Paper to be presented at the DRUID Academy 2012

on

January 19-21
at
University of Cambridge /The Moeller Centre

Too much of a good thing: the role of alliance portfolio diversity for R&D activity in the biotechnology industry

Wilfried Zidorn
University of Würzburg
Entrepreneurship and Management
wilfried.zidorn@uni-wuerzburg.de

Abstract

In the end of the 1990s, a wave of mergers increased the level of industry concentration in the pharmaceutical and biotechnology industry (Danzon, Epstein, and Nicholson, 2007). Firms in the latter industry moved from platform technologies (service orientation) towards a more product based approach and hence entered the market of pharmaceutical firms. This change was necessary to stay competitive and to satisfy the requirements of investors (Chaya, 2005). The originated new processes and challenges caused small biotechnology firms to engage in a variety of alliances to complement important resources and to extend their business with missing knowledge in management. Hence, alliance management during the last two decades became more complex due to its nature itself, as well as the increasing number of collaborative agreements. Increased managerial complexity is often recognized in high-tech industries, such as the biotechnology industry, and some scholars use it as a rational for the failure of alliances (Park and Ungson, 2001). However, only a small number of studies focus on possible R&D benefits that result from an increased alliance activity and complexity. To fill this gap the main research question of the paper is how an increasing complexity in alliance relationships affects the R&D activity of firms.

To answer this research question this paper uses patent panel data of the 20 leading biotechnology firms from the USPTO, which is combined with alliance information from the Deloitte RECAP Database. The R&D activity of a biotechnology firm is captured by the number of granted patents in a given year and forms the dependent variable. The independent variables are the number of alliances, and technology alliances as a subgroup. An additional independent variable separates young from old firms, which is combined with the two types of alliances to control for interaction effects. To test the relationships, several fixed effects negative binomial regressions are applied. These relationships are controlled by numerous firm-specific variables, such as firm size, R&D expenditure, a firm?s patent stock and a set of dummy variables.

The main result of this paper is that young and small firms in the biotechnology industry tend to obtain a higher number of issued patents when they form numerous collaborative agreements. That is to say innovative performance of a young biotechnology firm rises with the increasing complexity of its alliance portfolio. This effect is stronger for firms that engage in technology oriented alliances. The tasks within technology oriented alliances are more complex in particular for science driven biotechnology firms. Therefore, higher complexity in alliance portfolios, if handled effectively, yields higher innovative performance in the biotechnology industry.

Jelcodes:O32,-

Too much of a good thing: the role of alliance portfolio diversity for R&D activity in the biotechnology industry

Wilfried ZIDORN and Marcus WAGNER
University of Wuerzburg
Chair of Entrepreneurship and Management
Stephanstraße 1
97070 Würzburg, Germany
wilfried.zidorn@uni-wuerzburg.de
+49 931 31 80760

Abstract

The purpose of this paper is to show the impact of heterogeneous partners in a biotechnology firm's alliance portfolio on the R&D dynamics. Previous literature has stressed that investments into the heterogeneity of partners in an alliance portfolio is more important than just engaging in multiple collaborative agreements. The analysis of a unique panel dataset of 20 biotechnology firms and their 8602 alliances suggests that engaging in diverse alliances reduces a firm's R&D activity. However, this effect is positive for young biotechnology firms as they profit most from heterogeneous partners in terms of acquiring new resources, skills and information.

Keywords: Alliances, alliance portfolio, biotechnology, R&D dynamics.

JEL codes: O32, O34

Introduction

Schumpeter (1939) was one of the first scholars to define innovation as crucial for the long-term survival of a firm. Firms that are able to seize technological opportunities through their innovation management are most likely to achieve or maintain competitive superiority. Innovation and an effective R&D management are most important for firms in high-tech industries. Fast technology development, short product life cycles, and rising expenses for knowledge acquisition (Sampson, 2007), which characterize such industries, require fast actions and effective guidance. For firms in these industries it is inevitable to have a fast technology development to capture first mover advantages, such as early cash flows, external visibility, legitimacy and early market share (Schoonhoven et al., 1990). Yet, technology may be developed either internally and/or externally. While large firms have strong technological capabilities to develop their technologies in-house, small firms often lack such sophisticated resources, which they often compensate through alliances with external partners (Vanhaverbeke et al., 2007). These alliances are defined as *'…co*-operative agreements in which two or more separate organizations team up in order to share reciprocal inputs while maintaining their own corporate identities' (De Man et al., 2005 :1377) and range from loose and relational R&D partnerships to equity joint ventures (Contractor et al., 2002). The impact of alliances on innovation has been analyzed extensively, and it is found that firms profit by means of innovation and overall performance[1]. Recent studies found that firms profit most from heterogeneous partners in their alliance portfolio (e.g. Baum et al., 2000; Duysters et al., 2011; Faems et al., 2005). Still, empirical evidence how the diverse partners in an alliance portfolio influence a firm's R&D activity is scarce. Some mentionalble expectations are the studies by Faems (2005) and Duysters (2011). However, no study so far has made an empirical attempt to analyse the relationship between the alliance portfolio approach and a firm's R&D activity in the biotechnology industry. This paper attempts to fill this gap in

[1] For a collection of papers that analyze the effect of alliances on innovation see De Man and Duysters (2005).

literature and addresses the main research question on how an increasing number of collaborative agreements with heterogeneous partners in a biotechnology firm's alliance portfolio affect its R&D activity.

