Innovative Scope in Biotech Business

Effects of Aligning Partner Types with the Firm's Science Base

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Abstract

Using extensive patent data on Scandinavian Biotech firms together with associated firm level data, this paper explores factors that drive the innovative scope of biotech firms. Collaborating with pharmaceutical firms, universities and other dedicated biotech firms proves beneficiary in introducing innovations broadening the innovation scope of biotech firms. Contrasting large and small molecules research firms exhibit noteworthy differences in the type of collaboration partner that allows the firm to expand its innovative scope. This suggests that biotech firms need to align the partner type with its science base if the goal is to produce patents beyond the firms technological boundary. Additionally, we find that outsourcing and acquisition of innovations increase their scope, lending support to the view that outsourced R&D expands the boundary of the firm's innovative search.

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Introduction[1]

It is beneficial to draw on collaborative partners for knowledge as inputs into the innovation process converting it into an interactive and distributed process (see e.g. Von Hippel (1976, 1988), Rothwell (1977), Lundvall (1988)). Cooperation has become fundamental in the innovation process. As a result *the boundaries of the firm have become fuzzy* and alliances are almost necessities for a successful innovation process (Teece, 1992). The open model has become an essential element of the innovation literature. It emphasise that being open to external collaborators allow firms to draw on external sources of knowledge and capture opportunities that are inevitably lost when using a too internally focused search strategy (Chesbrough, 2003).

That open innovation leads to a higher innovative performance has been argued both theoretically (Cohen and Levinthal, 1990) and empirically (Laursen and Salter, 2006). We also know that boundary spanning significantly contributes to the impact level of a given innovation (Rosenkopf and Nekar, 2001). However, we know little about the degree to which openness extends the innovative scope of the firm. Do cooperative arrangements allow firms to innovate in different technologies than otherwise? To what extend do the type of collaborating partner shape the propensity to introduce innovations that increase the innovative scope of the firm? How does externally developed innovation add to the diversity of the firm's innovations? Finally, are the above relations to some degree dependent on the science base of the firm? These are all questions we address in the present paper.

Drawing on a comprehensive dataset on Scandinavian biotechnology firms and their patent applications, we explore to what extend the innovative scope of a firm may be attributed to its

[1] The authors are grateful to Rasmus Lund Jensen and Henrich Dahlgren for extensive help with data handling and understanding the data structure and key variables.

external innovation linkages. Extracting inventor data in the patent applications and linking these with inventor affiliation data provides sufficient information to contrast different partner types against each other. By exploiting the affiliation data for inventors we also investigate how innovations developed outside the firm play a role in shaping the diversity in the firm's innovations. We discriminate between outsourced innovation activities and acquired patent applications. Additionally we look for dissimilarities between two different sciences bases. We distinguish between firms that operate in large molecules biotechnology from those that operate in small molecule biotechnology.

Understanding the factors that allows a firm to become more exploratory in its innovation activities and hence expand its technological diversity is important for several reasons. First, extending the knowledge base and the innovative scope of a firm may play a crucial role in shaping its performance. Extending into new and for the firm otherwise uncharted technologies will *ceteris paribus* be less likely to lead to cannibalism than innovating narrowly. In particular biotechnology firms need to seek knowledge both internally and externally to keep up its performance (Decarolis & Deeds, 1999). Second, knowledge creation and innovation leads to overall welfare gains. Not least with respect to the biotechnology industry. Third, unravelling the factors that enables a firm to shift their innovation activities and expand their technological boundaries also extends our understanding of innovation and how firms become innovative.

The article is organised as follows. Section 2 presents the empirical and theoretical evidence on why firms need to collaborate to extend their innovation search boundary. Additionally we end the section by emphasizing the biotechnology industry and previous findings on the biotechnology industry in particular. Section 3 describes the data and the variables of interest. The method of

analysis is discussed in detail and a regression model presented. Section 4 presents our results and section 5 finalise the paper.

Theory

Innovation is a combination of ideas and capabilities that previously have not been combined. This definition has been adopted by among others Nelson and Winter (1982), Katila and Ahuja (2002) and Flemming and Sorenson(2004). Innovation is therefore said to be an integration of previously separate bodies of knowledge. Recent models of open innovation highlight the importance of relying on external sources of knowledge (see among others von Hippel (1988): Lundvall (1992) and Chesbrough (2003). In studying start-ups Baum et al (2000) perhaps put it best by saying *don't go it alone*. Accordingly it is vital for a firm to search among external sources to be successful in its innovative activities.

However, the game is not only about being innovative. It is one thing to innovate in technologies the firm previously has used in its innovation activities or in which it otherwise have experience in. Another is to develop new capabilities or new ideas in areas in which the firm have little or no experience or particular knowledge. The competitiveness of firms is not only shaped by its ability to integrate and build upon its current competencies, but also its ability to develop new capabilities (Teece, Pisano, & Shuen, 1997).

