Learning in Strategic Technology Alliances

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ABSTRACT *In this paper we examine the influence of strategic technology alliances on organisational learning. From an empirical perspective we examine the pre- and post-alliance knowledge bases of allying firms. We find that the pre-alliance knowledge base overlap of the allying firms has an inverted U-shaped relationship with the degree of learning taking place in the alliance. Alliances established for the purpose of learning also show a significantly greater increase in knowledge base overlap for the allying firms than for non-learning alliance or non-allying firms. This shows the particular importance of learning alliances as a vehicle for organisational learning and competence development. Contrary to what we expected we found that weak ties are more important than strong ties in organisational learning within strategic alliances.*

Introduction

The resources or capabilities of a firm are often seen as an important contributant to overall company success and competitiveness.[1] In the 'traditional' resource-based view of the firm, firms are viewed as a collection of distinctive and difficult to imitate, scarce resources or capabilities.[2] The deployment of these valuable, rare and idiosyncratic resources is expected to yield a distinct return or rent for the firm possessing them. Firm resources are thus, necessarily, seen as being heterogeneous across firms. This 'traditional' resource-based perspective sees a firm's bundle of resources as static and more or less fixed over time. Under conditions of change core competencies can then turn into 'core rigidities'.[3]

Whereas the 'traditional' resource-based view is mainly concerned with static competences, the dynamic capabilities view of the firm, concentrates on dynamic factors (innovation, organisational learning, etc.). Not the deployment of existing resources is at the focal point of this theory, but rather the change in a firm's resources.[4] This change in resources is necessary for firms in order to be able to respond effectively to changing environmental conditions. One of the dynamic capabilities view's main focus points is the acquisition of new capabilities through organisational learning.

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Over time, a consensus grew that organisational learning can be considered as the most important vehicle for competence development.[5] Following Cohen and Levinthal,[6] we see that two characteristics of the innovation process are very important: the creation of new knowledge within the firm itself, and the incorporation of existing external knowledge. On this junction of internal and external knowledge accumulation one often finds strategic technology alliances. Here the internal knowledge inherent to the company is combined with knowledge external to the company.[7] Both the resource-based view and the dynamic capabilities view help us to explain organisational learning within strategic alliances. However, both are unable to explain some of the key issues related to learning alliances. Therefore we turn to a third stream of literature, the knowledge-based view of the firm. In the knowledge-based view of the firm knowledge is considered the pivotal resource of a firm.[8] Knowledge can consist of codified knowledge contained in the patents or copyrights of a firm, but can also be incorporated in the tacit everyday routine operations carried out by workers. In line with the dynamic capability perspective this view also concentrates on the dynamics of the firm resources, rather than on its static posture. An important point of the knowledge-based view is that it provides a new explanation for the observed trend towards collaborative agreements between firms. It has been shown that firms collaborate, among other things, to get access to the knowledge of other firms.[9] According to a recent *Accenture* study learning was cited as a critical goal in over 40% of all alliances under study.[10] This percentage was expected to exceed 50% in 2003. As a result the use of collaborations is seen as an important vehicle for organisational learning and knowledge acquisition, and thus for the creation of new competencies.

Given the increasing importance of external knowledge appropriation by means of strategic alliances, it is of eminent importance to understand the particular nature of strategic technology partnering and to take a closer look at the impact of firm collaborations on organisational learning. In the rest of this paper we will therefore explore the influence of strategic technology alliances on organisational learning.

Theory and Hypotheses

Whereas the 'traditional' resource-based view concentrates primarily on the efficient use of internal competencies, the dynamic capabilities view of the firm argues that it is of vital importance to exploit external sources of capabilities. The knowledge-based view incorporates both perspectives and deals with the role of knowledge acquisition and integration within an organisational learning setting.

Firm specific capabilities are often difficult to create or imitate by other companies. Some capabilities are protected by patent law, while others are so idiosyncratic that taken out of their context they are hard to understand. Time constraints can hinder firms to create or imitate capabilities fast enough to be able to exploit them. Even firms possessing firm specific capabilities may not be able to use them effectively in other situations or other markets.[11] Also the market for capabilities is not perfect, making it difficult to obtain the resources externally.[12] The external acquisition of knowledge via a merger or acquisition is also complicated. Whereas mergers and acquisitions (M&As) can provide scale economies to organisations they hamper flexibility, efficient knowledge transfer and speed, the capabilities needed most in today's economy. As in the case of strategic alliances, recent studies have shown that, in spite of the unprecedented increase in the number of M&As, their overall contribution to firms' performance is very poor. Their

poor track record is primarily due to the massive integration challenges that arise after the acquisition in combination with the high acquisition premiums. Companies often get more than they want and need to sell parts of the acquired firm again. It might also be very difficult to use the acquired competences in the acquiring firm.[13] The most significant problem however, seems to be that the high costs associated with the merger or acquisition and the correspondingly high exit costs diminish the flexibility of firms to quickly adapt to turbulent changes in the economy. Strategic alliances suffer less from these problems, for they allow greater flexibility and they are less involving than for instance an acquisition. A firm can also be involved in several alliances at a time, something that is more difficult with M&As.

