



Cooperation and Innovation

Choices and Constraints for Low and High Tech Industry Firms
Engaging in Joint Research and Development Programs.

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Abstract

One of the most relevant purposes a firm has is to maintain its position on the market in ones domain. In this process being innovative and technologically ahead of the competition plays a big role. However, due to the strong technological development in the past forty years, competition has been growing between organizations. For this reason nowadays there is an increasingly amount of organizations which decide to join a Research & Development partnership.

At first sight it seems tempting for organizations to join a R&D partnership with similar organizations, due to the same technology that is applied in the production processes and the amount of information available for exchange. However there are more factors which have to be taken into account for a firm making the decision to join a R&D partnership. This research looks for the underlying patterns in R&D partnerships worldwide in the period from 1990 up until 2000 and provides predictive statistics for partner selection based on the nationality and the sector of operation of firms.

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1.1 Introduction

The world of organizations has been undergoing some drastic changes over the past forty to fifty years. With an ever faster exchange in information, shorter time spans between locations due to faster ways of travelling and other technological inventions the corporate environment has been reshaped in many ways. The goals the firms have still remain relatively the same, to provide the service, or produce goods they manufacture in the best way and as efficient as possible, if possible even better and more efficient than ones competitors. This is one of the factors which could have contributed to the fact that inter firm collaboration has taken a great rise since the 1960's. Current research mainly focuses on the description of these alliances whilst neglecting the possibility for predicting possible preferences. In our research we wish to focus ourselves on these preferences.

Due to an ever changing environment there has been an increasing focus on researching and developing new ways of more efficient ways as to produce these goods. One of the reasons firms need to keep reinventing their production processes, new technologies and new products is because of the increase in competition on local markets (Narula & Hagedoorn, 1999). Teece stressed the urge of this signifying that the cheaper form, imitation, leads to the downfall of markets and hinders innovation. It is therefore in the firms' best interest to keep innovating opposed to imitating (Teece, 1986). In the last half of the previous century globalization as a term emerged to signify and describe the process of international competition on, former, local markets. This term describes that there is an increase in similarity of consumption patterns and income levels across the world as well as a concurrent increase of cross border activities concerning firms from these countries (Narula & Hagedoorn, 1999).

Meaning that a firm based in, for example, the United States also produces goods for purchase in Europe and vice versa. Thus the number of possible areas of distribution, places to sell the produced goods, has increased tremendously. With this increase in areas of distribution also comes the increase in competitors, for example products formerly produced by European firms and sold in Europe now have to compete with products from the United States, Asia and so on also being sold in the European market. This is a situation which every company, based in countries who apply a free market system, has to cope with. Thus the need for increasing innovative solutions is something that is shared by, mostly, all producers of goods (Teece, 1986; Vivio, 2004).

The great technological advancement over the years also increased the uncertainty in

the markets. For one can understand that it is feasible to predict ones' own, local, market and, local, competitors. It is an entirely different matter to do this for every possible distribution area and competitor. This is something of great importance when a firm decides to start a process called research and development, or R&D in short. This is because the uncertainty also has an effect on the technologies or products which are currently being researched. It is entirely seemingly that a competitor finds a better way of improving a process or develops an even more successful new product. In a worst case scenario it is also a possibility that there is no market for the developed product or that the technology can not be applied due to financial, technological, legal or otherwise existing barriers.

Another problem that arises with changing markets and the sophistication of technology is the costs of a research and development process. These two factors combined have lead to, and are leading to, a multitude of joint programs where companies join forces to achieve a shared goal. This is called a joint research and development program or R&D partnership. These partnerships have also been referred to as being strategic technology partnerships, we however choose for the sake of clarity to constantly refer to such alliances as being a research and development partnership.

R&D partnerships are often characterized by firms who have a large interdependence (Hagedoorn, 2002; Gargiulo & Gulati, 1999). This implies that competitors sometimes choose to work together and share the costs of such a project then to research and develop new products or technologies on their own. Another factor that emerges is that due to the sophistication of technology this interdependence arises from other non competing firms in different sectors. When endeavouring in such a process a firm will restrict itself to the sector it is familiar in and will look for a suitable partner in the sector it is unfamiliar in.

With respect to the trends in R&D partnerships one of the first papers which provided longitudinal trends, was the paper by Hagedoorn and Kranenburg published in 2003. By using the MERIT-CATI database they had access to one of the few datasets which can provide quantitative data about R&D partnering. They displayed the growth patterns in international and national R&D partnering over the period ranging from 1960 trough 1998. Although they were not the first to display patterns of R&D emergence, which has been done since 1986, they still were the first to display the changes and developments this phenomenon has undergone.

However, before we describe these trends in the current and previous R&D partnerships it is wise to take a look at the process itself. What is exactly a research and development program? Are there different forms of achieving this joint development and

what motivates the choice for one of these forms? Moreover, the world economy cannot be seen as existing out of only one level of technology, you need only to take a brief look around the desk behind which you're currently seated and try to imagine the diversity of companies which produced the items present at your desk. Ranging from as low tech as a pencil to a high tech computer. It seems obvious that there is more than one sector of technology in production.

This research concerns the patterns in R&D alliances. With the help of a dataset belonging to Thomson - Reuters, which provides information about worldwide existing R&D alliances between 1991 and 2000, we focused ourselves on understanding these patterns. More about this focus will be described below.

First the main focus of our research will be described and afterwards the theoretical part of our thesis. We believe that, in the context of this research, it is relevant first to understand the theoretical basis in R&D alliances with respect to what exactly characterizes such a partnership, how these alliances exactly work out and which factors may be influential in this process.

1.2 Research question

The main focus in this research lies upon understanding the patterns in R&D alliances. After reading into the current literature on R&D alliances, the main interest for this research is to study which tendencies organizations have while joining such an alliance. The focus which is maintained has been separated into more sub focuses, which concern the possible influential factors, region and sector of industry, in joining an R&D alliance. Subsequently we will also take a look at the cross effects of these factors, thus effectively combining the regions of origin and technological sectors in which the firms operate.

We are investigating as to why some companies do collaborate with one another and others do not. It is evident that no investigation, no matter how thorough, will fully answer this question. However, what we shall investigate will concern two fundamental aspects that could be of importance in a potential cooperation as well as certain patterns that may be distinguished in R&D collaborations.

