R&D cooperation in a transaction cost perspective

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"R&D Cooperation in a Transaction Cost Perspective"

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Abstract:

R&D collaboration is a mode of governance of inter-firm relationships through non-market mechanisms. The objective of this paper is to present a theory-based empirical investigation of R&D co-operation. A framework is developed to analyse the odds of R&D cooperation between buyers and suppliers, drawing both on transaction cost theory and the resource-based theory of the firm. Several hypotheses are formulated and tested, using data from 689 industrial firms located in the Dutch region of North Brabant. In general, the results of logistic regression analyses support the assumptions of transaction cost theory. Frequent knowledge transfer and moderate and high levels of dependency ('asset specificity') increase the odds of R&D cooperation. In particular, Williamson's assumptions concerning the moderating influences of uncertainty on bilateral governance structure are confirmed. The extension of the original transaction cost model with several indicators derived from the resource-based theory of the firm appears to significantly increase the performance of the model.

Key words: R&D cooperation, transaction cost economics, logistic regression models

I. Introduction

Increased intensity of competition on markets for products and enhanced demands for high quality, fast delivery, and a high degree of customisation of products have brought about important changes in the way industries are organised. Particulary in the high-tech industries where a single company rarely has the full range of knowledge or expertise needed for timely and cost-effective product and process innovation, forging cooperative R&D links with external partners has become an important strategy. R&D collaboration enhance cost and risk reduction and provides access to knowledge and capabilities.

The advantages of these cooperations are compelling: it allows firms to share threshold costs in technology, realise economies of scope by improving utilisation of assets with different products, crack new markets, and control competitive forces. The following table classifies the most important motives for engaging in alliances as recognised in many studies e.g. Oerlemans (1996), Veugelers (1998), Nooteboom (1999).

Insert Table I: Motives for cooperation

The main goal of this paper is to present a theory-based empirical investigation of R&D cooperation. Focussing on the determinants of R&D cooperation, we use an adapted version of Williamson's transaction cost model (hereafter TCE) as our theoretical framework. This approach seems to be a productive point of departure for the theoretical and empirical analysis of inter-firm relations. After all, R&D alliances and R&D networks can be viewed upon as a specific way of coordinating innovative activity. In fact, as Williamson stated (1993: 122): 'the suggestion that network analysis is beyond the reach of transaction cost economics is too strong. For one thing, many of the network effects described by Miles and Snow correspond closely to the transaction cost treatment of the hybrid form of economic organization'.

TCE explains the use of these modes of coordination (governance structures) with dimensions of transactions as explanatory variables. This empirical study seeks to determine which specific dimensions of transactions between suppliers and buyers (frequency, asset specificity, and uncertainty) influence the propensity of buyers to cooperate with suppliers on R&D.

The remainder of this paper is divided in 5 sections. Section II reviews the way the core of research in industrial organisation handles R&D cooperation and positions the research presented in this paper. Section III deals with the key features of the transaction cost framework and the way in which technological innovation is dealt with in Williamson's framework. In Section IV, we develop our research model and put forward our research question, hypotheses, and measurements. Section V deals with the results of our analysis. The final section summarises and discusses the results of our analyses.

II. Main stream models in Industrial Organisation on R&D Cooperation

Main stream research of Industrial Organisation (hereafter IO) on R&D cooperation is mainly focussed at horizontal cooperation, i.e. between firms which are competitors in an output market. Most models make comparisons between modes of R&D cooperation and R&D competition. The following characterisation, introduced by Kamien, Muller and Zang (1992: 1295), is standard in literature:

- R&D cartelisation: firms coordinate their R&D activities so as to maximise the sum of overall profits.
- Research Joint Venture (RJV): firms share R&D findings. They may decide independently on R&D (RJV competition), but may also coordinate their R&D activities (R&D cartelisation).

Often two-stage models of investment behavior are used dealing with mutual impacts of R&D investments and output decisions through cost-reducing or demand-enhancing effects (Kamien et al. (1992), Vonortas (1994)). According to Veugelers (1998) the following model assumptions typically apply:

- R&D competition is of a non-tournament type. There are many ways to execute R&D. Competitors are not able to prevent others from getting comparable results with the same R&D effort. Uncertainty about the outcomes of R&D spending is neglected.
- R&D may be either process or product-oriented. Effective R&D focussed at production processes will result in the reduction of production costs. Successful product-oriented R&D results in the introduction of improved products of a higher quality.
- Cooperation is industry-wide. The firms involved in R&D alliances would otherwise compete in R&D. With whom and with how many firms alliances are formed is a question that is, most of the

times, not answered. Moreover, firms involved in alliances are symmetric, i.e. they have the same size or the same market power.

- Most mainstream IO models neglect institutional and organisational aspects of R&D cooperation. Frequently it is assumed that firms choose their R&D efforts jointly in order to maximise joint profits, other collective goals are disregarded.
- Moreover, it is possible that in each of these scenarios firms may extend their coordination to production. As Veugelers argues (1998: 424) this restriction to coordination is not trivial, because a number of other important motives for R&D cooperation cannot be included. Profiting from synergetic effects caused by the exploitation of asset complementarities is most of the times ignored in coordination models. This is a clear weakness of these models, since this is empirically one of the most important motives for R&D cooperation.
- The analysis of spillovers is central in most R&D models. This has, of course, to do with the appropriability of knowledge. In the case of spillovers, i.e. imperfect appropriability, parts of a firm's R&D results leaks out to rival firms, causing cost reductions or product innovations for these rivals. In most models, spillovers are modelled additively. But in some models, a firm has to invest in its own R&D, serving as absorptive capacity (Cohen and Levinthal, 1989), to profit from spillovers. In these cases, the R&D models are interactive and internal and external R&D are complementary.

