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Determinants of alliance portfolio complexity and its effect on innovative performance of companies

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Abstract
Alliance formation is often described as a mechanism used by firms to increase voluntary knowledge transfers. Access to external knowledge has been increasingly recognized as a main source of a firm's innovativeness. In this paper we examine decisions to form alliance portfolios of foreign and domestic partners by three groups of firms: innovators (firms that are successful in introducing new products to the market), imitators (firms that are successful at introducing new products, which are not new to the market) and product non-innovators. We consider an alliance portfolio that includes different partnership types (competitor, customer, supplier, university/research center). We develop a measure of portfolio complexity which we define as the number and diversity of elements of the alliance portfolio with which a firm must interact. We then estimate models that explain portfolio complexity and its impact on firm's innovative performance. Using panel data on more than 1800 firms in the Netherlands we find that foremost innovators have a strong propensity to form portfolios consisting of international alliances. Being an innovator or imitator also increases the propensity to form a portfolio of domestic alliances, relative to non-innovators; but this propensity is not stronger for innovators. Innovators appear to derive benefit from both intensive (exploitative) and broad (explorative) use of external information sources. The former sourcing is more important for innovators, while the latter for imitators. Finally, alliance complexity is found to have an inverse U-shape relationship to innovative performance.

Keywords: Innovation, R&D cooperation, Alliance portfolio

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1. **Introduction**

Alliance formation is often described as a mechanism used by firms to increase voluntary knowledge transfers (Contractor and Lorange, 2002; Mowery, Oxley and Silverman, 1996; Kogut, 1988). Such access to external knowledge can increase a firm's innovativeness by exposing it to novel technologies, increasing its problem solving arsenal and by providing it with new solutions (e.g., Ahuja and Lampert, 2001; Amabile, 1988; Vanhaverbeke et al., 2006).

Short-term technological alliances and other forms of cooperative R&D links are often described as being ideal sources of such novel incoming knowledge flows. The importance for innovation performance of learning from multiple and diverse ties carrying non-redundant information have been discussed in e.g. Duysters and Vanhaverbeke (1996) and Belderbos et al (2004). Recent contributions have argued that access to international knowledge flows is especially important for firms aiming to tap into leading-edge knowledge (Griffith, Harrison and van Reenen, 2004). International R&D alliance formation forms an additional channel allowing access to international knowledge flows along with such well studied channels as FDI, trade, foreign technology payments (Coe and Helpman, 1995; Eaton and Kortum, 1996, 1999; Van Pottelsberghe and Lichtenberg, 2001) and mergers & acquisitions (Bresman et al., 1999; de Man and Duysters, 2005). Collaborating internationally is a less risky alternative to mergers & acquisition or start-up strategy in new markets and can be useful for firms to access to the local technological expertise as well as for the process of learning foreign markets, facilitating expansion into these markets and reducing risks associated with new product introduction (Barkema and Vermeulen, 1998; Ciborra, 1991, Tether, 2002). Recent findings therefore show that in international ventures, firms tend to prefer alliances over mergers and acquisitions (VanHaverbeke et al., 2001).

A number of recent contributions have argued that by adopting a ‘portfolio approach’ to external innovation information sources, firms put themselves in a better position to achieve and sustain innovation (e.g., Cohen and Malerba, 2001; Faems et al., 2005; Laursen and Salter, 2005; Leiponen and Helfat, 2005; Katila and Ahuja, 2002). The main contribution of this paper to this strand of literature is to focus on an issue relatively unexplored in previous studies: the relationship between alliance portfolio complexity and innovative performance. Although from a practitioner’s perspective alliance portfolio complexity has become an important and recurrent issue, there is hardly any academic work that addresses this issue in an empirical setting. Some notable exceptions have made a first attempt to link portfolio issues to alliance formation and performance (Faems et al., 2005; Lavie, 2007; Marino, Strandholm, Steensma and Weaver, 2002; Powell, Koput and Smith-Doerr, 1996). However, except for the study of Faems et al (2005) these studies do not focus on innovativeness in relation to the specific nature of the alliance portfolio.

This research attempts to fill this gap in the literature. Although alliance portfolio complexity can come about in many different forms, we consider two major aspects that determine alliance complexity: 1) The international and domestic scope of alliance portfolios by exploiting differences in determinants to form international (EU, US, Japanese partners) and 2) the variety of different alliance types in the portfolio. In this sense we consider a rich composition of types comprising the alliance portfolio; i.e. links with competitors, customers, suppliers, universities, and research institutes. We focus our attention to those alliances in which innovative activities are part of the agreement.

We argue that firms at the frontier of innovativeness seek to establish alliances that are more diverse compared to firms that are further away from the frontier. Furthermore we pose that more innovative firms will tend to have alliance portfolios skewed towards foreign partners allowing them to derive disproportionately higher benefits from international knowledge flows and to ensure faster adaptation of new products in the foreign markets.

This research is the first which deliberately tries to identify the relationship between alliance portfolio complexity and innovativeness. In this paper we define alliance portfolio complexity as the degree to which alliance portfolios consist of different elements. In line with previous studies (Marino et al., 2002; Powell et al., 1996) our study therefore describes complexity in terms of diversity.

To address these questions, in contrast to most previous empirical work relying on alliance press reports, we use data collected through Community Innovation Survey (CIS). This harmonized biannual survey is organized by Eurostat and is aimed at collecting information pertaining to firms' innovation activities. These data include both large firms as well as smaller firms with a limited number of R&D alliances.

2. Hypotheses

The propensity to form alliances can be seen to depend on both ‘inducements’ and ‘opportunities’ to form such linkages (Ahuja, 2000). Heterogeneity of these inducements and opportunities goes some way in explaining why participation in inter-firm collaborations is largely uneven among firms. Firms that have a history of innovativeness can be regarded as technically competent (Stuart, Hoang and Hybels, 1999) and are attractive potential partners for other firms. Rapidly-innovating firms have a greater propensity to engage in R&D alliances and are more attractive partners for joint R&D (Singh and Mitchell, 2005). High levels of technical and commercial expertise can reduce the inducement to engage in collaboration with certain types of partners, e.g., when the risk of proprietary knowledge dissipation is high (Ahuja, 2000). However, these concerns are foremost relevant for horizontal type of cooperation, while propensity for vertical (customer, supplier) collaboration as well as collaboration with universities may be less affected and have been until now less explored. Following the studies of Stearns et al. (1987), Powell et al. (1996) and Marino et al. (2002) diversity among the types of alliances increases the complexity of the alliance portfolio (competitors, customers, suppliers, universities, and research institutes). A portfolio approach to alliance strategies can allow a firm to broaden the pool of technological opportunities and to draw on ideas from multiple external sources providing the firm with information advantages. In fact, Baum et al (2000) have argued that, in terms of innovativeness, the diversity of a firm’s alliance portfolio is likely to be a more important factor than the sheer number of alliances. This assertion is confirmed in the recent study of Faems et al (2005) which established that firms that apply a heterogeneous alliance portfolio are more innovative than other firms. Firms that are able to access a large and diverse stock of knowledge resources are said to be in ‘the thick of things’ (Freeman, 1979: 219) and might benefit from information advantages over other companies. Access to a greater diversity of knowledge sources should in principle should therefore lead to a higher rate of innovation. Ties to a broad number of different sources may also fulfill a ‘radar’ function in the sense of providing the firm with information on a broad number of relevant technological developments (Freeman, 1991; Ahuja, 2000).

