Alliance formation and firm performance: an inverse U-shaped relationship?

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September 2008

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Abstract

This research examines a relationship of diminishing returns between a firm's number of alliances and performance. Moreover, as alliance formations increase, negative returns may set in. Rising interdependency between firms, bounded rationality constraints of management, as well as resource overlaps and possible knowledge leakage are expected to overcome the more positive learning effects as alliance experience increases. The existence of this inverse U-shaped relationship is tested on a sample of 179 firms operating in the pharmaceutical industry from 1990 to 1999. Support for diminishing returns as well as a linear relation are found. The linear model contains a better fit to the data, rejecting a possible inverse U-shaped relationship.

Keywords: alliances, diminishing returns, social capital, pharmaceutical industry

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1. Introduction

During the past two decades, firms have become more embedded in organisational networks as the possible advantages to co-operative relations are pursued. Companies form alliances in order to expand their knowledge portfolio, increasing competitive advantage. Throughout this period, managing multiple alliance formations with multiple partners has become a more common phenomenon (Hoffmann, 2005; Koka & Prescott, 2002). Could this increasing number of collaborations backfire and be too much to handle?

Empirical research supports a positive relationship between the number of alliance formations and firm performance (Powell, 1999; Stuart, 2000; Sarkar et all, 2001). However, studies on a possible inverse U-shaped relationship remain scarce. Where Powell (1999) does find diminishing returns, this result is called provocative through a network literature perspective as too few studies address this subject. Traditional literature on social capital also states that its value would increase rather than decrease with subsequent use (Bourdieu, 1983/1986; Coleman, 1988; Putnam, 1993).

Economic theory provides support for increasing as well as diminishing returns concerning this rising number of inter-firm links. Learning effects increase the efficiency of management, giving higher potential benefits as firms gain experience in alliance formations (Hoang & Rothaermel, 2003; Sampson, 2005). Other arguments point more towards a relationship of diminishing returns. Moreover, after a certain amount of alliances, negative returns may set in. Bounded rationality constraints of management, a limited ability to apply the knowledge gained through alliances, as well as the possibility of resource overlaps, support this relationship of diminishing returns (Deeds & Hill, 1996; George et all, 2001; Park & Martin, 2002). Furthermore, as the number of alliances increases, knowledge appropriation can become more complex. Crucial resources may have a higher probability to leak to ones competitors, damaging a firm’s competitive advantage (Oxley & Sampson, 2004).

The economic interpretation of social capital is slightly different then the one formed by sociology. The work of Coleman defines social capital as a “’stock’ of trust and an emotional attachment to a group or society at large that facilitate the provision of public goods” (Fafchamps & Minten, 2002, pp. 173). The field of economics sees social capital more as an asset that can benefit the individual or the firm. Alliance formations can be a good alternative to the make or buy decision of intermediate goods (TCE), as well as give access to additional resources, creating value for the firm (Tsang, 2000; Das & Teng, 2000).

This research will address both social network literature as well as the field of economics, looking into the possible connection between alliance formations and firm performance. This leads to the following research question:

What is the influence of alliance intensity on firm performance?

Theory gives reason to empirically test for three different relationships:

- Is the relation between alliance intensity and firm performance positive?
- Do diminishing returns set in after a certain number of alliances?
- Do negative returns set in after a certain number of alliances?

The point where diminishing or negative returns will set in is likely to differ amongst companies, as every organisation has its own characteristics that can be deciding on how many alliances one can handle.

Besides contributing to alliance literature this research can also have relevance to firm managers. They should be aware that alliances have costs as well as benefits, and as the number of inter-firm links rises it can become more likely that costs will outweigh the additional returns. This research can thus provide insight in whether firms are engaged in too many alliances, in which case an inverse U-shaped relationship will be found. This may give mangers a signal as in where additional profits can be made. A more effective management may be in place or a reduction in the number of links as the alternative. Alliance management can be very crucial in the creation of a competitive advantage, as they have to select the appropriate partners and create a trust-based environment where cooperation can fully serve its purpose (Ireland et all, 2002).

This study will start with a literature review looking into the relationship between alliance formations and firm performance. Empirical testing will be done using data originating from the pharmaceutical industry. It is a highly innovative science based industry, where entrepreneurial start-up firms often lack the resources to develop a new product. Besides this, patent races tend to give high pay offs to the first mover. Thus overall firms have a strong incentive to enter alliances in the pharmaceutical industry (Deeds & Hill, 1996).

Figure 1 gives this relatively high number of alliance formations in high tech industries. These industries all share the characteristic that innovation would require specialization in multiple disciplines. Alliance formations can function as a way to retrieve these resources (Arora, 1990).

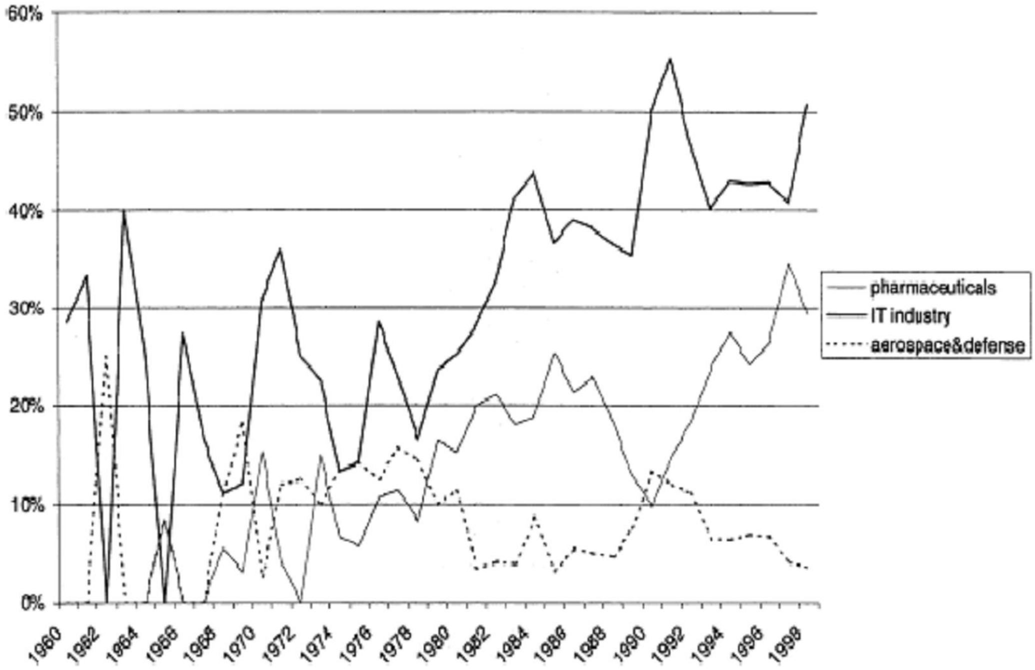

Figure 1 - Share (%) of high tech industries in overall alliance formations (1960 – 1998)
(J. Hagedoorn /Research Policy 31 (2002) 477-492)

Three data sources are used for testing. The SDC database provides information concerning the dates and type of alliance formations between mainly large pharmaceutical firms. Thomson One Banker will supply performance measures as well as different firm characteristics to control for. Finally, the effect of alliances on innovative performance is tested using the number of patent applications obtained from esp@cenet.

2. Literature review

This review will start by discussing the definition of strategic alliances used. The second section goes into the motives behind alliance formation and explains the possible positive relation between company performance and alliance formation. Thirdly, arguments are presented why diminishing and negative returns to alliances may be possible.

2.1 Defining strategic alliances

This research will focus on strategic alliances. The general term ‘alliance’ is defined as “any voluntarily initiated cooperative agreement between firms that involves ex- change, sharing, or co-development, and it can include contributions by partners of capital, technology, or firm-specific assets” (Gulati & Singh, 1998, pp. 781).

Where the term of ‘alliance’ can be anything from an arm’s length contract to a joint venture, strategic alliances are characterized by a greater amount of uncertainty. The way in which the relationship between firms will develop is difficult to predict. Also, managing the connection over time is usually of greater importance then the initial alliance formation itself (Doz & Hamel, 1998).