Our paper adds to this stream of research and performs several functions. The review of the main stream IO research on R&D cooperation allows us to explain the function of this paper. Whereas IO literature concentrates on the competitive motives for entering in R&D cooperation among *horizontal* partners that compete on the output market, we analyse R&D cooperation between suppliers and buyers, i.e. between *vertical* partners. Studying relations between vertical partners implies that the competitive and profit-maximising motives are less important, while exploiting asset complementarities become more important.

The influence of uncertainty on the outcomes from R&D spending in cooperation is not studied often in conventional IO models. In this paper, percieved environmental uncertainty is included in the analysis as a moderating variable. This allows us to study the influence of uncertainty on the odds that buyers have R&D relationships with suppliers.

Whereas in most IO models firms involved in alliances are considered symmetric, this notion is at odds with the concept asset specificity. Since asset specificity builds on the assumption of differing resource bases of firms, symmetry of firms involved in R&D cooperation is the expection and not the rule.

As Veugelers stated, institutional and organisational aspects of R&D cooperation are largely ignored in main stream IO models. In this paper, R&D cooperation is considered as an institutional arrangement. Especially transaction cost theory deals with this issue. This theoretical framework is most of the times used to study the 'make' versus 'buy' decision. But as several authors contend (Tyler & Steensma, 1995; Grandori, 1997; Veugelers, 1998), it is also useful for the analysis of technological collaboration, i.e. of the 'make' versus 'cooperate' decision. Alliances in general, and R&D cooperation in particular, are viewed as so-called hybrid forms of organisation between hierarchy and market. Technological transactions in the marketplace can have high transaction costs. Internal R&D limits these costs, but block the access to specialised knowledge bases in other firms. Through cooperation firms can get access to these specialised knowledge bases, while at the same time allowing for the transfer of technology at lower transaction costs as compared to transactions through the marketplace. In sum, TCE stresses some organisational and institutional aspects of R&D cooperation.

III. The transaction cost framework and technological innovation

Alliances in general and R&D cooperation in particular bring about problems of coordination and mutual dependence (Nooteboom, 1999). These problems have been studied, in particular, in transaction cost economics (TCE), as developed mainly by Oliver Williamson (1981, 1988).

The most important behavioral assumptions of TCE are that rationality is bounded and that economic actors may behave opportunistic. Although economic actors intend to be rational, their capacity to do so is limited, due to uncertainty. As a result, closed contracts covering all eventualities are not possible. Opportunism is defined as 'self-interest seeking with guile'. According to Williamson (1975: 47) 'this includes but is scarcely limited to more blatant forms, such as lying, stealing and cheating'. Due to bounded rationality, it is often difficult to distinguish between firms that may behave opportunistically and and those likely to maintain a more cooperative stance.[1]

Williamson (1981, 552) defined a transaction as a 'transfer across a technologically separable interface'. A transaction is an event during processes of exchange, in which the transaction has a past and a future. In Williamson's view these processes of exchange are not free of charge: transaction costs develop.[2]

Transaction costs arise especially when actors become dependent upon each other due to costs of switching to a different partner. In particular, these arise when the transactions bring about specific investments, that are worth less or nothing outside the relation. These transaction specific investments exist at both user and producer and consist of four kinds of investments: 'site specificity', 'physical asset specificity', 'human asset specificity', and the so-called 'dedicated assets'.

The higher the transaction costs due to specific investments, the more reasons an actor has to integrate the activities within a single firm. Integration of activities is in this case a better way to cope with problems caused by opportunism and uncertainty. So, TCE predicts that there will be more integration to the extent that there are more investments of a transaction specific kind and uncertainty is higher. Integration, or 'unified governance' as Williamson calls it, can be achieved in several ways. Through sales of assets, an acquisition or merger, or through an equity joint venture.

But, a non-integrative, contractual agreement between different independent firms, a so-called bilateral form of governance, has some advantages over integration. Nooteboom (1999: 19) names amongst others: more high-powered incentives in separate firms that are responsible for their own survival; economies of scale and scope in production by specialised firms, and a greater flexibility in the configuration of complementary resources. These hybrid forms of organisation of transactions between market and hierarchy (alliances, partnerships and networks) have their disadvantages too. Separate actors have to deal with the risks of (asymmetric) dependence between partners and related problems of coordination and problems of involuntary spillover.

These lines of thought are also applied in Williamson's reflections on technological innovation (Williamson, 1985: 142-144). Compared to his initial explanations of the nature and formation of economic institutions (including frequency, uncertainty, and asset specificity), Williamson adds two new causal forces to this framework when he deals with the relation between technological innovation and the emergence of governance structures. On the one hand it regards the innovation potential of a good or service supplied, defined as its potential to realise cost savings for the buyer. On the other hand it regards the appropriability of cost savings. If cost savings are easy to recognise and imitate by other firms, they are generic and easy to appropriate by competitors. If cost savings can not be easily recognised and imitated, the buyer can appropriate the savings. Thus, Williamsons concept of appropriability is quite similar with the concept of spillover. Next, the forementioned two new causal factors are combined with 'asset specificity'. In this way, specific combinations of the three variables result in appropriate governance structures for organising innovative activity.[3]

IV. Towards a model for the empirical analysis of R&D cooperation in a transaction cost perspective

1. Research question

Tyler & Steensma (1995: 44) define technological collaboration as 'any activity where two or more partners contribute differential resources and technological know-how [knowledge and skills required to do something correctly] to agreed complementary aims'. This definition excludes one-way transfers of know-how such as licensing, marketing agreements, or simple one-time contracts. Rather, technological cooperation is an ongoing arrangement to which partners mutually contribute resources. It represents a range of inter-organisational modes of coordination. What these modes of coordination have in common in the case of R&D cooperation is the commitment of two or more firms to perform R&D cooperatively to develop technology. This will help them to keep pace with technological advances and to enhance their competitiveness.