Although beneficial for imitators and imitators, we expect the diversity of ties to be more important for innovators than for imitators. Information from a wide diversity of sources is likely to contain novel information, which is more important for innovators than for imitators. Moreover, the establishment of a ‘radar’ function seems to benefit innovators more than imitators because firms that search for a broader range of novel information and opportunities might be more successful in generating radical new innovations (March, 1991). As a consequence, we expect the benefits of portfolio diversity to be higher for innovators than for imitators.
Therefore we hypothesize:

H1: Alliance portfolios of innovators are broader in terms of the different types of alliance partners as compared to those of imitators and portfolios of imitators are broader compared to non-innovators.

The recent sharp increase in industrial R&D expenditures has been accompanied by two major trends (Doz and Hamel, 1998), the growing internationalization of R&D activities and the spectacular rise in the number of international strategic R&D alliances. These trends gave way to the fact that technological knowledge has become more and more dispersed over the world. The traditional monopoly of the US in terms of technological know-how has gradually decreased in favour of new hubs of knowledge in Asia and Europe. Global technology sourcing has therefore become a key strategy for firms in order to benefit from geographically dispersed knowledge hubs (Florida, 1997; Cantwell and Harding, 1998).

Access to qualified R&D personnel at foreign locations, adaptation to local needs, lower costs of R&D personnel and improved access to external knowledge at scientific competence centers located abroad have been mentioned as the most important motives to source technology globally (Brockhoff, 1998). Initial evidence for this is provided by Subramaniam and Venkatraman (2001) who find evidence that international knowledge sourcing enhances firms' capability of producing successful new products for multiple international markets. Furthermore Subramaniam (2006) concludes in his study that cross-national collaboration is an effective channel of international knowledge transfer and integration leading to development of new products. Innovative firms simply have to go beyond the frontiers of their local networks because searching for information in well known domains (local search) significantly lowers their chances for finding new information. This creates a need to explore new sources of knowledge outside existing network through establishing linkages outside their traditional (geographic) regions and networks. This is in line with Burt's (1992) view that innovative firms should gain access to non-redundant contacts in order to obtain novel information. There is therefore a growing consensus in the literature that in order to be innovative firms have to scan for new technologies globally. Imitators, on the other hand, tend to develop dense networks consisting of strong, cohesive ties which are characterized by frequent interaction among a selected group of partners. Strong ties as defined by Granovetter (1973) can be seen as solid, reciprocal and trustworthy relationships.

These ties create a large basis of trust and intimacy and therefore facilitate knowledge sharing and learning among partners (Granovetter, 1973; Brass et al., 1998). Those firms rather replicate their existing ties within their local community than search for new ones (Gulati, 1995, 1998; Walker et al., 1997). Therefore this pattern of repeated alliance formation is based on a local search process that facilitates exploitation and mimics behaviour among firms that eventually develop similar technological skills and know-how (Gilsing et al., 2007; Knoke and Kuklinski, 1982).

Therefore we hypothesise:

H2: Alliance portfolios of innovators are more internationally oriented, allowing firms at the frontier of innovativeness to derive disproportionately higher benefits from international knowledge flows and to ensure faster adaptation of their new products in the foreign markets.

Engagement in multiple cooperative agreements allows firms to exploit synergetic effects between these strategies -- forming a new alliance in one type of R&D linkages can enhance the effectiveness of other existing R&D collaborations. Such a synergy, or complementarity, has been formally defined by Milgrom and Roberts (1990) and is assumed to exist if the implementation of one practice or strategy increases the marginal return to other practices. Belderbos et al. (2006) assess the performance effects of simultaneous engagement in R&D cooperation links with different partners and find that there are benefits of pursuing multiple cooperation strategies simultaneously, especially if the appropriability concerns are low. On the other hand, they also find that engaging in different types of R&D alliances, to the extent that they also relate to pursuit of different innovation objectives, will lead to an increase in managerial costs and complexity, resulting in inferior performance, especially in smaller firms. According to organizational perspective on alliances, firms may find it optimal to separate horizontal and vertical partnerships as long as they entail profoundly different objectives (Gilsing, 2005; Noteboom, 2000; Rothaermel and Deeds, 2005). While firms pursue vertical integration in order to achieve a 'bullwhip effect' in realizing cost efficiencies, to improve core competences and to ensure successful commercialization of *existing* products and services (Lee, Padmanabhan, Whang, 1997; Metters, 1997; Rosenzweig, Roth and Dean, 2003) they tend to engage in strategic collaboration with competitors to develop *new* technology for prospective markets (e.g., Miotti and Sachwald, 2003). However, simultaneous engagement in exploitative vertical and explorative horizontal linkages can have a negative effect on performance and expose a firm to the appropriability risks (Belderbos et al., 2006; Rothaermel et al., 2006).

To summarize, engagement in multiple simultaneous cooperation links brings with it benefits of broader pool of technological opportunities and knowledge acquisition from multiple sources allowing exploitation of synergetic effects. At the same time it also increases the complexity of alliance portfolio and associated management costs and appropriability concerns.

Compared to the management of individual alliances, managing a portfolio of alliances is even more challenging. The more complex an alliance portfolio, the more management attention is required. Overall a too high degree of alliance portfolio complexity is expected to have a negative effect on portfolio performance because of the increased burden on managing the alliance portfolio (Hoang, 2001). In cases of extreme complexity, the cognitive limits of firms to deal with such a degree of complexity are quickly reached. This suggests that each firm has a certain cognitive limit in terms of the degree of complexity it can handle. Therefore we might argue that because of the noted advantages of an increasing level of alliance portfolio complexity firms perform better until a certain inflection point after which marginal costs of managing complexity are higher then the expected benefits from this increased complexity.