Learning within strategic alliances is however a complex phenomenon[14] and, of course, also has its problems and shortcomings. We will touch on the most obvious ones here. Firms must critically evaluate their partner's knowledge and the relevance of this knowledge for their own operations.[15] They should make sure that the partnering firm really has the desired knowledge and that it is possible to get access to the knowledge via the proposed alliance. Partners in an alliance must also be willing to actively exchange knowledge and be able to understand what they are learning.[16] Therefore this also implies a capacity to learn and the appropriate processes and systems to facilitate learning.[17] Experience with earlier alliances can be helpful in successfully learning from later alliances[18] and experience with domestic alliances can be a stepping-stone to international alliances.[19] The management of international alliances is of course more difficult than that of domestic alliances. A last important point is the alignment of parent and alliance managers' culture, thereby avoiding that parent managers see the alliance as a threat and try to frustrate the alliance's success.[20] The largest problem in alliance learning is the loss of knowledge to the alliance partner and the accompanying threat of opportunistic behaviour by the partner. Trust is therefore a very important prerequisite for a successful alliance.[21]

Given these shortcomings strategic alliances are nevertheless frequently considered an effective means of accelerating the accretion of new capabilities. Via inter-organisational learning, alliance partners can acquire resources or transfer knowledge. More in particular, alliances can play a major role in the efficient transfer of tacit knowledge. Whereas codified knowledge can be absorbed by studying, e.g. a blueprint or recipe, without personal interaction, in the case of tacit knowledge interpersonal contact is very important.[22]

Strategic technology alliances are therefore increasingly used for organisational learning and knowledge transfer.[23] Such organisational learning can take on many different forms. We can distinguish among three main forms of organisational learning within strategic alliances.[24] First, firms make use of alliances to learn how to handle and manage future alliances. This type of learning primarily affects the managerial processes in the parent company. In this specific case no product or process knowledge is transferred. Second, knowledge might also be transferred merely for use in the present alliance operations. In this case no attempt is made to internalise the knowledge in the parent operations, nor was this the intent from the beginning. All the knowledge stays within the alliance itself. The third form of learning takes place when parent companies transfer the alliance knowledge to their own operations. Learning is primarily directed towards helping the parent companies to enhancing their own strategy and business operations. These three forms of learning obviously do not exclude each other. There might be combinations of these three forms of learning within alliances. Only when the last form of learning is included can we call it a learning alliance. So we consider an alliance a

learning alliance if, and only if, product or process knowledge used in the alliance is trans-ferred to the parent firm, and is used in the parent firm's operations.

Various studies have argued that for effective learning processes in alliances, a suffi-cient degree of absorptive capacity is required. Cohen and Levinthal define absorptive capacity as the whole of the abilities of firms to use their prior related knowledge to value external information, assimilate it and use it for their own commercial ends.[25] The absorptive capacity of a company is for a large part dependent on the current degree of knowledge in a specific technological field.[26] Therefore we might argue that if a firm lacks a sufficiently developed technology base it is likely to have problems absorbing the newly acquired external technological knowledge. Alliance partners can only be expected to learn from the alliance as long as they have at least some prior knowl-edge in a specific field, so that they can incorporate the new knowledge and use it for their own means. Without an adequate degree of absorptive capacity, a firm will not be able to learn. Firms will be better at internalising a partner's knowledge when they possess at least some overlap in knowledge bases.[27] Too little overlap in knowledge bases between the allying firms is likely to inhibit learning and therefore a minimal level of overlap in knowl-edge bases is necessary to facilitate learning.[28] However, when there is too much overlap there will be no learning either, because there is almost nothing the firms could learn from each other that they do not already know.[29] We can therefore expect that there is an optimal level of overlap, which will facilitate the learning the best. Therefore we hypothesise:

H1: *The degree of overlap in the allying partners' initial knowledge bases has an inverted U-shaped relationship with the degree of learning taking place in the alliance.*

Although building absorptive capacity and a corresponding internal development of resources is important, learning from external sources is considered to be equally import-ant for successful innovation.[30] In particular in turbulent high technology environments in which a firm's competitive position is determined by its ability to innovate, alliances seem to be the most preferred option. Under conditions of change continued reliance on intern-ally developed core competences makes firms extremely vulnerable.[31] Firms are therefore increasingly engaged in strategic technology alliances. Strategic technology alliances have enabled them to cope with the rising costs of R&D efforts and the speed and complexity of technological developments. An alliance with a competent partner enables firms to share development costs and to go faster down the learning curve. This might result in an improved time-to-market and a corresponding increase in the level of innovativeness. Because innovation has become one of the key competitive drivers, the use of alliances might therefore provide a means to achieve sustained competitive advantages. The effec-tiveness of strategic alliances for organisational learning is demonstrated by a recent study which showed that the most successful alliance firms are five times more likely to incorporate learning as an explicit goal of their alliances than their non-successful counterparts.[32]

The usefulness of strategic technology alliances for external learning of companies is tested in several studies.[33] It turns out that strategic technology alliances are a very effec-tive vehicle for organisational learning. Learning via strategic technology alliances has many advantages. Alliances often enable firms to accelerate their capability development

and allow them to reduce the time and risk involved in developing new products and technologies.[34] Also the combination of knowledge of the firms involved in an alliance may prove to provide important synergistic effects, leading to new and better knowledge that neither of the partners could have realised independently. Furthermore, a set of alliances can often be seen as a radar function, which enables firms to explore new technologies developed by other companies. If one of these technologies proves to be successful the firm may choose to extent the alliance or to integrate the knowledge in-house. This decreases the risk of loosing out on new interesting technological opportunities and spreads the costs and risks among partners.[35]