Innovative activities that go beyond the technological boundaries of the firm have been termed exploratory innovation. It involves expanding the innovative scope of the firms thereby meaning introducing innovations in technological areas in which the firm previously have not been innovating.

An innovation strategy that involves exploration is highly risky. Contrary to an exploitation strategy it involves experimentation and uncertainty and the returns from exploration are usually more remote in time. It is therefore often beneficial to combine exploration and exploitation strategies (March, 1991; Levinthal & March, 1993; Burgelman, 1994; Gavetti and Levinthal, 2000). It is fundamental to overcome *innovation* or *learning myopia* in order to become successful in exploratory innovation activities. In particular it is important to overcome what Levinthal and March (1993) call *temporal myopia*. Firms become rather specialised in distinctive competencies and niches resulting in knowledge boundaries. Competencies outside its boundaries become highly difficult to obtain. Firms experience a lock-in effect which may lead to substantial long-run vulnerability in terms of its competitiveness. From a transaction cost point of view temporal myopia represent a cost which the firm needs to pay if it wishes to break free of the lock-in to specific capabilities and innovation trajectories.

To achieve the combination of exploitation and exploration it is necessary to jump the hurdle of innovation myopia and make exploratory strategies less uncertain and risky. Levinthal and March's (1993) solution to temporal myopia is a flow of competences between organisation where individuals and sources of capital continuously are exchanged between organisations. However, such an exchange of competencies may often be of limited value in terms of promoting an exploratory search. Organisations may be reluctant to provide the necessary autonomy to new additions to staff in which case experimentation with different ways of thinking is highly unlikely.

Alternative ways to break away from the liability of temporary myopia is to search externally and engage in collaborative activities. Collaboration has become one of the central elements in the study

of innovation and innovation performance. Collaborating firms are clear candidates of becoming novel innovators and therefore introduce products that are new to the market rather than simply new to the firm (Tether, 2002). Such findings suggest collaboration to be an engine for exploratory search rather than a part of an exploitation strategy.

Collaboration is induced by accessibility of resources which is not otherwise available to the firm (Ahuja, 2000). The firm is much less likely to engage in collaboration if the resource obtainable is available within the firm or on the market. Linking this with the notion of exploratory strategies, collaboration on innovative activities may be a way to explore other parts of the knowledge landscape and enjoy the advantage of having more opportunities through an increased number of possible new combinations of existing knowledge bodies. However, not only does it suggest the firm becomes more innovative, but it also imply that firms through collaboration are able to extend their innovative scope. Collaborative partners become the firm's engines for innovating in knowledge bodies or technological areas in which it otherwise lack competences. Collaborating is means to which the firm is able innovate beyond its technological boundaries and hence break away from its innovation myopia.

The Biotech industry

The biotechnology industry has been studied with respect to collaboration and innovation in several papers. Powell et al. (1996) emphasised the importance of the network of interorganizational relationship in shaping the locus of innovation. They emphasised that firms in the biotechnology industry in particular may be subject to Baum and Olivers (1992) liability of unconnectedness. Powell et al. suggest firms suffering from this particular liability and hence only have few ties are becoming increasingly rare and thereby relating the ability to build a network of collaborators to

survival. In particular, Powell et al. accentuates the role of collaborating with other dedicated biotechnology firms.

In a study on the effect of alliance network compositions on the performance of biotechnology start-ups, Baum et al. (2000) found significant differences according to the type of partner with whom the alliance is formed. Their analysis suggests both upstream and downstream alliances and a diversified network to support the initial performance of the biotech start-up. These findings define a starting point for new studies of partnerships and the effect on the innovative activities of the biotechnology firm. It is essential to investigate the type of partners and to insist on aligning this to the biotechnology in question. Firms in small molecules biotechnology may need to form alliances with one type of collaborative partner while firms in large molecules biotechnology may find it beneficiary to form an alliance with another type.

Also investigating the biotechnology industry, Gilsing and Nooteboom (2006) emphasise how exploitation and exploration builds upon each other. Dynamics of innovation shifts according to a cycle of discovery in which different phases may be overlapping. Both sectoral and firm level dynamics play a role in shaping the transition from one phase to another. Among other things Gilsing and Nooteboom emphasise the change in the mindsets of the firms. Moving along the cycle of discovery also shift the mindset of the firm with respect to innovative activities. The exploratory stage requires an in-depth understanding of stand-alone, science-based knowledge. The exploitation oriented stages does so to a lesser extend. A shift between these two innovation regimes has significant implications for the network structure of a given firm. A dense network and creating a network with high level of diversity on the input side of the knowledge creation process are almost necessities in an exploratory innovation regime. Gilsing and Nooteboom also stress that the

composition of partner types in networks should change as the innovation regime shift stage in the cycle of discovery.

