger process innovations or 'changes in the ways in which products are created and delivered' (Tidd, Bessant & Pavitt, 2005: 10). Such process innovations allow improving the efficiency of the production process, which in-turn decreases the share of the personnel costs in the added value (Davenport, 1993).

The Overall Impact of Technology Alliances on Profit Margin

To evaluate the net effect of technology alliance portfolio diversity on financial firm performance, we added the firm's profit margin as a final variable in our conceptual framework. As we expected, we found a significant negative relationship ($p<0.01$) between the share of personnel costs in the added value and the profit margin of the firm.

Table 5 summarizes the direct, indirect and total effects of technology alliance portfolio diversity on different performance measures. As expected, we find a positive indirect effect of technology alliance portfolio diversity on share of personnel costs in the added value. In line with our initial expectations, we also observe a negative direct effect of technology alliance portfolio diversity on share of personnel costs in the value added. When we sum the indirect and direct effects of technology alliance portfolio diversity on share of personnel costs in the value added, we find a positive total effect. As a result, we see that the total effect of technology alliance portfolio diversity on the profit margin of firms is negative. These findings suggest that, in the particular time frame that we observed, the cost-increasing effects of technological alliance portfolio diversity are higher than its value-enhancing effects. In the next section, we discuss the theoretical and managerial implications of these findings.

----- Insert Table 5 about here ----

Impact of Control Variables

As Table 4 indicates, we found a significant positive relationship between the size of the firm and alliance portfolio diversity. These findings are in line with previous research (Hagedoorn, 2002; Lichtenthaler, 2008), providing evidence that larger firms are more active in external innovation strategies than small firms. We also find that the technology alliance portfolio diversity of firms, which are a subsidiary of another firm, is significantly higher compared with independent firms. Finally, we observe a marginal positive effect of previous financial performance (i.e. profit margin on 2001) on technology alliance portfolio diversity.

We also found a significant negative relationship between firm size and internal innovation efforts, measured as the relative share of R&D employees in the total number of employees. In addition, our data indicate that the internal innovation efforts within the Machines and Equipment industry are significantly higher than in the food industry. As expected, we observed a significant relationship between profit margin in 2001 and the financial performance indicators (i.e. share of personnel costs in value added and profit margin) in 2004. Finally, our data point to a number of industry differences with respect to the applied performance measures (see Table 4).

DISCUSSION AND CONCLUSION

Implications for the Open Innovation Model

In his seminal work, Chesbrough (2003) describes a shift from a closed to an open innovation model. Recently, numerous companies (i.e. IBM, Intel, P&G) have started to adopt the concept of open innovation. At the same time, academic research on the concept of innovation is also proliferating (Chesbrough, Vanhaverbeke & West, 2006). In this study we have developed and tested a conceptual model that connects technology alliance portfolio diversity, innovation performance, and financial performance. This study contributes to the open innovation literature in two fundamental ways.

Connection between internal and external innovation activities

In his open innovation model, Chesbrough (2003) refers to collaboration with external partners as an important mechanism to create purposive inflows of knowledge, which allow accelerating internal innovation. In other words, Chesbrough (2003) expects an explicit connection between external and internal innovation activities. Existing research (e.g. Baum et al., 2000; Faems et al., 2005; Nieto & Santamaria, 2007) on the impact of technology alliance portfolio diversity and product innovation performance has largely ignored the connections between internal and external innovation though. Although these studies incorporated internal R&D intensity as a control variable, they focused on the independent effect of technology alliance portfolio diversity on innovation performance. However, our study suggests the existence of particular connections between internal and external innovation strategies. In particular, we observed an indirect relationship between technology alliance portfolio diversity and product innovation performance via internal innovation efforts. In this way, our data support the existing open innovation paradigm that emphasizes the impact of external collaboration on internal innovation efforts, which in-turn influences product innovation performance

Financial Performance Implications of the Open Innovation Model

The existing open innovation model tends to focus on the value-generating properties of collaboration with external partners. In particular it seems to assume that collaboration with external partners improves product innovation performance, which in-turn has a positive impact on financial performance. At the same time, the open innovation model remains relatively silent on the cost implications of collaborative strategies. In this paper, we addressed this research gap by making an explicit distinction between the value-enhancing cost-increasing effects of technology alliance portfolios. In this way, we were able to show that greater technology alliance portfolio diversity indirectly (i.e. via increased internal innovation efforts and product innovation performance) decreases the share of personnel costs in the added value. At the same time, though, we also found greater technology alliance portfolio diversity directly increases the share of personnel costs in the added value. Moreover, our analyses indicated that, the direct cost-increasing effect supersedes the indirect value-enhancing effect. As a result, the total effect of the technology alliance portfolio on the profit margin of the firm turned out to be negative.