Therefore we hypothesize:

H3: Alliance complexity, as measured by the combination of three aspects is inverse U-shaped related to innovativeness

3. Methods

3.1 Sample and descriptive statistics

To test our hypotheses we use data from two consecutive Community Innovation Surveys (CIS) conducted in 1998 and 2000 in the Netherlands, as well as information from the production statistics database in the same years. The bi-annual CIS surveys are conducted by Statistics Netherlands (CBS) on behalf of Eurostat and are aimed at collecting information pertaining to firms' innovative activities. The method and types of questions used in the survey are described in the OECD Oslo Manual (OECD, 1997). An additional advantage of the Dutch CIS surveys is that they have been held every other year rather than in four-year intervals as has been customary in other EU countries. The CIS surveys contain information concerning R&D and innovation activities of the firm, including innovation expenditures, innovation in partnership data and sources of knowledge used in the innovation process. The CIS and production statistics surveys are sent to all large firms and to a random sample of smaller firms (ten and more employees) in the Netherlands. The questionnaire asks firms directly whether they were able to introduce an innovation and whether the innovation was new to the firm or new to the market. The definition of product innovation is based on the following questionnaire question: “During the period of 1998-1996 (1996-1994 in case of CIS2) did your enterprise introduce onto the market any new or significantly improved products?” The questionnaire further details that “Product innovation is a good or service which is either new or significantly improved with respect to its fundamental characteristics, technical specifications, intended uses or user friendliness”. We also use the following survey question to construct the R&D alliance variables: “Did your enterprise have any (if yes, please indicate the type of organization) co-operation arrangements on innovation activities with some other enterprises or institutions in 1998-1996 (in case of CIS2 in 1996-1994)”. The reliability of the harmonized questionnaire has been tested by the Eurostat and is used to collect official statistics on innovation activities of firms in the EU. To create a longitudinal data set, innovating firms in 2000 survey are matched using the enterprise id number to those from 1998 survey. We then linked these firms via a unique id number to the production statistics data. Due to the missing values for some of the explanatory variables the complete sample includes 1889 firms.

Table 1 describes the construction of the variables that were used in the statistical analysis and their descriptive statistics. There are 331 firms (17.5% of the sample) with R&D alliance of any type among the firms in the sample. Partnerships with competitors, the focus of much of the literature on R&D cooperation, are not the most frequently adopted alliance strategy (7.3 % cases). Alliances with suppliers are most frequently adopted, with 11.2% of the cases, followed by alliances with customers (11.4 %), and university cooperation (6.7 %). Some 1558 observations have none of the four types of links. The comparison across industries indicates that the propensity to cooperate is higher in (petro) chemicals, and metals. Firms in science-based industries such as electronics and chemicals, but also basic metal industries, report a relatively high share of university cooperation. Collaborating firms are characterized by significantly higher share of new or improved products introduced to the market.

TABLE 1 IS ABOUT HERE

In the analysis we use the variable aimed at indicating the firm success at introducing products new to the market (and not only to the firm). In our sample there are 531 firms (28% of firms in the sample) that have introduced new to the market products. The average share of sales due to new to the market products is about 5%. In addition, there are 518 firms (38%) that introduced new to the firm products, but no new to the market products (imitators). Chemicals, machines, electronics and basic metals industries are characterized by a relatively high share of radical innovators compared to the average. Low-technology industries have generally lower than average share of both innovators and imitators.

3.2 Variables and measures

To test our hypotheses we estimate two models: a model explaining a firm’s decisions to form and expand the links in its alliance portfolio and a performance model in which the complexity of its alliance portfolio is allowed to impact the innovative performance. Below, we will explain how we measure variables used in the estimation.

Dependent variable in the alliance portfolio equation

Our dependent variable in the portfolio formation model is the count of the number of elements in the alliance portfolio. The alliance types include international and domestic cooperation links with competitors, customers, suppliers, universities and research centers. In each of these types cooperation can take place within national borders (i.e. with domestic partners), and with foreign partners e.g., in the EU, in the new EU countries, in the US, Japan or elsewhere. For each type of alliance firms are asked to indicate if their partner is located within the national borders or abroad. Adding elements within and across various types of partners produces an overall measure of the alliance portfolio with a maximum of 30 link-types (five types of partners with 6 sub-types for each). These are non-exclusive types of links and firms often report more than one link. In fact, in our sample the majority of firms have fewer than 6 link-types. A large share of firms in the sample report zero links. The CIS surveys do not measure the number of links within each sub-type. It is likely, however, that the number of types of links is highly correlated with the number of agreements within each category.

TABLE 2 IS ABOUT HERE

Independent variables in the alliance portfolio equation

Based on our review of the literature, in this section we discuss the specification of our empirical model and describe our focal variables that explain the scope and complexity of firms' alliance portfolios.

Intellectual property protection

Effectiveness of means available to a firm to protect their innovations and intellectual property from imitators may have substantial influence on its decision to form external cooperative agreements (Ahuja, 2000). In the model we use a direct measure of firms' perceptions about the effectiveness of various protection mechanisms it employs. In the survey firms are asked to rate the effectiveness of several methods of protecting own innovations. We distinguish between the following measures: *legal* methods of protection (through patents, brand names, or copyright); and *strategic* protection through 1) secrecy, 2) complexity of existing firm-specific processes and 3) lead time. The responses pertaining to each of the categories are measured on a Likert scale ranging from not important to very important. For the legal protection methods we sum over the corresponding responses. Arguably, these appropriability variables are subjective measures based on the management's beliefs about the firm's external environment. Other studies (e.g., Cassiman and Veugelers, 2002; Cohen and Levinthal, 1989; Levin, 1988) have shown that these firm-specific measures capture appropriability effects quite accurately, and influence the managements' decisions on whether to engage in cooperative R&D.

Foreign multinationals

We also include a control dummy variable for firms that are part of a multinational group. This dummy takes a value of 1 if an establishment's headquarters is located outside the Netherlands. Previous studies have generally found that foreign MNEs tend to outperform their local competitors. This is attributed to their efficiency in transferring accumulated tacit knowledge on production (e.g., Aitken and Harrison, 1999). Foreign MNEs are also more likely to form alliances with foreign partners compared to purely domestic firms.

Strategy firm objectives

We also include variables controlling for different objectives of firms' innovation strategies. We distinguish between a "cost push" objective, that is capturing the importance of cost-saving objectives of the innovation process and a "demand pull" objective that is capturing the demand-enhancing, product oriented goals of the innovation.

Bottlenecks to innovation

Another control included in the equation is a dummy for existing bottlenecks to innovation. This variable aims to capture the hampering factors to the firm innovation activities, potentially pushing a firm to seek cooperation partners to overcome existing bottlenecks.

Firm size

The literature indicates that the size of companies also plays a role in propensity to form partnerships. Larger firms have more abundant resources and may find it less problematic to handle multiple innovation objectives and management of multiple R&D collaborations (e.g., Belederbos et al., 2006; Harrigan, 1988). We therefore control for firm size, measured as the logarithm of the number of employees.