To answer this question the present study focuses on the 20 most successful biotechnology firms (MedAdNews, 2004) and analyses alliance portfolios with a focus on newly established biotechnology firms. The remainder of the paper is structured as follows: In the first part extant literature on the different dimensions of alliances and their effects on innovation are reviewed. Subsequently, testable hypotheses are derived. The following part describes the data and the empirical setting used to test the hypotheses. The results are reported and discussed in the subsequent part and finally concluding remarks are drawn.

Literature Review

During the last three decades inter-firm relationships between firms have experienced rapid growth. Especially during the 1980s, firms have started to support their internal development through alliances, such as joint ventures, license agreements, technology alliances, and other collaborative relationships (De Man et al., 2005). This development is based on several advantages for firms that result from inter-firm collaboration. Alliances give firms access to complementary assets (Hagedoorn, 1993; Hamel, 1991; Powell et al., 1996; Teece, 1986), reduce risks, costs (Ciborra, 1991; Hagedoorn, 1993, 2002; Harrigan, 1988a; Ohmae, 1985) and uncertainties (Dollinger et al., 1992), and promote the transfer of tacit and codified knowledge (Ahuja, 2000; Das et al., 1996; Doz et al., 1997; Eisenhardt et al., 1996). These organizational, financial and technological advantages permit firms to improve their innovativeness (Ahuja et al., 2001; Amabile, 1988; Vanhaverbeke et al., 2002). Therefore, most studies find that successfully managed alliances have a positive effect on a firm's R&D activity (De Man et al., 2005). However, if alliances are managed inadequately, severe consequences will follow, which is shown in the fact that 60% of all alliances fail (Bleeke et al., 1993; Harrigan, 1988b). Reasons for alliance failure are opportunistic behavior by partners (Pisano, 1990), unintended knowledge spillovers (Teece, 2002; Veugelers, 1998), different objectives of the focal firms (Larsson et al., 1998; Lorange et al., 1992), in particular within vertical agreements (e.g. supplier-manufacturer relationships), inferior flexibility to adapt to altering management structures induced by the alliance (Doz, 1996), and increasing alliance complexity (Killing, 1988).

The concept of alliance complexity is most interesting for analyzing previous literature on the research interest of this paper and resembles an emerging topic in scientific research. Killing (1988) divides complexity into task and organizational complexity. Task complexity may be caused by the alliance scope, the environmental uncertainty and the skills of the alliance partners. Especially for environments of high uncertainty, such as the biotechnology industry, he finds tasks performed by the alliance to be most complex. Combined with other factors, the task complexity influences the organizational complexity of an alliance. He finds organizational alliance complexity to be highest for firms that are engaged in several alliances but have less routine in managing them. Engaging in several alliances simultaneously increases both task and organizational complexity, but allows firms to benefit from access to a broader pool of technological opportunities and knowledge acquisitions (Duysters et al., 2011).

Literature refers in this context to alliance portfolios, which are defined as *"a firm's collection of direct alliances with partners"* (Lavie, 2007 :1188). To manage the increasing complexity in alliance portfolios, dedicated alliance management functions and alliance programs have to be established (Kale et al., 2002). The numerous alliances do not only allow the accumulation of new resources and skills (Balakrishnan et al., 1993; Kogut, 2000), but also help a firm to gain experience in alliance portfolio management to effectively seize the full potential of its collaborative agreements (Powell et al., 1996). Once such an efficient portfolio management is established, firms may benefit from relational rents based on synergy effects, which cannot be realized by dyadic alliances (Dyer et al., 1998). The composition of an alliance portfolio has attracted scholars' attention (Baum et al., 2000; Goerzen et al., 2005). Baum (2000) finds that a combination of heterogeneous partners in an alliance portfolio is more important than to simply have multiple alliances. To access non-redundant resources through a diverse alliance portfolio leaves a firm with information advantages (Duysters et al., 2011) and puts it into a favorable position to achieve and sustain innovation (Cohen et al., 2001; Faems et al., 2005; Katila et al., 2002; Leiponen et al., 2010). Furthermore, the access to information from different types of collaborative partners provides firms with a wide range of information on technological developments (Ahuja, 2000; Freeman, 1991).

Summarizing the literature review on the question how heterogeneous alliances in an alliance portfolio affect a firm's R&D activity, alliances are, if managed effectively, a promising strategy tool to sustain innovation. Therefore, firms strive to engage in multiple collaborative agreements with heterogeneous partners which are combined in an alliance portfolio. This results in a trade-off between increased complexity, which often leads to alliance failure, and better innovative performance, by accessing a broad pool of complementary resources, skills and information.