Yoshine & Rangan (1995) provide a specific definition of strategic alliances by three conditions:

- The firms pursue a set of agreed upon goals and remain independent after forming the alliance.
- The benefits of the alliance as well as control over the performance of the assigned tasks are shared.
- The partner firms contribute continuously to key strategic areas such as technology, production, and so forth.

By this definition, licensing and franchising agreements are not strategic alliances. These links represent relatively simple ex post knowledge exchanges; they do not require the continuous investments in information and technology transfers. Mergers and acquisitions are also excluded by this definition. As one company completely takes control over its target firm, the first condition of independency of both partners is violated. Figure 2 from Yoshine & Rangan (1995) categorizes the type of links between companies that strategic alliances go by. Besides M&A and traditional contracts, the figure shows that subsidiaries of multinational corporations, often to penetrate new geographic markets, are also not taken as strategic alliances. The reason for this is again that the control remains mainly at one of the parties, in this case the multinational. Also, in this case the pursued goals of the firms are not very separated.

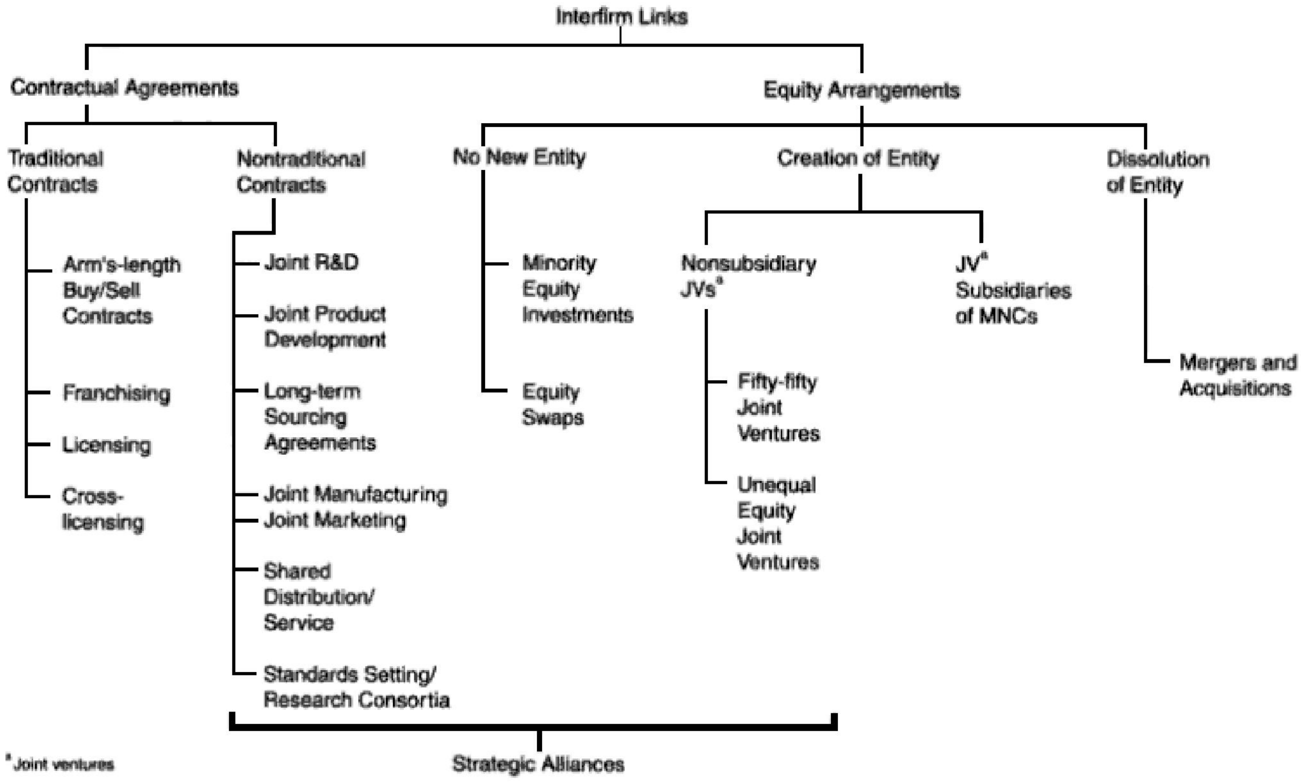

Figure 2: Range of interfirm links (Yoshino & Rangan, 1995)

The typology of alliances differentiates between equity and non-equity alliances. Equity alliances are links that involve the exchange of equity and thus shared ownership, where non-equity links are characterized by contractual agreements. The choice of governance structure depends on the probability of opportunistic behaviour (Gulati, 1995). When one of the partners is likely to maximize its individual benefits, this often goes at cost of the collective interest, damaging the other player(s). In order to prevent opportunistic behaviour, high ex ante negotiating costs and constant ex post monitoring are required. Equity alliances will then provide a more effective solution, lowering the incentive to behave opportunistically. As both players share profits, maximizing ones individual benefits would mean to serve the collective interest (Das & Teng, 1996).

2.2 Strategic alliances and firm performance

The relation between alliance formation and firm performance shows contradicting evidence in the existing literature. Where Powell et all (1999), Stuart (2000), and Sarkar et all. (2001), find a positive connection between alliance formation and firm performance, Callahan (2006) measures an increase in operating risk as well as a negative effect on firm performance. To my knowledge the work of Callahan is the only research that provides support for this negative connection. However, surveys among management positions report failure rates of alliances between 50 and 70 percent (Saebi & Dong, 2008; Park & Ungson, 2001). It must be noted though that these are subjective perceptions of managers, and may not be directly connected to financial performance measures. Managers may have other goals in mind when forming an alliance. This could mean that they might consider an alliance to be failed, even though firm performance increased.

Although there is some evidence against performance increase resulting from alliances, during the last two decades alliance formation increased drastically, especially in the biotech and IT industries. Motivations for the pursuit of this positive relation between alliances and firm performance are found on the cost cutting side as well as in value creation.

A common motivation as to how companies can profit by entering alliances is explained by transaction cost theory (Williamson, 1975). Because of market imperfection, firms may choose not to obtain resources from the market, but rather produce them internally. Where a market exchange may be inefficient because of the high transaction costs, coordinating production within the firm can be a good alternative. The literature states that when transaction costs are high, but not high enough to start producing internally, alliance formation may be an efficient alternative (Gulati, 1995; Chen & Chen, 2003). An Alliance is somewhat in between the two extremes of the make or buy decision. Both firms produce part of the good, but there are still transaction costs through contracts and management of the alliance.

However, transaction costs theory only provides part of the explanation behind why companies form alliances. A critique point of the TCE approach is that it looks mainly at the cost minimizing side, and pays little attention to value creation (Tsang, 2000).

Eisenhardt and Schoonhoven (1996) state that in difficult market situations, alliances can provide critical resources that may improve a firm’s strategic position. From this perspective the strategy of a firm should thus be based on its resources and capabilities (Seppälä, 2004). Where the TCE approach looks at the nature of the transaction, this resource-based view focuses on the alignment of the available resources through alliance formation. In this sense alliances have an important advantage over M&A: A selection can be made of the required resources instead of taking over an entire firm (Das & Teng, 2000).

Besides the TCE approach and the resource-based view explaining a potential positive relation between alliances and firm performance, as the number of links increased during the last two decades, firms became more focussed on their portfolio of alliances. Goerzen & Beamish (2005) state that alliance portfolio's become more diverse to improve market access, reduce innovation time-span and finally to match complementary technological capabilities. An alliance portfolio can also have real option value. Holding a differentiated resource portfolio through alliance formations gives a firm a great amount of flexibility, gaining the option to access resources that would be too costly to maintain by itself (Smit & Trigeorgis, 2004). Literature recognizes this possible competitive advantage and also stresses the importance of an effective management when participating in multiple inter-firm collaborations (Hoffmann, 2005).

However, innovating with a single company portfolio has become hard because of the increasing complexity of necessary resources. Introducing a new product often requires a company to be specialized in more than one discipline. It thus becomes more likely that innovation will only be possible through a network of different organisations (Arora, 1990). The next section goes into social network literature and its possible link to the firm level.