According to this, the main research question which will be studied in the context of this research is:

What is the structure of a R&D partnership network?

With respect to the separation of the main focus this research lies upon, two sub questions will help to accomplish this research in total.

These two sub questions contain:

- *Are there differences in patterns of R&D partnerships between sectors of industry?*

For this question we will mainly focus our attention on the difference in participation between high and low tech firms. Because we want to investigate more than just the difference in participation in R&D partnerships in and across sectors, we will also pay attention to this phenomenon with respect to regions in which firms are based.

- *Are there differences in patterns of R&D partnerships between World Regions?*

Here our focus will be the difference between firms from developed countries and firms from developing countries. The main goal which will be strived for to accomplish, is to give the reader an enriching view in the world of R&D alliances and the belonging patterns.

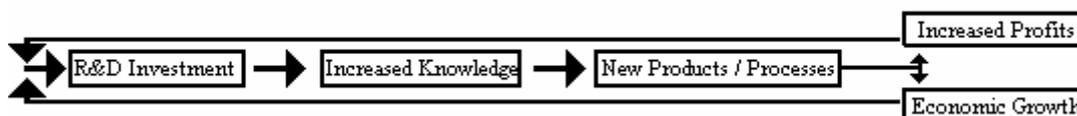
2.1 Research & Development partnerships

Before we look at the sectors the partnering takes place in it is wise to first take a look at the phenomenon of R&D. This involves the process of increasing either technological or scientific knowledge and applying this knowledge in the form of new products or production processes (Hagedoorn & Schakenraad, 1994; Hagedoorn, 2001; Neill, Pfeiffer & Young-Ybarra, 2001).

In our research we intend to look at joint R&D programs. This can shortly be described as two or more firms, joining hands and resources together in order to achieve certain goals in research and development mutually decided upon. Or as Vivio stated: ‘... *an agreement that combines cooperation and competition into a single strategy*’ (Vivio, 2004). This fact is related to strategic alliances that can exist between companies however these are intended to ‘*affect the long-term product market positioning of at least one partner*’ (Narula & Hagedoorn, 1991).

This has previously been done in the form of joint ventures, however due to the rising costs of such undertakings and the severe risk of failing of joint ventures this option has lost the favour of most of the firms. The firms’ scope has swayed more towards cooperative research and development programs (Hagedoorn, 1993; Mowery, Oxley & Silverman, 1996; Hagedoorn, 2002). These programs have the benefit that they can be executed within the firms’ own research department instead of starting up a separate research department as was the case with joint ventures. Another advantage over joint ventures is that R&D partnerships can be very flexible, allowing firms to cooperate with different sets of partners over short time spans (Hagedoorn, 2001). This suggests that firms can make optimal usage of their corporate network. This in contrast to a joint venture which basically implies two firms starting up their own research firm which means a cost and time heavy method of joint research and development. The following figure displays the linear form of the, ideal, R&D process which emphasizes its continuity, in other words, there is a cycle of R&D; once a research is completed another one is started to keep ahead of the competition.

Fig. 1 The Linear cycle of R&D (Source: Robertson & Patel, 2007)



2.2 The beneficial factors of R&D partnering; Why do companies involve in joint R&D?

There are different reasons why companies should endeavour into an R&D project and of course there are different benefits, apart from the shared cost in resources. Because beneficial factors are directly related to the reasons why companies involve in joint R&D, this will be discussed as a whole. Apart from the beneficial factors firms can also use specific strategies as an underlying principle to join a R&D partnership, table 1 will describe this distinction, which will be explained below:

Table 1 Beneficial factors versus Strategies in R&D partnerships

Beneficial factors	Strategies
Knowledge	Cost-economizing
New markets	R&D / Turnover > 5%
Expansion	

One of the reasons is, as Narula and Hagedoorn suggest, the obtaining of market knowledge through a cooperating partner. This suggests the active selection of possible R&D partners on the basis of what they can add to the current knowledge of the market within a company (Narula & Hagedoorn, 1999). We understand that this can be very beneficial for firms but we reject the idea that there will be active screening merely based on this point. We much rather see it as a benefit of having a R&D partnership than a selection criterion before entering one. In the same article are however two other beneficial factors of a R&D partnership on which we believe selection can be based. One being the ability to cross borders, and possibly reaching whole new local markets (Narula & Hagedoorn, 1999). We do believe that given the strategic component of several R&D partnerships this can be an important selection criterion. Given the fact that there are two possible partners for cooperation but only if one of them provides the ability to explore a whole new market the choice seems obvious.

The other possible benefit of partaking in a R&D partnership is that of horizontal or sector wide expansion (Narula & Hagedoorn, 1999). This means that a firm has the opportunity to broaden its foothold within its own sector by producing more, diverse, goods. We also believe that this is a criterion which is important for the selection of R&D partnerships. As stated before, firms need to stay competitive; one way of achieving this is by

being innovative in the products they manufacture. One way of achieving this is by broadening their already existing market establishment by the release of new diverse products.

Cooperation has been largely associated with failure in the past, however as research by Dunning suggests there has been a shift in mentality. Cooperation amongst firms is now considered a healthy form of competing given the benefits that arise when knowledge is shared amongst firms (Dunning, 1995). Apart from the perks that arise there are two main factors for starting a R&D partnership with another firm. One being the cost economizing factor, this implies that resources are scarce, as is often assumed in social sciences. In order for achieving certain goals it is sometimes wiser to use the bundled resources of several firms then to use merely ones own resources. The main reason being that it is more affordable for both companies to share their R&D prospects then to pursue them on their own. This not only contains truth for the process of R&D but also for the failing opportunities which arise in this process. As stated before due to market uncertainties, there is a chance of failing to meet the markets' needs. Therefore it is wiser to cooperate in R&D so that, even if the project fails, the costs are shared and the financial backdrop for a firm is not as steep as it would be when a firm decides on researching and developing on its own.