R&D cooperation between buyers and suppliers is, following the TCE logic, considered as a form of 'relational contracting', or more specific as a form of 'bilateral governance'. After all, two independent actors (buyer and supplier) are involved in the R&D relation. On the one hand an important component of the transactions in the collaborations is the transfer of knowledge. On the other hand the transactions are given the object of cooperation, R&D and innovation, surrounded by moderate or high levels of uncertainty. Williamson (1985: 143) makes some interesting statements concerning this form of organisation of R&D: 'The tension is that while the buyer will want both to participate in the benefits of innovation and to encourage supply stage investments of an efficient (transaction specific) kind, the supplier's incentive to innovate [......] will be diminished if the supply stage is integrated. A complex trade-off situation is thus posed when the potential benefits are great and the transaction is characterised by substantial asset specificity'.[4] In sum, 'unified governance' is not applicable in this case because it kills the incentive to innovate and collaborate. Due to the substantial asset specificity involved, 'market governance' is not an efficient option either. Therefore, the most efficient form of organisation is the bilateral governance structure.[5]

Considering the above it is of interest to empirically examine to what degree the TCE framework can be used to analyse R&D cooperation. So our main research question is: *to what extent do asset specificity and frequency, under varying levels of uncertainty, influence the odds that buyers have R&D relationships with suppliers?*

2. Research model and hypotheses

Our research model is an application of the original transaction cost model using the dimensions of transactions as independent variables, complemented with some other variables that draw on the resource-based theory of the firm (see figure 1).

Insert figure 1: Determinants of R&D cooperation between buyers and suppliers

The dependent variable in our research model is R&D cooperation between buyers and suppliers. The choice for this type of R&D relations with suppliers is straightforward. To a large extent the statements in the TCE model refer to the view of buyers, especially if technological innovation is the theme considered. It is only consistent to take the same perspective in our empirical analyses.

Four independent variables are used: dependency, frequency, internal R&D activities, and the use of technology policy instruments. These variables enable us to hypothesise about the relations in our model.

The concept 'dependency' is used as a proxy of asset specificity. If transactions are characterised by substantial specific investments, actors feel a strong pressure to continue the exchange relation (Nooteboom, 1999: 19). Because of the duration and complexity of the relation, actors become dependent.

An important component of R&D cooperation is the exchange of information and knowledge aimed at the realisation of an innovation. Williamson's concept 'frequency' usually refers to the number of exchanges of goods. In our model the concept is 'translated' to the frequency of the transfer of knowledge between supplier and buyer.

So, our first hypothesis is in line with traditional transaction cost argumentation. High levels of frequency and dependency indicate high transaction costs. High transaction costs urge exchanging actors to use specific governance structures to minimise these costs. To secure an ongoing exchange of this kind, bilateral governance seems to be appropriate. High levels of specificity imply a strong dependency between buyer and supplier. They are locked in and switching costs are significant. Also in this case a specific governance mechanism is applicable. So, hypothesis 1 reads:

Hypothesis 1: Higher levels of frequency of knowledge transfer and higher levels of dependency increase the odds of R&D cooperation between buyers and suppliers.

Internal R&D activities and the use of technology policy instruments are added to the original transaction cost model. The main reason for this is that this model mainly refers to features of organisational activity (i.e. organising transactions) and neglects the resource bases needed for R&D cooperation. As stated in Section IV.1, technological collaboration is not only a mode of coordination stressing the organisational aspects of cooperation, but also an activity where resources and know-how are needed and developed.

In Section III, we discussed briefly Williamson's treatment of technological innovation. Several problems come to the fore if we want to apply the concept 'innovation potential' to the analysis of R&D cooperation. On the one hand the concept is only loosely coupled with the original transaction cost framework. It does not refer directly to the orgination or the level of transaction costs itself.[6] On the other hand, Williamson's view of innovation potential refers to the extent to which supplied goods or services have the potential to realise cost savings for the buyer. This definition of innovation potential requires two important presuppositions that are lacking in the TCE framework. First, the buyer must *recognise* the potential of cost saving of the good supplied. Second, the buyer must be capable to *utilise* this potential. Both recognition and utilisation require the presence of resource (esp. knowledge) bases in firms. The use of these resource bases enables firms to really benefit from the innovative potentials of the goods supplied.

Summarising, the features of transactions as distinguished in the TCE framework only give a partial explanation of R&D cooperation. In this paper, a more comprehensive understanding is achieved by extending the features of transactions with concept referring to the resource bases involved. The two additional variables used are: internal R&D activities and the use of (external) technology policy instruments.

As far as R&D activities are concerned we refer to an ongoing discussion about the relation between internal R&D and R&D cooperation. Some authors (e.g. Brouwer & Kleinknecht, 1996: 118) state there is a negative relation, indicating that R&D cooperation is a compensation for low levels of internal R&D. Others (e.g. Gemünden & Heydebreck, 1995; Mowery & Teece, 1996) disagree with this view and assume a positive relation. If a proper R&D effort is lacking in one of the partners involved, there is an increasing possibility of free rider behavior. In TCE terms, this is a matter of opportunistic behavior causing higher transaction costs. Moreover, an internal R&D effort is necessary to recognise and utilise the potentials of the external knowledge acquired (cfg. the 'absorptive capacity' argument of Cohen & Levinthal (1989)).