Besides establishing alliances for knowledge transfer, firms also form alliances in order to exploit their existing resources in new markets. In this case the alliance might not be a learning alliance, but rather a complementary alliance.[36] In a complementary alliance each partner brings in its own core competencies. One partner might have the knowledge of the market whereas the other might have the technical or process knowledge. One can think of the way in which alliances were established in many developing countries. Most Western firms have no knowledge about the local customs in for instance China and thus form an alliance with a local firm in which they supply the technical knowledge and the local firm supplies the knowledge about the market peculiarities. Although knowledge sharing is possible, the aim of these kinds of alliances is not to share knowledge, but rather to complement the partner. The learning that takes place in these kinds of alliances is also more concerned with the management of the alliance itself and not with the learning of the technical production knowledge involved in the alliance. Doz and Hamel make the distinction between learning alliances and co-specialisation alliances, where the former is aimed at learning from the alliance partner and the latter is primarily directed towards exploiting new markets.[37] We define learning alliances as a cooperative agreement formed by two or more organisations aimed at the sharing of know-how with reciprocal inputs from all the partners. For this paper we include a number of specific cooperative forms in this definition, i.e. joint development agreements, joint research corporations (JVs), research consortia, joint R&D pacts as well as mutual technology exchange agreements (such as mutual second sourcing and cross licensing). Because of the emphasis on learning, marketing, production and mere single licensing agreements are not included in our definition.

The effect of a learning alliance on the relative post-alliance knowledge base overlap of the allying firms will be inversely related to the effect of a co-specialisation alliance. A learning alliance can be expected to provoke an increase in overlap between the allying firms, because the intention of the alliance is to learn. For firms working together in a co-specialisation alliance, one would expect no increase, or even a decrease in overlap, because firms will specialise in different technological fields and thus resemble each other less after the alliance. Also for firms that are not involved in an alliance we would expect a decrease, or at least no increase, in knowledge base overlap for the measuring period. Therefore the knowledge bases of allying partners in a learning alliance will show greater increase in overlap than do the knowledge bases of firms not involved in a learning alliance, or not involved in an alliance. There might of course be other ways in which firms start to resemble each other technologically, for instance by using the same generally accepted production techniques; shared research trajectories; or commonly recognised business models. We however expect that the results of a pure learning alliance on the post alliance knowledge base overlap will be significantly greater than for a

non-learning alliance or for a firm without an alliance. It should furthermore be kept in mind that if firms start to resemble each other more by other mechanisms than only through the learning via a learning alliance, this would actually strengthen our results if we find that there is indeed a difference between learning alliances on one side and non-learning alliances or non-allying firms on the other side.

This leads to our second hypothesis:

> *H2*: *Learning alliances will show significantly greater learning among the allying firms compared to firms that are not engaged in learning alliances, or not engaged in alliances at all.*

In the social network literature the distinction between strong and weak ties has been posed to bear important implications on the nature of organisational learning.[38] Weak ties are considered to be more important for the diffusion of unrelated knowledge whereas strong ties are more important for the diffusion of related knowledge. According to Granovetter the strength of a tie is 'a combination of the amount of time, the emotional intensity, the intimacy, and the reciprocal services which characterize the tie'.[39] Firms connected via strong ties know each other well and are also to some degree aware of the knowledge of the other partner. Firms connected through weak ties are usually less familiar with each other and with each other's knowledge base. In weak tie relationships, firms can learn from dissimilar knowledge bases whereas in the case of strong ties they can deepen their understanding of their existing knowledge. Weak ties are therefore more efficient as drivers of explorative research. They also tend to fulfil a bridge function between two, more or less unrelated business cliques and are therefore geared towards combining previously distinct knowledge. The lack of 'social capital' (trust, comfort) is however likely to fuel opportunism and a lack of commitment among the alliance partners. Strong ties, however, are used more often in exploitative research settings where firms from the same 'clique' or technological field work together in order to deepen their existing knowledge. Therefore, we expect that the scope of the learning in a network comprised of weak ties is broader and in a network characterised by strong ties is deeper.

The degree of intimacy in the tie is related to the concept of trust.[40] Before firms are willing to exchange information or knowledge they want to make sure that their sharing partner is trustworthy. Firms will be very wary of opportunistic behaviour, especially when the exchange touches on their core knowledge.[41] According to transaction cost theory, the type of contact between firms depends on the anticipated transaction costs. Especially with core capabilities involved firms will be very protective, and choose for a reliable partner. Also the resource-based theory of the firm considers reputation an important resource.[42] In combination with strong and weak ties we can expect that there will be more trust between partners with strong ties, than with partners who are connected via weak ties. As argued by Krackhard these '... strong ties constitute a base of trust that can reduce resistance and provide comfort in the face of uncertainty'.[43] In strong ties, opportunistic behaviour affects the reputation of firms more than in a situation of weak ties. If a firm is considered a non-trustworthy partner in a network of strong ties this news will travel quickly and its effect on the opportunistic firm will be considerable. In a weak tie situation both problems are less critical and might even be outweighed by the application of the knowledge gained in the own clique. Although firms might use strong and weak ties for different reasons, when learning is involved we can expect firms

to work together in weak tie alliances primarily when their peripheral competencies are concerned. For learning which involves their core competencies they will relay on strong ties.

So while firms could potentially learn a great deal from weak tie contacts, the fear for opportunistic behaviour and consequently the lack of trust might inhibit knowledge flows. Although learning in a strong tie situation will be less broad, we can expect more knowledge flows in these kinds of interactions as a result of greater trust between partners. This leads us to expect that most of the observed knowledge flows will be between firms connected via strong ties. We would therefore expect more learning to take place in a strong tie alliance as opposed to a weak tie alliance.