Indicators of firm's innovativeness: innovators, imitators and non-innovators

In order to test our hypotheses H1 – H2 that predict that firm's portfolio complexity is partly determined by the firm's position relative to the innovative frontier we include in our model two binary indicators. The CIS survey allows the classification of each firm as either an innovator, imitator or non-innovator. Our binary variables take the value one if a firm is an innovator or imitator, respectively, and else zero. It is classified as imitator if in this period it introduced products new to the firm, but no product new to the market. A firm is classified as product innovator if it introduced products new to the market (these firms could also have products new to the firm only). Finally, a firm is classified as non-innovator if it did not introduce in 1998-2000 period any product innovations onto the market. Non-innovator firms are taken as a control group. It is possible that in the group of non-innovators there are firms that have introduced process innovations. In this paper we limit our focus on product innovations only.

Dependent variable in the innovation output equation

In order to test our third hypothesis pertaining to the effect of portfolio complexity on firm's innovative performance, we estimate a model in which the dependent variable is a share of the new products introduced by a firm into the market over the past 2 years. Product newness can be defined based on the technological significance of the invention or based on the position in the market or relative the user (Trajtenberg, 1990). The Community Innovation Survey (CIS) uses the latter approach.

Independent variables innovation output equation

Alliance portfolio complexity

Measuring complexity of alliance portfolio is challenging, because there are many potential sources of such complexity. In our approach we focus on two aspects that determine the complexity of firm's alliance portfolio: the diversity of types of partners and the number of elements portfolio contains. For each firm in our sample we calculate a score measure $r_{ij} = \frac{\theta_{ij} x_{ij}}{\sum_{i=1}^{2} x_i \sum_{j=1}^{5} x_j}$ $(i = 1,2;\ j = 1,...,5)$ which gives the proportion of each link-type x_{ij} out of total number of link-types. This score is computed by differentiating between foreign and domestic partners (given by index $i = 1,2$). The complexity of the alliance portfolio increases along each of the dimensions and is bounded on a unit interval. Rothaermel and Deeds (2006) find evidence that alliance portfolio complexity varies depending on types of partners in it. Different values of θ_{ij} can be used to give different weights to r_{ij} to allow for such differentiation between portfolios, for example, populated relatively more densely with foreign partners. Our measure of complexity is then expressed as:

$$d = 1 - \sum_{i=1}^{2} \sum_{j=1}^{5} r_{ij}^{2}$$

When θ_{ij} are all unity, this measure is equivalent to the Blau's index of heterogeneity which has been used in the alliance literature to measure portfolio diversity (e.g., Powell et al., 1996). The use of weights (which sum to one) increases variation in the data lost due of the dichotomous nature of our alliance variables. Our empirical results are not sensitive to the different values of weights.

R&D intensity

We include the R&D expenditures variable as a control in the innovation output equation. A positive correlation between technological input and output is predicted in the literature (e.g. Pakes and Griliches, 1984). In line with the previous literature we include the R&D intensity measure (which is preferable to simple R&D expenditure due to scale effects), and its square term. We expect an inverted U-shape relationship between innovation input and output measures, reflecting the decreasing returns on R&D (e.g., Acs and Isberg, 1991). The R&D intensity is measured as the R&D expenditures divided by total sales. These expenditures include ,in addition to internal innovation expenditures, outlays on extramural R&D on contracts paid to other parties, such as research centers and expenditures on technology licenses. Hence, the intensity measure also controls for the impact of external technology acquisition. Increasing levels of R&D intensity up to a point will be closely correlated with absorptive capacity. Further increases may be less effective in expanding absorptive capacity due to diminishing scale economies. To eliminate outliers we exclude observations with R&D intensity measure higher than 50%. The R&D intensity is taken from a 1998 survey to allow a 2-year lag with which innovation investments affect innovation output.

Knowledge sources

Several recent contributions have argued that firms can better achieve and sustain innovation by adopting a broad sourcing strategy to external innovation information channels (e.g., Faems et al., 2005; Laursen and Salter, 2005; Leiponen and Helfat, 2005; Katila and Ahuja, 2002). A greater degree of openness in external search channels allows firms to broaden the pool of technological opportunities and to draw on ideas from multiple external sources. According to March (1991) using both explorative and exploitative information scanning strategies are important. Access to a greater range of knowledge sources should lead to a higher rate of innovation. In particular, Laursen and Saulter (2005) find that both breadth and depth of information sourcing can affect the probability of successful introduction of new products into the market. However, importance of search depth, rather than breadth increases with the degree of novelty of the innovation output of firms. We include two source-specific incoming spillover variables 'breadth' and 'depth' in equation (2). Following Laursen and Salter (2005) 'breadth' is constructed as the number of knowledge sources that a firm draws on. 'Breadth' is capturing the extensive dimension of the use of knowledge sources, while 'depth' measures the intensive dimension of their usage. To construct 'breadth', for each firm in each year we sum over all sources of knowledge that a firm reported it had used (the minimum is zero, the maximum is ten). The variables capturing sources of knowledge have a high degree of internal consistency (Chronbach alpha coefficient between 0.75). The variable 'depth' measuring the intensive use of knowledge sources is constructed in a similar fashion. Here we sum over those sources that have been rated by firms as important or very important in their innovation activities.

Firm Size and Industry controls

Larger firms have more abundant resources and may find it less problematic to handle multiple innovation objectives (e.g., Belederbos et al., 2006; Cohen and Klepper, 1996). We control for firm size by including a logarithm of the number of employees. Further control variables include a set of 2-digit industry dummies.

3.3. Modeling approach

The dependent variable in the equation explaining the composition of alliance portfolio is a count variable taking on discrete non-negative integer values, including zero. Use of a Poisson or Negative Binomial model is standard for such models. One complication is that the explanatory variable we use as a proxy for the firm's position (radical innovator, imitator or non-innovator) relative to the innovation frontier may be endogenous. In such a case a use of a standard Poisson or Negative Binomial model will lead to biased estimates. The main reason for the endogeneity is a bidirectional relationship between alliances and innovation performance of firms. Firms that have a history of innovativeness are more attractive potential partners for other firms compared to less innovative firms. The most innovative firms have the biggest opportunities to form technological alliances compared to firms behind the innovation frontier, while their inducements to inter-firm link formation may vary depending on the type of potential partner (Ahuja, 2000).

For this reason we apply a Negative Binomial model with endogenous covariates, which in our case is a multinomial variable. We coded this variable to take the values one, if a firm is a non-innovator, two if it is an imitator and three if it is an innovator.