Relations between internal R&D activities and R&D cooperation are dealt with in hypothesis 2.a and 2.b. We distinguish two forms of internal R&D activities: R&D effort and the presence of a R&D department. Concerning R&D intensity, one may assume that R&D cooperation necessitates the presence of sufficient internal knowledge. So, in line with our argumentation in the previous section, hypothesis 2.a reads:

Hypothesis 2.a: Higher levels of R&D intensity of the buyer increase the odds of R&D cooperation between buyers and suppliers.

But a proper level of internal R&D effort is not sufficient. If the R&D activities performed are not well organised and identifiable, this hampers the functioning of the R&D cooperation. The presence of an R&D department is needed to structure internal R&D and to address problems emerging in the R&D relationship.

Hypothesis 2.b: The presence of an R&D department increases the odds of R&D cooperation between buyers and suppliers.

The second variable added, the use of technology policy instruments, refers to the obtainment of an external financial resource. Several Dutch and European technology policy instruments are used to stimulate R&D collaboration between firms using financial incentives and as such facilitate R&D activities in and between firms.

Hypothesis 3: The use of technology policy instruments increase the odds of R&D cooperation between buyers and suppliers.

Uncertainty, the third dimension in the TCE model, is included in our model as a moderating variable. It is indicated by the perceived environmental dynamics on the supply side of the firm. It concerns the perceived stability of economic relations with suppliers. Williamson (1985: 103) takes the view that bilateral governance structures, such as R&D alliances, are susceptible to uncertainty. Increasing levels of uncertainty cause exchanging parties to shift from bilateral governance to other, more efficient governance structures. Only if uncertainty is moderate, bilateral governance is thought to be a suitable mechanism to coordinate transactions.

If R&D cooperation between buyers and suppliers is indeed sensitive to uncertainty, this can have two consequences. On the one hand, the explanatory power of our estimations must be influenced by uncertainty. More specificly, the explanatory power should be the highest if uncertainty is moderate. High or low levels of uncertainty ought to be associated with lower levels of variance explained. On the other hand uncertainty ought to influence the power of the relations in our models. The influence of highs levels of frequency and dependency on R&D cooperation should be the strongest if uncertainty is moderate. Only under this condition, actors feel the strongest need to choose bilateral governance as an efficient mechanism to coordinate their R&D relations. Summarising, hypothesis 4 reads as follows:

Hypothesis 4: If uncertainty is moderate the explanatory power of the model is highest and the influence of frequency and dependency on the odds of R&D cooperation between buyers and suppliers is strongest.

The next section deals with the measurement of the variables used in the research model.

4. Measurement of the variables used in the analyses and sample

The variables used in the analyses are listed in Table II. The way most of these variables are measured is rather straightforward and needs no further explanation. There are a few exceptions. This regards the measurement of 'dependency', 'frequency', and 'uncertainty'.

Insert TABLE II: List of variables used in the analyses

The independent variable 'dependency' is a proxy of asset specificity. Buyers were asked to what extent they thought it was possible to replace existing relations with suppliers.[7] The more difficult it is to replace existing suppliers, the higher dependency is due to for example highly specific investments.

The independent variable 'frequency' refers to the frequency of information and knowledge transfer from supplier to buyer.[8] Examples of these transfers are technical assistance, and hints and suggestions for innovative use of these inputs. The variable is computed as the sum of the three items used, divided by three. A higher value of the variable stands for a higher frequency of the transfer of knowledge and information.

Our measurement of the moderating variable 'perceived environmental uncertainty' is based on Duncan (1972). According to his empirical research the variability and dynamics of environmental elements are good predictors of perceived environmental uncertainty. Because relations between buyers and suppliers are the subject of investigation, the perceived uncertainty concerns the input side of the firm. One the one hand, buyers were asked to indicate to what extent the composition of the group of their supplier of raw material, product parts and components, and machinery and tools has changed in the period 1987-1992.[9] On the other hand, buyers were asked how often they considered other suppliers than the one presently used.[10] The variable uncertainty is computed as the average of the 6 items involved.

Next, 'frequency', 'dependency', and 'uncertainty' are edited using a ranking procedure. In this way, 'dependency' and 'uncertainty' are divided into three percentiles, producing cases with low, moderate, and high levels of dependency or uncertainty. Frequency is ranked into two percentiles, producing cases with low or high frequencies of information and knowledge transfer.

Regarding the collection of data, a questionnaire was administered to industrial firms with five or more employees in the region of Noord-Brabant (a province in the southern part of the Netherlands). The data collection was done in a region with specific features. First, it is one of the most industrialised regions in the Netherlands. In 1993 the total number of jobs in manufacturing was roughly 210,000 (28.8% of total employment, 19.5% for The Netherlands). Second, at the time of the survey this sector faced a severe economic crises. Large firms such as DAF, Volvo (automotive), and Philips (electronics) had extreme losses that resulted in radical reorganisations and massive job loss. Of course the small and medium-sized firms, often suppliers of the larger firms, also suffered. In other words, there were strong environmental pressures, possibly influencing relations between firms. Moreover, the manufacturing sector has shown a relatively high performance in R&D and exports (Meeus & Oerlemans, 1995).