Gilsing and Nooteboom's findings suggest it to be important to split bio-technology into sub-samples. Because firm level dynamics play a significant role in shaping the shift between exploratory to exploitation regimes, it is possible that the shift between different phases takes place on a lower level of aggregation than the biotechnology industry level.

Finally Pisano (1990) discussed the difference between in-house and external R&D. He emphasised that internalizing new biotechnology capabilities may be costly. This may in particular be supported by the notion of learning myopia in which the lock-in effect makes it more difficult to move into new areas of research and hence represent a high cost of transformation. Pisano points out that biotechnology firms consequently may choose to procure a large share of their R&D outside the firm regardless of a long history of successful R&D activities. Such a strategy enables the firm to move into new product markets and hence extend its innovative scope. Outsourcing and acquisition of patents is therefore an alternative way to cross technological boundaries which otherwise is costly for the firm to attempt if strictly done so in-house.

Data, method and Descriptive Statistics

The data

The aim of the paper is to study how different types of collaboration partners and external R&D activities shape the innovative scope of firms. We use the SCANBIT database to study these questions. SCANBIT is continuously developed and maintained by Research Centre on Biotech Business at Copenhagen Business School. It contains a substantial share of the Scandinavian

Biotech industry only missing a limited number of micro-firms. We extracted the Danish and Swedish firms concentrating on these two countries and hence leaving out Norway whose biotechnology industry is somewhat less developed. The dataset operates on two levels of measurement. It contains firm level panel data including such variables like firm size, firm age, and firm science base. This is combined with patent data for each of the firms included in the dataset. The dataset has proven useful and acceptable in previous publications (see e.g. Valentin and Jensen (2007) and Valentin et al. (2007))

In order for the database to be consistent throughout the years, we controlled for mergers and acquisitions by considering the merged firms as a single firm in the entire database. By doing that, we do not consider an expansion of a technological boundary brought about by a merger or an acquisition of another firm as an extension of the innovative scope of the firm. Additionally we have cleaned the dataset for co-inventors from foreign subsidiaries. We consider foreign subsidiaries as a business extension of the firm rather than a technological extension.

Dependent variable

We exploit the International Patent Classification (IPC) code attached to each patent to identify the innovation scope of the firms. IPC codes has been used for similar purposes by among others Jaffe (1986; 1989), Granstrand et al.(1997), Patel and Pavitt (1997; 2000) and Dahlgren et al. (2004). We follow the approach by Dahlgren et al. by calculating a revised concentric index first introduced by Caves et al. (1980). This measure use the three digit IPC code by comparing patents two by two. We first compare the first digit if the IPC and assign the value 1 if the two differs. If these are similar we compare the second digit and assign the value 0.5 if they differ. Finally we compare the third digit of the IPC codes of the patents if the first two digits were equal. We assign the value 0.25

if these differ. Otherwise the patents are considered to be in the same technological classification and hence assign a zero innovation scope value between those two particular patents.[1] Dahlgren et al. compared each patent with all previous patents and used the average deviation of the patent to indicate to what extend the patent differed in the IPC code compared to other patents applied for by the firm. By taking the average value the indices may be compared regardless of the number of patents the firms has applied for at any given point in time.

Rather than comparing each patent application with the firms previous patent applications like Dahlgren et al., we measure how each patents deviates from all other patent application the firm has filed regardless of time. There are three reasons for doing this. Firstly, we would loose a number of observations had we taken time into account. First time patent applicants would otherwise be disregarded because there would be no previous patent to compare with. Secondly, each patent with the same firm is subject to the same pool of objects of comparison. We would be comparing a measure based on a different sample had we limited the comparisons to being backwards looking. The second patent application would only be compared with one other patent while the 10^{th} patent would be compared to a pool of nine patents. While taking the mean deviation goes a long way to correct this, it will nevertheless be a partial adjustment. A firm that has many patents is more likely to have exhausted the pool of possible patent classes while a firm that only holds a limited number of patents is less likely to have exhausted patent classifications. By measuring how much on average each patent deviates from the remaining patents of the firm disregarding time, we maximize the number of patents comparisons of each firm. We hope by doing so the possible bias created by differences in extend of patenting will be minimized. Thirdly, by comparing each patent by all other patents rather than just previous patents we ensure that the comparisons pool exhibits a much clearer picture of the in-house technological boundaries rather than simply a time specific pattern.

This dependent variable permits us to studying the factors that enable firms to apply for a patent that deviates from the firms' other patent applications. It may be perceived as a technological distance measure between a given patent and the rest of the firms patent port folio. The variable therefore allows us to investigate practices that extend the innovative scope of the firm and hence drive technological heterogeneity.