The other factor for cooperating lies in the earlier described perks obtained from R&D partnering, thus using R&D partnerships as the means of obtaining a strategical advantage by either receiving the possibility for horizontal expansion, obtaining market knowledge or establishing a foothold in previously unexplored markets. This is often called the strategic factor or strategic rationality. This rationality implies that when getting involved in R&D a firm will try to limit itself to its capabilities and will try to find a suiting partner for the unknown area of research (Teece, 1986; Gulati, 1995). Moreover these strategic alliances tend to create extra value for the partnering firms since they are given access to the knowledge of each others R&D processes. This gives the firms the ability to learn from each other by means of obtaining critical information, know-how about processes or the access to specific capabilities that the partner may have (Neill, 2001).

2.3 Finding the right partner, national or international?

Given the fact that international cooperation tends to be more expensive then national cooperation why do firms deliberately choose to do so? We have stated that one of the reasons for R&D is of an economic nature, thus implying that international cooperation can help establish a firm in the country where its international partner is based.

Aside from this reason, what motivates the choice for looking international or staying within ones country when looking for a partner for a R&D program? The tendency to look abroad is derived from the country the firm resides in as Narula and Hagedoorn suggest (Narula & Hagedoorn, 1999). Moreover, if a firm is internationally competitive, thus also operating outside the local market, the tendency to have international R&D partners increases. However when a firm is relatively small, or based in a small country, thus implying a smaller local market, they have the tendency to look for international partners due to the smaller scale of their local economy.

Companies which have a strong, large, local market such as firms based in the United States, tend to be larger in size and thus have a greater availability of resources. Also large countries tend to have a more diverse array of firms available as opposed to smaller countries. This presence of several firms specialized in diverse industry niches often motivates the choice to keep cooperation on a national level. In smaller countries there is less diversity amongst the firms once again due to a smaller distribution area. To make optimal use of ones capabilities it is therefore for firms in smaller countries wiser to look abroad for a partner who can substantially complement the firms own qualities and add their own specialization in the R&D process (Narula & Hagedoorn, 1999).

Studies also show that there is a preference for selecting partners which have already been part of a cooperation process or firms allied to those partners, thus having a secondary link to the firm (Narula, 1995).

This implies relational factors in partner selection which have a few advantages. First of all the information received about secondary partners is cheaper. Secondly there is a bias of trust amongst the partaking corporations due to the fact that they are currently cooperating with firms that cooperate with the firm looking for a partner. This is because it is in every firms' interest not to jeopardize or break up currently existing projects and thus have an incentive to be honest when cooperating (Granovetter, 1985 in Narula, 1995; Gulati, 1998).

We can therefore conclude that the main motivational factors behind the choice of either a national or international partner is motivated by meeting opportunities, as provided by the difference in small and large countries, as well as the strategic element which enables the exploration of new markets and innovative solutions by specialized partners or the finding of new partners trough old partnerships.

2.4 Sectors of industry

So far we have been talking about firms and corporations as being composed of a single sector of industry. As we have showed in the introduction via the means of the desk example it is clear that this generalization must be clarified. The industries are commonly divided into three sectors displaying the level of technology applied in the manufacturing of the goods they produce, we shall use the division made by the OECD. These sectors are the low tech, medium tech and high tech sectors. The sectors are divided by the complexity of the technologies used and the relative spending on R&D. This means how large a percentage of the yearly turnover rate of a company is being invested in R&D, which is displayed in table 2.

Table 2 OECD classification of technology intensity (Source: OECD)

Sector	Annual R&D Turnover Rate
High Tech Industries	> 5%
Medium Tech Industries	$\geq 0.9\% \leq 5\%$
Low Tech Industries	< 0.9%

This table displays that especially in the high tech sector a lot of money is being spend on R&D projects. Also due to a higher degree of uncertainty in this sector about the possible usage for the technology the firms operating in these sectors are more likely to cooperate in R&D projects (Robertson & Patel, 2007).

The low tech sector of industry is composed of the more established industries. This sector is often interpreted as the sector in which production is the main domain. Low technology industries are ‘more mature’ and are for example firms specialized in producing textiles, metal and wood products, food and beverages or mining corporations (Hirsch-Kreinsen, Jacobson, Robertson, 2006.OECD). These industries are characterized as being relatively stable in their market future and there is generally a low level of R&D taking place in this sector, as is shown by the classification of the OECD in table 2. Due to this market stability the research and technology is of a relatively ‘safe’ nature, meaning there is very little uncertainty about its practical usage and most of the R&D processes are not as sophisticated as their high tech counterparts. Globalization and the rapid technological developments do not have a large influence on the markets which are owned by low tech industry. Their distribution area is not dominated by technological changes and developments and therefore, low-tech industry companies does not necessarily need to cooperate in R&D

processes, due to the lower risks and costs and the lower costs associated with the R&D processes.

The medium technology sector consists, amongst other, out of non pharmaceutical chemical producers, consumer electronic manufacturers, and car manufacturers. This sector has a higher focus on R&D and also has a somewhat more uncertain market, which has particularly become clear for the automotive industry after the recent surge in gas prices. Due to a higher degree of uncertainty there are higher costs in R&D and therefore firms are more likely to cooperate in R&D as compared to low tech firms (Kranenburg & Hagedoorn, 2003).

However, this sector is less clear and composed of much more different branches of industry than the high or low tech sectors of industry and for the purpose of better comparison we shall not analyze this sector in this study; we mainly wish to focus ourselves on the low and the high tech sector.

The high tech sector is considered to be the leading sector in research and development, being a relatively young sector made up from firms in Information Technology, Pharmaceuticals and Aeronautical engineering these corporations are on the frontline of joint research and development programs. The sector has become so predominant that it currently makes up 80% of all the new joint research and development programs (Kranenburg & Hagedoorn, 2003). This because of the deindustrialization since the 1970s, also meaning the rapid technological developments and therefore higher risk of failure due to the high market uncertainty, because this industry has become more and more complex in its technologies, which resulted in the higher risks of being not innovative enough and dependant on the rapid innovations ones companies competitor may accomplish. Having just been established as a market, compared to their low and medium tech counterparts, the future of this market is more uncertain than in other sectors. This, in combination with the higher degree of sophistication in the researched technologies leads to very high costs for R&D programs. To share these costs and to overcome these uncertainties high tech firms are among the most likely corporations ready to join a shared R&D program.