These latter findings also have important managerial implications. First, they suggest that, when making technology alliance decisions, managers should not only consider the potential benefits of such collaborative strategies, but also should take into account the additional costs of intensifying the technology alliance portfolio. At the same time, our findings point to the need of applying a cautious approach toward evaluating the performance implications of technology alliance investments in the short-term. After all, our analyses suggest that, within a 2 year time frame, the financial costs of technology alliance investments are likely to be more visible than the potential benefits of such investments. An exclusive focus on the short-term implications of technology alliances might therefore give a too pessimistic view on their potential financial contribution, ignoring the long-term benefits that such collaborative strategies might bring along.

Limitations and Future Research

A first important limitation of this study concerns the use of similar time-frames to measure the value-enhancing and cost-increasing effects of technology alliance portfolio diversity on financial performance. In this study, we assessed how the diversity of the technology alliance portfolio between 2002 and 2004 affected financial performance in

2004. Although we think that this time-frame is adequate to assess the cost implications of external collaboration, we realize that it might be too short to fully grasp the value-enhancing effects of collaboration with external partners. This is especially the case for explorative alliances (alliances with universities and research institutes), where the added value of the collaboration only manifests itself in the long term (Faems et al., 2006; Neyens et al., In Press). We therefore stress the importance of future research that systematically assesses the performance implications of alliances across different time-frames.

Although we were able to control for past financial performance in our analyses, we could not control for past product innovation performance and past internal innovation efforts in our model. As a result, we could not assess how previous internal innovation efforts and innovation performance might influence the firm's technology alliance portfolio diversity. In addition, whereas our data point to an indirect relationship between technology alliance portfolio diversity and product innovation performance via internal innovation efforts, Cassiman and Veugelers (2006) provide first evidence for a complementary relationship between external and internal innovation efforts on innovation performance. In our SEM model, however, it was not possible to control for the potential complementarities of internal and external innovation efforts[3]. Additional research on the complex interactions between external and internal innovation activities and their product innovation performance implications therefore seems to be necessary.

[3] Testing for complementarity between technology alliance portfolio diversity and internal innovation efforts would have required adding an interaction effect in our SEM model. However, given the limited size of our sample, adding such interaction effects would trigger huge multicollinearity and distributional problems (Rigdon, Schumacker & Worthke, 1998; Williams, Vandenberg & Edwards, 2009).

Previous research (e.g. Deeds & Hill, 1996; Rothaermel & Deeds, 2006) has provided first indications that not only the diversity of the technology alliance portfolio (i.e. the amount of different partners), but also the intensity of the technology alliance portfolio (i.e. the amount of alliances in which a firm participates) influences product innovation performance. However, the CIS IV survey does not allow assessing the impact of technology alliance portfolio intensity as respondents were only asked to indicate whether or not they collaborate with particular kinds of partners. Future research on the value-enhancing and cost-increasing impact of technology alliance portfolio intensity on financial performance might therefore be fruitful.

Several scholars (e.g. Hoang & Rothaermel, 2005; Rothaermel & Deeds, 2006; Zollo, Reuer & Singh, 2002) have emphasized the importance of alliance experience in understanding the performance effects of collaborative innovation strategies. For instance, it is argued that previous collaboration might trigger the emergence of alliance capabilities which in-turn decreases the costs of monitoring and controlling future alliances (Rothaermel & Deeds, 2006). Because of the cross-sectional nature of the CIS IV survey, we did not have information on the extent to which the firms had collaborated in the past. We therefore encourage scholars to engage in longitudinal research that allows examining the moderating impact of alliance experience on the relationship between alliances and financial performance.

Despite these limitations, we believe that this study has provided valuable insights in both the value-enhancing and cost-increasing implications of technology alliance portfolios. We hope that our findings may help managers in optimizing their alliance portfolio decision making processes and that our suggestions for future research might stimulate academic research in further examining the financial implications of the open innovation model in general and of technology alliances in particular.

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Table 1: Industry frequencies

Industry	Frequency	Percent
Food, Beverages and Tobacco	45	14.8
Textile, Clothing, Fur and Leather	23	7.5
Wood, Paper and Printing	18	5.9
Chemical Products, Rubber and Plastics	57	18.7
Non-Metal Mineral Products	18	5.9
Metallurgy	9	3.0
Metal Products	31	10.2
Machines and Equipment	91	29.8
Furniture	9	3.0
Recycling	2	0.7
Production and Distribution of Electricity, Water and Gas	2	0.7

Table 2: Descriptive statistics and correlations
(* Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level)

Variable	Mean	S	Diversity of Technology Alliance Portfolio	Internal Innovation Efforts	Product Innovation Performance	Personnel Costs in Value Added	Profit Margin 2004	Ln(Size)
Diversity of Technology Alliance Portfolio	1.89	2.00	1					
Internal Innovation Efforts	0.07	0.11	0.050	1				
Product Innovation Performance	0.06	0.10	0.111	0.248**	1			
Personnel Costs in Value Added	0.66	0.24	0.106	-0.047	-0.059	1		
Profit Margin 2004	5.00	8.86	-0.050	0.105	0.125*	-0.642**	1	
Ln(Size)	4.86	1.51	0.489**	-0.127*	0.089	0.033	-0.051	1
Profit Margin 2001	2.80	11.80	0.028	-0.015	0.016	-0.362**	0.407**	-0.064