2.3 Social network literature

Compared to Coleman's definition, a more general characterization of social capital used in literature is "investment in social relations with expected returns" (Lin, 2001). Where Coleman and Bourdieu introduced social capital in the second half of the 1980s, it was Burt who extended it to the firm level. According to these authors, access to beneficial networks can be seen as a form of social capital that will show increased value when used more often. Relationships between firms can be seen as social capital because they are information channels that can create business opportunities (Burt, 1992). Besides this, connections between companies can be seen in a window of norms, obligations and expectations similar to the core characteristics of its theory in sociology (Koka & Prescott, 2002).

Network literature generally does not address the direct relation to firm performance; this would be more in the field of economics. However, Burt (1992) states that there are three important economic benefits to having an efficient portfolio of connections with other firms. The first is access to information through the network. Secondly, timing would be important.

Information that reaches the firm within a short amount of time may give a competitive advantage. Finally, referrals can be beneficial to a firm, spreading a good reputation amongst other parties (Goerzen & Beamish, 2005). Granovetter (1985) also discusses this reputation effect, stating it would keep actors from behaving opportunistically. Through social control, embeddedness can thus discipline potential cheaters.

Research of social network capital on financial relationships finds that a connection to 'elite' partners has positive effects on firm growth and profitability (Koput et al, 1998). Diminishing and negative returns however are not broadly discussed in the literature on social capital. Where Powell et all (1999) do find diminishing returns to network experience, they consider this result provocative. Few researchers would have addressed possible limits to the amount of social connectedness that is desirable. Other studies of Granovetter (1985) and Uzzi (1997) go into the risks of being too embedded or locked-in into a network, however their focus is on the type of connection, rather then the number of links. The consequences of having an embedded network vs. a network of arm's-length ties are compared.

Overall, from the perspective of social network literature, the following hypothesis will be tested:

Hypothesis 1: **There is a positive linear relationship between the number of strategic alliances and firm performance.**

The field of economics also recognizes this positive relation. However, where research in sociology is scant, arguments that support possible diminishing and negative returns to the number of inter-firm links do exist in economic literature. Beyond decreasing benefits, it is also likely that the costs to alliance formation will diminish as the number of connections increases. The next section goes into this economic interpretation, starting with diminishing costs.

Table 1 provides an overview of all arguments that are addressed concerning the relation between the number of alliances and its influence on firm performance.

Table 1 - Effects of increasing alliance formation on firm performance

Relation to firm performance	Findings	Author(s)
Positive (linear) relation	*Social network literature* Social capital increases in value with subsequent use.	Putnam, (1993) Burt, (1992) Coleman (1988, 1990) Bourdieu (1980, 1983 /1986)
Decreasing marginal costs to alliance formation	*Experience effect* Learning from prior alliances lowers coordination costs and contributes to more effective management.	Sampson, (2005) Hoang & Rothaermel, (2003) Anand & Khanna, (2000)
Decreasing marginal returns to alliance formation	*Limitations to experience effect* One can only learn so much from experience. Experience depreciates rapidly over time through turnover and 'lock in' of organisational routines.	Sampson, (2005) Hoang & Rothaermel, (2003) Deeds & Hill, (1996)
	Bounded rationality constraints More alliance partners increase coordination costs. Bounded rationality then lowers the quality of screening and monitoring ones partners.	Goerzen & Beamish, (2005) Park & Martin, (2002) Gulati & Sign, (1998) Deeds & Hill, (1996)
	Increasing firm interdependence Alliances are linked to a loss of individual control over ones own business activities.	Gomes-Casseres, (1996)
	Knowledge overlaps (Redundancy) Higher likelihood of information overlapping as the number of links increases. Resource value of additional alliances is thus likely to decrease.	Mowery et all, (1998) Deeds & Hill, (1996)
	Constraints on partner choice Competitive dynamics may limit partner choice. Less beneficial deals are usually left for the future.	Hoang & Rothaermel, (2003) Silverman & Baum, (2002)
	Absorptive capacity The ability of a firm to value and apply knowledge may limit returns as the number of alliances rises.	Grant & Fuller, (2004) George et al, (2001) Cohen & Levinthal, (1990)
Negative returns to alliance formation	*Increasing vulnerability* Difficult for management to recognize the point where possible negative returns may set in. As inter-firm links increase, the above stated downsides may weigh heavy enough to cause an inverse U shaped relation.	Goerzen and Beamish, (2005) Mowery et all, (1998) Deeds & Hill, (1996)

2.4 Diminishing costs

Alliances can give significant management and coordination costs. Where firms work together, they are likely to have different expectations concerning the alliance; they also tend to differ in company culture and the type of management style. It is thus no surprise that the knowledge transfer between companies can give rise to communicative problems. Besides this, uncertainties surrounding a partner's contribution and interests, as well as the effect of the market environment can make managing an alliance very difficult, endangering possible benefits (Sampson, 2005). The survey-based evidence of failure rates mentioned earlier also provides some support. In more than half of the cases, management is dissatisfied with the results of an alliance (Saebi & Dong, 2008; Park & Ungson, 2001).

The theory that supports diminishing costs to alliances is one originating from the experience curve literature. This concept states that because of the learning effect, unit production cost would decrease as cumulative production volume increases (Yelle, 1979). Similar reasoning in the alliance context states that firms learn to manage and coordinate alliances more effectively as previous alliance experience increases. This points toward a diminishing relationship between costs and previous alliance formations. This reasoning makes sense as a firm can develop effective organisational routines on inter-firm relationships by learning from its mistakes in the past.

An example is that alliance experience may contribute to the skills of selecting and screening the right future partners to work with (Hoang & Rothaermel, 2003). Firms with a higher experience level will also be more able to assess the suitable contract structure. Sampson (2005) states that the choice of contract structure has often been linked to performance. Finally, assessing the performance of an alliance on a continuing basis during the cooperative relationship can be an important skill that is likely to develop with experience. Overall, as firms develop a repertoire of experiences, they are also more likely to influence the performance outcome of multiple alliance types (Sampson, 2005).

Learning effects are greatest for the alliance manager, who can be central to the success of an alliance. His primary task is to claim responsibility and keep a steady course towards the goals of an alliance. However, alliances managers fill in many different roles on both sides to keep the alliance alive and going in a trustworthy environment. Besides deciding on the future direction of the firm, he must also be able to convince middle management into feeling for his vision and be a mediator when conflicts arise among partners. Networking will be an essential skill as well when coordinating the activities and functions among the firm's employees (Spekman et all, 1996; Ireland et all, 2002).

Anand & Khanna (2000) are the first to check for empirical support concerning this learning effect on managing alliances. They find that learning effects do exist and are greatest for R&D joint ventures. Where research joint ventures can be somewhat more complex then licensing agreements, it was also in line with their expectations that learning effects will be more important as contractual ambiguity increases.

The outcome of this research would suggest that benefits to alliances increase more and more, as management gains experience from previous alliances. This would give rise to a relation of increasing returns to alliances, rather then the diminishing and negative returns that are tested for in this study. Literature states however that there are limitations to the learning effect of alliances. The next section will go into this and other arguments, pointing more towards a relationship of diminishing returns.

2.5 Diminishing returns

Even though there are learning effects to previous alliances, theory does give support to suggest a relationship of diminishing returns:

2.5.1 Experience effect declining over time

There are limitations to the amount of cost reduction that is possible through the managerial learning effect discussed above. Hoang & Rothaermel (2003) and Sampson (2005) provide empirical support for this claim.

Companies could get ‘locked in’ to organisational routines that may be working, but will also prevent the firm from trying new, possibly better and more effective ways of managing an alliance (Levitt & March, 1988). Moreover, the knowledge gained through experience may be embedded in a firm’s managers. This capital can then be lost easily through turnover, giving a company only a short amount of time to enjoy the benefits of increased alliance experience. Thirdly, continuing technological changes in an industry can make the appropriate management to alliances change in a short amount of time. By this reasoning only the most recent experience in managing alliances will be beneficial from a learning perspective (Spekman et all, 1996; Sampson, 2005).

Diminishing costs are thus likely to be limited. Returns however are not likely to stop diminishing as the number of links increases.