More formally, the model can be described with the following equations (Deb and Trivedi, 2006). Assuming a mixed Multinomial Logit distribution, the probability of being non-innovator, innovator or imitator can then be expressed as:

$$\Pr(\mathbf{d}_i \mid \mathbf{z}_i, \mathbf{l}_i) = \frac{\exp(\mathbf{z}_i'\alpha_j + \delta_j l_{ij})}{1 + \sum_{k=1}^{J} \exp(\mathbf{z}_i'\alpha_k + \delta_k l_{ik})} \qquad (1)$$

Here **z** is a vector of explanatory exogenous variables, with parameters α_j to be estimated, and $l_{ij} = (l_{i1}, l_{i2}, l_{i3})$ is a latent variable incorporating one of the three firm's *i* innovation states.

The expected outcome equation (number of elements in a portfolio) for firm *i*, *i* = 1,.,N, is formulated as:

$$E(y_i \mid \mathbf{d}_i, \mathbf{x}_i, \mathbf{l}_i) = \mathbf{x}_i'\beta + \sum_{j=1}^{J} \gamma_j d_{ij} + \sum_{j=1}^{J} \lambda_j l_{ij} \qquad (2)$$

where $\mathbf{x}_i$ is a vector of exogenous variables, γ_i are the coefficients of the endogenous firm innovation type variable relative to the control group and $\mathbf{l}_{ij}$ are the latent factors. The maximum likelihood function is given in Deb and Trivedi (2006) and can be estimated with simulated maximum likelihood methods.

The dependent variable in our second model, explaining firms' innovation performance as a function of the alliance complexity measure and other controls is a censored variable taking on value on a unit interval. Symbolically:

$$y_i^* = \beta \mathbf{w}_i + u_i \tag{3}$$

where the dependent variable y_i, the share of innovative sales is defined as

$$y_i = \begin{cases} 0 & if \quad y_i^* \leq 0 \\ y_i^* & if \quad y_i^* > 0 \end{cases}$$

$\mathbf{w}_i$ is the vector of explanatory variables in the innovation performance equation and they are described in section 3.2; β is the vector of parameters to be estimated. Prior to the estimation we pass our dependent variable, y_i through a logistic transformation, allowing us to treat it as a continuous variable in the estimation.

3. Results

Table 3 presents the regression results testing Hypotheses 1 and 2. Hypothesis 1 states that alliance portfolios of innovators are broader in terms of the different types of alliance partners as compared to those of imitators and portfolios of imitators are broader compared to non-innovators. The results obtained in portfolio formation model provide clear support for Hypothesis 1.

TABLE 3 IS ABOUT HERE

First we find that both of the coefficients on the focal innovativeness dummy variables in the ‘all alliance links’ equation are positive and significant for both imitators and innovators, suggesting that their respective portfolios are broader compared to those of non-innovators, which is the base group. Second, the magnitude of the coefficient is statistically significantly higher for innovators than for imitators. We test this formally, using F-test to check if this difference is significantly different from zero. The F-test value is 6.25 ($p<0.01$) and therefore it rejects the null that the difference in coefficients is zero. This result suggests that the alliance portfolios of innovators are broader in range compared to imitators.

Most of our control variables in the alliance equations are significant. According to the results, the use of the intellectual property rights protection measures encourages broader alliance formation. We distinguished between *legal* methods of protection using patents, brand names, or copyright and *strategic* protection through secrecy, complexity of existing firm-specific processes and the lead time on competitors. All of the strategic protection measures are statistically significant at 1% level, while the legal measure in not different from zero.

Our overall obstacles to innovation measure is significant at 5%, suggesting that those firms that experience bottlenecks in their innovation processes have a higher propensity for alliance formation. The foreign group dummy is also positive and significant, indicating that foreign firms are more active in forming alliances compared to their domestic counterparts. Firm size is also positive and significant in the alliance equation. Larger firms are more likely to have the critical size and absorptive capacity required to engage in R&D cooperation and forming broader portfolios.

To test our second Hypothesis whether each type of innovator has different propensities in forming *international* alliances, we re-estimated the model now focusing on firms' portfolios including only foreign links, subsequently using it as separate dependent variable. These results are reported in Table 3, column 2. Consistent with Hypothesis 2 the innovator variable is positive and highly statistically significant, while the magnitude of the coefficient on the imitator variable is less than half of that for innovator in the foreign alliances equation. Both are statistically significant. This result indicates that relative to the base group (non-innovators), innovators tend to have broader foreign alliance portfolios and so do the imitators. We again tested for the difference in the respective coefficients and rejected it at the 1% level (F-test is 8.85, p-value<0.01). To check the robustness of our results we also estimated separately a domestic alliance equation (these results are not tabulated). While we found that both innovator and imitator variables are positive and significant, when we tested whether this difference in coefficients is statistically significant we could not reject that it is not at the conventional level of significance. This result points that innovators and imitators are different with respect to their international alliances but not domestic alliances.

The impact of the control variables is similar between the ‘all’ and ‘foreign alliance’ equations. The appropriability protection mechanism through secrecy and lead time seems more important for the propensity to form foreign alliances. Foreign groups have a higher propensity to form foreign alliances compared to domestic firms. The relationship between size and propensity to form alliances is also positive in the ‘foreign’ alliances model. Some authors (e.g., Narula and Hagedoorn, 1999) have argued that there might be a negative correlation between propensity to form foreign alliances and size because smaller firms compensate for their limited resources by actively engaging in foreign cooperation, while larger firms have preference for more permanent forms of entry, such as investment in the wholly owned R&D laboratories. This is not confirmed in our data. Our result is indicative that bigger firms due to their resources are able to manage larger and more complex alliance portfolios compared to smaller firms.

Hypothesis 3 predicts that alliance complexity measured by the aspects pertaining to the diversity of links within the portfolio and their number has an inverted U-shape relationship to innovative performance. To test this hypothesis we estimate a model of innovative performance in which the dependent variable is the logistic transformation of the share of sales due to the new products introduced by a firm. In this model we control for R&D intensity, size of a firm, whether it is foreign or domestic and the informational sourcing variables as well as industry dummies. In column 1 of Table 4 we report the results of a regression in which we include a simple count (and its square term) across types and links within type to proxy for the portfolio complexity. One advantage of this approach is that it allows computing the inflexion point in terms of the number of elements in a portfolio (cf. Rothaermel and Deeds, 2006). We find that the linear term is positive and the quadratic term is negative and significant, suggesting a curvilinear relationship between complexity and performance. Using the estimated coefficients we can compute the inflexion point which is about 5 linkages.