Explanatory variables

The analysis contains two groups of explanatory variables. The first group of explanatory variables relates to collaboration. We measure collaboration by identifying the affiliation of the authors of the patent applications. This enables us to say if there has been a formal collaboration between the firm and other organisation. We operate with three types of organisations; pharmaceutical firms, universities, and other dedicated biotech firms. This provides three dummy variables attached to each patent. These three dummies allow us to look for different types of partners and their role in shaping the innovative scope of the firm.

The second batch of explanatory variables expresses whether the patent has been acquired or the firm has outsourced their R&D. We categorise patent applications with no in house authors as outsourced if the firm itself is the assignee. Contrary an acquired patent is a patent application where none of the authors are affiliated to the firm and the firm itself is not an assignee on the patent. These variables are used to test the notion that external R&D allow firms to patent in technological areas which are outside the boundary of the firm and which the firm find to be too costly to embark on internally.

We also include a number of control variables. The first captures the number of inventors and is based on the number of authors on the patent application. Multiple authors may suggest a more extensive opportunity landscape being searched and circumstances which are not associated to the explanatory variables but which may be correlated and hence otherwise be a source of spurious correlation in the regression analysis. We also add a firm size variable hoping to capture the availability of extensive complementary assets within the firm which may permit a broader search parameter regardless of the collaborative behaviour of the firm. By introducing year fixed effects, we ensure the results cannot be attributed to changes in the innovative behaviour of the Scandinavian biotech industry across time. Finally we will include a dummy for whether the firm in question is operating in large or small molecule biotechnologies.

The method

Figure 1 is a histogram of the heterogeneity index and reveals that its empirical distribution is not normally distributed.[2] It would therefore be dubious to use the traditional regression techniques as a tool of analysis. Alternatively we categorised the patents in two. Patents that contributes with a high level of innovative scope and patents that contributes with a low level of innovative scope. We used the mean innovation scope index across all patents and all firms as a classification point.[3] This leaves us with a binomial dependent variable dictating a logistic regression technique.

< INSERT FIGURE 1 ABOUT HERE >

Some patent applications are filed by the same firm and may therefore not be independent observations. A firm exhibiting a high level of innovative scope in one patent may also exhibit a high level of innovative scope in another patent. There are two reasons for this. First, the calculation

of the heterogeneity index of one patent dependent on another patent taken by the same firm and vice versa. So heterogeneity in the first leads unavoidably to increased heterogeneity in the second. Secondly, it may be an integrated part of a firm strategy to search broadly for new intellectual assets and hence be an integrated goal of the firm to have a high heterogeneity across its patents applications. Violating the independency between observations assumption may render the regression estimates biased if left unattended. To avoid bias attributed to this particular feature of the data we relax the assumption of independence between observations within firms and only treat observations from different firms as truly independent. Put differently, we run cluster corrected estimations and thereby obtain adjust the standard errors for intra-group correlations. This also provides robust estimates consistent regardless of heteroskedasticity.

< INSERT FIGURE 2 ABOUT HERE >

Figure 2 illustrate the use of collaborative partners in patent activities when separating the sample into large and small molecules biotech companies. The three types of collaborative partners are represented in both samples and the frequency of collaboration with the three types of partners rank equally between the two sub-samples. However, the relative percentages suggest there to be some difference in the usage of different types of collaborative partners. It is for instance relatively more likely that a firm in small molecule research use other dedicated biotechnology firms compared to universities than large molecules research firms. With this in mind we tested the difference in the innovative scope index across large and mall molecules research firms using a simple t-test. We found the small molecules research firms to generate higher innovative scope than their large molecule counterparts. These facts may suggest differences in the dynamics of collaborative

behaviour and the effects on the innovative scope when comparing large and small molecules research firms. This may be the result of a difference in the relative strength of exploration and exploitation innovation strategies between the two sub-samples. We accordingly investigate the differences between the two sub-samples in the results section. This also enables us to say something about the necessity to align the type of partner with the science base of the firm.

Finally we found no multicollinearity problems in the estimated models. We report the associated maximum variance inflation factors for each model in the regression table showing it never exceeds a critical 10.

Descriptive Statistics

Table 1 contains the descriptive statistics of the variables included in the model. It also contains the correlation coefficients between these variables. From Table 1 it is obvious that collaboration with other dedicated biotechnology firms is the predominant form of collaboration in the Danish and Swedish bio-technology industry. The firms do not seem to be discouraged to collaborate with potential rivals. This may suggest using other dedicated biotechnology firms allows the firm to shifts its innovative locus as suggested by Powell et al. (1996). The second most frequent type of partner is universities with only a bit less than 14% of the firms collaborating with pharmaceutical firms.