2.5.2 Bounded rationality constraints

Burt (1992) states that 'optimal network returns' will be limited to the amount of time a firm has available to maintain its connections. The time of people is a scarce resource. As managers only have so much energy to allocate, this bounded rationality makes diminishing returns more likely to occur. An increasing number of alliances could go to the point where managers don't have the time anymore to fully benefit from another alliance. This is where diminishing returns will set in (Goerzen & Beamish, 2005). The effect can be seen on the cost side of the alliance. With more links to maintain, coordination costs will increase; also possible damage can be done to the quality of screening and monitoring of ones partners.

Coordination costs are related to the degree of resource overlap within an alliance. A more intense relationship would bring more interdependency and thus higher coordination costs (Gulati & Sign, 1998). As the number of links rises, necessary information exchange will also increase. Where Park & Martin (2002) state that the 'marginal returns from additional alliances may decrease due to increasing coordination costs', also Goerzen & Beamish (2005) find that as the diversity of a firm's alliance portfolio increases, managing becomes less efficient and more expensive, making diminishing returns a more likely scenario.

Bounded rationality constraints also give limitations to the amount of screening and monitoring that can take place. Strategic alliances do not come without risks. A partner's resources may turn out to be less complementary to ones own portfolio as expected, giving little additional value. Also a partner could show opportunistic behaviour, exploiting another firm's resources while giving little in return. These are possible causes to why an alliance may fail to accomplish its goals, explaining part of these high failure rates in surveys.

By ex ante screening potential partners, a firm can lower the risk of a possible mismatch. Opportunistic behaviour can then be reduced by ex post monitoring. However, as the number of links increases, the quality of screening and monitoring will be limited by the available time management has to allocate (Deeds & Hill, 1996). There is thus a trade-off between the gains of an additional connection verses the resources that are involved to successfully support this link. The overall benefit is likely to decline as the number of links increases, until a certain point where the cost to maintain an additional link will be greater then its benefits (Goerzen & Beamish, 2005). These possible negative returns will be discussed in a later stadium.

2.5.3 Rising inter-firm dependence

As discussed above, within one alliance, a more intense relationship will give more inter-firm dependency and bring higher coordination costs. As an increasing number of alliances will also increase the size of a network or 'constellation', firms become more and more dependent of one another. Gomes-Casseres (1996) states that a rise in the number of links can stimulate diminishing returns through the loss of control over ones own business activities.

When firms enter an alliance there is often a trade-off. They gain capital but in return decisions are made through the joint venture, losing some control over its initial resources. As the number of links increases and a firm may focus its business strategy around alliances, it can lose more and more control over its individual performance. An example is how the technology of a firm is used by its partners. Gomes-Casseres (1996) gives the situation that Sun found itself in, where the SPARC chip was implemented in different ways through multiple alliances, making these designs incompatible at the hardware level.

2.5.4 Resource overlaps

Besides an increase in coordination costs and a lower quality of screening and monitoring, more inter-firm links may also cause redundancy, lowering benefits because of information overlaps.

Because of the complexity of resources it is difficult for a single company to introduce new products to a market on its own strength. Therefore alliances are used to shorten the innovation time span and to match complementary technological capabilities. In this context, partner selection will become essential (Arora, 1990; Goerzen & Beamish, 2005).

Under these conditions, as the number of alliances increases, the contribution of an additional partner is likely to become smaller. As firms gain resources through alliance formation, it becomes more likely that newly formed links will contain knowledge that is already in the firm's possession (Deeds & Hill, 1996). Mowery et all (1998) provide some support by finding an inverse U-shaped relationship between the degree of technological overlap and the likelihood of alliance formation.

An additional downside to alliance formation from this perspective is the risk of knowledge leakage. As the firm shares its resources in order to get something in return it must find the right balance between open knowledge exchange to achieve the goals of the alliance, and on the other hand control the knowledge flows in order to keep valuable technology to itself. In other words the level of inter-organizational and technological proximity between partners has to be taken into account. If vital knowledge leaks out to other firms, a company could lose its competitive advantage (Oxley & Sampson, 2004).

2.5.5 Constraints on partner choice

Involvement in an increasing number of links may also put constraints on the remaining potential alliance partners. According to Silverman & Baum (2002) 'entering an alliance with a certain partner may foreclose alliance opportunities with other potential players due to alliance-based competitive dynamics' (Hoang & Rothaermel, 2003). For example horizontal alliances can have a limiting effect. Since these are links to direct competitors in the same industry, they would involve more management problems as well as possible learning races. Because of theses additional downsides only a few of these types of links can be formed.

Also firms tend to enter the most promising alliances first, leaving less beneficial deals for the future (Hoang & Rothaermel, 2003).

2.5.6 Absorptive capacity

Absorptive capacity is defined as 'a firm's ability to value, assimilate, and apply knowledge received from external sources such as suppliers, customers, competitors, and alliance partners' (George et all, 2000). This ability is positively linked to innovation and also proves to moderate the effect between a firm's position in a network and firm performance. Performance depends on network position, but in order to benefit from this social network capital, a firm should own a certain amount of absorptive capacity. Firms with a higher absorptive capacity are more able to benefit from a central network position (Tsai, 2001).

This reasoning also gives insight into possible diminishing returns. Firms with a lower absorptive capacity are likely to see marginal returns decrease in an earlier stage as the number links increases. The lack of ability to apply the knowledge gained through additional alliances make potential benefits lower (Grand & Fuller, 2004).

A common proxy used in previous research for absorptive capacity of the firm is R&D expenditure. According to Cohen & Levinthal (1990), R&D expenditures do not just create new knowledge but also contribute to the absorptive capacity of a firm. A firm's ability to exploit additional knowledge would be a by-product of its R&D expenditures.

This research will control for R&D expenditures as it can have a serious impact on firm performance without relating directly to alliance formations.

Overall, the above stated arguments give reason to test for the following hypothesis in the empirical study of this paper:

Hypothesis 2: **The relationship between the number of strategic alliances and firm performance is one of diminishing returns.**

2.6 Negative returns

As the number of alliances increases, one or more of the above stated arguments for diminishing returns could make the costs of an additional alliance outweigh its benefits. This is the point where negative returns set in. Deeds & Hill (1996) give the decreasing quality of screening and monitoring as a main argument to possible negative returns. As the number of links rises, the firm becomes more vulnerable to possible mismatches or partners that show opportunistic behaviour. Past some point this could lead to negative returns.

Another answer to why negative returns may be observable is provided in the work of Goerzen and Beamish (2005). They point to developments as globalisation and increased competition in markets that would make firms search intensely for new capabilities. Because of possible imitation by rivals, firms would have to continually innovate in order to maintain their competitive advantage. This set-up makes managers enter alliances with multiple firms, hoping that some percentage will seriously pay off. Decisions are thus made with a large risk factor involved.

Mowery et all (1998) discuss the possibility of negative returns from the resource-based view. They state that some technological resource overlap is a necessity to support an alliance, but as this overlap becomes larger, negative return may be possible. (Mowery et all, 1998) The likelihood of technological overlap occurring would be higher with a more diverse portfolio of resources. Since alliances strongly contribute to this resource portfolio, an overlap is more likely to occur with a higher number of inter-firm links.

But why then would management go beyond such a point? This reasoning does suggest that it would be difficult to make the right call when deciding whether to participate in an additional alliance. Managers would thus face a certain amount of uncertainty on the outcome of inter-firm relations. It could also suggest that managers may not be perfectly rational in their decision-making.

The possibility of diminishing, and finally negative returns to set in after a certain threshold number of alliances is tested using the third and final hypothesis:

Hypothesis 3: **The relationship between the number of strategic alliances and firm performance is inverse U-shaped.**

This relationship would mean that some companies would be involved in too many, and others in too few alliances. The assumption made by Deeds & Hill (1996) is that the economy would have to be in constant disequilibria, as most companies would not be performing at the optimal number of alliances. Another argumentation however could be that the outcome of strategic alliances is often uncertain, and will be more risky once the point of negative returns is approaching. However, as it is tempting to take the gamble, and managers may be blinded by their increasing resource portfolio's, only some will win, spreading the outcome around the point of negative returns.

An important note is that the optimal number of alliances is likely to differ amongst firms. Each organisation has its own characteristics in the sense of experience, the quality of management, absorptive capacity, but also in its current resource base and the complementary resources a company would need for its product type (Deeds & Hill, 1996).