Innovation is often associated with the spending on research and development however arguments have arisen against this, still commonly shared opinion. In their research in 2006 Hirsch-Kersen, Jacobson and Robertson argue that it is biased to base innovation on merely R&D spending alone. This argument has been picked up by the European Union and has led to the PILOT program which focuses on the innovation of low tech industries via other means than traditional R&D (Hirsch-Kersen, Jacobson & Robertson, 2006).

2.5 Trends in cooperation

Having clarified the need for R&D, the perks, choices and constraints it involves and having explained how this works on a network level we can take a look at the trends based on the MERIT-CATI data as they have been presented by Hagedoorn in 2002 and 2003. We shall however only review the trends for the low tech and high tech sector due to the focus of our research.

As we stated there has been a decline in the usage of joint venture structures for cooperation. This early form of cooperation was the most popular method for joint R&D up till the period 1980-1989 as displayed in table 2. Furthermore we see a dominance of partnerships within member states of the OECD, the Organization for Economic Cooperation and Development. These member states currently consist of most European Countries, The United States, Canada, Mexico, New Zealand, Australia, Japan and Korea (oecd.org). We also notice that their dominance is somewhat declining but still makes up 94.1 % of the total amount of new partnerships.

Table 3

Distribution of R&D partnerships within the OECD and High tech Sector (Kranenburg & Hagedoorn, 2003)

Period	New R&D partnerships	Within OECD	% Within OECD	High Tech R&D	% High Tech
1960-1969	107	104	97,2%	31	29,0%
1970-1979	592	569	96,1%	264	44,6%
1980-1989	3627	3375	93,1%	2271	62,6%
1990-1998	4743	4464	94,1%	3795	80,0%

Another trend that emerges is the gradual dominance of the high tech sector in research and development programs. This sector is, as we discussed earlier, suffering from the biggest market uncertainties therefore the need for cooperation arises earlier as to remove a part of this uncertainty. The research costs are also the highest amongst any of the sectors due to the earlier explained sophistication of technology. This causes further pressure on firms to share the costs and split the risks when starting up a research and development program.

When looking at partnerships from an international scope we see that the trend has it is ups and downs in the period ranging from 1960 through 1976 and is now slowly declining to about 50% of all newly established R&D partnerships. Hagedoorn explains this phenomenon by the vast amount of intra-US partnerships. Given the fact that almost 70% of the R&D partnerships over the past forty years were with at least one US firm this explains why due to Intra-US partnerships the international level of cooperation has remained relatively stable

(Hagedoorn, 2002). When regarding companies from non OECD countries it becomes clear that they, until up to 1998 haven't played that big a part in international or intranational R&D partnerships. Averaging about 7.3 % of all newly established partnerships it becomes clear that there is still a lot of catching up to do before firms from developing countries become interesting partners for international cooperation.

2.6 Hypotheses

As described above in this research high and low-technology companies will be studied and medium tech companies will be held out of study. Therefore for both low and high tech industries different assumptions have been formed.

Concerning the low-tech sector we assume that there will be lower R & D costs than there will be in the high-tech sector, due to the fact that the markets are more stable and the future of the technology is more certain. Because of the lower costs of the R & D there will be less need for cooperation in the low tech sector. This is because of the greater amount of certainty within the sector which leads to more security due to the slighter chance of failure of a researched technology.

Our expectation is that the market is far less dominated by technological developments in this sector. In order to support this view another assumption is made with respect to low tech companies namely, in the low tech sector there is less hinder from a technological barrier; a barrier associated in technology between firms from OECD and firms from non OECD countries and therefore we also expect that due to the relative absence of a tech barrier, firms from developing countries are as likely a cooperating partner as their OECD counterparts.

We therefore formed the following hypotheses with respect to the low tech sector:
Hypothesis 1: *Low tech firms cooperate less as a whole than high tech firms due to the lesser need for, joint, R & D programs.*

2. *When cooperating internationally, the low tech sector has a higher tendency to cooperate with firms from non OECD countries as opposed to high tech firms.*

Regarding the high-tech industry it is assumed that R & D in a high tech environment is costlier than in a low tech environment and because of the higher costs of R & D there is a stronger need for cooperation amongst high tech enterprises. With respect to the strong qualitative aspect of forming an R & D partnership we also expect high tech industry companies to maintain the "no gain principle", which holds that when a potential partner has

no complementary factor in the R & D process, there is no stimulus to cooperate with the company in question since it doesn't bring anything to the table. In other words, the strategic alliance must be profitable for both competitors, which indirectly heralds the next assumption that technological barriers hinder cooperation with lesser developed countries due to the "no gain" principle.

In the high technology sector there are a lot of technological restrictions, which can make it more complex for a company to find the right partner with whom to form such a strategic alliance. Another obstacle for these companies can be the difference between the technological levels of development. In combination with the "no gain" principle we therefore expect international cooperation on a high tech level not likely to exist between a western and a company from a developing nation, in this case firms from non OECD member states, with the exclusion of Russia. After listing these assumptions with respect to the high technology sector we formed the following hypotheses:

- 1. Amongst high tech firms there is a higher degree of R & D partnerships than in the low tech sector.*
- 2. There will be a lower degree of cooperation with internationally developing countries as compared to low tech firms*

3.1 Data and Operationalisation

In this research we made use of a dataset belonging to Thomson Reuters, a Canadian company which, amongst other things, concerns itself with keeping track of previous and current existing alliances. However this dataset, the Thomson SDC Platinum Worldwide M&A database (Thomson Reuters), contains more information about inter firm partnering, from 1990 up until 2000, then the information that is actually used in this research. It also contains for example information on manufacturing and licensing agreements. Although this also is a valuable form of strengthening a firms' market position it has less to do with partnering in research and development. Therefore we had to reduce our original alliance count from 4693 to the alliances which are actually R&D partnerships (n=2632).

The division by groups and industries were done by the currently existing OECD guidelines. These lines sketch out which firms belong in which sector and give an overview of the currently industrialized, developed countries. The Asia group does however also contain firms from Australia and New Zealand; this was deliberately done due to low firm count in these two countries. It would therefore be statistically unwise to create a special Oceanic region group. The other groups contain firms from the Northern America region which includes Canada, Mexico and the United States, a group consisting of European firms and a group consisting of firms from develop countries which includes, amongst others, firms from India, Thailand, Brazil and Africa.