< INSERT TABLE 1 ABOUT HERE >

The descriptive statistics also reveal that more firms outsource their innovative activities rather than acquire a patent. Only about 3.5% of the observations are patents that were acquired while more

than 33% were outsourced patent applications. A bit more than half of the observations are patents applied for by firms operating in small molecules bio-technology. Finally the correlation coefficients confirm that the analysis do not suffer multicollinearity. Many of the coefficients are highly significant. But only between outsourcing and collaboration with other dedicated biopharmaceuticals do we see a high correlation coefficient (0.77).

Results

The results of the regression are summarized in table 2. Three regressions are shown. The first includes all types of biotech firms while the last two only investigate firms operating in large and small molecules respectively. This allows us to compare the overall pattern of the biotech industry to that of two different science bases and consequently study whether aligning the type of partner to the science base is of importance.

The regression using the unsplit sample reveals a strong support for collaboration being a driver of innovative scope. The variables indicating collaborating with pharmaceutical firms and collaborating with universities exhibits positive significant parameter estimates. The parameters suggest collaborating with these two types of partners more than double the likelihood of expanding the innovative scope of the firm. Likewise we find support that acquired patents and patents from outsourced innovation activities extends the innovative scope of the firm. Outsourcing of technological innovation activities and acquiring patents from externals partners is hence used as a strategy for moving into new technologies rather than doing research in knowledge areas in which the firm is already operating.

< INSERT TABLE 2 ABOUT HERE >

Looking to the split sample regressions we see noteworthy differences between patents applied for by firms in large molecules biotechnology compared to firms in small molecules biotechnology. With respect to collaboration, the small molecules biotechnology firm regression confirms the results of the findings of the regression using all observations. Collaborating with pharmaceutical firms and universities extend the innovative scope of the firm. However, the pattern is some what different when studying patents applied for by large molecules biotechnology firms. In this case collaborating with universities is insignificant while collaborating with other dedicated biotechnology firms is significant. In this particular science base of the biotechnology industry, we see a distinct and separate pattern from that of the overall biotechnology results indicating the importance of aligning the type of collaboration partners with the science base.

The regressions also reveal a difference in the way patent acquisitions and technology outsourcing is used. While firms in large molecules biotechnology use these two means to extend their innovative scope, firms in small molecules biotechnology do not rely on these measures to move into new technologies.

With respect to the controls variables, large firms are significantly more likely to extend their innovative scope than small firm. Large firms have complementary assets which enables them to extend their search boundaries beyond their current technologies.

Discussion

Several studies have shown formal collaboration to be of major importance in a firm's struggle to become innovative. Collaborating partners provide knowledge and know-how to the innovation

process which positively influence the likelihood of a firm's innovation success rate. However, rather than simply facilitating innovation in the firm's own area of research, external partners contribute with knowledge which is outside the scope of the firm's expertise. As Pisano (1990) emphasised, partnering may be a relative inexpensive way to get access to knowledge which the firm otherwise do not have access to in-house. By collaborating with other organizations and institutions, the firm broadens its innovative scope by moving in new areas of patenting.

Studying the Danish and Swedish biotechnology industry, we find support for the proposition that collaboration extends the innovative scope of the firm. In particular we found collaborating with pharmaceutical firms and universities extends the range of technologies the firm operates in. These particular two types of partners seem either deliberately to be used to move into new technologies, or unintentionally to provide particular types of knowledge that extends the firm's innovative scope.

We also found that the firm should align the partner type to its science base. We established that the type of partners contributing significantly to extending the innovative scope of the firm differed between firms specialised in large and small molecules biotechnology. While small molecule firms exhibit similar patterns to those found studying the entire sample of biotech firms, firms operating in large molecule biotechnology seem to benefit from other dedicated biotechnology firms rather than from universities. The two sub-industries of biotechnology may be in different stages of the cycle of discovery (Gilsing and Nooteboom, 2006) and therefore need different knowledge input to expand its knowledge boundary and be classified as extending its innovative scope. .

Both acquisition and outsourcing was found to facilitate innovative scope. In particular firms in the large molecules biotechnologies exhibit significant parameter estimates for external innovation

activities. In the spirit of the work by Pisano (1990), this might suggest these firm find it to costly to invest in in-house capabilities that would allow them to move into new technological areas and hence extend their innovative scope. Instead firms in large molecules biotechnologies find outsourcing and acquisition of patents to be the preferred way to expand their innovative scope.

Future research on the innovative scope of the firm could productively explore how the innovative scope of firms changes in accordance with shift in the focus on exploration versus exploitation. However, before we can explore this, it is necessary to investigate the interaction between exploitation, exploration, collaboration, and the types of collaborative partners. A more dynamics investigation into this relationship may prove beneficiary and have major implications for understanding how and when a firm should try to expand its innovative scope.