Therefore our third hypothesis:

H_3: *The learning, taking place in strong tie alliances is larger than in weak tie alliances.*

Data

Our sample of firms is taken from the Fortune 500 list in 1997.[44] We selected all firms in the medium- to high-tech sectors. This provided us with a set of 171 parent firms in 12 sectors. Using the Dun & Bradstreet Linkages dataset we searched all the subsidiaries of these 171 firms to construct a 'group' list per firm. This 'group' list makes it possible to trace back more of the patents of the multinationals we studied. This enables us to include the patents and patent citations of their subsidiaries and not just those of only the parent company. The version of the Dun & Bradstreet Linkages database that we used originates from 1998 and thus represents the 'group' list at that particular moment in time, or actually a bit earlier. Of course, the parent–subsidiary relationships will change over time, so we want our measuring moment to be as close as possible to the moment of the sample construction.

For the data on patents we made use of the European Patent Office (EPO) data set. Based on the 'group' lists that we constructed, we searched the EPO data set for all patents of the multinational. In the EPO database the patents are recorded by applicant name. Sometimes we found names that only partly corresponded with the names of the firms we were looking for, in which case we compared the address obtained from Dun & Bradstreet with the address contained in the EPO database. If they were identical we included the patents in our sample, otherwise we excluded them. We also used the patent citation data present in EPO so that we could end up with a list of all the patent citations per patent.

We made use of the well-known MERIT-Cooperative Agreements and Technology Indicators (CATI) database for the information on alliances. The CATI database is a relational database containing over 15,000 cooperative agreements involving about 9500 firms. Systematic collection of inter-firm alliances started in 1987, but earlier years were searched in retrospect. Different sources were used for the construction of the database, among the most important are newspapers and trade journal articles. Even though the dataset will be inevitably incomplete and biases might be present, CATI is likely to be the most complete and dependable source available on cooperative technology agreements.

We only researched allying firms and did not include, for instance, information on learning through an M&A. M&As however turn out to have only limited influence on

the innovative performance of firms especially for the very large firms we are research-ing.[45] Our dataset is also constructed for only one year, namely 1998. All the firms that belonged to the 'group' at that moment are included. The patents are thus only included for the subsidiaries that the parent firm had in 1998. M&A activity, even if it would have had an influence on the firms in our dataset, is thus not influencing our results. Only the subsidiaries of 1998 are taken into account, regardless whether these firms were sold later on or whether other firms were taken over and became part of the 'group' after 1998.

For data on R&D expenditures and number of employees we made use of the World-scope database. The data on R&D expenditures was converted to US dollars to facilitate comparison.

Methods

The knowledge that a firm possesses can be thought of as residing in the patents owned by the firm. Patents are by definition representations of new and unique pieces of knowl-edge, and as such, the collection of patents a firm has, represents its total set of knowl-edge. Following Ahuja and Katila,[46] we also include the patents that the firm is citing in its own patents, for also the knowledge included in these patents must, to some extent, be known to the firm. Even though the firm itself, just for legal reasons, might include some of the patent citations, or they might be included by the patent officer reviewing the patent, these citations indicate a knowledge relationship and the firm can be expected to have at least some idea of the knowledge involved, especially at the multinational level. The general knowledge base of a firm in our sample is then defined as the total of a firm's own patents, plus the patents cited there in. The individual patents in each firm's knowledge base can then be compared with the patents in other firms' knowledge bases.

Patent-based measures of course have their limitations—see for instance Griliches[47]. The propensity to patent for instance might differ per industry. Some industries rely heavily on patents while others do not and so we therefore include a dummy variable for alliances between firms from different industries and alliances between firms from the same industries. Furthermore, alliances are especially important for the transfer of tacit knowledge,[48] but the patents we are using are by definition examples of codified knowledge. This could lead us to exclude the tacit knowledge component from our analy-sis. The tacit knowledge flowing over firm boundaries, however, is almost impossible to measure, but there is substantial evidence that tacit knowledge flows are closely linked with codified knowledge flows[49] and thus we feel confident in the use of patent data.

We started our analysis by extracting alliance pairs from the CATI database for our base year, 1993, which belong to our set of medium- to high-tech firms from the Fortune 500 list of 1997. For these alliance pairs we calculated or collected the necessary variables. We found 78 unique alliance pairs, which we used for our analyses.

We used 1993 as our base year for two reasons. The first reason to do this is because the year 1993 is close to 1998, the year of our database construction. The closer we are to 1998 the more confident we can be that the results we find can be extrapolated to the 1998 configuration of firms and interconnections. Furthermore taking 1993 as a base year still gives us enough measuring years to be able to retrieve reliable information from our data.

Dependent Variable

As our dependent variable we took the knowledge base overlap after the alliance was established (KBO_A). The knowledge base overlap is defined as the number of patents that appear in both firms' general knowledge bases, divided by the total number of patents in both firms' general knowledge base. We are thus looking at the relative use the firms are making of the allying firms' patents—we are not for instance looking at patenting activity. We measure this overlap for the five years after the establishment of the alliance, i.e. from 1994 to 1998. This has to do with the time it takes to obtain a new patent and the time to undertake subsequent patent citations. So the knowledge base overlap for a certain alliance between $Firm_i$ and $Firm_j$ after the alliance is:

$$KBO_{Aij} = (KB_{Ai} \cap KB_{Aj})/(KB_{Ai} \cup KB_{Aj}).$$

Independent Variable

Our independent variable is the knowledge base overlap before the alliance is established (KBO_B). Here we measure the overlap in the firm's general knowledge bases in the five years before the establishment of the alliance. Again this is a measure of the relative use of the other firms' patents by the focal firm. The knowledge base overlap for the alliance between $Firm_i$ and $Firm_j$ before the alliance is defined as:

$$KBO_{Bij} = (KB_{Bi} \cap KB_{Bj})/(KB_{Bi} \cup KB_{Bj}).$$

We will use KBO_{Bij} as well as $(KBO_{Bij})^2$.