Table 3: Goodness-of-fit measures

Industry	Theoretical model	Optimized model
Bentler’s Comparative Fit index	0.99	1.00
Bentler and Bonett’s Non-normed index	0.73	0.92
Bentler and Bonett’s Normed Fit index	0.99	1.00
Chi-Square test (p-value)	0.04	0.25

Table 4: Standardized path coefficients (†p<0.10; *p < 0.05; **p<0.01; ***p<0.001)

Path from / to	(1)	(2)	(3)	(4)	(5)
(1) Diversity of Technology Alliance Portfolio		0.1458*	0.0596	0.1928***	
(2) Internal Innovation Efforts			0.1948***	-0.1006†	
(3) Product Innovation Performance				-0.1121*	
(4) Personnel Costs in Value Added					-0.6172***
(5) Profit Margin 2004					
Control variables					
(6) Ln(Size)	0.4457***	-0.1924**	0.0972	-0.0304	-0.0205
(7) Subsidiary	0.1126*	-0.0283	0.0376	-0.0781	-0.0188
(8) Profit Margin 2001	0.0938†	-0.0410	0.0040	-0.4455***	0.1616***
(9) Textile, Clothing, Fur and Leather	0.0192	-0.0498	-0.0554	0.1419*	0.0337
(10) Wood, Paper and Printing	0.0930†	-0.0420	-0.0672	0.0653	0.0170
(11) Chemical Products, Rubber and Plastics	0.0687	0.0332	-0.1284†	0.1456*	0.1054†
(12) Non-Metal Mineral Products	-0.0847	-0.0519	-0.0761	0.1229*	0.1627***
(13) Metallurgy	0.0498	-0.0332	-0.1199*	-0.0638	0.0557
(14) Metal Products	0.0392	-0.0467	-0.0617	0.1476*	0.1003†
(15) Machines and Equipment	0.0509	0.2212**	0.1321†	0.3725***	0.2270***
(16) Furniture	-0.0104	0.0213	-0.0134	0.0973†	0.0527
(17) Recycling	-0.0193	0.0214	-0.0080	0.0294	-0.0076
(18) Production and Distribution of Electricity, Water and Gas	0.0641	-0.0129	-0.0605	-0.1765***	-0.0080

Table 5 Direct, indirect and total effects of technology alliance portfolio diversity on financial performance

Performance outcomes	Direct effects	Indirect effects	Total effects
Personnel Costs in Value Added	0.1928	-0.0245	0.1683
Profit Margin	-	-0.1039	-0.1039

Figure 1 Conceptual Framework

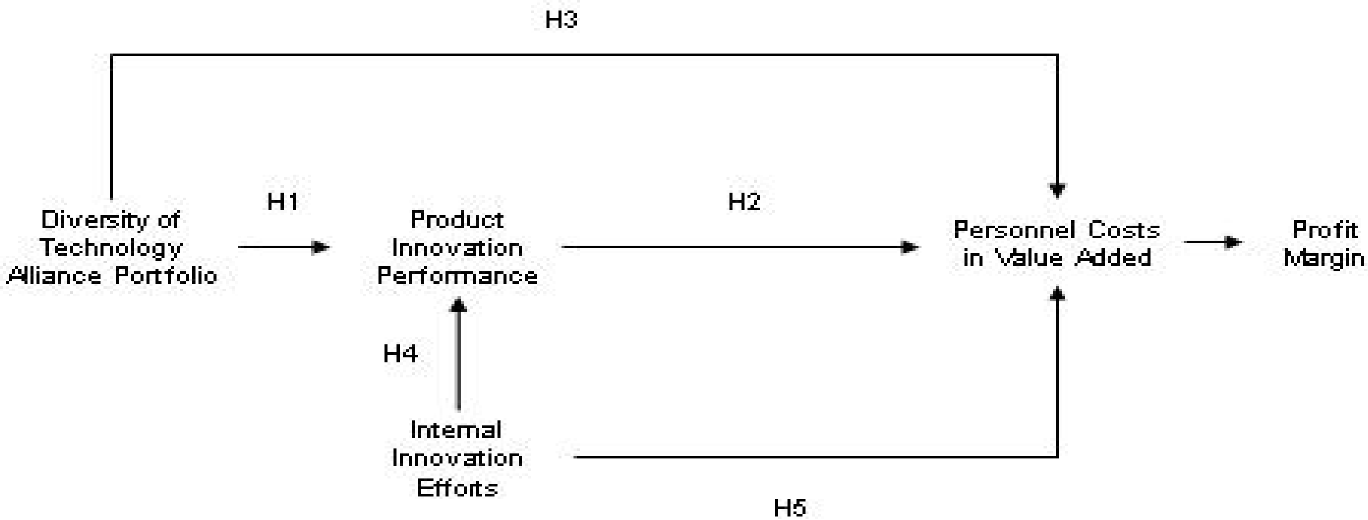

Figure 2: Results of optimized model †p<0.10; *p < 0.05; **p<0.01; ***p<0.001