Considering the rather crude division of collaborative partners into three categories also represent some potential for future research. Additionally, we find it to be of importance to investigate to what extend these results are governed by the disaggregation into large and small molecules. Using a more comprehensive data may open up for the possibility to disaggregate even further and find a different pattern than the one found in these data? Furthermore we find it to be of importance to study whether the results rely on our measure of innovative scope? Creating a new index for accessing the technology in which a given patent may be classified may prove beneficiary. Relying on IPC codes is at any rate at least partially subjective and may therefore have an impact on our results. We therefore propose future work on developing methods for categorising patents into technological groups according to their patent application descriptions. Finally, we suggest extending the analysis into other industries and study to what degree our findings are robust across industry borders.

References

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

Baum, J. A. C., Calabrese, T & Silverman, B. S. (2000) “Don’t Go It Alone: Alliances, Network Composition and Start-ups’ Performance in Canadian Biotechnology”, Strategic Management Journal, Vol. 21(3), pp. 267-294.

Baum, J. A. C. & Oliver, Christine (1992), “Institutional Embeddedness and the Dynamics of organizational Populations”, American Sociological Review, Vol. 57pp. 540-559.

Burgelman, R. (1994), “Fading memories: A process theory of strategic business exit, Administrative Science Quarterly, Vol. 39, pp. 24-56.

Caves, R. E., Porter, M. E., Spence, A. M. (1980), ”Competition in the Open Economy: A model applied to Canada”, Havard University Press, Cambridge, MA.

Chesbrough, H. (2003), “The era of open innovation”, Sloan Management Review, Summer, pp. 35-41.

Cohen, W. M. & Levinthal, D. A. (1990), “Absorptive Capacity: A new perspective of learning and innovation”, Administrative Science Quarterly, Vol. 35(1), pp. 128-152.

Dahlgren, H., Jensen, R. L. & Valentin, F. (2004), ”Heterogeneity of Intellectual Assets – A method for identification and measurement with patent data”, Biotech Business Working Paper No. 04-2004.

Decarolis, D. M & Deeds, D. L. (1999), “The Impact of Stocks and Flows of Organizational Knowledge on Firm Performance: And Empirical Investigation of the Biotechnology Industry”, Strategic Management Journal, Vol. 20, pp. 953-968.

Flemming, L. & Sorensen, O. (2001), “Technology as a complex adaptive system: Evidence from Patent Data”, Research Policy, Vol. 30(7), pp. 1019-1039.

Gavetti, G and D. Levinthal (2000), “Looking Forward and Looking Backward: Cognitive and Experimental Search”, Administrative Science Quarterly Vol. 45(1), pp. 113-137.

Gilsing, V. & Nooteboom, B. (2006), “Exploration and Exploitation in Innovation Systems: The case of pharmaceutical biotechnology”, Research Policy, Vol. 35(1), pp. 1-23.

Granstrand, O, Patel, P. & Pavitt, K. (1997), “Multi-Technology Corporations: Why they have ‘distributed’ rather than ‘distinctive core’ competences”, California Management Review, Vol. 39(4), pp. 8-25.

Jaffe, A. B. (1986), “Technological Opportunity and Spillovers of R&D: Evidence from firms’ patents, profits, and market value”, American Economic Review, Vol. 76(3), pp. 984-1001.

Jaffe, A. B. (1989), “Characterizing the ‘Technological Position’ of Firms, with application to quantifying technological opportunity and research spillovers”, Research Policy, Vol. 18(2), pp. 87-97.

Katila, R. & Ahuja, G. (2002), “Something Old, Something New: A Longitudinal Study of Search Behaviour and New Product Introduction”, Academy of Management Journal, Vol. 45(8), pp. 1183-1194.

Laursen, K. Salter, A. J. (2006), “Open for Innovation: The Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms”, Strategic Management Journal, Vol. 27, pp. 131-150.

Levinthal D.A. & March, J.G. (1993), “The Myopia of Learning”, Strategic Management Journal, Vol. 14(winter), pp. 95-112.

Lundvall, B.-Å. (1988), “Innovation as an Interactive Process - from User-Producer Interaction to National Systems of Innovation”, in Dosi, G. et. al. (eds.): Technology and Economic Theory, Pinter Publishers, London.

Lundvall, B.-Å. (1992), “National Innovation Systems: Towards a Theory of Innovation and Interactive Learning”, Pinter, London.

March, J. (1991), “Exploration and exploitation in organizational learning”, Organization Science Vol. 2, pp. 71-87.

Nelson R.R. & Winter S.G. (1982), “An Evolutionary Theory of Economic Change”, Harvard University Press, Cambridge, MA.

Patel, P & Pavitt, K. (1997), “The Technological Competencies of the World’s largest Firms: complex and path-dependent, but not much variety”, Research Policy, Vol. 26(2), pp. 141-156.