Hypotheses Development

Fast product development has become an important strategy tool to capture first mover advantages, such as early cash flows, external visibility, legitimacy, and early market share (Schoonhoven et al., 1990). Especially in high-tech industries fast patenting of new technologies is important for firms to sustain competitive advantages. Deeds and Hill (1996) argue that one way to rapidly develop new technologies is to enter strategic alliances with complementary partners. The majority of leading scientific studies find that alliances have a positive effect on firm performance (De Man et al., 2005). Powell et al. (1996) find that alliances can give firms access to resources in terms of new knowledge. Gulati (1998) argues that firms that are engaged in strategic alliances have higher growth rates and tend to be more profitable. Deeds and Hill (1996) analyze the impact of alliances on firm performance and find that firms with numerous collaborative agreements are more innovative and have higher rates of new product development. Furthermore, firm profit most if they maintain alliance portfolios with partners with diverse backgrounds (Baum et al., 2000). The resulting relational rents that stem from efficiently selected partners in an alliance portfolio can never be achieved independently through a single dyadic alliance (Dyer et al., 1998). Literature finds that efficient alliance portfolios consist of partners with heterogeneous expertise (Baum et al., 2000; Duysters et al., 2011; Faems et al., 2005; Goerzen et al., 2005). This allows firms to access a diverse pool of skills and resources and leave them with information advantages (Duysters et al., 2011) by screening a broad number of technological developments (Ahuja, 2000). Proactive firms build and maintain extensive alliance portfolios with heterogeneous partners (Marino et al., 2002), which protect them from environmental uncertainties (Dollinger et al., 1992). Therefore, firms that build an alliance portfolio with heterogeneous partners are assumed to develop high R&D activities. This leads to the following hypothesis:

H1: Alliance portfolio diversity positively associates with innovation output.

Several scholars define complexity as diversity (e.g. Duysters et al., 2011; Marino et al., 2002; Powell et al., 1996). Yet, the management of many diverse alliances is considerably more demanding than the management of few diverse or more similar alliances. Firms that have partners from diverse backgrounds (e.g. competitors, customers, suppliers, universities, and research institutes) in their alliance portfolio are exposed to higher managerial costs and increasing complexity (Duysters et al., 2011). Alliances that become too complex tend to fail (Killing, 1988). Therefore, and in line with the study of Hoang (2001) it is expected that firms that engage in multiple alliances with partners from diverse backgrounds perform less good in terms of innovation output. This leads to the following hypothesis:

H2: Alliance portfolio diversity negatively moderates the relationship of biotechnology firm alliancing extent with innovation output.

Finally, a careful chosen alliance portfolio is most relevant for small firms (and thus more relevant than for larger firms) in innovation driven industries (Lerner et al., 1998). Small firms have to develop important capacities to survive in the highly competitive high-tech industries. Innovativeness (Gilsing et al., 2008; Griliches, 1990) and technological diversity (Almeida et al., 1997) support these firms to develop such capacities. While large firms already have developed technological capabilities, which allow them to focus on fields where they already have expertise in (Giuri et al., 2004; Vanhaverbeke et al., 2007), small firms still have to find their technology path and hence focus on opportunities from a broader technological perspective. An effectively chosen alliance portfolio with multiple diverse partners helps a small firm to acquire information, skills and resources from various sources (Baum et al., 2000; Duysters et al., 2011; Marino et al., 2002), which should positively influence its innovation output. And due to the resulting spillover and synergy effects (Duysters et al., 2011; Dyer et al., 1998) small firms should profit most from heterogeneous partners in their alliance portfolio. Therefore, alliance diversity by itself should especially help firms new to the market to gain access to network resources, which leads to the following hypothesis:

H3: Alliance portfolio diversity positively moderates the relationship of biotechnology firm newness with innovation output.

Methodology

To test these hypothesis, data of the 20 most successful biotechnology firms (MedAdNews, 2004) has been acquired, which ranges from 1980 to 2008. In this industry an increasing complexity of allying behavior and the relevance of patents by means to effectively protect intellectual property rights are both well established. Furthermore, the biotechnology industry shows a representative setting of a high-technology industry, where R&D processes are considered to be of highest importance (Khilji et al., 2006). Measuring patenting activity among firms within the same industry is clearly more informative than data on patenting across industries or countries (Basberg, 1984). Additionally, a focus on one industry helps to control for industry trends, such as scale economies or new technologies (Pangarkar, 2003).

Table 1 provides an overview on the biotechnology firms of interest. In the sample Amgen has the highest average annual sales (4.1 billion US dollar), whereas MGI Pharmaceuticals the lowest (43.2 million US dollar). From a descriptive perspective, the alliance portfolio diversity is similar for all focal firms. That is to say, the biotechnology firms in the sample prefer to have heterogeneous partners in their alliance portfolio. Some expectations are Celgene, Imclone Systems and Nabi Biopharmaceuticals, which show values below 80% of alliance portfolio diversity, which however still reflects a high degree of diversity among their alliance partners. Firms with average sales below 300 million US dollar have reluctant patenting strategies. No patenting pattern can be observed for firms that exceed this amount of average sales.

Insert Table 1 about here

Methods

To determine the age of each firm, the year of establishment for each firm has been identified. The average firm in the sample has an age of 15 years[2]. The mean is used to separate young from more sophisticated firms and to create the binary variable Young. That is to say firms with an age of 15 years and less are considered to be young and are coded with 1. Firms that were established more than 15 years ago are considered as being not young and are coded with 0. Since the study is based on a panel dataset, this status is dynamic and young may change to not young when time passes.

Table 2 presents the definitions and a short description of the dependent variable as well as the independent and control variables.

Insert Table 2 about here

Dependent Variables

To measure the R&D activity of each biotechnology firm, the yearly count of patents by the USPTO is used and forms the dependent variable Patents for the analysis. Only patent applications of granted patents are used, since they are most likely to represent successful research of the biotechnology firms of interest. Following the convention, granted patents are assigned to the application year.