Control Variables

We also included the number of prior alliances of the firms (PA_{Gij}) in general, so with all other firms it allied with, and the number of prior alliances 'special' thus with the same other firm (PA_{Sij}), as independent variables. For both variables we looked at the alliances the firms had since 1970 and for the five successive years before the alliance, and used the average of both firms in the alliance. This provided us with four variables $PA_{Gij}70$, $PA_{Sij}70$, $PA_{Gij}5$, and $PA_{Sij}5$. We expect that the number of prior alliances will have a positive influence on the learning taking place. Firms that work together more often will experience more trust within the relationship, so this might increase the learning. Furthermore, firms that had more alliances will have more experience in dealing with an alliance and also this will increase the likelihood of a knowledge transfer. We expect thus a positive influence from the number of prior alliances on the learning.

To further test the influence of strong and weak ties in a relationship we also used the number of prior equity alliances ($PEAs5$) with the same other firm in the five years before the alliance as a proxy of the strength of the tie between the two firms in the alliance. In an equity alliance the allying firms have strong commitments to each other, inhibiting opportunistic behaviour. Non-equity alliances, however, have more characteristics of the looser relationship of a weak tie. The more equity alliances two firms have prior to the measuring alliance of 1993, the stronger we can expect their tie to be. We thus expect a tie to be stronger according to the number of past equity alliances the firms have had, thus prior to the

current alliance. The current tie between the firms is supposed to be stronger when the number of past equity alliances is larger. We also included a dummy variable (EQUITY), which is represented by a one (1) in case of an equity alliance in 1993 and a zero (0) for a non-equity alliance between the two firms in 1993. We included this variable to correct for a possible influence of the current form of the alliance.

Other control variables that we included are the logarithm of R&D spending of the firms in the alliance ($R\&D_{ij}$). If firms dedicate a larger amount of spending to R&D they will have more in-house knowledge to process the new knowledge. Furthermore, these firms are likely to have a learning attitude. Further we included the logarithm of the number of employees ($SIZE_{ij}$) of the allying firms. Size is likely to have a positive effect on knowledge flows. A larger firm can be expected to have a larger pool of knowledge to draw from, and will thus be better at incorporating new knowledge. Also larger firms have more resources for incorporating the new knowledge. However, smaller firms are usually considered more innovative than larger firms, which would lead us to expect less learning in bigger firms. For both variables, $R\&D_{ij}$ and $SIZE_{ij}$, we use the average values of both firms in the alliance.

We also included a dummy variable for firms from the same industry allying ($SECTOR_{ij}$). We might expect more learning to take place between firms from the same industry, because the knowledge overlap between the firms will be bigger. However, because of competition sensitivities firms might be more reluctant to share knowledge with firms from the same industry. We expect the first influence to be more influential. This means that it will be represented by a zero (0) if two firms from different industries are allying and by a one (1) if they are from the same industry.

To test our hypotheses we test the following empirical specification:

$$KBO_{Aij} = f(KBO_{Bij}, (KBO_{Bij})^2, PA_{Sij}, PA_{Gij}, PEAs_{ij}5, \ R\&D_{ij},$$
$$SIZE_{ij}, SECTOR_{ij}, EQUITY_{ij}).$$

The testing of Hypothesis 2 requires the construction of a control group. To be able to test if firms working together in a learning alliance learn more than firms who are not involved in such an alliance, or not allying, we needed to construct a control group of firms who had not worked together in a learning alliance. For every alliance pair A–B in our dataset we searched in the CATI-database for a firm C that did not have an alliance with either A or B and that resembled B as close as possible, concerning industry, firm size, R&D spending and number of patents. The 'new' firm C was than put together with the 'old' firm A. This 'matched' pair A–C was used as control group in the testing of hypothesis 2.

Results

Before we can start testing our hypotheses we first take a closer look at our data and at its specific characteristics. The results are reported in Table 1.

For the testing of hypotheses 1 and 3, on the relationship between prior knowledge and alliance learning, and the influence of strong and weak ties in alliances on learning, we test our model using regression analysis. Because our dependent variable is left censored (see Figure 1) we cannot use standard OLS regression, but instead have to use Tobit regression.

Table 2 shows the correlations for hypotheses 1 and 3. It turns out that there are no severe correlations among our independent variables, except for $R\&D_{ij}$ and firm size

Table 1. Descriptive statistics for the variables in hypotheses 1 and 3

Variable	Mean	Std dev.	Min.	Max.
1 KBO_A5 ($\times 1000$)	4.45	5.11	0	30.43
2 KBO_B5 ($\times 1000$)	4.36	5.44	0	26.40
3 $(KBO_B5)^2$ ($\times 1000$)	48.22	108.86	0	696.93
4 $PA_{Sij}70$	1.60	1.86	0	7
5 $PA_{Sij}5$	0.92	1.49	0	7
6 $PA_{Gij}70$	68.12	41.32	5	182.50
7 $PA_{Gij}5$	32.94	23.43	1	85.50
8 $PEA_{Sij}5$	0.29	0.65	0	3
9 $R\&D_{ij}$	6.99	0.93	4.77	8.71
10 $SIZE_{ij}$	11.76	0.64	10.48	13.09
11 $SECTOR_{ij}$	0.35	0.48	0	1
12 $EQUITY_{ij}$	0.24	0.43	0	1