Insert TABLE III

Table III shows that the reponse is a reliable representation of the population of industrial firms in the region of Noord-Brabant. The maximum deviation between the percentages of the population sample and the response is in between 5%-point boundaries, except for the metal industry. The mean deviation between the percentage of the population sample and the percentage of responding firms is 2.6%.

V. Results

1. Introduction

The results of our analyses are presented as follows. First, a straightforward transaction cost model is tested using frequency, dependency, and uncertainty as variables influencing R&D cooperation between buyers and suppliers (subsection 2). Second, in the third and last subsection, we use logistic regression analyses to test the extended version of our model. This model not only includes the aforementioned variables but also variables that are indicators of the resource base of the firms.

2. R&D cooperation between buyers and suppliers: the 'simple' transaction cost model

In this first analysis, we divided firms up into six groups according to their score on the ranked variables 'frequency' and 'dependency'.[11] Next, for every combination of frequency and dependency, the percentage of buyers with R&D relations with suppliers was computed.

Insert TABLE IVa: Dependency and frequency: percentages of buyers with R&D relations with suppliers

On the basis of the information in Table IVa it can be seen that the higher frequency and dependency are, the higher the percentage of buyers with R&D cooperation with suppliers. Consequently, it can be concluded that hypothesis 1 is confirmed.

In Table IVa we did not control for perceived environmental uncertainty. To clarify this influence we used the ranked variable 'uncertainty', dividing firms into three levels of perceived environmental uncertainty (low, moderate, and high). Next, we computed the percentage of buyers with R&D relations with suppliers again. The results of these computations can be found in Tables IVb – IVd.

Insert TABLES IVb – IVd

From a comparison between Table IVb – Table IVd it can be deduced that R&D cooperation between buyers and suppliers is indeed the most frequent if the perceived level of uncertainty is moderate.[12]

As was mentioned before, Williamson assumes that the bilateral governance structure is vulnerable to uncertainty. This coordination mechanism is unstable if uncertainty rises. After all, if uncertainty rises R&D cooperation is less attractive because the related parties have even more problems taking all possible contingencies into account. This results in higher transaction costs and as a consequence bilateral governance is no longer the most efficient way to coordinate transactions. For our analyses, this means that the cell percentages in Table IVd should be systematically lower in comparison with the same percentages in Table IVc.

A comparison of the two Tables reveals that in three out of six cases the percentages in Table IVd are indeed lower than in Table IVc.[13] In the other three cases the relation is the other way around. Higher levels of uncertainty are associated with a higher percentage of buyers engaged in R&D relations with suppliers. On the basis of these descriptive statistics, one can draw the conclusion that hypothesis 4 is only partially confirmed.

3. R&D cooperation in a transaction cost perspective: an extended model

In Section IV we argued that the TCE perspective on R&D cooperation should be complemented by a resource-based perspective. In this section the inter-organisational features of R&D cooperation and variables describing the use of innovative resources in firms are combined in one model. In other words, the influence of R&D activities, the use of technology policy instruments, frequency, and dependency on R&D cooperation is estimated using multivariate logistic regression models.[14] In the estimations 9 independent variables are used, R&D intensity (RDI, logarithm), R&D department (RDD), the number of technology policy instruments used (TP), and variables indicating various combinations of frequency of knowledge transfer and dependency (GS(1) to GS(5)). The way in which this last variable were calculated, is described below. First, the six (2x3) possible combinations of frequency (high, low) and dependency (low, moderate, high) were constructed. Second, this variable was coded as a categorical variable using the new variable 'frequency low, dependency low' as the reference category or contrast variable.[15] This means that any statement about the effects of a particular category (GS(1) to GS(5)) was compared to this reference category.[16]

Several additional assumptions can be made with these variables. These can be viewed as an elaboration of hypothesis 1:

- Relations characterised by high frequency and moderate [GS(3)] or high dependency [GS(5)] are positively associated with the odds of R&D cooperation between buyers and suppliers.
- The remaining combinations [GS(1), GS(2), GS(4)] are negatively associated with the dependent variable.

The explanation of these assumptions is comparable with other reasoning in this paper. The use of specific governance structures depends on the size of transaction costs. The size of these costs is a result of specific combinations of frequency, dependency, and uncertainty. High transaction costs are caused by high frequencies and moderate or high levels of dependency. In these cases, the bilateral governance structure is efficient.

Four estimations were made. The first concerned all firms. In addition, three estimations were performed, i.e. cross-sections using levels of perceived uncertainty as a moderating variable. The results are of these analysis are in Table V.

All estimated models are statistically significant.[17] However, the percentages of variance explained are rather low.[18]

Insert Table V: Multiple logistic regression analysis....

In linear regression, the interpretation of the beta coefficient is straightforward. It shows the amount of change in the dependent variable for a one-unit change in the independent variable. The interpretation of coefficient in a logistic regression model is different. A logistic model can be written in terms of the odds of an event occurring. These odds are defined as the ratio of the probability that an event will occur against the probability it will not. In the table this is expressed by the Exp(B) coefficients.[19]

Looking at the estimation for all firms (column 1), hypothesis 1 appears to be confirmed. If the relations between buyers and suppliers are characterised by high levels of frequency of knowledge transfer and moderate or high levels of dependency, the odds of R&D cooperation increases. The strongest impact comes from GS(3) [high frequency, moderate dependency].

A more detailed inspection of the results leads to a further interesting finding. The contribution of high levels of frequency proves to be more important than that of dependency. After all, the combination of high frequency with every level of dependency leads to a statistically significant, and positive, result.