The High Tech, Low Tech and Medium Tech division has been described by the OECD and via means of Standard Industry Classification Codes, SIC, we could easily assign each firm to its respective group. The SIC classification describes and orders each firm by their core activity in the same way the Dutch SBC-92 system does for job classifications. The Sectors include Aeronautical engineering and Defence, Information Technology, IT, Pharmaceutical Engineering, Low Technology and Medium Technology. The Medium Technology sector is mainly used as a reference category and consists of car manufacturers and chemical producers amongst others. Whilst this category consists of all industries that could not be subdivided in the High or Low technology sectors we deliberately choose to refer to this category as Medium tech instead of "Other" since it is somewhat more informative as a classification and gives a clearer view of the technology sectors. Lastly, the Low Technology sector contains firms from food and beverage industries, mining and heavy industry.

3.2 General Data Overview

After cross tabulating the sector by sector cooperation and the region by region cooperation it was decided that for the ease of analysis it was better to make the cross tabulations a-symmetrical. This means that all the information can only be read in one direction instead of two. Statistically this does not disturb the results since the partnerships are considered equal and it therefore does not matter which firm is named first and which second in the dyadic partnerships which our dataset provides. The a-symmetrical division also is of great help when creating the odds-ratios for participation, the likeliness of firms to cooperate with either their own sector or region or to participate heterogeneous, outside their own sector or own region. The division of firms and sectors is as followed.

Table 3.1 A-symmetrical cross tabulation of region wise alliances

Firm 1 by Region		Europe	Asia	North America	Developing	Total
Firm 2 by Region	Europe	88	0	0	0	88
	Asia	80	153	0	0	233
	North America	340	496	1448	0	2284
	Developing	7	4	16	0	27
Total		515	653	1464	27	2659

Table 3.2 A-symmetrical cross tabulation of sector wise alliances

Firm 1 by sector		Aero	IT	Pharma	LowTech	MedTech	Total
Firm 2 by sector	Aero	35	0	0	0	0	35
	IT	67	132	0	0	0	199
	Pharma	1	3	14	0	0	18
	LowTech	3	16	6	16	0	41
	MedTech	233	405	163	110	1428	2339
Total		339	556	183	126	1428	2632

Note here the dominance of firms from North America, this is however mentioned within the literature and should give no problems with our analysis. Another thing that catches the eye is the large division of firms in Medium Tech. This is because for the High Tech sector we restrict ourselves to the three dominant sub sectors and since they and the Low Tech sector are closely marked out by the OECD classifications we are left with a large residue of firms from Medium Technology sectors.

Before we started the analysis we wanted to make sure that there is a certain degree of statistical dependence amongst the firms, region wise or sector wise. An accurate tool to give us such an indication is the Chi² test.

By calculating the expected value for each cell per table ($(\text{Bottom total group1} * \text{Bottom Total group2}) / \text{End Total}$) we could then calculate the Chi2 for each individual cell. So the expected value for the cooperation between European and Asian firms would be $((88 * 80) / 2659) = 335$. Once the expected value is taken for every cell and used in the following formula $((\text{Observed} - \text{Expected})^2 / \text{Expected})$ the Chi2 outcomes would be as following. The values for the Degrees of freedom are calculated as $(n_{\text{rows}} * (n_{\text{columns}} - 1)) / 2$ so that it yields respectively 6 and 10.

Table 3.3 Chi2 findings for the A-symmetrical tables

Approach	Chi2	Df	Significance
Region wise Alliances	776,11	6	0,000
Sector wise Alliances	926,92	10	0,000

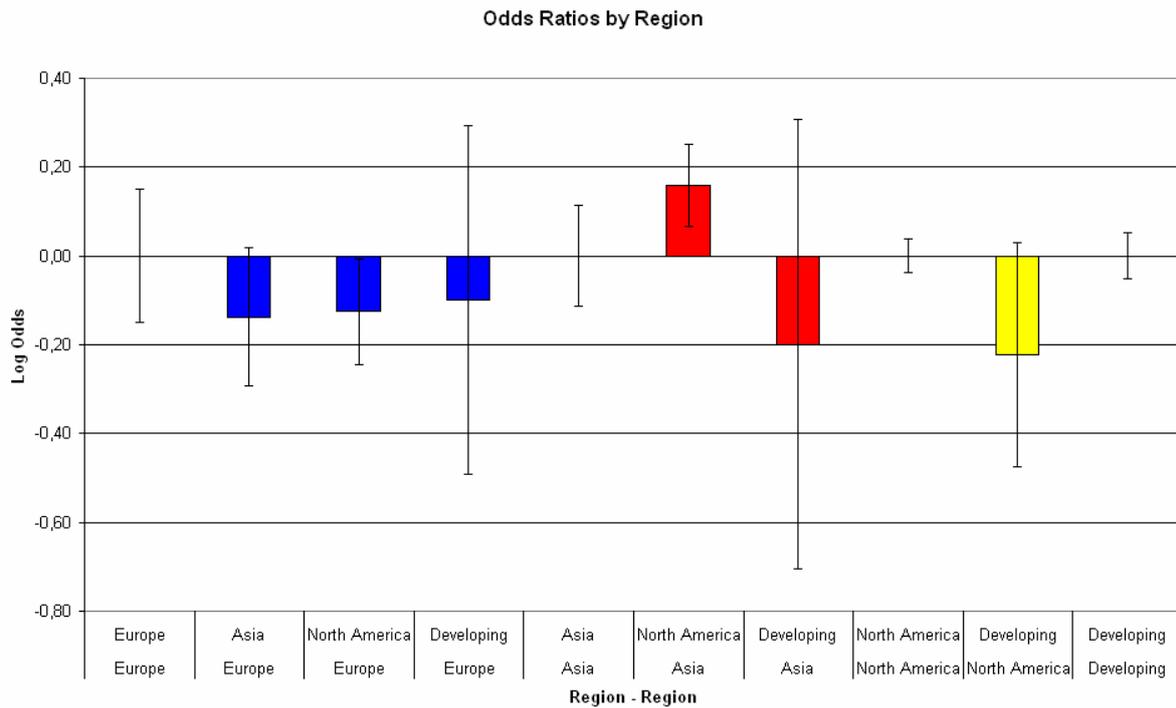
The high significance of the Chi² measurement suggests a high statistical dependence of the sector on sector alliances as well as the region on region alliances. It does however say nothing about the direction and trends in these interdependencies.