Independent Variables

To measure the effect of alliances on the patenting behavior of firms, data from RECAP is involved, which is a longitudinal dataset containing cooperation event dates of biotechnological firms, ranging from 1980 to 2008. All alliance events are counted for each

[2] Haeussler et al. (2010) define high-technology new firms as *"small and medium*-sized enterprises that are too young to have completed a full new *product development (NPD) cycle"*. Yet in the biotechnology industry new product development can take up to 15 years (Rothaermel et al., 2004), hence firms below this age may still be considered to be young.

year and are captured by the variable Alliances[3]. The variable Portfolio Diversity (PD) is created using RECAP information on 27 different types of alliances, which are used by the focal firms. The dataset provides information when a specific alliance event has occurred, which allows to accumulate all events to yearly observations for each firm in the sample. According to the total number of firm's alliances in a specific year, the relative number of events of the alliance types is calculated. The inverted Herfindahl index is used to analyze whether a firm concentrates on a small number of alliance types, or whether it has a heterogeneous alliance portfolio and is more formally described as follows:

$$PD_{j,t} = 1 - \sum_{i=1}^{27} \bar{a}_{i,t}^2 \qquad \text{with } \bar{a}_{i,t} = \frac{a_{i,t}}{\sum_{i=1}^{27} a_{i,t}},\ j = [1,20], t = [1,28]$$

Values for PD can range from 0 to 1, where 1 indicates a heterogeneous alliance portfolio and 0 stands for a homogenous portfolio of firm j in period t. In other words, if firm j focuses on similar alliances within period i, then PD reaches low values, if the alliance portfolio of firm j in period i is heterogeneous, high values for PD are reached.

To test for the hypotheses derived above an interaction variable Alliances*Portfolio Diversity is created. Here, both constituting variables are centered to prevent issues of multicolliniarity. Following the same logic, the variable Young*Portfolio Diversity (centered) is developed.

Control Variables

Three financial variables control for Size, which is the logarithm of total firm sales, *Tobin's Q,* which represents the market to book value of a focal firm, and R&D intensity, which is the ratio between R&D expenditures and a firm's total assets. Large firms with a

[3] Mergers have been identified and eliminated.

high R&D intensity are more likely to benefit from economies of scale by more effectively processing R&D resources, which in turn increase a firm's technological activity (e.g. Griliches, 1990; Leten et al., 2007). To control for a firm's expansion strategy, the variable Acquisitions is included in the models. Changes in a firm's knowledge base are controlled by the variable Patenting. Here, a moving average of five years from a firms patent portfolio represents a firm's current R&D stock and hence indicates the knowledge base of a firm[4].

Descriptive Analysis

Descriptive statistics and the correlation matrix are provided in Table 3. The average biotechnology firm of the sample receives 27.75 patents each year. Using the mean of firm age to separate into young and old firm gives an approximately symmetric distribution of the dataset with a value for the variable Young of 0.56. The firms of interest show high diversity in the types of collaborative agreements in their alliance portfolios. This is illustrated through a mean of 0.88 of the variable Portfolio Diversity (PD). The low correlation levels between the variables and the moderate values for the variance inflation factor (VIF) indicate no issue of multicollinearity.

Insert Table 3 about here

Results

The estimation is based on 305 observations, which represent unbalanced panel data on 20 biotechnology firms. All estimations use a fixed effects negative binomial model. The Log-Likelihood and the Wald test values indicate good model fit.

All regression models are illustrated in Table 4. Model 0 is a baseline model, which takes the effects of the control variables into account. Unlike Size that has a negative effect at

[4] Studies about R&D depreciation (Griliches, 1979) argue that knowledge capital loses most of its economic value within 5 years.

a 10% significance level on the dependent variable Patents, the control variables *Tobin's Q,* Acquisitions and Patenting have a positive effect at a 1% significance level. There is no sign change of the control variables, however, a change of the significance levels of the variable Size and the constant when further independent variables are included in the models. In Model 1 the variables Young, Alliances, Portfolio Diversity (PD) and the interaction variable Alliances*Portfolio Diversity (centered) are added. Despite Young, all other variables in Model 1 have a significant influence on the dependent variable at the 1% significance level. The variable Alliances has a positive effect and Portfolio Diversity (PD) shows a negative impact on the innovation output of a focal biotechnology firm, which supports H1. The interaction between the two independent variables negatively influences the dependent variable. That is to say biotechnology firms that concentrate on alliances with heterogeneous partners perform worse in terms of innovativeness than alliances that have similar partners in their alliance portfolio, which supports H2. When the interaction variable Alliances*Portfolio Diversity (centered) is replaced by the interaction variable Young*Portfolio Diversity (centered), as in Model 2, then only the newly added interaction and the variable Alliances remain significant. The results illustrated in Model 2 show that increasing partner heterogeneity of a young biotechnology firm's alliance portfolio has a positive effect on the firms innovation output, which supports H3. Finally, the full Model 3 confirms these results.

Insert Table 4 about here

In summary, H1 assumes that firms with more diverse alliances have more patents than young firms with less diverse alliances, is not supported. Opposed to this H2 that proposes biotechnology firms with many heterogeneous alliance partners in their portfolio are less successful in terms of innovation is confirmed. H3 assuming that young firms with a high diversity of partners within their alliance portfolio have a higher patent output than firms with homogenous alliance partners is supported through Model 2.