Patel, P & Pavitt, K. (2000), “How technological Competences Help Define the Core (not the Boundaries’ of the Firm”, in Dosi, G., Nelson, R. R. and Winter, S. (eds), “The nature and Dynamics of Organizational Capabilities”, Oxford university Press, Oxford, pp. 311-333.

Pisano, G. (1990), “The R&D Boundaries of the Firm: An Empirical Analysis”, Administrative Science Quarterly, Vol. 35(1), pp. 153-176.

Powell, W. W., Koput, K. W. & Smith-Doerr, L. (1996), “Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology”, Administrative Science Quarterly, Vol. 41(1), pp. 116-145.

Rothwell, R. (1977), “The Characteristics of Innovations and Technical Progressive Firms”, R&D Management, Vol. 7(3), pp. 191-206.

Rosenkopf, L. & Nerkar, A. (2001), “Beyond Local Search : Boundary-Spanning, Exploration, and Impact in the Optical Disk Industry”, Strategic Management Journal, Vol. 22(4), pp. 287-306.

Teece, D. J. (1992), “Competition, Cooperation, and Innovation – organizational arrangements for regimes or rapid technological progress”, Journal of Economics Behaviour and Organization, Vol. 18, pp. 1-25.

Teece, D. J., Pisano, G., & Shuen, A. (1997), “Dynamic capabilities and strategic management”, Strategic Management Journal, Vol. 18, pp. 509-533.

Tether, B. (2002), Who co-operates for innovation, and why - An empirical analysis”, Research Policy, Vol. 31, pp. 947-967.

Valentin, F. & Jensen, R. L. (2003), “Discontinuities and distributed innovation – the case of biotechnology in food processing”, Industry and Innovation, Vol 10(3), pp. 275-310.

Valentin, F. & Jensen, R. L. (2007), “Effects on academia-industry collaboration of extending university property rights”, Journal of Technology Transfer, 32 (3), pp.

Valentin, F., Jensen, R. L. & Dahlgren, H. (2007), “Research strategies in science-based start-ups. Effects on performance in Danish and Swedish biotechnology”, Technology Analysis & Strategic Management, 19, pp.

von Hippel, E. (1976), "The Dominant Role of Users in the Scientific Instrument Innovation Process", Research Policy, Vol. 5(3), pp. 212-39.

von Hippel, E. (1988), “The Sources of Innovation”, Oxford University Press, New York.

FIGURES

Figure 1: Density plot of Heterogeneity Index and its associated normal density function.

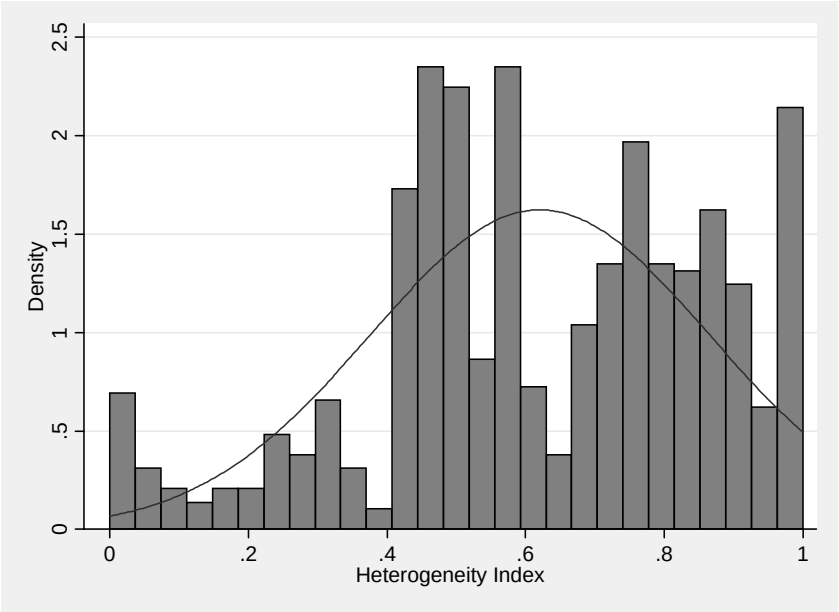
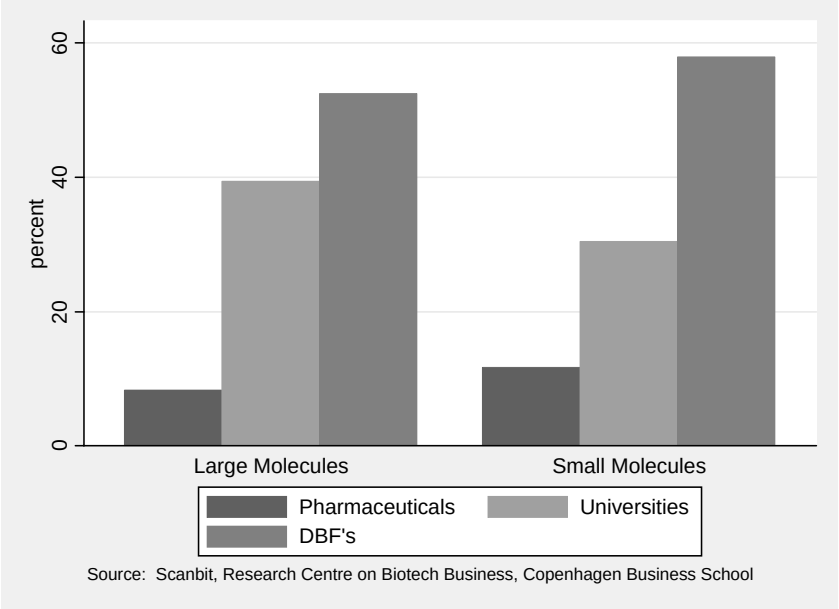