3. Data & methods

3.1 Data

Three different data sources are used, analysing the pharmaceutical industry. The SDC platinum database provides the alliance participants, the date of alliance formation, as well as the main activity of the alliance. Empirical research will focus on collaborations that entail some degree of research and development. This type of strategic alliance contains a somewhat more complex relationship compared to simple contractual agreements such as licensing. An intense relation could make diminishing returns more likely to occur as the number of alliances increases. Since coordination costs are higher, bounded rationality constraints are more likely to play a role. Where learning effects to R&D relations are limited, bounded rationality constraints would only become larger as the number of links increases. Also the absorptive capacity of both firms will be crucial, where for licensing agreements only one firm obtains resources from its partner.

The SDC database is a Thomson financial product that keeps track of major corporate events such as new debt and equity issues, M&A, as well as alliance formations. As most alliances are reported in SDC from 1990 to 1999 the focus will be put on this time span. Reverting the alliance-based data to an individual firm level gives the number of R&D collaborations of 1613 companies.

Thomson One Banker (TOB) provides annual report data of mainly public companies. 306 of the firms obtained from SDC also had a listing in Thomson One Banker. Sales, R&D expenditures, as well as the number of employees are taken into account. As TOB gives data on stock exchange listed companies, observations of larger companies with often a higher ability to form multiple alliances remained intact.

As a delay is likely to exist between the date of alliance formation and the financial payoff, the effect of alliance formations is measured for the performance of period 1999 to 2002. The average duration of an alliance is assumed to be three years (Phelps, 2003). By taking average performance until the year 2002, the effect of alliances formed in the late 90s is also taken into account to a certain level. As each alliance has its own characteristics it is difficult to define the exact period for which it will have an influence on performance. Also, the effect of alliances formed in the early 90s may have worn of through these years. However these connections may still benefit the firm through the progress booked, increasing competitive advantage and potential in the future. Overall this can be considered to be a limitation to this research.

Finally, the effect of alliance formation on innovative performance is tested using the cumulative number of patents filed by these companies from 1999 to 2002, taken from esp@cenet. In previous research on innovative performance it is not unusual to use patent applications as a proxy. When applying for a patent, firms undergo a cost to retrieve an intellectual property right. The firm thus finds that is has found new knowledge that is in need of protection. (Rogers, 1998)

3.1 Dependents

The effect of alliances on firm performance is measured using two indicators. First, average absolute sales growth is taken for the years 1999 to 2002. Firms that develop a superior technology or product will be able to take over market shares from competitors. A higher number of R&D alliances is thus likely to, through trial and error, positively effect sales growth (Monte & Papagni, 2001). Second, the cumulative number of patent applications, also taken from 1999 to 2002 measures the effect on innovative performance. As R&D alliances aim for innovation, the number of patent applications gives an indication of the output produced by these collaborations. Table 2 gives an overview of all variables used in this study.

Table 2 - Variables

Name of variable	Variable description
Dependents	
Salesgrowth99-02	Average yearly absolute sales growth from 1999 to 2002.
Patents99-02	Cumulative number of patent applications from 1999 to 2002.
Explanatory variables	
Alliances90-99	Cumulative number of alliance formations from 1990 to 1999.
R&Dexp90-99	Average yearly R&D expenditures from 1990 to 1999.
Firmsize-small	Average number of employees (1990 to 1999) - less then 1.000.
Firmsize-med	Average number of employees (1990 to 1999) - 1.000 to 10.000.
Firmsize-large	Average number of employees (1990 to 1999) - more then 10.000.

3.2 Explanatory variables

The main focus of this study will be the effect of *Alliances90-99* on each of the individual performance measures. This variable gives the cumulative number of inter-firm links a company was involved in from 1990 to 1999.

Table 3 presents the number of firms observed with each frequency of alliance formations. Where the total number of firms was 306, we now work with 258 observations. A reduction of 45 observations is due to outliers. Many of the variables worked with had a value that was extreme compared to the uniform dataset. As this study works with values on a yearly basis from 1990 to 2002, the number of variables is high. Three companies were removed because their primary activity did not lie in the pharmaceutical industry.[1]

[1] Removed companies: Eastman Kodak Co, Asahi Glass Co Ltd and Yuen Foong Yu Paper Mnfg Co.

Table 3 – Observed firms with each frequency of alliance formations

Nr. of alliances	Firms
1	126
2	47
3	26
4	14
5	7
6	6
7-9	11
10-12	7
13-15	4
15+	10
Total	**258**

Absorptive capacity is controlled for with *R&Dexp90-99*, measuring the average yearly amount of R&D expenditure from 1990 to 1999. It gives an indication of a firm's ability to value and apply knowledge gained through alliances. Besides serving as a proxy for absorptive capacity, it also controls for the effect of internal research and development expenditures on sales.

Firm size may also affect a firm's innovativeness and performance. Large firms are likely to have more resources available to stimulate performance. (Tsai, 2001) The average number of employees for 1990 to 1999 is taken, using three dummy variables: *Firmsize-small* (firms with less then 1.000 employees), *Firmsize-med* (firms with 1.000 to 10.000 employees) and *Firmsize-large* (firms with more then 10.000 employees).

Table 4 provides the number of firms for each category. The total number of observations is 220; the reduction is due to missing values in Thomson One Banker.

Table 4 – Division of observations among firm size categories

Firm size	N
Small	125
Medium	64
Large	31
Total	**220**

Pearson correlations of all variables are given in table 5. The significant relations seem in line with intuition. The greater capacity of large firms is reflected in a positive correlation with absolute sales growth and a greater number of patent applications compared to small firms.

Table 5 – Correlations among dependent and independent variables

		1	2	3	4	5	6	7
Dependents	(1) *Patents99-02*	1						
	(2) *Salesgrowth99-02*	,418**	1					
Independents	(3) *Alliances90-99*	,442**	,387**	1				
	(4) *R&Dexp90-99*	,533**	,477**	,448**	1			
	(5) *Firmsize-small*	-,317**	-,198**	-,202**	-,411**	1		
	(6) *Firmsize-med*	-,049	-,077	-,026	-,086	,735**	1	
	(7) *Firmsize-large*	,507**	,382**	,321**	,671**	,465**	-,259**	1

Larger firms also tend to be positively correlated to the amount of R&D expenditures and the amount of alliance formations. Furthermore, alliances as well as the amount of R&D expenditures are positively linked to firm performance.

High correlation values between the independents *R&Dexp90-99* and *Firmsize-large* (,671), as well as *R&Dexp90-99* and *Alliances90-99* (,448) will not cause a multicollinearity problem in the following stages of this research[2].

3.4 Methodology

Hypothesis 1, stating there is a positive linear connection between the number of alliances and firm performance is tested using the basic linear regression model:

$$Y = \beta 0 + \beta 1.Alliances90\text{-}99 + \ldots + \beta ixi + u$$

Where Y relates to firm performance, B1 represents the cumulative number of alliances, followed by the control variables.