Discussion

One finding of this paper is that young biotechnology firms in the biotechnology industry tend to obtain a higher number of issued patents when they are involved in numerous collaborative agreements. Especially in the biotechnology industry, fast patenting of new technologies is an important strategy tool to survive within the competitive environment. Alliances are a commonly used strategy to cope with the increasing pace of technology development, short product life cycles and high expenses (Sampson, 2007). This is most important for young firms in the industry as they still have to increase their market share. Collaboration may also help to capture first-mover advantages, such as early cash flows, external visibility, legitimacy and early market share (Schoonhoven et al., 1990). That is to say developing and patenting of new technologies are core tasks for young biotechnology firms. Therefore, firms that engage in technology supporting strategies such as allying with complementary partners have a higher chance to survive in this mushrooming industry and as a consequence will obtain more issued patents.

This effect is negative when looking at firms that focus on heterogeneity among the partners in their alliance portfolio. That is to say the innovative performance of a biotechnology firm decreases with the increasing number of heterogeneous alliance partners. This result is somehow surprising as previous studies find heterogeneity among alliance partners to be most beneficial (e.g. Baum et al., 2000; Duysters et al., 2011). This effect has to be analyzed more profoundly. When taking firm size into account, which allows looking at small firms exclusively, the relationship switches to a positive influence of alliance partner diversity on R&D activity. This finding is in line with previous studies that find small firms to be technological diverse while larger firms concentrate on single technological fields, where they are already active in (Almeida et al., 1997; Giuri et al., 2004). This result is also in line with the findings of Duysters and Lokshin (2011), who found a positive impact of the alliance portfolio diversity on innovation performance. They found a positive relationship on innovation performance up to a threshold, it seems that more diverse an alliance portfolio, the more complex it becomes in terms of task and organizational complexity, which in turn leads to alliance failure (Killing, 1988; Marino et al., 2002). Especially small firms have decreasing returns when managerial costs and complexity become too high (Gilsing, 2005; Rothaermel et al., 2004). However, small firms that have an effective alliance management, profit in terms of innovative performance from diverse alliance partners within their portfolio, even more than firms that try to accelerate their innovation output through technology alliances. An explanation for this finding could be that firms that have diverse alliance portfolios have access to resources from a wide range and are more likely to seize technological opportunities (Ahuja, 2000; Duysters et al., 2011).

Conclusions

This paper focuses on the research question how an increasing number of heterogeneous partners in a firm's alliance portfolio influences the firm's innovative performance. Despite first attempts in literature to link alliance portfolio performance to innovativeness (Duysters et al., 2011; Faems et al., 2005), no study addresses this question empirically for biotechnology firms. Furthermore, previous studies fail to combine the issue of firm age and heterogeneity of partners in an alliance portfolio (Duysters et al., 2011). However, young firms are more likely to benefit from alliances, since these have still to develop capacities to survive in the competitive biotechnology industry (Baum et al., 2000; Suarez-Villa, 1998; Vanhaverbeke et al., 2007). This paper seeks to close these gaps in literature by focusing on young biotechnology firms. A set of hypotheses on the relationship between a young firm's alliance portfolio and its R&D activity are derived and then tested. It is shown that the effect of alliancing extent on innovation output is strongest if young firms maintain a heterogeneous alliance portfolio.

The empirical results show that young firms engaging in diverse alliances have higher R&D activity then young firms that only have a less diverse alliance portfolio. This result is not too surprising, due the multiple benefits young firms may obtain from alliancing (Baum et al., 2000; Dollinger et al., 1992; Stuart, 2000).

However, further result shows that firms in the biotechnology industry do not generally benefit by means of innovation from increasing diversity of their partners in their alliance portfolio. This result somehow surprising since it contradicts several previous studies. However, it confirms Hoang (2001) study that finds a negative impact of increasing diversity on a firm's innovative performance. The engagement of both simultaneously causes managerial costs and complexity to increase rapidly and with it the risk of alliance failure (Gilsing, 2005). Nevertheless, firms that effectively manage increasing complexity levels, (e.g. allying with less opportunistic partners), benefit from alliances with multiple partners (Belderbos et al., 2006).

This study has a number of managerial implications. The locus of innovation lies in the composition of a firm's alliance portfolio (Powell et al., 1992). Engaging in diverse alliances reduces risk, costs and uncertainties, provides access to complementary resources, and serve as a radar function to screen promising new technologies (Ahuja, 2000). Literature associates alliance diversity with increasing innovation output, and ultimately positively effects firm performance. However, this study draws conclusions from a more detailed perspective. Management of young firms has to be careful when selecting alliance partners (Lerner et al., 1998). The analysis suggests that firms profit most by means of innovation from a heterogeneous alliance portfolio, which supports the scarce empirical evidence on this topic (e.g. Baum et al., 2000; Duysters et al., 2011) for small firms in the biotechnology industry.

The research contains a number of limitations. This study is based almost entirely on data from one country. On the one hand the most successful biotechnology firms are located in the United States and thus the sample represents the parent population. On the other hand country specific characteristics could limit the generalization of the results. Therefore, the data should be extended by biotechnology firms across the world. Furthermore, some firms of interest have not been public throughout their economic life-time, which makes financial data unavailable. Therefore, survey research should be used to extent the database. To become a better view on alliance portfolio, more information about the diversity of the alliance partners of the focal firms is required.