measured as the logarithm of the number of employees (0.758), and between one of the PA_{Gi} variables (PA_G70) and both $R\&D_{ij}$ (0.817) and $SIZE_{ij}$ (0.710). We ran our regressions with different combinations of these variables and it turns out to make no difference for our results. The same applies to PA_G5 and $R\&D_{ij}$ (0.742). Some other high correlations are among variables that were never regressed together, thus posing no problem. The different prior alliance variables for instance are highly correlated, which is logical, but we only use one of these variables at a time in our regressions.
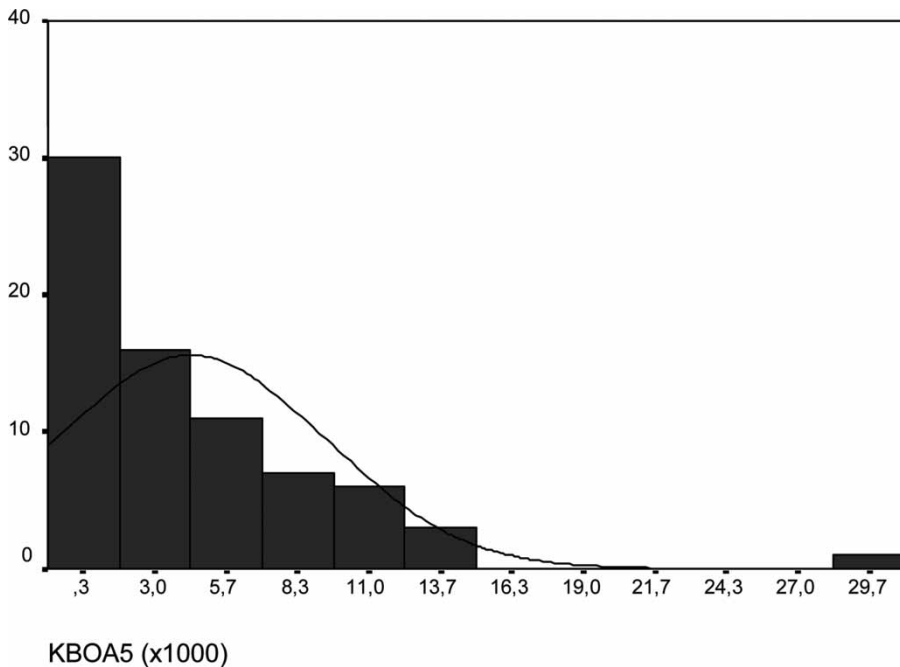
Figure 1. Spread of the dependent variable KBO_A5

Table 2. Correlations for the variables in hypotheses 1 and 3

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1 KBO_A5	1.00											
2 KBO_B5	0.739**	1.00										
3 $(KBO_B5)^2$	0.628**	0.918**										
4 $PA_{Sij}70$	0.321**	0.349**	0.245*	1.00								
5 $PA_{Sij}5$	0.181	0.288*	0.204	0.793**	1.00							
6 $PA_{Gij}70$	0.305**	0.410**	0.350**	0.470**	0.359**	1.00						
7 $PA_{Gij}5$	0.356**	0.447**	0.392**	0.466**	0.402**	0.939**	1.00					
8 $PEA_{Sij}5$	0.027	0.163	0.134	0.541**	0.710**	0.257*	0.253*	1.00				
9 $R\&D_{ij}$	0.299**	0.405**	0.338**	0.448**	0.400**	0.817**	0.742**	0.331**	1.00			
10 $SIZE_{ij}$	0.180	0.224*	0.202	0.355**	0.334**	0.710**	0.552**	0.288*	0.758**	1.00		
11 $SECTOR_{ij}$	0.413**	0.311**	0.289*	0.171	0.201	−0.018	−0.018	0.253*	0.038	0.059	1.00	
12 $EQUITY_{ij}$	−0.054	−0.076	−0.067	0.025	−0.051	0.037	−0.025	−0.028	−0.004	0.075	−0.162	1.00

**Significant at the 0.01 level (2-tailed); *Significant at the 0.05 level (2-tailed).

We also regressed every independent variable on all the other independent variables (values not reported here). This shows no serious multicollinearity among the independent variables. All the VIF values were well below 5 (where 10 is the standard cut-off value).

Table 3 provides the empirical results for the Tobit regression for hypotheses 1 and 3. We only show those regressions that we ran with different combinations of variables that give extra information, more regressions were carried out but they gave no different results. As extra control we also regressed using OLS regression. The results are in line with the results as reported under Tobit regression. KBO_{Bij} turns out to be very significant every time we ran the regression and the sign is always positive. Our independent variable $(KBO_{Bij})^2$ is also significant in every regression and this time the sign is always negative. Put together these two variables provide strong proof for our first hypothesis, which argues that there is an inverted U-shaped relationship between the learning taking place in an alliance and the prior knowledge overlap between the firms. To further test this relationship we investigated the shape of this relationship, using the first regression in Table 3. We plotted the relationship between KBO_B5 on the X-axes and the learning effect on the Y-axes (see Figure 2). This gives us the gross learning effect.