The following Logarithmic model measures the relationship of diminishing returns stated by the second hypothesis (see figure 2):

$$Y = \beta 0 + (\beta 1.\ln(Alliances90\text{-}99)) + \ldots + \beta ixi + u$$

[2] the condition index is not above 15. Also the tolerance levels are acceptable (see appendix).
References:
http://www2.chass.ncsu.edu/garson/PA765/regressa.htm,
http://www.ats.ucla.edu/stat/spss/webbooks/reg/chapter2/spssreg2.htm

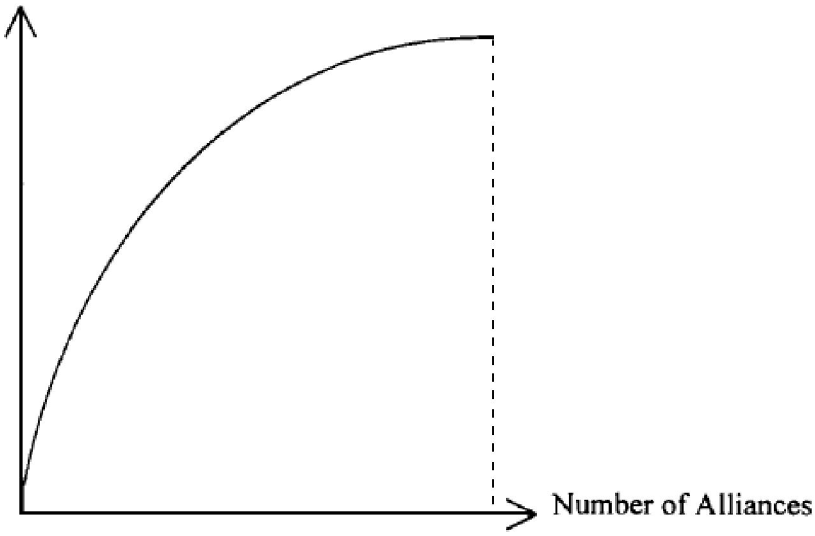

Figure 2 - Relationship of diminishing returns (figure adapted from Deeds & Hill, 1999)

$\beta 1$ now gives the absolute change in Y (performance) occurring from a 1% increase in the amount of alliances. If this coefficient is positive and significant, performance will increase at a decreasing rate as the amount of alliances rises, supporting a relationship of diminishing returns.

The third hypothesis, stating negative returns may set in after a certain number of alliances, is tested by a Quadratic model:

$Y = \beta 0 + \beta 1.Alliances90\text{-}99 + \beta 2.Alliances90\text{-}99^2 + \ldots + \beta ixi + u$

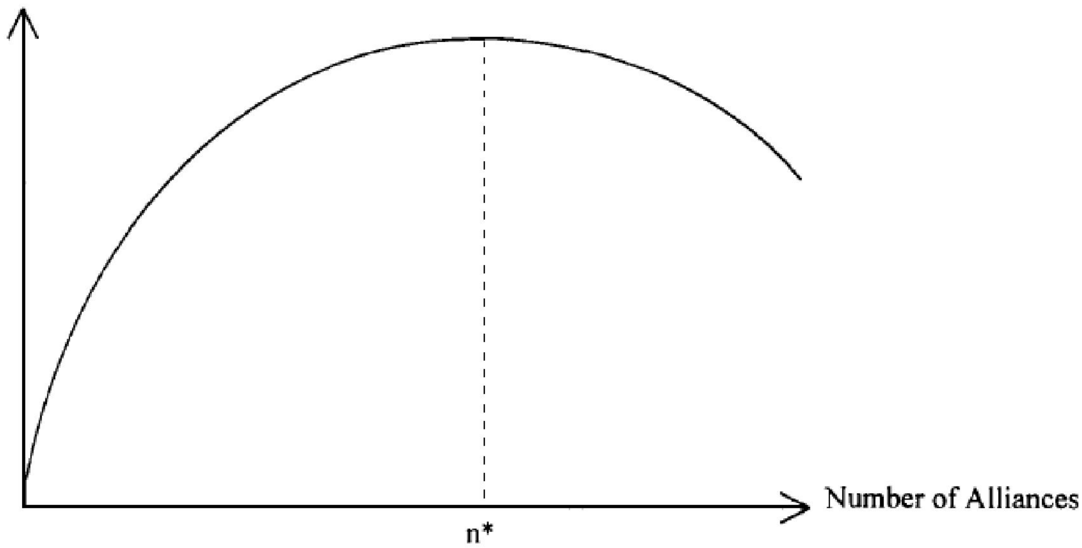

Figure 3 - Inverse U-shaped relationship (figure imported from Deeds & Hill, 1999)

For an inverse U shaped relation, β1 has to be positive and β2 negative. Both variables should give significant values.

When more than one model contains significant values for the number of alliances, an additional test is done deciding which model provides the best fit. In this case, the residuals are taken from a regression of only the control variables on Y. These residuals will give the variance in performance that is not captured by the control variables. Next, the different models are regressed against the residuals in order to check for the most suitable fit, looking at P-values and explanatory power by the R-squared.

Where a significant model is found, it would be interesting to take an additional step in the analyses and check whether the effect of alliance formations on performance differs between smaller and large firms. This is done using the interaction term *Alliances90-99*firmsize*. Details of this method are provided in a later stadium.

4. Results

4.1 Linear relationship

Table 6 presents the results on a possible linear relationship between the number of alliance formations and firm performance.

Table 6 - Linear model: Alliances and firm performance

	Salesgrowth99-02 (av. absolute one year change of sales)		**Patents99-02** (cumulative nr. of patents 1999-2002)	
	Coefficient	P-value	Coefficient	P-value
Alliances90-99	25,351**	,001	48,687**	,001
R&Dexp90-99	,005**	,002	,007*	,020
Firmsize-med	30,245	,748	168,540	,354
Firmsize-large	218,88	,167	1200,456**	,000
R^2	,281		,384	
N	179		174	

Note: Reference category of firm size is *Firmsize-small* (less then 1.000 employees)
** Significant at the 1% level (2-tailed)
* Significant at the 5% level (2-tailed)

The results support hypothesis 1, the coefficient of *Alliances90-99* is both positive and significant when regressing on *Salesgrowth99-02* and *Patents99-02*. As Thomson One Banker does not provide complete data on all variables, the number of firms worked with is 179 for sales growth and 174 for patent applications. Observations with a relatively high number of alliances remain intact.

Absorptive capacity (*R&Dexp90-99)* also shows a positive significant effect on firm performance. A greater capacity to value and apply knowledge will thus stimulate firm performance. Finally large firms filed more patent applications over the period of 1999 to 2002 compared to small firms. A possible explanation could be that because of their size and visibility in a market, larger firms can attract more potential partners, selecting the most promising alliances from these companies. Also larger firms who have shown their survival skill in the market may have better employees in R&D compared to smaller companies.

4.2 Diminishing returns

The logarithmic model also gives a positive significant coefficient for alliances on both dependents (table 7). This supports the second hypothesis.

The positive value of *log.Alliances90-99* indicates that performance will increase at a decreasing rate as firms form more R&D collaborations. P-values for the logarithmic model are somewhat higher for both sales growth and the number of patent applications. The number of patent applications is significant at a 5% confidence level, versus a 1% level in the linear model.

Table 7 - Logarithmic model: Alliances and firm performance

	Salesgrowth99-02 (av. absolute one year change of sales)		**Patents99-02** (cumulative nr. of patents 1999-2002)	
	Coefficient	P-value	Coefficient	P-value
log.Alliances90-99	119,596**	,010	179,449*	,043
R&Dexp90-99	,006**	,000	,009**	,004
Firmsize-med	47,852	,615	203,134	,274
Firmsize-large	250,677	,118	1258,374**	,000
R^2	,264		,359	
N	179		174	

** Significant at the 1% level (2-tailed)
* Significant at the 5% level (2-tailed)

When testing which of these two models fits the data best, the linear model tends to explain more of the variance in performance compared to the logarithmic model. When regressing *Alliances90-99* and *log.Alliances90-99* on the residuals of Y, the linear model shows lower p-values and a higher R-squared for sales growth as well as the number of patents (appendix F).

4.3 Inverse U-shaped relationship

The third hypothesis, stating negative returns may set in after a certain number of alliances, is not supported by the data (table 8).

Table 8 - Quadratic model: Alliances and firm performance

	Salesgrowth99-02 (av. absolute one year change of sales)		**Patents99-02** (cumulative nr. of patents 1999-2002)	
	Coefficient	P-value	Coefficient	P-value
Alliances90-99	46,651*	,013	1,706	,962
Alliances90-99²	-,799	,213	1,758	,149
R&Dexp90-99	,005**	,002	,007*	,026
Firmsize-med	29,873	,750	169,535	,350
Firmsize-large	235,507	,138	1163,231**	,000
R^2	,287		,392	
N	179		174	

** Significant at the 1% level (2-tailed)
* Significant at the 5% level (2-tailed)

Where *Alliances90-99* is positive and significant for sales growth, the negative quadratic value *Alliances90-99²* does not show a P-value below 0,05. Also the cumulative number of patent applications does not support an inverse U-shaped relation at the 5% level.
Where the logarithmic model gives significant values for both sales growth and the number of patents, supporting diminishing returns, negative returns do not seem to set in as the amount of alliances increase. Hypothesis 3 can thus be rejected.