Further research could combine theories about alliance portfolio with the concept of ambidextrous innovation. In this context different types of alliances may either lead to explorative or exploitative R&D activity. Only scarce empirical evidence by means of innovation output is provided on this topic and has not been addressed in a systematic way. Also, future research using qualitative approaches could develop further the core managerial implication emerging from this paper in that it could identify specific alliancing or knowledge management capacities that could help to overcome the issue that startups may overdo their alliancing activities, leading to too much of a good thing that overloads their management capacities.

References

Ahuja G. 2000. The duality of collaboration: inducements and opportunities in the formation of interfirm linkages. Strategic Management Journal **21**(3): 317-343.

Ahuja G, Lampert CM. 2001. Entrepreneurship in a large corporation: a longitudinal study of how established firms create breakthrough inventions. Strategic Management Journal **22**: 521-543.

Almeida P, Kogut B. 1997. The exploration of technological diversity and geographic localization in innovation: start-up firms in the semiconductor industry. Small Business Economics **9**(1): 21-31.

Amabile T. 1988. A model of creativity and innovation in organizations. In Research and Organizational Behavior. Straw BM, Cummings L (eds.), JAE Press.

Balakrishnan S, Koza MP. 1993. Information asymmetry, adverse selection and joint-ventures: theory and evidence. Journal of Economic Behavior & Organization **20**(1): 99-117.

Basberg BL. 1984. Patent statistics and the measurement of technological change - an assessment of the Norwegian patent data, 1840-1980. World Patent Information **6**(4): 158-164.

Baum JAC, Calabrese T, Silverman BS. 2000. Don't go it alone: alliance network composition and startups' performance in Canadian biotechnology. Strategic Management Journal **21**(3): 267-294.

Belderbos R, Carree M, Lokshin B. 2006. Complementarity in R&D cooperation strategies. Review of Industrial Organization **28**: 401-426.

Bleeke J, Ernst D. 1993. Collaborating to compete: using strategic alliances and acquisitions in the global marketplace. John Wiley: New York.

Ciborra CU. 1991. Alliances as learning experiments: cooperation, competition and change in high-tech industries. In Strategic Partnerships: States, Firms and International Competition. Mytelka LK (ed.), Pinter Publishers: London.

Cohen WM, Malerba F. 2001. Is the tendency to variation a chief cause of progress? Industrial and Corporate Change **10**(3): 587-608.

Contractor FJ, Lorange P. 2002. Cooperative strategies in international business (2nd ed.). Elsevier Science: Oxford.

Das TK, Teng B-S. 1996. Risk types and inter-firm alliance structures. Journal of Management Studies **33**(6): 827-843.

De Man AP, Duysters G. 2005. Collaboration and innovation: a review of the effects of mergers, acquisitions and alliances on innovation. Technovation **25**(12): 1377-1387.

Deeds DL, Hill CW. 1996. Strategic alliances and the rate of new product development: an empirical study of entrepreneurial biotechnology firms. Journal of Business Venturing **11**(1): 41-55.

Dollinger MJ, Golden PA. 1992. Interorganizational and collective strategies in small firms: environmental effects and performance. Journal of Management **18**(4): 695.

Doz Y, Hamel G. 1997. The use of alliances in implementing technology strategies. In Managing Strategic Innovation and Change: A Collection of Readings. Tushman ML, Anderson P (eds.), Oxford University Press: New York.

Doz YL. 1996. The evolution of cooperation in strategic alliances: initial conditions or learning processes? Strategic Management Journal **17**(S1): 55-83.

Duysters G, Lokshin B. 2011. Determinants of alliance portfolio complexity and its effect on innovative performance of companies. Journal of Product Innovation Management **28**(4): 570-585.

Dyer JH, Singh H. 1998. The relational view: cooperative strategy and sources of interorgaizational competitive advantage. Academy of Management Review **23**(4): 660-679.

Eisenhardt KM, Schoonhoven CB. 1996. Resource-based view of strategic alliance formation: strategic and social effects in entrepreneurial firms. Organization Science **7**(2): 136–150.

Faems D, van Looy B, Debackere K. 2005. Interorganizational collaboration and innovation: towards a portfolio approach. Journal of Product Innovation Management **22**(3): 238-250.

Freeman C. 1991. Networks of innovators: a synthesis of research issues. Research Policy **20**(5): 499-514.

Gilsing VA. 2005. The dynamics of innovation and interfirm networks, exploration, exploitation and co-evolution. Edward Elgar: Cheltenham.

Gilsing VA, Nooteboom B, Vanhaverbeke WP, Duysters G, van den Oord A. 2008. Network embeddedness and the exploration of novel technologies: technological distance, betweenness centrality and density. Research Policy **37**(10): 1717-1731.

Giuri P, Hagedoorn J, Mariani M. 2004. Technological diversification and strategic alliances. In The Economies and Management of Technological Diversification. Cantwell J, Garmbardella A, Granstrand O (eds.), Routledge: London

Goerzen A, Beamish PW. 2005. The effect of alliance network diversity on multinational enterprise performance. Strategic Management Journal **26**(4): 333-354.

Griliches Z. 1979. Issues in assessing the contribution of research and development to productivity growth. Bell Journal of Economics **10**(1): 92-116.

Griliches Z. 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature **28**(4): 1661-1707.

Gulati R, Singh H. 1998. The architecture of cooperation: managing coordination costs and appropriation concerns in strategic alliances. Administrative Science Quarterly **43**(4): 781-814.

Haeussler C, Patzelt H, Zahra SA. 2010. Strategic alliances and product development in high technology new firms: the moderating effect of technological capabilities. Journal of Business Venturing.