TABLE 4 IS ABOUT HERE

In column 2 in Table 4 we present the results when we use our complexity measure constructed as explained in section 3.2. The advantage of this measure over a simple count variable is that by taking both diversity in types and number into account it further allows assignment of different relative weights to different types of links. The disadvantage of the measure is that it does easily produce a prediction on the optimal number of elements in the portfolio and does not specify how to devise the weights for different types of partners. Based on our review of the literature we gave a higher weight to foreign linkages, reflecting a situation in which a portfolio with relatively higher share of foreign links is more difficult to manage than the one populated with predominantly domestic partners. Again, in our results the linear term is positive and the quadratic term is negative and significant, suggesting an inverted U-shape relationship between our complexity measure and performance. We experimented with assigning different weights to foreign and domestic alliances, but found out that our empirical results are not very sensitive to the different values of weights.

3. Discussion and conclusions

Despite the vast and still growing attention devoted to strategic alliances in both theory and practice, the study of alliance portfolio's is still in its infancy. In this paper we examined the effect of alliance portfolio complexity on innovativeness. More in particular, we studied decisions of firms to form alliance portfolios of foreign and domestic partners by three groups of firms: innovators (firms that are successful in introducing new products to the market), imitators (firms that are successful at introducing new products, which are not new to the market) and product non-innovators. In line with our first hypothesis we found that alliance portfolios of innovators are broader in terms of the different types of alliance partners as compared to those of imitators and portfolios of imitators are broader compared to non-innovators. This finding can be seen as an extension of the findings of Faems et al (2005) and points to the importance of establishing a "radar function" of links to various different partners in accessing novel information in a world which is dynamic and not very transparent. In order to be innovative firms should therefore try to develop non-redundant ties that provide access to new information (Burt, 1992).

Non-redundant information can also be found in international alliances. The growing internationalization of R&D activities and the spectacular rise in the number of international strategic R&D alliances has provided us with evidence that global technology sourcing is an important trend. In this study we found that foremost innovators have a strong propensity to form portfolios consisting of international alliances. Being an innovator or imitator also increases the propensity to form a portfolio of domestic alliances, relative to non-innovators; but this propensity is not stronger for innovators. Innovators appear to derive benefit from both intensive (exploitative) and broad (explorative) use of external information sources. The former sourcing is more important for innovators, while the latter for imitators. This points out at the importance to access non-local non-redundant ties to achieve access to novel information.

Finally, alliance complexity is found to have an inverse U-shape relationship to innovative performance. On the one hand, complexity facilitates learning and innovativeness; on the other hand we find that each organization has a certain management capacity to deal with complexity and that this managerial capacity seems to set limits on the amount of alliance portfolio complexity that can be managed within firm. This clearly suggests that firms face a certain cognitive limit in terms of the degree of complexity they can handle. Therefore we argue that despite the noted advantages of an increasing level of alliance portfolio complexity firms will at a certain stage reach a specific inflection point after which marginal costs of managing complexity are higher than the expected benefits from this increased complexity. Of course, the managerial capability of firms to handle complex alliance portfolios might differ from firm to firm. The nature of the data allowed us to focus on two aspects that determine complexity: international and domestic scope of alliances and variety of their types in the portfolio. Although the sheer number of alliances can also be a factor influencing alliance portfolio complexity, Baum et al (2000) have however argued that, in terms of innovativeness, the diversity of a firm's alliance portfolio is likely to be a more important factor than the sheer number of alliances. More research is needed to assess the specific alliance capabilities needed to support such complex portfolios (Duysters, Heimeriks and Jurriens, 2004).

Overall, this study highlighted both the beneficial nature of portfolio diversity as well as its limits from an innovation performance perspective. This can be seen as an important step into expanding our, so far limited, knowledge of the effects of alliance portfolio's on innovative performance. Of course, the international nature and the type of alliances are not the only dimensions of alliance portfolio complexity and further study is needed to include additional aspects of portfolio complexity. However, this study has shown that both the international nature and the type of relationships in a portfolio can have a substantial impact on a company's innovative performance.

Table 1 Description of variables

Variable name	Definition	Mean	S.D.
All alliances portfolio	Sum of all partnership types a firm reports to be engaged in. The alliance types include international and domestic partnerships	0.55	1.60
Foreign alliances portfolio	Sum of partnership types a firm reports. The alliance types include international partnerships only	0.28	1.04
R&D intensity	Total innovation expenditures/sales	0.02	0.04
R&D intensity squared	Total innovation expenditures/sales squared	0.00	0.01
Firm size	Logarithm of number of employees	4.60	1.16
Breadth	Constructed as the sum of knowledge sources (customers, suppliers, universities, research centers, etc.) that a firm draws on	2.60	1.87
Depth	Constructed as the sum of scores on the knowledge sources that have been rated by firm as important or very important in its innovation activities.	0.68	0.92
Innovation constraints	1 if the firm has experienced bottlenecks in its innovation process related to lack of skills, knowledge, rigid organization structure, economic risks or lack of financing	0.61	0.87
Secrecy protection measure	Importance of secrecy as protection of firm's innovations, measured on a 5-point Likert scale	0.13	0.34
Complexity protection measure	Importance of product or technological complexity as protection of firm's innovations, measured on a 5-point Likert scale	0.17	0.37
Lead time protection measure	Importance of lead time as protection of firm's innovations measured on a 5-point Likert scale	0.35	0.48
Legal protection measures	Importance of patents, copyrights and trademarks as protection of firm's innovations, sum of scores, measured on a 5-point Likert scale	0.22	0.47
Foreign multinational	1 if the firm is an affiliate of a foreign multinational, else 0	0.15	0.36
Demand pull	Importance of demand-enhancing objectives for the firm's innovations. Constructed as a sum of scores on two categories of objectives, relating to product quality and new products and markets	2.25	0.92
Cost push	Importance of cost-saving objectives for the firm's innovations. Constructed as a sum of scores on two categories of objectives, relating to processes, labor, materials and energy	3.40	2.27

Note: all independent variables are for 1998; the dependent variables are for 2000.

Table 2 Count of foreign and domestic alliances

Frequency, number of firms	All alliances, number of firms	Foreign alliances, number of firms	Domestic alliances, number of firms
0	1558	1672	1619
1	93	86	127
2	86	63	78
3	42	28	41
4	38	13	15
5	31	6	9
6	10	7	
7	11	6	
8	3	3	
9	4	1	
10	4	2	
11	2	2	
12	4		
13	1		
14	1		
16	1		
Total firms	1889	1889	1889