Adding variables indicating the use of resource bases to the original transaction cost model turned out to be useful. On the hand, the presence of an R&D department and the use of technology policy instruments are positively related to the odds of R&D cooperation between buyers and suppliers, although the influence of the latter is not strong. But on the other hand, the internal R&D effort has no effect at all on the odds of R&D cooperation. In sum, hypothesis 2.b and 3 are confirmed and hypothesis 2.a is not.

Perceived environmental uncertainty strongly moderates the relations in the model estimations (Table V, column 2-4). With the exception of the variable indicating the presence of an R&D department, different variables are included in the model if the level of environmental uncertainty changes. Furthermore, two interesting observations can be made. First, frequency of knowledge transfer seems to be more important than dependency.[20] Second, the model with a moderate level of environmental uncertainty is the best model in terms of variance explained as well as in terms of the number of variables included. This leads to a confirmation of hypothesis 4.

These findings are a confirmation of Williamson's assumptions concerning the influence of (moderate levels of) uncertainty on the use of bilateral governance mechanisms such as R&D cooperation. Moreover, the 'moderate' model also performs well in comparison with both other models in terms of the percentages of cases correctly classified. But this does not mean that we have powerful models. Both the variance explained and the percentages of cases correctly classified are too low.

Furthermore, the effects of high levels of frequency and moderate and high levels dependency have the expected positive influence on the odds of R&D cooperation. This means that these two dimensions of relations in the transaction cost framework indeed have the effects assumed.

VI. Conclusions and discussion

R&D cooperation is a specific opportunity for joining resources and acting pairwise for economic actors. The research question submitted in this paper examines factors that affect the occurrence of R&D cooperation between buyers and suppliers. To explain this kind of R&D cooperation we have drawn on transaction cost economics.

In general, our findings supported the behavioral assumptions of transaction cost economics. Both the influence of features of relations (frequency and dependency) between buyers and suppliers and the moderating influence of uncertainty were confirmed in our estimations. Moreover, our extension of the model with indicators of resources, with the exception of R&D effort, appeared to add to the performance of the estimations.

But the overall performance of the estimations was rather poor. Apparently, concepts provided by the transaction cost framework were not capable of giving a full explanation of R&D cooperation as a form of bilateral governance. Maybe there are some limitations of transaction cost economics with regard to the analysis of technological cooperation. As Yamin (1996: 166) points out technological cooperation not only has to do with exploiting already existing capabilities but also with creating capabilities. With regard to the latter, transaction cost economics does not seem to pay sufficient attention to the organisational requirements of collaborative learning as such. The main problem is that these arrangements do not have known or stable transactional characteristics, which can lead to asymmetric learning. This is especially the case if the cooperation is aimed at the development of new knowledge and capabilities. According to Yamin, this situation has no obvious governance solution.

Another limitation has to do with one of the basic assumptions of TCE. It assumes that the various governance structures are feasible alternatives for organising any transaction. Especially if technological collaboration is concerned, it is not obvious at all that there is as much organisational choice as TCE assumes. As Oerlemans showed (1996: 367) technological cooperation is not entirely an act of free will of innovating firms, due to the complexities of technologies and of the innovation process. Through technological cooperation innovating firms are able to obtain necessary resources and produce technological knowledge externally, they lack internally.

Of course, the poor performance of the model estimations can be caused by the way we measured the concepts in our research model. The use of proxies for asset specificity and frequency is possibly somewhat problematic. In the TCE model these concepts are defined at the level of the transaction, whereas in our model their proxies are measured at the level of the interaction between buyers and suppliers. This may cause some distortions in our estimations. Because TCE does not specify the difference between transaction and interaction, it was not possible to derive theoretical arguments to match methods of measurement and units of analysis from Williamson's framework. By raising these issues we add to the discussion of the definition and measurement of transactions.

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Figure 1: Conceptual model; determinants of R&D co-operation between buyers and suppliers