3.3 Preferences in Participation

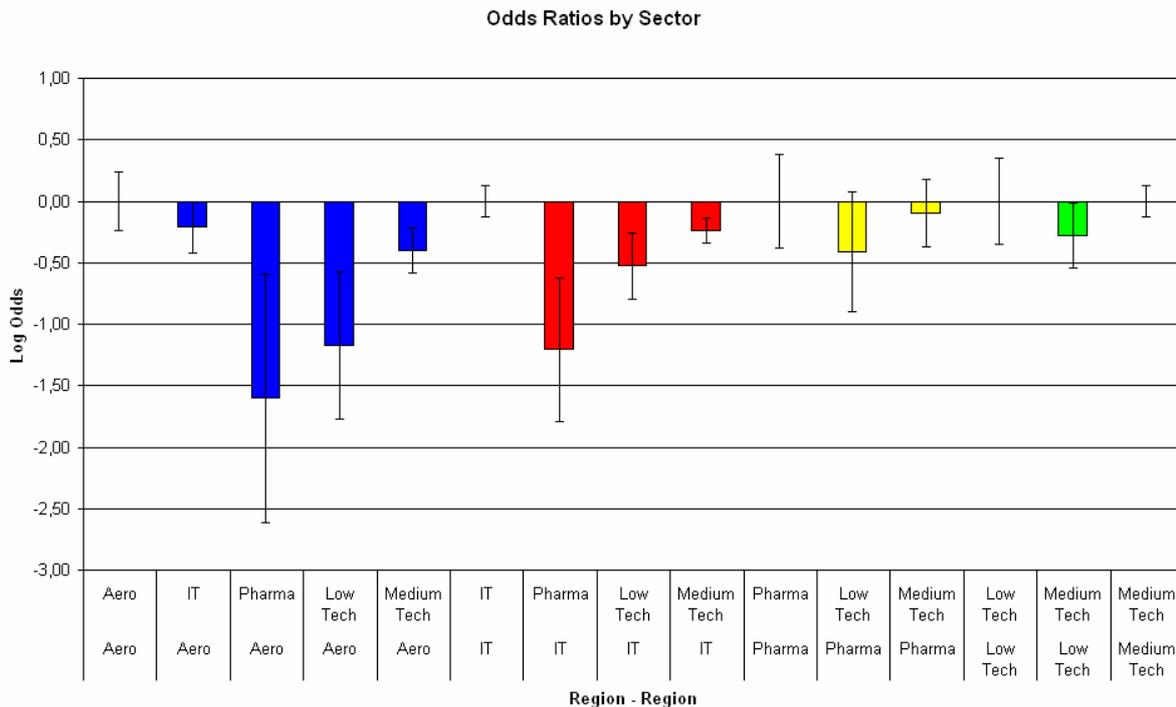
Our hypotheses suggests preferences in cooperation between firms, we suppose that firms operating in a low sector have a lesser tendency to cooperate and will, when they cooperate, participate more with firms from developing countries as opposed to firms in high tech sectors. A good measure to indicate the tendency to cooperate is via the usage of odds ratios. These ratios are often presented as the logarithm of the odds ratios; therefore all the odds ratios presented in this research follow this train of thought and are presented as such.

However since odds ratios require the maximum amount of possible partnerships between groups we first needed to find out the unique firms within our dataset. This is done because some, mainly large, firms form more then one partnership and are therefore sometimes two or more times present in our dataset. When looking at unique partnering opportunities we want to filter out the occurrences where firms are double or more times present, sector wise and region wise, within our dataset. Given these odds ratios we can determine the preference of intra region and sector cooperation opposed to inter-region and sector cooperation as displayed by the following graphs.

Graph 3.1 Odds Ratios for the different firm regions.



Graph 3.2 Odds Ratios for the different firm technology sectors.



Every Odds ratio is reported with its own error bar and is compared for significance with the respective intra-regional partnership. This also explains why there are no odds ratio reported for the relations between firms from Europe and Europe, Asia and Asia and so forth. The only significant, on a 0,05 level, find in this graph is the Asia – North America partner preference, which is surprisingly also the only positive preference as opposed to an overall tendency to stay within the known region when looking for possible partnering firms

When looking at the odds ratios for the intra-sector preference as opposed to inter-sector preference we once again see a strong negative tendency to participate in activities which are outside the sector in which the firms operate. Significant results, on a 0,05 level are found for the relations between Aeronautical Engineering and Low-tech, Aeronautical and Medium Tech, and all inter-IT partnerships with the exception of the Aeronautical – IT relation. These preferences however don't confirm or reject our hypotheses since they only give a two-dimensional view of inter-firm relationships; namely the sector on sector or region on region relation.

3.4 A four dimensional view on participation

Thus far we have only shown the preferences in participation from a two dimensional view, the sector on sector participation and the region on region participation. It is however our goal to show these trends in a single four dimensional model. To do this we first need to take a closer look at what the odds ratios showed, as stated before there seems to be a strong homogenous preference when participating. However, the odds ratios assume participation as a given factor. It is on the other hand highly likely that firms from different regions also have different budgets for participating and one the same note that firm from different technology sectors have different budgets. The latter is also one of the parts of the OECD classification for technology sectors as displayed in the literature review.

To show the willingness to participate we need to split the dataset into possible unique alliances and those which actually occurred and were recorded within the dataset. This greatly increases the respondents in our dataset which went from 2.632 to 2.149.620. This also shows that an inter firm alliance is somewhat of a rare occurrence given the huge amount of possibilities. The first model displayed below shows the firms' willingness to partake in such an alliance in which firms from low tech countries are set as a benchmark and represent the value 1, for technology sectors our benchmark is the medium tech sector which also has the value 1 as an index to measure the willingness of low and high tech firms to participate in

alliances as opposed to the medium tech firms. The second model also includes the willingness to form an alliance with a homogenous partner, sector wise or region wise. This is done to check for the strong homogenous preference found in the odds ratio graphs.