Hagedoorn J. 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. Strategic Management Journal **14**(5): 371-385.

Hagedoorn J. 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. Research Policy **31**(4): 477-492.

Hamel G. 1991. Competition for competence and inter-partner learning within international strategic alliances. Strategic Management Journal **12**(Summer Special Issue): 83-103.

Harrigan KR. 1988a. Joint ventures and competitive strategy. Strategic Management Journal **9**(2): 141-158.

Harrigan KR. 1988b. Strategic alliances and partner asymmetries. In Cooperative Strategies in International Business. Contractor F, Lorange P (eds.), Lexington Books: Lexington, MA.

Hoang HT. 2001. The impact of organizational and alliance based complexity on the development of alliance capacity. INSAD Working paper series.

Kale P, Dyer JH, Singh H. 2002. Alliance capability, stock market response, and long-term alliance success: the role of the alliance function. Strategic Management Journal **23**(8): 747-767.

Katila R, Ahuja G. 2002. Something old, something new: a longitudinal study of search behavior and new production introduction. Academy of Management Journal **45**(6): 1183-1194.

Khilji SE, Mroczkowski T, Bernstein B. 2006. From invention to innovation: toward developing an integrated innovation model for biotech firms. Journal of Product Innovation Management **23**(6): 528-540.

Killing JP. 1988. Understanding alliances: the role of task and organizational complexity. In Cooperative Strategies in International Business. Contractor FJ, Lorange P (eds.), Lexington Books: Lexington, MA.

Kogut B. 2000. The network as knowledge: generative rules and the emergence of structure. Strategic Management Journal **21**(3): 405.

Larsson R, Bengtsson L, Henriksson K, Sparks J. 1998. The interorganizational learning dilemma: collective knowledge development in strategic alliances. Organization Science **9**(3): 285–305.

Lavie D. 2007. Alliance portfolios and firm performance: a study of value creation and appropriation in the U.S. software industry. Strategic Management Journal **28**(12): 1187-1212.

Leiponen A, Helfat CE. 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strategic Management Journal **31**(2): 224-236.

Lerner J, Merges RP. 1998. The Control of technology alliances: an empirical analysis of the biotechnology industry. The Journal of Industrial Economics **46**(2): 125-156.

Lorange P, Roos J. 1992. Strategic alliances: formation, implementation, and evolution. Blackwell: Oxford.

Marino LK, Strandholm HK, Steensma, Weaver KM. 2002. Harnessing complexity: the moderating effect of national culture on entrepreneurial orientation and strategic alliance portfolio complexity. Entrepreneurship Theory and Practice **26**(4): 145-161

MedAdNews. 2004. Top 100 biotechnology companies. http://www.pharmalive.com/magazines/archive.cfm?mag=medad&year=2004 (7 November 2006).

Ohmae K. 1985. Triad power: the coming shape of global competition. Free Press: New York.

Pangarkar N. 2003. Determinants of alliance duration in uncertain environments: the case of the biotechnology sector. Long Range Planning **36**(3): 269-284.

Pisano GP. 1990. The R&D boundaries of the firm: an empirical analysis. Administrative Science Quarterly **35**(1): 153-176.

Powell W, Brantley P. 1992. Competitive cooperation in biotechnology: learning through networks? In Networks and Organizations. Nohria N, Eccles R (eds.), Harvard Business School Press: Boston.

Powell WW, Koput K, Smith-Doerr L. 1996. Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. Administrative Science Quarterly **41**(1): 116-145.

Rothaermel FT, Deeds DL. 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. Strategic Management Journal **25**(3): 201-221.

Sampson RC. 2007. R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation. Academy of Management Journal **50**(2): 364-386.

Schoonhoven CB, Eisenhardt KM, Lymman K. 1990. Speeding products to market: waiting time to first product introduction in new firms. Administrative Science Quarterly **35**: 177-207.

Schumpeter JA. 1939. Business cycles: a theoretical, historical, and statistical analysis of the capitalist process. McGraw-Hill: New York.

Stuart TE. 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. Strategic Management Journal **21**(8): 791-811.

Suarez-Villa L. 1998. The structures of cooperation: downscaling, outsourcing and the networked alliance. Small Business Economics **10**(1): 5-16.

Teece DJ. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy **15**(6): 285-305.

Teece DJ. 2002. Managing intellectual capital. Oxford University Press: Oxford.

Vanhaverbeke WIM, Duysters G, Beerkens B. 2002. Technological capability building through network strategies within high-tech industries. Paper presented at the Academy of Management Best Paper Proceedings, Denver, CO, August 2002.

Vanhaverbeke WIM, Gilsing V, Duysters G. 2007. Exploration and exploitation in technology-based alliance network. UNU-MERIT Working Paper Series 2007-018.

Veugelers R. 1998. Collaboration in R&D: an assessment of theoretical and empirical findings. Economist **149**(3): 419–443.