Figure 2: Share of patents that has an author with external affiliation. Differences between large and small molecule biotech business considered.



TABLES

Table 1: Descriptive statistics and Pearson's Correlation Coefficients (N=781)

	Mean	Std.Dev.	1	2	3	4	5	6	7	8
1. Innovative Scope	0.678	0.467								
2. Collaborating with Pharmaceutical	0.137	0.344	0.1151 0.0013							
3. Collaborating with University	0.458	0.499	0.1260 0.0004	-0.0447 0.2126						
4. Collaborating with Dedicated Biotech Firm	0,732	0,443	-0.1193 0.0008	-0.1122 0.0017	-0.3622 0.0000					
5. Acquired Patent	0,035	0,183	0.0554 0.1223	0.0876 0.0144	0.0935 0.0090	-0.1071 0.0027				
6. Outsourced Patent	0,332	0,471	0.1768 0.0000	0.0275 0.4438	0.2976 0.0000	-0.7720 0.0000	-0.1335 0.0002			
7. Log(No. of inventors)	1,141	0,644	-0.0243 0.4987	0.2602 0.0000	0.2222 0.0000	0.2401 0.0000	0.1454 0.0000	-0.2572 0.0000		
8. Log(No. of Employees)	3,671	1,566	0.1076 0.0026	0.2001 0.0000	-0.2463 0.0000	0.2334 0.0000	-0.0772 0.0310	-0.2864 0.0000	0.0998 0.0053	
9. Small Molecule Firm	0,535	0,499	-0.0650 0.0697	0.0807 0.0243	-0.0921 0.0100	0.1203 0.0008	-0.0624 0.0818	-0.1663 0.0000	0.0607 0.0903	0.2465 0.0000

Note: Figures below correlation coefficients are the corresponding P-values.

Table 2: Determinants of Innovative Scope, results of logistic regressions with robust and cluster corrected standard errors

	All Molecules	Large Molecules	Small Molecules
Collaborating with Pharmaceutical	0.835**	1.293*	0.998**
	[0.379]	[0.698]	[0.470]
Collaborating with University	0.729**	0.370	0.809**
	[0.313]	[0.419]	[0.408]
Collaborating with Dedicated Biotech Firm	1.138	1.867**	0.609
	[0.729]	[0.785]	[1.028]
Acquired Patent	1.847*	2.184**	1.859
	[1.042]	[1.106]	[1.351]
Outsourced Patent	1.855**	2.991***	1.004
	[0.790]	[0.779]	[1.039]
Log(No. of inventors)	-0.300	-0.303	-0.240
	[0.233]	[0.256]	[0.379]
Log(Employees)	0.316*	0.020	0.566**
	[0.177]	[0.236]	[0.251]
Small Molecule Firm	-0.224		
	[0.523]		
Year Fixed Effects	Yes	Yes	Yes
Number of Observations	780	363	417
Number of firms	73	44	29
Maximum VIF	6.240	3.070	3.340
Pseudo R_square	0.100	0.135	0.147
Chi-Square	32.370***	92.861***	67.615***
Bayesian Information Criterion (BIC)	995.224	472.138	557.343

* p<0.1, ** p<0.05, *** p<0.01

[1] We tested whether different value combination would entail different results. Comparing (0.50,0.25) with (0.66,0.33), (0.60,0.30), (0.75,0.50), and (0.75,0.25) yielded similar results suggesting the results to be robust with respect to the chosen weighting values between different levels of IPC code levels.

[2] This was supported by a Kolmogorov-Smirnov normality test.

[3] We tested whether the results were sensitive to using the median as opposed to the mean as a divisional level between high and low level heterogeneity piloting patents. We found no substantial differences between the two approaches.