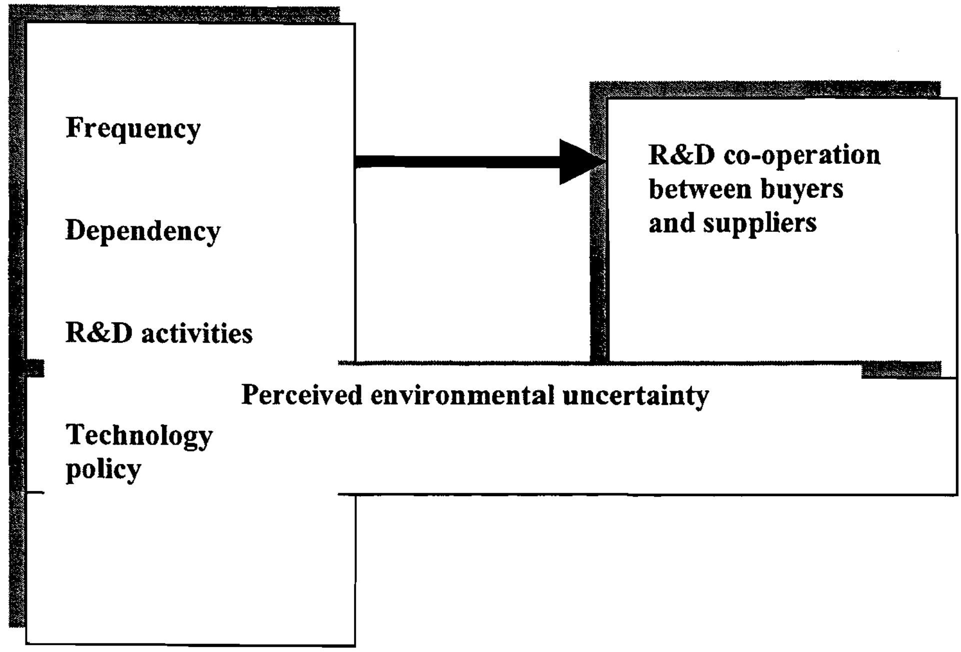

Table I: Motives for allying

- Sharing of costs/risks
- Access to partner's know-how/markets/products
- Efficiency enhancements
  •economies of scale in production/distribution/R&D
  •synergy effects from exchanging/sharing complementary know-how
- Competitive considerations
  •monitor/control partner's technology/markets/products
  •influence other alliance activities (pre-emption, followers)
  •influence competitive structure
- Governement policy (industrial, trade and competition policy)
  •e.g. subsidies for cooperation, local content, anti-trust

TABLE II: List of variables used in the analyses

Variables	Indicators
R&D co-operation with suppliers	R&D co-operation with suppliers (dummy; 1 = yes, 0 = no)
Dependency	Dependence on suppliers of raw materials, components, machines and tools
Frequency	The extent to what supplies of raw materials, components, machines and tools are accompanied by knowledge transfer
R&D intensity (RDI)	Percentage of the total workforce dedicated to R&D activities
R&D department (RDD)	Presence of a R&D department (dummy; 1 = yes; 0 = no)
Use of technology policy instruments (TP)	Number of instruments used (min = 0; max. = 6)
Uncertainty	Perceived environmental uncertainty regarding suppliers

TABLE III: Population sample and response for sectors

Industrial sector	Absolute number population sample	Percentage of the population sample	Percentage responding firms (N = 689)
Food	311	8.9%	6.5%
Textile/leather	370	10.6%	7.5%
Wood/furniture	480	13.7%	12.7%
Paper/printing	323	9.3%	5.3%
Chemicals	227	6.5%	8.1%
Metal manufacturing	1,266	36.3%	43.6%
Other industries	514	14.7%	16.1%
Total	3,491	100.0%	100.0%

TABLE IVa: Dependency and frequency: Percentage of buyers with R&D co-operation with suppliers

		Level of dependency		
		Low	Moderate	High
Frequency Knowledge Transfer	Low	22.1%	20.3%	22.9%
	High	27.5%	37.7%	38.5%

TABLE IVb: Percentage of buyers with R&D co-operation with suppliers: frequency, dependency and low levels of perceived environmental uncertainty

		Level of dependency		
		Low	Mixed	High
Frequency Knowledge Transfer	Low	15.0%	10.0%	19.0%
	High	0.0%	27.8%	40.0%

TABLE IVc: Percentage of buyers with R&D co-operation with suppliers: frequency of knowledge transfer, dependency and medium levels of perceived environmental uncertainty

		Level of dependency		
		Low	Mixed	High
Frequency Knowledge Transfer	Low	21.7%	27.8%	17.6%
	High	26.3%	53.6%	56.5%

TABLE IVd: Percentage of buyers with R&D co-operation with suppliers: frequency of knowledge transfer, dependency and high levels of perceived environmental uncertainty

		Level of dependency		
			Mixed	High
Frequency Knowledge Transfer	Low	29.2%	23.8%	33.3%
	High	41.7%	29.0%	24.0%

TABLE V: Multiple logistic regression analyses with R&D co-operation between buyers and suppliers as the dependent variable and the factors influencing R&D co-operation between buyers and suppliers as independent variables conditioned by low, medium and high levels of perceived environmental uncertainty

Independent Variables	Total Response	Level of perceived environmental uncertainty		
	(1)	Low (2)	Moderate (3)	High (4)
Constant	-1.98 (0,000)	-1.77 (0.000)	-2.35 (0.000)	-1.06 (0.036)
RDI	0.98 (0.106)	0.51 (0.475)	0.97 (0.325)	0.08 (0.774)
RDD	2.49 (0.000)	3.48 (0.001)	1.95 (0.076)	2.18 (0.031)
TP	1.40 (0.010)	0.45 (0.504)	2.01 (0.008)	1.24 (0.265)
GS (1)	2.06 (0.062)	4.71 (0.030)	1.99 (0.289)	0.99 (0.989)
GS (2)	1.26 (0.480)	0.11 (0.745)	1.35 (0.667)	0.75 (0.664)
GS (3)	3.90 (0.000)	0.89 (0.345)	6.68 (0.000)	3.14 (0.205)
GS (4)	1.09 (0.797)	1.34 (0.248)	1.22 (0.781)	0.84 (0.797)
GS (5)	1.80 (0.037)	2.16 (0.141)	4.26 (0.004)	0.44 (0.190)
-2LL	685.796	199.372	211.785	191.275
Model Chi^2	70.237	10.138	45.835	14.256
Significance Chi^2	0.0000	0.0015	0.0000	0.0269
R_L^2	9.3%	4.8%	17.8%	6.9%
Goodness of fit	669.222	215.000	198.777	168.666
% correct overall	76.4%	80.9%	74.9%	73.1%
% correct (1)	20.0%	0.0%	40.0%	19.6%
% correct (0)	95.8%	100.0%	90.9%	96.6%
n	589	215	207	167

RDI = R&D intensity; RDD = R&D department; TP = use of technology policy instruments; GS (1) = relations with high frequency and low dependency; GS(2) = relations with low frequency and moderate dependency; GS(3) = relations with high frequency and moderate dependency; GS(4) = relations with low frequency and high dependency; GS(5) = relations with high frequency and high dependency.