Table 1: Sample overview

Firm	**Years of observation**	**Sales** (in Million US$)	**Alliance Portfolio Diversity** (in %)	**Granted Patents**
Amgen	24	4104.956	93.90	45.23
Genentech	23	2897.525	93.24	91.84
Merck Serono	5	1870.945	91.51	2.81
Genzyme	11	1806.716	92.92	27.10
CSL	13	1520.477	86.69	2.19
Gilead Science	16	1000.145	90.47	11.90
Life Technologies	8	875.799	90.63	13.35
Actelion	6	650.172	93.42	0.81
Biogen	19	638.172	90.88	22.97
Chiron	22	600.235	91.67	59.26
Cephalon	16	529.457	94.00	9.68
Medimmune	15	469.848	90.20	9.32
Genencor International	4	356.481	91.73	32.81
Millennium Pharmaceuticals	6	307.428	82.54	3.84
Celgene	20	277.569	78.03	0.10
Imclone Systems	16	131.699	74.37	3.32
Nabi Biopharmaceuticals	11	109.832	77.48	1.32
QLT	19	66.646	86.56	2.45
Regeneron Pharmaceuticals	16	56.292	85.54	8.97
MGI Pharmaceuticals	23	43.214	90.04	0.45

Notes: Average values per year

Table 2: Variables definitions

Variable Name	Variable description
Dependent Variable	
Patents	Number of granted patents a firm i holds during period t
Independent Variables	
Young	Dichotomous variable that takes 1 for all firms have a age below 15 years in period t-1
Alliances	Number of alliances of firm i in period t-1
Portfolio Diversity	Level of heterogeneity within a firm's alliance portfolio
Alliances*Portfolio Diversity (centered)	Interaction variable between the variables Alliances and Portfolio Diversity
Young*Portfolio Diversity (centered)	Interaction variable between the variables Young and Portfolio Diversity
Control Variables	
Size	Logarithm of total sales of firm i in period t-1
Tobin's Q	Market to book value of firm i in period t-1
R&D intensity	Ratio of R&D expenditures to total assets of firm i in period t-1
Acquisitions	Number of acquisitions of firm i in period t-1
Patenting	Accumulated number of patents a firm i has obtained during a 5 year time-span

Table 3: Descriptive statistics and correlation matrix

		Mean	S. D.	1	2	3	4	5	6	7	8	9	10	VIF
1	Patents	27.75	47.28											
2	Alliances	22.59	21.79	0.57 *										3.31
3	Young	0.56	0.50	-0.27 *	-0.33 *									1.46
4	Portfolio Diversity	0.88	0.15	0.12 *	0.25 *	0.04								8.01
5	Alliances*Portfolio Diversity (centered)	0.84	2.85	0.07	0.15 *	-0.13 *	-0.85 *							7.36
6	Young* Portfolio Diversity (centered)	0.003	0.08	-0.08	-0.11	-0.01	-0.28 *	0.17 *						1.15
7	Size	4.71	2.63	0.40 *	0.48 *	-0.49 *	0.13 *	0.05 *	0.03					1.99
8	Tobin's Q	4.13	5.70	0.04	0.06	-0.11 *	0.04	-0.03	0.05	-0.05				1.15
9	R&D intensity	0.19	0.17	-0.20 *	-0.14 *	0.20 *	0.01	-0.04	-0.01	-0.44 *	0.29 *			1.38
10	Acquisitions	0.40	0.94	0.23 *	0.37 *	-0.21 *	0.11	0.02 *	-0.08	0.31 *	-0.05	-0.17 *		1.22
11	Patenting	0.19	1.15	0.85 *	0.64 *	-0.40 *	0.16 *	0.08 *	-0.13 *	0.52 *	0.02	-0.24 *	0.22 *	2.00

Notes: * p<0.05; n=305

Table 4: Impact of alliances on innovation output (number of patents) of biotechnology firms: 1980 - 2007

	Model 0			**Model 1**			**Model 2**			**Model 3**		
	Coeff.	(SE)		Coeff.	(SE)		Coeff.	(SE)		Coeff.	(SE)	
Independent Variables												
Young				0.16	(0.14)		0.09	(0.14)		0.11	(0.14)	
Alliances				0.02	(0.003)	***	0.01	(0.003)	***	0.02	(0.003)	***
Portfolio Diversity				-2.00	(0.60)	***	-0.43	(0.38)		-1.56	(0.65)	**
Alliances*Portfolio Diversity (centered)				-0.09	(0.03)	***				-0.07	(0.03)	**
Young*Portfolio Diversity (centered)							1.68	(0.70)	**	1.46	(0.76)	*
Control Variables												
Size	-0.05	(0.03)	*	-0.04	(0.03)		-0.05	(0.03)		-0.05	(0.03)	
Tobin's Q	0.02	(0.01)	***	0.02	(0.01)	**	0.02	(0.01)	**	0.02	(0.01)	**
R&D intensity	-0.19	(0.46)		-0.39	(0.45)		-0.32	(0.44)		-0.32	(0.44)	
Acquisitions	0.12	(0.04)	***	0.11	(0.04)	**	0.11	(0.04)	**	0.12	(0.04)	***
Patenting	0.35	(0.05)	***	0.24	(0.06)	***	0.27	(0.06)	***	0.26	(0.06)	***
Constant	0.53	(0.20)	***	1.96	(0.55)	***	0.70	(0.39)	*	1.65	(0.58)	***
Observations (Groups)	305 (20)			305 (20)			305 (20)			305 (20)		
Log Likelihood	-941.4622			-928.2526			-928.6755			-926.2958		
Wald Chi² (df)	77.92 (5) ***			123.44 (9) ***			117.85 (9) ***			128.34 (19) ***		

Notes: *** p<0.01; ** p<0.05; *p<0.1 (two sided tests). Results of a fixed effects negative binomial model. Standard deviations in parentheses.