On the line $Y = X$ both KBO_A5 and KBO_B5 have the same value and no learning is taking place. Learning takes place for the part of our parabola that is above the $Y = X$ line. If we thus want to know the net learning effect we need to subtract the line $Y = X$ from our parabolic relationship. By doing this we end up with a new parabola with a

Table 3. Results of Tobit regression: hypotheses 1 and 3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
KBO_B5 ($\times 1000$)	5.062***	5.098***	4.833***	5.158***	5.219***	4.876***	5.351***
	(0.203)	(0.199)	(0.204)	(0.203)	(0.206)	(0.210)	(0.204)
$(KBO_B5)^2$ ($\times 1000$)	−2.253**	−2.287**	−1.877*	−2.239**	−2.119**	−2.130**	−2.165**
	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
$PA_{Sij}70$			2.044**				
			(0.285)				
$PA_{Sij}5$					0.707		
					(0.415)		
$PA_{Gij}70$				1.481			
				(0.013)			
$PA_{Gij}5$	1.945*	1.984**				1.467	
	(0.023)	(0.022)				(0.023)	
$PEA_{Sij}5$	−2.323**	−2.361**	−2.767***	−2.221***	−1.862*		−1.898*
	(0.657)	(0.671)	(0.756)	(0.676)	(0.921)		(0.660)
$R\&D_{ij}$	−1.782*					−1.709*	−0.598
	(0.143)					(0.147)	(0.101)
$SIZE_{ij}$		−1.918*	−1.300	−1.619	−0.908		
		(0.080)	(0.062)	(0.087)	(0.061)		
$SECTOR_{ij}$	3.972***	4.052***	3.722***	3.831***	3.577***	3.562***	3.474***
	(0.865)	(0.865)	(0.823)	(0.876)	(0.842)	(0.824)	(0.834)
$EQUITY_{ij}$	0.364	0.410	0.214	0.260	0.366	0.360	0.220
	(0.813)	(0.810)	(0.802)	(0.818)	(0.828)	(0.832)	(0.823)

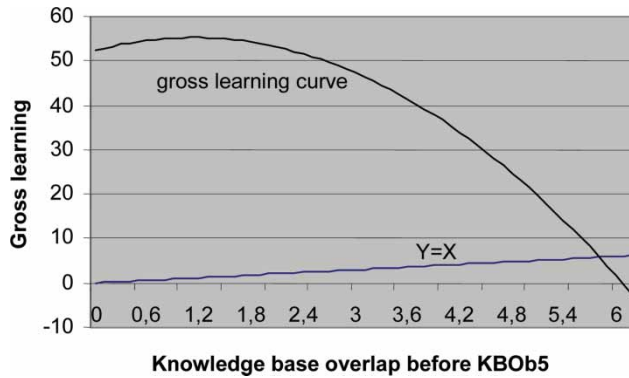***$p < 0.01$; **$p < 0.05$; *$p < 0.10$. Standard errors in parentheses.

Figure 2. Gross learning effect

maximum for KBO_A5 at $KBO_B5 = 0.9$ (see Figure 3). The formula of the parabola is $-2.253X^2 + 4.062X + 52.42$: the control variables are added up to give one value for the constant. The parabola crosses the X axes at $X_1 = -4.01$ and $X_2 = 5.81$. Because our dependent variable has a mean of 4.45 and a standard deviation of 5.11 we know that 95% of our results are in the area of $X = 4.45 \pm (2 \times 5.11)$, i.e. from $X = -5.77$ to $X = 14.67$. Our results are well within this range and the net learning does indeed show an inverted U-shaped relationship, where the learning first increases with increasing before knowledge base overlap (KBO_B5), reaches a maximum for $KBO_B5 = 0.9$ and decreases after this point.

Hypothesis 3 is not supported by our data. We find, on the contrary, strong evidence for the opposite, weak ties are more important for learning than strong ties. Our variable PEAs5 is every time significant and negative. This thus indicates that more prior equity alliances with the same firm leads to less learning. Our prior alliance variables all give positive results though not always significant. Thus the number of prior alliances has a positive influence on the learning in strategic alliances. These two results combined, support strong evidence that the alliances in our sample learn more from weak ties than from strong ties. It could be that complementarity outweighs trust for the firms in our sample. Another explanation for this remarkable result might be that the firms are suffering
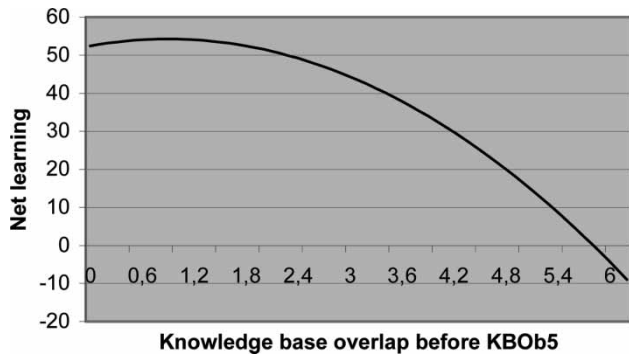

Figure 3. Net learning effect

from 'over-embeddedness'.[50] Embeddedness influences the firms' allying behaviour,[51] leading to preferential allying partners, because trust is an important basis for knowledge exchange and partner selection.[52] This would lead firms to search for allying partners among their trusted partners with whom they have had beneficial partnerships in the past.[53] This reduces search costs and alleviates opportunistic behaviour between the partners.[54] The more firms rely on these same partners, the more they are going to resemble the partner and the less they are able to learn from it. When partners become more familiar with each other, they start to resemble each other more.[55] The proximity between partners reduces the divergence of the attitudes between the partners, especially for partners who are connected via strong ties.[56] They might develop core rigidities,[57] which can cause them to fall into competency traps.[58] Alliance firms thus get isolated from possible alliance partners outside the current alliance partners; therefore they will suffer from decreasing possibilities for learning and innovation.[59] The more firms work together, the greater the trust and intimacy between them will grow.[60] Over time this may lead to 'over-embeddedness' where firms get too similar and this will lead to decreasing opportunities for learning and innovation.[61] Learning via strong ties is thus still beneficial and very important for the allying firms, but research suggests that there is a limit to the positive effects observed. The stronger firms work together and especially the longer they work together in stronger ties, the less their innovative performance and the less they can learn from each other.[62] This outcome is in line with our findings and serves as a good explanation for the results we are finding.