4.4 Moderation effect - firm size

A moderation or interaction effect states that the effect of one independent variable on Y (performance) depends on the magnitude of another independent variable (Norton et all, 2004). In this case the effect of alliance formations on firm performance may be different for smaller compared to large firms. Figure 3 displays this interaction effect. Here Z stands for firm size and X the cumulative number of alliances.

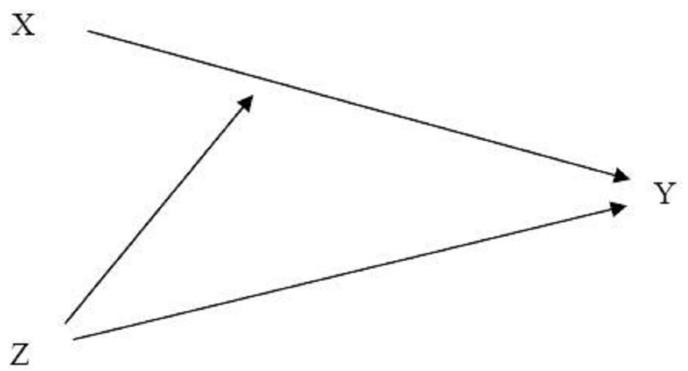

Figure 3: Interaction effect (Imported from Hargens, (2006))

In order to check for an interaction effect, the variable firm size is now divided into two categories: firms having more then 10.000 employees versus firms with less then 10.000 employees. With this new dummy variable for firm size, *Alliances90-99*Firmsize-large* is created. An interaction effect exists where this variable gives a significant value for firm performance.

The linear model is used, as this model contains the highest explanatory power on the data. Results are given in table 9.

Table 9 - Interaction effect of firm size and alliances on performance

	Salesgrowth99-02 (av. absolute one year change of sales)		**Patents99-02** (cumulative nr. of patents 1999-2002)	
	Coefficient	P-value	Coefficient	P-value
Alliances90-99	3,372	,770	34,727	,121
R&Dexp90-99	,005**	,004	,007*	,020
Firmsize-large	36,649	,822	1010,077**	,002
*Alliances90-99*Firmsize-large*	36,700*	,013	24,069	,395
R^2	,305		,384	
N	179		174	

** Significant at the 1% level (2-tailed)
* Significant at the 5% level (2-tailed)

The interaction term shows a significant positive value for sales growth, meaning the positive effect of alliance formations on absolute sales growth is larger for firms with more then 10.000 employees. This seems a logical result as larger firms have greater capacity to benefit from possible innovation through R&D collaborations.

Firm size does not influence the effect of alliances on the number of patent applications. The innovativeness of an additional alliance, translating itself into patent applications, is thus not significantly different for smaller compared to large firms. The difference between patents and absolute sales growth may be that patents reflect the success rate, which does not differ in firm size, where sales growth also indicates the ability to put this success into practice. Large firm have more resources to produce and transform innovativeness into sales growth.

5. Discussion

Overall the linear relationship as well as the relationship of diminishing returns are supported by the data, H1 as well as H2 cannot be rejected. Where the logarithmic model does gives significant values on the number of alliances, the explanatory power is lower for both performance measures. Greater support is thus provided for the linear model.

Main arguments from literature supporting this relation are theories of value creation, accessing additional resources through alliance formations, as well as cases where collaboration can function as an alternative to the make or buy decision. Furthermore, each additional link contributes to the creation of a firm's portfolio of alliances, gaining flexibility through real option value, increasing competitive advantage. Social network literature shares the view of linear returns, where an increasing number of links would positively affect firm growth.[3]

Arguments supporting a relationship of diminishing returns (see table 1) do not seem to affect this linear connection. However, an explanation could be that they are somewhat offset by the learning effects giving rise to diminishing costs. Although these learning effects are proved to be limited, they may still offset the diminishing returns enough to give rise to a linear relationship. The focus on R&D alliances may increase the likelihood of diminishing returns to set in because of higher interdependency and more coordination costs. However, as R&D relations are more complex and demand effective management, learning effects will also be greater as alliance experience increases. The number of alliances in the pharmaceutical industry may not be pushed far enough for diminishing returns to take over these more limited learning effects.

[3] As this research has been done within a single industry, the increasing number of alliances can also be seen as a proxy for a firm's centrality within a network. Connectedness in this sense does seem to contribute to performance. Seppälä (2004) argues that a firm's network position is interesting to examine further, an alliance may be valuable if it can provide a more central position to the firm. This network perspective is however beyond the scope of this research.

As the dataset does not show negative returns to alliances, no such arguments are supported. Bounded rationality constraints, in practice, do not seem to lead to negative returns because of the lower quality of monitoring and screening followed by a higher probability of opportunistic behaviour. Also no support is found for the argument that firms would be involved in too many alliances caused by increased competition through globalisation. As the linear effect has most explanatory power, managers seem to be still in control, not taking irrational decisions in the sense of to risky or to many R&D collaborations.
The third hypothesis, concerning an inverse U-shaped relationship, can thus be rejected. An explanation can be that managers thoroughly know the capabilities of their company, not going beyond a point where alliances form to great a risk. Each firm's individual characteristics will be important for the amount of alliances a firm can handle. Small firms are likely to have a lower amount of absorptive capacity than large firms, as they have fewer funds available for R&D. Smaller firms may thus reach the optimal number of alliances more rapidly. The correlation matrix provides some support for this difference in alliance formations concerning a firm's capabilities, saying that managers of small firms would participate in fewer alliances compared to large firms.
Not finding an inverse U-shaped relationship does not mean it could not exist, if firms were to form alliances indefinitely. Managers may stop forming additional alliances before this point occurs on their horizon. However, firms can be too careful, not fully allocating the potential gains of additional alliance formations. As the linear connection dominates one of diminishing returns, the point where alliances become too risky may not yet be reached. Thus, possible additional benefits may still be allocated by increasing the number of R&D collaborations. It must be noted that these are pure speculations, not knowing the possible effects of increasing the number of alliance formations beyond its current scope.

Concerning firm size, larger firms tend to benefit more from alliances in absolute sales growth, where this effect is non-existent for patent applications. As sales growth has a higher potential to rise, diminishing returns may also be observed in a later stadium compared to smaller firms. Where smaller firms may have a lower ability to value and apply knowledge (absorptive capacity), small firms also have less capacity to obtain potential gains in sales growth. A possible explanation for this could be that smaller firms in the pharmaceutical industry are more likely to be biotech firms. This smaller type strives for innovation, after which the knowledge of the new product or technology is sold to a large pharmaceutical company. For these biotech firms, sales growth will not be a primary objective.

6. Conclusion

In sum, alliances do seem to effect firm performance, a linear positive connection best supports this relationship. Where diminishing returns provide a somewhat weaker fit into the data, no inverse U-shaped relation is found.

One could conclude that the returns to additional alliance formations in the pharmaceutical industry may not be fully exhausted. Whether a potential inverse U-shaped relation can be observed when alliance formations are further increased is beyond this study. As economic intuition may support a relationship of diminishing and potential negative returns, no such connection is observed in practice.

A possible flaw of this research is that the effect of alliance formations on performance may wear off on the time span that is used. An alliance formed in the early '90s may not find it's way to performance of 1999 if its life is short. On the other hand they may still benefit the firm through the progress booked, increasing competitive advantage and potential in the future. Another note is that no specific features of individual alliances are taken into account, no information was found on the possible age or structure of the alliances, possibly effecting performance.

As other high tech industries as information technology and the aerospace & defence industry show similar characteristics, occurring from more complex production procedures, these results may also be observed outside the pharmaceutical industry. However this is a generalisation yet to be explored by possible future research.