Table 3 Determinants of the alliance portfolio formation

	Alliance portfolio, all links	**Alliance portfolio, foreign links**
	(1)	(2)
Innovator	2.80*** (0.39)	3.01*** (0.41)
Imitator	1.81*** (0.26)	1.24*** (0.46)
Legal protection	0.10 (0.13)	0.17 (0.17)
Protection through secrecy	0.50*** (0.18)	0.77*** (0.23)
Protection through complexity	0.39** (0.17)	0.35* (0.21)
Protection through lead time	0.56*** (0.15)	0.63*** (0.20)
Firm size	0.32*** (0.06)	0.38*** (0.08)
Foreign group	0.39** (0.19)	0.48** (0.21)
Obstacles	0.19** (0.08)	0.19** (0.10)
Demand oriented strategy	0.18** (0.09)	0.25** (0.12)
Cost oriented strategy	-0.01 (0.03)	-0.03 (0.04)
Industry dummies	Included	Included
Number of observations	1889	1889
Log-likelihood	-3202.84	-2716.27
Wald Chi2(64), p-value	647.84 (0.00)	683.63 (0.00)
F-test (p-value)	6.25 (0.00)	8.86 (0.00)

Notes: Robust standard errors are in parentheses.
*** Indicates significance at 1%, ** at 5%, * at 10% level.
The following exogenous explanatory variables taken from 1998 survey are used in the Multinomial Logit treatment model (estimated coefficients and their standard errors are in parentheses): R&D intensity (19.37 [3.63] innovators and 10.33 [3.90] imitators) R&D intensity SQ (-53.06 [13.73] innovators and -36.99 [16.26] imitators), Spillover Breadth (0.19 [3.63] innovators and 0.12 [0.04] imitators), Spillover Depth (0.31 [0.09] innovators and 0.07 [0.09] imitators).
Reported F-test is on the significance of the difference in coefficients on innovators and imitators

Table 4 Innovative performance and complexity

	Innovative performance and alliance complexity	**Innovative performance and alliance complexity**
	(1)	(2)
Alliance portfolio complexity	0.21*** (0.05)	2.64*** (0.89)
Alliance portfolio complexity squared	-0.02*** (0.00)	-2.60** (1.02)
Firm size	0.11*** (0.04)	0.11*** (0.04)
R&D intensity	5.54*** (1.33)	5.63*** (1.31)
Foreign group	0.33** (0.15)	0.31** (0.15)
Breadth knowledge sourcing	0.08*** (0.03)	0.10*** (0.03)
Depth knowledge sourcing	0.16*** (0.06)	0.16*** (0.06)
Industry dummies	Included	Included
Number of observations	2071	2071
Wald Chi2(64), p-value	13.42 (0.00)	12.94 (0.00)

Notes: Robust standard errors are in parentheses.
*** Indicates significance at 1%, ** at 5%, * at 10% level.
Complexity measure in column (1) is a simple total additive score on the ‘variety’ and ‘number’ dimensions
Complexity measure in column (2) is constructed as explained in section 3.2.

References

Acs, Z.J. and S.C. Isberg, 1991, 'Innovation, firm size and corporate finances'. *Economics Letters*, 35: 232-326.

Ahuja, G., 2000, 'The duality of collaboration: inducements and opportunities in the formation of inter-firm linkages', *Strategic Management Journal*, 21: 317-343.

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

Aitken, B. and A. Harrison, 1999, 'Do domestic firms benefit from direct foreign investment? Evidence from Venezuela', *American Economic Review*, 89(3): 605-618.

Amabile, T., 1988, 'A model of creativity and innovation in organizations', in *Research and Organizational Behavior*, Vol 10, Straw B.M., Cummings, L. (eds.) JAE Press, 123-167.

Barkema, H. and F. Vermeulen. 1998. 'International expansion through start-up or acquisition: a learning perspective', *Academy of Management Journal* 41: 7-26.

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

Belderbos, René, Martin Carree, Boris Lokshin, 2004, 'Cooperative R&D and firm performance', Research Policy 33(10), 1477-92.

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

Brass, D.J., K.D. Butterfield, and B.C. Skaggs (1998), Relationships and Unethical Behavior: A Social Network Perspective, *Academy of Management Review*, 23(1): 14-31.

Bresman, H. J. Birkinshaw, R. Nobel, 1999, 'Knowledge transfer in international acquisitions', *Journal of International Business Studies*, 30, 439-62.

Brockhoff, K., 1998. Internationalization of Research and Development. Springer, Berlin.

Burt, R.S. (1992). Structural Holes: The Social Structure of Competition. Cambridge, MA: Harvard University Press.

Cantwell, J. and Harding, R., 1998. The internationalisation of German companies' R&D. *National Institute Economic Review* **40** 1, pp. 99–115.

Cassiman, B. and R. Veugelers, 2002, 'R&D cooperation and spillovers: some empirical evidence from Belgium', *American Economic Review*, 92(4), 1169-84.

Ciborra, C. U., 1991, 'Alliances as learning experiments: cooperation, competition and change in high-tech industries.' In *Strategic Partnerships: States, Firms and International Competition*, edited by L. K. Mytelka, 51-77. London: Pinter Publishers.

Coe, D. and E. Helpman, 1995, 'International R&D spillovers', *European Economic Review*, 39: 859-887.

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

Cohen, W. and S. Klepper, 1996, 'A reprise of size and R&D', *Economic Journal* 106: 925-951.

Cohen, Wesley and Daniel Levinthal. 1989. ‘Innovation and learning: the two faces of R&D’, Economic Journal, 99(397), 569-96.

Contractor, F. and P. Lorange, 2002, *Cooperative strategies and alliances*, Amsterdam, Elsevier.

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

Deb, P. and P. Trivedi. 2006. ‘Specification and simulated maximum estimation of a non-normal treatment-outcome model with selection: Application to health care utilization’, *Econometrics Journal* 9(2): 307-331.

Duysters, G. and W. Vanhaverbeke, 1996, ‘Startegic interactions in DRAM and RISC technology: a network approach’, *Scandinavian Journal of Management*, 12: 437-61.

Duysters G., K. Heimeriks and J. Jurriens, 2004, ‘An integrated perspective on alliance management’, *Journal on Chain and Network Science*, 4: 83-94.

Eaton, J. and S. Kortum, 1996, ‘Trade in ideas: patenting and productivity in the OECD’, *Journal of International Economics* , 40 (3-4), 251-78.

Eaton, J. and S. Kortum, 1999, ‘International technology diffusion: theory and measurement’, *International Economic Review*, 40, 537-570.

Faems, D., B. Van Looy, and K. Debackere, 2005, ‘Inter-organizational collaboration and innovation: towards a portfolio approach’, *Journal of Product Innovation Management*, 22: 238-50.

Florida, R. (1997), ‘The globalization of R&D: results of a survey of foreign-affiliated R&D laboratories in the USA’, *Research Policy*, 26(1), 85-103.