Looking further at Table 3 it turns out that also our control variable $SECTOR_{ij}$ is significant and positive for every regression analysis. This indicates that indeed there is more learning taking place in an alliance between firms from the same sector, compared to firms from different sectors.

We find slight positive results for our control variable EQUITY (but never significant), this might indicate that this specific form of the alliance is important for learning. Further research is however needed here. We also ran the regressions without this control variable and it turned out to make no difference for our results.

For our size variable we find only very weak evidence for our expected relationship between size and learning, more research is needed here to draw any conclusions although it seems that our results support the view that smaller firms are more innovative.

Almost the same goes for our variable R&D intensity, we find slight negative results, but they are not significant enough to make any concrete statements about the influence of this variable on the learning.

To test our second hypothesis we used two different methods. First we used a *t*-test to see if there was a difference between the two groups, the alliance group and the control group. Because our data is not fully normally distributed we used a Wilcoxon Signed Ranks test,

Table 4. Results of *t*-test and Wilcoxon signed ranks test

	Mean	Std dev.	*t*	Sig. (2-tailed)
t-test	0.972	4.601	1.865	0.066
			Z	Sig. (2 tailed)
Wilcoxon signed ranks.			−2.176	0.030

$N = 78$.

Table 5. Regression results: hypothesis 2

Variable	
KBO$_B$5 ($\times 1000$)	0.743***
	(0.041)
ALLIACon	-0.183***
	(0.438)

***$p < 0.01$. Standard errors in parentheses.

next to a normal *t*-test, to compare the two groups. We find that our groups are significantly apart at the 5% significance level for both the normal *t*-test and the Wilcoxon Signed Ranks test. The increase in learning is significantly greater for the firms from the alliance group as compared to the firms from the control group. The results are reported in Table 4.

As a second test for the difference we regressed the knowledge base overlap before and after, for the two groups, the alliance group and the control group, using a dummy variable (ALLIACon). The dummy variable is zero (0) if the firms belong to the alliance group and one (1) if they belong to the control group. It turns out that the dummy variable is significant and negative, indicating that the firms in the alliance group learn significantly more than the firms in the control group (for results, see Table 5). It turns out that alliances are an important vehicle for learning among firms.

Discussion and Conclusions

In this paper we empirically investigated the effect of strategic technology partnering on the knowledge bases of companies involved in learning alliances. The alliances we thus research are established for the sole purpose of learning from the allying partner. From a knowledge-based perspective we hypothesised that the degree of overlap in the allying partners initial knowledge base is inverted U-shaped related to the degree of learning taking place in the alliance. Our empirical results indeed show that a medium degree of knowledge overlap between alliance partners is more effective for learning from the partner firm than a degree of knowledge overlap that is either too high or too low. This supports the existing literature on absorptive capacity, which argues that if firms have too little overlap in terms of their technological know-how they will be unable to absorb the know-how of their partners. However, if firms are too similar they might suffer from a lack of synergy in the alliance. If similar players are linked in an alliance chances increase that the information flows between partners are redundant.[63] Besides learning there are of course many other reasons for firms to establish an alliance with another firm. Learning might not be the most important reason for establishing an alliance, but merely one of a multitude of reasons. Even if learning is not the prime reason but just one of the reasons, it turns out that it is very important for managers of these companies to understand the relationship between pre-alliance knowledge base overlap and the learning taking place. Depending on where they are on the curve, they might be in a position to learn, or not to learn from the allying partner. Knowing this they might want to search from another partner with whom the learning potential is higher, or they might want to reassess the learning potential. This conclusion holds of course even more for alliances that have learning as their main goal.

Our second hypothesis argued that firms engaged in learning alliances will show higher degrees of learning than firms not engaged in these alliances. The results from our analysis show that alliances can be seen to have a significant and positive effect on the learning rate of the companies in our study. This might be surprising given the high failure rates of strategic alliances that can be found in the literature.[64] The finding is however in line with more recent work in the area of innovation studies.[65] This body of literature shows that learning alliances seem to be a particularly effective means of knowledge acquisition.

Our third and final hypothesis was concerned with the differences in learning rates of strong *vs* weak ties. We argued that strong ties would be more effective in transferring technological know-how because firms are more familiar with each other and will show higher trust levels. As a result, the chances of opportunistic behaviour between partners are considered to be lower and therefore we expect that information will flow more effectively between partners. Our findings however indicate that weak ties are more effective than strong ties. This seems to suggest that complementarity outweighs trust in alliance relationships. Synergetic effects might be higher in weak ties than in the case of strong ties. Furthermore, new knowledge generated in weak ties is likely to be more innovative than knowledge that is generated in strong ties relationships. However, firms connected via strong ties might also suffer from 'over-embeddedness', leading them to develop core rigidities and decreasing the learning potential from their partner. Therefore, the chances that knowledge exchange leads to the application of patents is likely to be higher in weak tie relationships.

Overall, we can conclude that alliances have established themselves as an important means of (external) knowledge acquisition but that partner selection forms a critical determinant for the effectiveness of the knowledge exchange process. In this partner selection process the knowledge overlap between the allying firms and the strength of their tie seems to be of eminent importance.

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