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Appendix

Appendix A - Correlations among dependent and independent variables

Correlations

		patents.99_02	av.absol. salesgrowth99_02	alliances90_99	av.R.and.D. exp.90_99	firmsize_small	firmsize_med	firmsize_large
patents.99_02	Pearson Correlation	1	,418**	,442**	,533**	-,317**	-,049	,507**
	Sig. (2-tailed)		,000	,000	,000	,000	,475	,000
	N	251	241	251	188	213	213	213
av.absol. salesgrowth99_02	Pearson Correlation	,418**	1	,387**	,477**	-,198**	-,077	,382**
	Sig. (2-tailed)	,000		,000	,000	,003	,254	,000
	N	241	248	248	193	220	220	220
alliances90_99	Pearson Correlation	,442**	,387**	1	,448**	-,202**	-,026	,321**
	Sig. (2-tailed)	,000	,000		,000	,003	,703	,000
	N	251	248	258	193	220	220	220
av.R.and.D.exp.90_99	Pearson Correlation	,533**	,477**	,448**	1	-,411**	-,086	,671**
	Sig. (2-tailed)	,000	,000	,000		,000	,252	,000
	N	188	193	193	193	180	180	180
firmsize_small	Pearson Correlation	-,317**	-,198**	-,202**	-,411**	1	-,735**	-,465**
	Sig. (2-tailed)	,000	,003	,003	,000		,000	,000
	N	213	220	220	180	220	220	220
firmsize_med	Pearson Correlation	-,049	-,077	-,026	-,086	-,735**	1	-,259**
	Sig. (2-tailed)	,475	,254	,703	,252	,000		,000
	N	213	220	220	180	220	220	220
firmsize_large	Pearson Correlation	,507**	,382**	,321**	,671**	-,465**	-,259**	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	
	N	213	220	220	180	220	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix B - Hypothesis 1: Linear relationship

Linear model: Alliance formations (1990-1999) and average absolute yearly sales growth (1999-2002)

N = 179
R-Squared: ,281

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-60,976	58,408		-1,044	,298		
	alliances90_99	25,351	7,602	,240	3,335	,001	,796	1,256
	av.R.and.D.exp.90_99	,005	,002	,285	3,089	,002	,484	2,066
	firmsize_med	30,245	93,904	,022	,322	,748	,907	1,103
	firmsize_large	218,880	157,878	,125	1,386	,167	,502	1,994

a. Dependent Variable: av.absol.salesgrowth99_02

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	alliances90_99	av.R.and.D.exp.90_99	firmsize_med	firmsize_large
1	1	2,672	1,000	,04	,05	,04	,02	,03
	2	1,225	1,477	,06	,00	,05	,27	,07
	3	,475	2,371	,01	,69	,08	,25	,10
	4	,403	2,576	,56	,13	,20	,22	,11
	5	,225	3,443	,33	,13	,64	,24	,69

a. Dependent Variable: av.absol.salesgrowth99_02

Linear model: Alliance formations (1990 -1999) and the cumulative number of patent applications (1999 - 2002)

N = 174
R-Squared: ,384

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-13,302	111,529		-,119	,905		
	alliances90_99	48,687	14,393	,228	3,383	,001	,797	1,254
	av.R.and.D.exp.90_99	,007	,003	,203	2,345	,020	,484	2,068
	firmsize_med	168,540	181,381	,059	,929	,354	,909	1,101
	firmsize_large	1200,456	298,730	,341	4,019	,000	,502	1,990

a. Dependent Variable: patents.99_02

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	alliances90_99	av.R.and.D.exp.90_99	firmsize_med	firmsize_large
1	1	2,671	1,000	,04	,05	,04	,02	,03
	2	1,223	1,478	,06	,00	,05	,28	,07
	3	,474	2,373	,01	,67	,09	,27	,10
	4	,406	2,566	,57	,15	,19	,21	,11
	5	,226	3,439	,33	,13	,64	,22	,69

a. Dependent Variable: patents.99_02

Appendix C - Hypothesis 2: Diminishing returns

Logarithmic model: Alliance formations (1990-1999) and average absolute yearly sales growth (1999-2002)

N = 179
R-Squared: ,264

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-77,985	64,480		-1,209	,228
	log.alliances90_99	119,596	45,690	,179	2,618	,010
	av.R.and.D.exp.90_99	,006	,002	,325	3,573	,000
	firmsize_med	47,852	94,970	,034	,504	,615
	firmsize_large	250,677	159,557	,144	1,571	,118

a. Dependent Variable: av.absol.salesgrowth99_02

Logarithmic model: Alliance formations (1990 -1999) and the cumulative number of patent applications (1999 - 2002)

N = 174
R-Squared: ,359

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-9,846	124,779		-,079	,937
	log.alliances90_99	179,449	87,834	,132	2,043	,043
	av.R.and.D.exp.90_99	,009	,003	,254	2,949	,004
	firmsize_med	203,134	185,008	,071	1,098	,274
	firmsize_large	1258,374	304,639	,358	4,131	,000

a. Dependent Variable: patents.99_02

Appendix D - Hypothesis 3: Inverse U-shaped relation

Quadratic model: Alliance formations (1990-1999) and average absolute yearly sales growth (1999-2002)

N = 179
R-Squared: ,287

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-110,201	70,387		-1,566	,119
	alliances90_99	46,651	18,669	,441	2,499	,013
	alliances90_99squared	-,799	,640	-,223	-1,249	,213
	av.R.and.D.exp.90_99	,005	,002	,293	3,173	,002
	firmsize_med	29,873	93,754	,021	,319	,750
	firmsize_large	235,507	158,188	,135	1,489	,138

a. Dependent Variable: av.absol.salesgrowth99_02

Quadratic model: Alliance formations (1990 -1999) and the cumulative number of patent applications (1999 - 2002)

N = 174
R-Squared: ,392

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	96,609	134,514		,718	,474
	alliances90_99	1,706	35,409	,008	,048	,962
	alliances90_99squared	1,758	1,211	,244	1,451	,149
	av.R.and.D.exp.90_99	,007	,003	,194	2,246	,026
	firmsize_med	169,535	180,795	,059	,938	,350
	firmsize_large	1163,231	298,866	,331	3,892	,000

a. Dependent Variable: patents.99_02

Appendix E - Interaction effect: Linear model

Effect of alliance formations on absolute sales growth: smaller vs. large firms

N = 179
R-Squared: ,305

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21,576	56,891		,379	,705
	alliances90_99	3,372	11,536	,032	,292	,770
	av.R.and.D.exp.90_99	,005	,002	,263	2,904	,004
	av.employees.higher.10.000	36,649	162,623	,021	,225	,822
	alliances90_99.x.employees.higher.10.000	36,700	14,626	,315	2,509	,013

a. Dependent Variable: av.absol.salesgrowth99_02

Effect of alliance formations on patent applications: smaller vs. large firms

N = 174
R-Squared: ,384

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	88,473	111,434		,794	,428
	alliances90_99	34,727	22,286	,163	1,558	,121
	av.R.and.D.exp.90_99	,007	,003	,204	2,351	,020
	av.employees.higher.10.000	1010,077	313,977	,287	3,217	,002
	alliances90_99.x.employees.higher.10.000	24,069	28,201	,103	,853	,395

a. Dependent Variable: patents.99_02

Appendix F – Model fit

Regression - *Alliances90-99* and residuals of *Salesgrowth99-02* (controlled for firm size and absorptive capacity)

N = 179
R-Squared: ,048

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-81,880	48,882		-1,675	,096
	alliances90_99	20,190	6,770	,218	2,982	,003

a. Dependent Variable: res.av.absol.salesgrowth99_02

Regression - *log.Alliances90-99* and residuals of *Salesgrowth99-02* (controlled for firm size and absorptive capacity)

N = 179
R-Squared: ,034

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-89,859	54,295		-1,655	,100
	log.alliances90_99	107,908	43,115	,184	2,503	,013

a. Dependent Variable: res.av.absol.salesgrowth99_02

Regression - *Alliances90-99* and residuals of *Patents99-02* (controlled for firm size and absorptive capacity)

N = 174
R-Squared: ,050

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-160,141	93,820		-1,707	,090
	alliances90_99	38,815	12,826	,224	3,026	,003

a. Dependent Variable: res.patents99_02

Regression – *log.Alliances90-99* and residuals of *Patents99-02* (controlled for firm size and absorptive capacity)

N = 174
R-Squared: ,022

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-137,666	105,499		-1,305	,194
	log.alliances90_99	162,226	82,883	,147	1,957	,052

a. Dependent Variable: res.patents99_02