Freeman, C., 1979, ‘Centrality in Social Networks: Conceptual Clarification’, *Social Networks*, 1: 215-239

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

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

Gilsing, V, C.E.A.V. Lemmens, G. Duysters, 2007, ‘Strategic alliance networks and innovation: a deterministic and voluntaristic view combined’, *Technology Analysis & Strategic Management*, 2007

Granovetter, M (1973), The Strength of Weak Ties, *American Journal of Sociology*, 78: 1360-1380,

Griffith R., R. Harrison and J. Van Reenen, 2004, ‘How special is the special relationship? Using the impact of US R&D spillovers on UK Firms as a test of technology sourcing,’ CEP Discussion Papers dp0659, Centre for Economic Performance, LSE.

Gulati, R, 1995, ‘Does Familiarity Breed Trust? The Implications of Repeated Ties for Contractual Choice in Alliances’ *Academy of Management Journal* 38(1), 85-112.

Gulati, R, 1998, ‘Alliances and networks’, *Strategic Management Journal*, 19(4), 293-317.

Hamel, G., Y. L. Doz, C. K. Prahalad, 1989, ‘Collaborate with your competitors and win’, *Harvard Business Review*, 67(1): 133-39.

Harrigan, K., 1988, ‘Joint ventures and competitive strategy’, *Strategic Management Journal* 9(2): 141-58.

Hoang, H.T. and Rothaermel, F.T. (2005) 'The effect of general and partner-specific alliance experience on joint R&D project performance', *Academy of Management Journal*, 48 (2): 332-345.

Kale, P., H. Singh and H. Perlumutter, 2000, 'Learning and protection of proprietary assts in strategic alliances: Building relational capital', *Strategic Management Journal*, Special Issue, 21: 217-37.

Katila, R, and G. Ahuja, 2002, 'Something old, something new: a longitudinal study of search behavior and new product introduction', *Academy of Management Journal* 45(6): 1183-94.

Khanna, T., R. Gulati, and N. Nohria. 1998. 'The dynamic of learning alliances: competition, cooperation and relative scope', *Strategic Management Journal* 19: 193-210.

Knoke, D and J.H. Kuklinski, 1982, 'Network Analysis', Sage, California.

Kogut, B., 1988, 'Joint ventures: theoretical and empirical perspectives', *Strategic Management Journal*, 9: 319-332.

Laursen, K. and A. Salter, 2005, 'Open for Innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms', *Strategic Management Journal*, 27, 131-50.

Lavie, D (2007), Alliance Porfolios and Firm Performance: A study of value creation and appropriation in the U.S. Software Industry, *Strategic Management Journal*, 28: 1187–1212.

Lee, H.L., V. Padmanabhan, and S. Whang. 1997. 'Information distortion in a supply chain: the bullwhip effect', *Management Science*, 43(4): 546-558.

Leiponen, A. and Helfat, C.E. 2005. 'Innovation objectives, knowledge sources and the benefits of breadth': Ithaka, NY and Hanover, NH.

Levin, Richard. 1988. 'Appropriability, R&D spending and Technological performance', *American Economic Review*, 78(2), 424-48.

Lichtenberg, F. and van Pottelsberghe de la Potterie. 2001. 'Does foreign direct investment transfer technology across the borders?' *The Review of Economics and Statistics*, 83(3), 490-497.

March, James G. 1991. 'Exploration and exploitation in organizational learning', *Organization Science*, 2: 71-87.

Marino L., K. Strandholm, H.K. Steensma and K.M. Weaver, 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.

Metters, R. 1997, 'Quantifying the bullwhip effect in supply chains', *Journal of Operations Management* 15: 89-100.

Milgrom, P. and J. Roberts. 1990, 'The economics of modern manufacturing: technology, strategy and organization'. *American Economic Review*, 80(3): 511-28.

Miotti, L. and F. Sachwald, 2003, 'Co-operative R&D: why and with whom: and integrated framework of analysis', *Research Policy*, 32, 1481-99.

Mowery, D. C., J. E. Oxley and B.S. Silverman, 1996, 'Strategic alliances and inter-firm knowledge transfer', *Strategic Management Journal*, Winter Special Issue, 17: 77-92.

Narula, R. and J. Hagedoorn, 1999, 'Innovating through strategic alliances: moving towards international partnerships and contractual agreements', *Technovation*, 19: 283-94.

Nooteboom, B., 2000, *Learning and innovation in organizations and economies*, Oxford University Press.

Pakes, A., and Z. Griliches, 1984, 'Patents and R&D at the firm level: a first look', in Z. Griliches (ed.) *R&D, Patents and Productivity*, 55-72.

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

Rosenzweig, E. D., A.V. Roth, and J. W. Dean. 2003, 'The influence of an integration strategy on competitive capabilities and business performance: an exploratory study of consumer products manufacturers', *Journal of Operations Management*, 21: 437-456.

Rothaermel, F. T. and D.L. Deeds, 2004, 'Exploration and exploitation alliances in biotechnology: a system of new product development', *Strategic Management Journal*, 25(3), 201-221.

Rothaermel, F. and D.L. Deeds, 2006, 'Alliance type, alliance experience and alliance management capability in high-technology ventures', *Journal of Business Venturing*, 21: 429-60.

Singh, Kulwant and Will Mitchell, 2005, 'Growth Dynamics: the bi-directional relationship between inter-firm collaboration and business sales in entrant and incumbent alliances', *Strategic Management Journal*, 26: 497-521.

Stearns, T., Hoffman, A., and Heide, J. (1987) Performance of Commercial Television Stations As An Outcome of Interorganizational Linkages and Environmental Conditions. *Academy of Management Journal*, 30: 71-90.

Stuart, T.E., H. Hoang and R.C. Hybels, 1999, 'Inter-organizational endorsements and the performance of entrepreneurial ventures', *Administrative Science Quarterly*, 44: 315-49.

Subramaniam, M. and N. Venkatraman 2001, 'Determinants of transnational new product development capability: testing the influence of transferring and deploying tacit oversees knowledge'. *Strategic Management Journal*, 22: 359-378.

Subramaniam, M. (2006). 'Integrating cross-border knowledge for transnational new product development', *Journal of Product Innovation Management*, 23: 541-555.

Tether, B., 2002, 'Who co-operates on innovation and why: an empirical analysis', *Research Policy*, 31: 947-67.

Trajtenberg, M. 1990. 'A penny for your quotes: patent citations and the value of innovations', *RAND Journal of Economics*, 21(1): 172-87.

Vanhaverbeke, Wim, Bonnie Beerkens, Geert Duysters, Victor Gilsing, 2006, 'Explorative and exploitative learning strategies in technology-based alliance networks', Technische Universiteit Eindhoven.

VanHaverbeke, W, Duysters, G and N. Noorderhaven (2002), 'External technology sourcing through alliances or acquisitions: an analysis of the application-specific integrated circuits industry', *Organization Science*, 13: 714-733.

Walker, G., B. Kogut, W. Shan. 1997. Social capital, structural holes and the formation of an industry network, *Organization Science*, 8 109-125.

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