Notes

[1] It is important to note that Williamson does not state that all actors are opportunistic in the same way. The problem is that an actor entering the exchange process does not know in advance which actor is acting honestly and which is not.

[2] Nooteboom (1999: 17) distinguished three stages in this process of exchange, each of them causing specific transaction costs. Before the arrangement of a contract arises, one must find a transaction partner. This brings about search costs on the part of the buyer and marketing costs on the part of the supplier. In the contract stage there are costs of preparing and concluding a contract or other type of agreement. In the control stage there are costs of monitoring the execution of the agreement, problem solving, renegotiation and adjustment of the contract or agreement.

[3] For example, if cost savings are generic, innovation potential and asset specificity are low, market governance is the most applicable governance structure. However, if transactions are characterised by substantial asset specificity, innovation potential is high, and cost savings are not generic, the hybrid governance mechanisms are suitable.

[4] Williamson illustrates his argument with an example (1985: 159). A manufacturer of peripherals cooperates with a produces of software in developing a graphical application. Instead of taking over the software producer (integration) the manufacturer decides on a co-makership (bilateral governance), even taking a share of the necessary investments.

[5] Of course, one must assume that the transactions are frequent. If transactions were not frequented 'trilateral governance' would be the most efficient way to organise.

[6] Innovation potential only concerns properties of a good or service and appropriability has to do with the ease in which knowledge embodied in the supplied goods can or can not be imitated. Moreover, formerly considered important concepts such as frequency and uncertainty are absent in Williamson's discussion of technological innovation.

[7] Answers ranged from (1) easy, (2) not easy/not difficult, to (3) difficult. Three groups of suppliers were distinguished: (1) suppliers of raw materials, (2) suppliers of product parts and components, (3) suppliers of machinery and tools.

[8] Buyers were asked to indicate the frequency of the transfer of information and knowledge accompanying supplies of (1) raw materials, (2) product parts and components, (3) machinery and tools. Answers: (1) never, (2) sometimes, (3) regular, (4) often, (5) always.

[9] Answers: (1) no change, (2) a little change, (3) much change.

[10] Answers: (1) sometimes, (2) regularly, (3) often.

[11] As was stated before frequency was ranked into two percentiles and dependency into three. A combination is these two ranked variables leads to six categories: (1) frequency low, dependency low, (2) frequency low, dependency moderate, (3) frequency low, dependency high, (4) frequency high, dependency low, (5) frequency high, dependency moderate, and (6) frequency high, dependency high.

[12] As one can see in Table IVb, the combination of high frequency and moderate or high levels of dependency results in a percentage of buyers with R&D cooperation with suppliers of 27.8% and 40.0%. These percentages increase up to 53.6% and 56.5% under the condition of moderate perceived uncertainty (Table IVc). They decrease to 29.0% and 24.0% if perceived uncertainty is high (Table IVd).

[13] This is the case if: (1) low levels of frequency are combined with moderate levels of dependency. The percentage of buyers with R&D relations with suppliers decreases from 27.8% (uncertainty is moderate) to 23.8% (uncertainty is high), (2) High frequency is combined with moderate levels of dependency (uncertainty moderate = 53.6%, uncertainty high = 29.0%), (3) High frequency is combined with high levels of dependency (uncertainty moderate = 56.5%, uncertainty high = 24.0%).

[14] The goals of logistic regression analysis are (1) to develop a model that summarises the relationship between a dichotomous dependent variable and a set of independent variables, (2) to determine which independent variables are useful for prediction, (3) to predict the value for the dependent variable from the values of the independent variables.

[15] So the variable GS(1) denotes the combination 'frequency high, dependency low', GS(2) = 'frequency low, dependency moderate', GS(3) = 'frequency high, dependency moderate', GS (4) = 'frequency low, dependency high', and GS(5) = 'frequency high, dependency high'.

[16] For example, if one has a variable that represents the combination 'high frequency, high dependency'[GS(5)], one can only make statements such as 'the combination of high frequency and high dependency compared to the combination low frequency and low dependency increases the chance of R&D cooperation with suppliers'.

[17] There are various ways to assess whether or not the model fits the data. First, one can use the model chi-square. It tests the null hypothesis that the coefficients for all the terms in the current model,

except the constant, are 0. This is comparable with the overall F-test for regression. If the significance levels is < 0.05, this null hypothesis is rejected. Second, one can use the goodness-of-fit statistic. It compares observed probabilities to those predicted by the model. If the observed significance level is large, one does not reject the hypothesis that the model fits the data.

[18] The values of R_L square is calculated as the model chi-square divided by the sum of the model chi-square and –2LL. This indicator is comparable with R square in linear regression analysis. If R_L is 0, the independent variables have no predictive value. If R_L equals 1, the independent variables are perfect predictors.

[19] If the Exp(B) value of a variable is > 1, this means that the odds of R&D cooperation between buyers and suppliers are increased. If Exp(B) < 1, the odds are decreased. A value of 1 leaves the odds unchanged. For example, one can look at the Exp(B) value of RDD (R&D department) in the second column of the table. When RDD changes from 0 to 1, the odds are increased by a factor of 2.49. So, if buyers have an R&D department, the odds of R&D cooperation with suppliers are increased. The level of significance (0.0000) of this coefficient is between brackets.

[20] In Table V, column 2, low level of uncertainty, GS(1) is statistically significant. GS(1) is a combination of high frequency and low dependency. In column 3, moderate level of uncertainty, GS(3), i.e. high frequency and moderate dependency, and GS(5), i.e. high frequency and dependency, have significant coefficients.

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