Table 3.4 Participation Willingness for sectors and regions n = 2.149.620.

	Model 1	Model 2
Europe Participation	2,009***	2,150***
Asia Participation	2,527***	2,825***
North America Participation	1,647***	1,919***
High Tech Participation	1,675***	1,571***
Low Tech Participation	0,841***	0,688***
In Region Participation	-	0,823***
In Sector Participation	-	0,757***
Constant	0,000***	0,000***

$\chi^2_{\text{Model 1}} = 367,58$ Sig-Model 1 = 0,000 $\chi^2_{\text{Model 2}} = 412,99$ Sig-Model 2 = 0,000

Results with *** are significant at a 0.05 level

What we can clearly read from both these models is the higher willingness of High Tech firms to cooperate. In the first model they are 1,675 times as likely to cooperate and although this effect is a little less in the second model, 1,571 times as likely, we still can see a great difference with their low tech counterparts who are respectively 0,841 and 0,688 times as likely to participate in a strategic alliance. This means that our first hypotheses about low and high tech firms with respect to their willingness to participate are confirmed. High tech firms are more willingly to participate and low tech firms are less willingly to do so.

Another factor which is clearly visible in both models is the strong willingness to participate in alliances from firms residing in developed countries, this effect gets even stronger in the second model and we clearly see a distinction between firms from those regions as opposed to firms from developing countries. This however does not confirm or reject any of our hypotheses about the willingness to participate in a R&D partnership with firms from developing countries.

Finally, in contrast with the results we gained from the odds ratios we see that there is a lesser tendency to cooperate in homogenous alliances, region based or sector based. This means that when we control for the willingness to participate, thus to form an alliance out of all the possibilities, instead of assuming participation the effect for homogeneity turns into a negative one. The fact that these values are smaller than the heterogeneous benchmark means that firms are more willingly to join a vertical, thus sector or region crossing alliance as opposed to a horizontal one. One explanation for this phenomena can be that firms want to strengthen their market position and therefore are less willingly to participate with a direct

competitor from either the same technology sector or region. By expanding vertically new markets become available whilst this may not be the case with horizontal participation.

As stated before we are also looking for the willingness to participate with firms from developing countries. By combining the willingness from firms from developing countries and the sector based willingness we get three variables, one for each tech sector, which describe the sectors willingness to participate in an alliance with said firms.

Our third model provides almost the same information as the first model with the exception for the fact that the benchmarks in our analysis are now changed to the North America region for region participation and the low tech sector for sector participation these variables represent the value 1 as a preference, other preferences are measured in the higher or lower preference as opposed to these reference categories. This was done to give a better, and more significant view of participation, the fourth model includes differential homogeneous predictors for the different sectors and regions instead of a general homogenous variable, the fifth and final model also contains predictors about cooperation with firms from developing countries.

Table 3.5 Differential Participation Willingness for sectors, regions and developing countries n = 2.149.620.

	Model 3	Model 4	Model 5
Europe Participation	1,219***	1,153***	1,153***
Asia Participation	1,534***	1,731***	1,730***
Developing Participation	0,607***	0,603***	2,912
High Tech Participation	1,993***	2,407***	2,462***
Medium Tech Participation	1,190***	1,377***	1,397***
In Europe Participation	-	1,234	1,234
In Asia Participation	-	0,723***	0,726***
In Developing Participation	-	0,000	0,000
In High Tech Participation	-	0,652***	0,646***
In Medium Tech Participation	-	0,833	0,833
High Tech - Developing	-	-	0,504
Medium Tech - Developing	-	-	0,207***
Constant	0,001***	0,001***	0,000***

Chi²_{Model 3} = 367,58 Sig._{Model 3} = 0,000 Chi²_{Model 4} = 413,93 Sig._{Model 4} = 0,000 Chi²_{Model 5} = 420,60 Sig._{Model 5} = 0,000
 Results with *** are significant at a 0.05 level

What emerges in the fourth model is that the differential participation for developing countries gives somewhat of an odd value, it is also highly insignificant, 0,994, we suspect that this is the result from having relatively few inter developing alliances. What we also see is that European firms, in comparison with Northern American ones, have a higher yet insignificant tendency to cooperate within their own region. Finally, we can also see that out

of the three technology sectors the low tech sector has the greatest preference for homogenous alliances. The High tech sector on the other hand has a stronger preference for heterogeneous alliances and is 0,652 times as willingly, or $1 / 0,652 = 1.53$ as unwillingly to cooperate homogenously compared to low tech firms.

In our fifth and final model we included the variables which display the tendency to cooperate with firms from developing countries. By setting cooperation for low tech firms as a benchmark, 1, we can clearly make the distinction with the high tech firms. We see that firms from high tech sector are 0,207 times as likely or $1/0.207 = 4.83$ times less likely to participate in alliances with firms from developing countries.

We can therefore safely conclude that it is more likely for low tech firms to participate more with developing countries and less likely for high tech firms and thus confirm our second hypotheses about low and high tech firms.

In summary we can say the following about our hypotheses:

Hypothesis 1: *Low tech firms cooperate less as a whole than high tech firms due to the lesser need for, joint, R & D programs* – Confirmed, low tech firms cooperate 0,841 times as often as medium tech firms which was used as a benchmark with value 1, in the same model the high tech firms cooperate 1,675 times as often as medium tech firms.

Hypothesis 2: *When cooperating internationally, the low tech sector has a higher tendency to cooperate with firms from non OECD countries as opposed to high tech firms* – Confirmed, in model 5 the cooperation between low tech firms and firms from developing countries was set as a benchmark with value 1. This model also showed that high tech firms are 0,207 times as likely to do so. So there is a clear distinction between non-OECD partnering between the two technology sectors.

Hypothesis 3: *Amongst high tech firms there is a higher degree of R & D partnerships than in the low tech sector.* – Confirmed, In our first model the medium tech sector was used as a benchmark with value 1, the high tech sector was however 1,675 times more inclined to participate. Whilst the low tech sector was 0,841 less inclined to do so.

Hypothesis 4: *There will be a lower degree of cooperation with internationally developing countries as compared to low tech firms* – Confirmed, our fifth model showed that high tech firms are 0.207 times as likely to partake in such an alliance whilst the low tech sector, which was used as a benchmark with value 1, showed almost 5 times as much willingness to collaborate with firms from developing countries.

With regards to our research question we can distinguish several patterns in R&D partnering. Whilst our odds ratios lead us to believe that there was a strong homogenous preference this effect was later refuted by our logistic regression models. When controlling for actual willingness to cooperate the pattern emerges that firms would rather look for a partner outside their own region or sector as opposed to a partner within. According to us the main reason behind this is that since R&D partnering is a strategic move it would make more sense for a firm to expand vertically, thus explore new markets then to share its knowledge with a direct competitor, region wise or sector wise.

Concerning the sectors we see that the high tech firms are more willing to cooperate than low tech firms, which is in accordance with the literature. We do however want to state that this pattern can also be contributed to the fact that high tech firms may have a bigger budget for R&D processes. It can therefore be assumed that these firms, given their possible larger budgets, will participate more in R&D alliances as opposed to low tech firms.

The difference in regions mainly displays a partition between firms from OECD and firms from non OECD countries. The firms based in the developed countries have a greater tendency to join a R&D partnership than the firms based in developing countries. It can be assumed that the OECD firms possess a larger budget, much like the high tech firms, than the non – OECD firms which would in a similar way lead to a higher degree of participation. We do however not possess data for the annual turnover of a firm, its size or the gross domestic product, GDP, of the nations. This is something which will be paid more attention to in the discussion.

4.1 Conclusion

In this study we have tried to find the preferences for firms to cooperate and engage in R&D partnerships based upon their respective regions of origin and the technology sectors in which they operate. Based upon the current literature we derived four hypotheses concerning participation of high and low tech firms in general and more specific with developing countries. We expected that high tech firms will cooperate more often in a R&D partnership and lesser with firms from developing countries, we also expected that low tech firms would behave opposite from low tech firms. Over the course of this research these hypotheses were developed from existing literature with respect to the, until then, existing trends.

After determining partner selection criteria by means of odds ratios a certain tendency for homogeneity was found. This was in accordance with the previous study done by Narula and Hagedoorn which suggests horizontal expansion as one of the determining factors in partnering, (Narula & Hagedoorn, 1999). This homogenous preference was however later enfeebled by our logistic models and when we controlled for the firms' willingness to participate we found that there is a greater tendency to cooperate heterogeneously.

Due to the fact that we used the OECD classifications for both technological sectors and regions of origin, this research fits quite nicely within the currently existing studies concerning R&D partnering. However, there has not been paid much attention to the medium technology sector within the dataset with the exception of using it as a reference category. This was done because the research done mainly focuses on the difference between high and low technology sectors.

By using logistic regression methods we were able to display a certain pattern in participation, selection criteria for firms are largely based on dissimilarity as opposed to a more homogeneous alliance. After these tests we derived the following results.

There is a strong tendency for high tech firms to cooperate as opposed to low and medium tech firms. This is in accordance with the literature which suggests that high tech firms compose about 80% of the total newly formed alliances, whilst this number is not entirely correct for our dataset we clearly see somewhat of a high tech dominance in participation preferences although this dominance is not carried over to the actual completed alliances. In other words, high tech firms are more willingly to participate but our dataset was not dominated by mainly high tech alliances.

Also, these high tech firms participate more often in developed, OECD, countries. This is once more in accordance with our expectations which suggest that there is a no gain principle for high tech firms and the current literature which supports our view on this behalf.

For the low tech sector we found that there is a lesser tendency to participate in R&D alliances and a higher tendency to engage in partnerships with firms from developing countries in comparison with high tech firms. Concluding, we found patterns for heterogeneous preferences in R&D partnerships, firms from more sophisticated, higher technology sectors are more willingly to join R&D partnerships and firms from OECD countries are also more inclined to partake in a strategic alliance.

4.2 Discussion

Do high tech firms or firms from developed countries cooperate more or is this a logical effect of the greater funds they have available for cooperation? This is one critical question we should ask ourselves, one could argue that high tech firms have a higher budget for cooperation and thus cooperate more often by default. The Thomson dataset gives no values for the firms' turnover rate or budget for R&D partnering so therefore we were not able to analyze this. We are however convinced that there should be strong evidence to assume that the high tech sector cooperates more by default, one recommendation for further research would also be to include financial variables for the firms, thus including amongst others the budget for R&D projects so it can become clear if there is a form of cooperation by default or a significant difference between regions and sectors based on choices and constraints.

Another thing is the under representation of developing countries and firms. We were however unaware of this complication when forming the hypothesis. Our first and foremost recommendation for further research on this notion is to expand the scope towards Developing countries and Low-Tech firms because even though the results aren't significant the direction of the odds-ratios suggested some truth in our hypothesis.

We could have expanded the low tech group sector by including more types of industry under this denominator, however after some debate and readjusting the groups for a second time we came to the conclusion that further expanding this group would lead to a variable representing the low tech sector whilst including a lot of medium tech industries. Moreover we were somewhat restricted by the OECD classifications for low tech firms. Therefore we concluded that it was better to continue with a smaller low tech sector than to

proceed with a variable which doesn't represent the very thing it was created for, namely firms from low tech sectors.

We were also unable to expand our set of developing countries, given the OECD definition of which countries are considered developed and the lack of countries which did not fall under this description we were forced to use a very small amount of alliances with firms from developing countries. We would also like to add that when reviewing and analyzing our dataset we came across no firms from Russia or China what so ever. This in our opinion disturbs the view of worldly inter-firm cooperation since we refuse to assume that the exclusion of those countries within our dataset actually means that firms from those countries don't engage in R&D partnerships. We therefore stress the need for further research upon this subject in that area not in the least part due to the strength of the economies.

As a final note we want point out that in this analysis we didn't provide for trends over the time span from 1990 – 2000. We did however show the willingness to cooperate based on regions and sectors. A note for further research would be to expand our findings over a longer time span so that a possible shift in preferences might be found.

Appendix A

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