CHAPTER 14

THE EFFECT OF STRATEGIC TECHNOLOGY ALLIANCES ON COMPANY PERFORMANCE: A LISREL APPROACH

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Abstract

The paper examines the effects of strategic technology alliances on corporate performance. In using a LISREL-model the following five different (groups of) factors were specified to analyze these effects: sectoral features, national circumstances, company structure, innovativeness and external linkages. The paper explaines the theoretical and statistical reasons why a particular LISREL-model was chosen to analyze effects of strategic technology alliances on corporate performance instead of applying other multivariate techniques. It describes the application of a particular LISREL approach, a structural equation model with observed variables. It concludes that there apparently is no straightforward relationship between strategic technology partnering and company performance. However, the application of LISREL models certainly did improve the general understanding of the effects of strategic technology alliances beyond more traditional statistical approaches.

Introduction

The LISREL model used in this study is part of a set of powerful multivariate data techniques called structural equation modeling (SEM) that have emerged in social science research during the last two decades. The origins can be traced back to the first half of the century, when Spearman developed factor analysis and Wright introduced path analysis. Based on the works by Karl Jöreskog and associates in the 1970s, SEM techniques became available to a wider social and behavioural research community (Mueller 1996, Long 1994a, 1994b). Before LISREL models actually have been adopted in economics and management science, they were extensively tested in political science, psychology and sociology. It took some time and a growing dissatisfaction with more traditional statistical techniques until economists and business analysists also acknowledged their usefulness in these disciplines.

M. Ghertman et al. (eds.), Statistical Models for Strategic Management, 309–329.

In the following analysis instead of more 'traditional' multivariate techniques a LISREL-model was used in order to examine the effects of strategic technology alliances on corporate performance. As discussed below, a general problem in applying regression equations to explain profitability has been, traditionally, the low, but not necessarily insignificant, proportion of explained variance (R^2) and the low number of relevant variables that are specified. Moreover, these approaches did not take into account that the causality between performance and co-operative activity or any other measure of external linkages may run in both directions. Other problems of using regression techniques in this context are related to their well-known potential to create difficulties in assessing the significance of the effect parameters and the model as a whole or to reduce the significance of the estimated relationship.

In developing a general theoretical model on these effects Section 1 gives an outline about the different variables and describes the proposed relationships among them. In order to characterize the general theoretical model a path diagram exhibits the proposed effects and summarises them in an effect matrix. The theoretical and statistical reasons for choosing a LISREL-model to analyse effects of strategic technology alliances on corporate performance instead of applying other multivariate techniques are explained. The description of the LISREL approach and its application to our theoretical model is the main focus in Section 2. In the final part of the paper, the results of the LISREL analysis are related to previous research in the area and some conclusions with respect to the usefulness of LISREL approaches to examine the phenomenon of strategic alliances, its causes and indirect effects are drawn.

1. The expected effects on company performance

In order to examine the relationship between profitability and co-operative activity five different (groups of) factors were specified in the following way:

Sectorial features. The industrial sectors examined were information technologies and electronics (*IT*), mechanical engineering (*ME*) and process industries (*PI*). For the *IT* sector firms have at least one business activity in the following industries: microelectronics, computers, industrial automation, telecommunications, instrumentation, consumer electronics and heavy electrical equipment; for *ME* in automotive, aviation, and defence industries; and for *PI* in oil and (petro)chemicals, chemicals, pharmaceuticals, and food and beverages.

National circumstances. The factor (*TRIAD)* focused on the analysis of companies in the so-called Triad countries (Europe, USA, Japan) (Ohmae, 1985). Companies based in the European Union and EFTA were regarded as European firms

Company structure The variable (*SIZE)* was constructed by using two indicators: average worldwide employment and company average turnover. In order to adjust both indicators logarithms were taken to correct for potential disturbing influences of a small number of extremely large companies. The factor analysis defined the principal factor accounting for the greatest part of the covariance of the indicators. The factor-scores of the companies on the principal factor were used to arrive at the variable *Size*.

Innovativeness. This factor was assessed by the indicator patent intensity (*PATINT*) of a firm, i.e. the total number of assigned US patents set against the firm's average turnover. In the literature, the use of this indicator is widely accepted (Patel and Pavitt 1991).

External linkages. Three indicators were used to define this phenomenon: Firstly, the intensity or the weight of strategic partnering *(WSPART); s*econdly, a technology-to-market ratio (*T/M*), and thirdly, a generation to attraction ratio (*G/A)*. The indicator *WSPART* was defined by the natural logarithm of the ratio between the firm's total number of strategic linkages (dyads), set against the natural logarithm of average turnover. A dyad (A-B) is considered as an alliance between two partners (A and B); a project with three partners, called A, B and C, results in three different dyads (A-B, A-C, and B-C), etcetera. A technology-to-market ratio (*T/M*) defined the contents of a strategic link. It was defined as the logarithm of the ratio between the firm's total number of prevailing R&D inclined strategic linkages to its total number of predominantly 'market'-related strategic linkages. A neutral score of zero indicated an equal weight for the technology and the market aspects of strategic cooperation. A positive value marked an inclination towards 'pure' technology cooperation; negative scores indicated a dominance of motives primarily related to market access. The generation to attraction ratio *(G/A)* was specified to identify within the directed links of firms 'generators', i.e. firms suppling technology. Directed links are strategic equity investments, strategic second-sourcing arrangements and research contracts. They are distinguished from 'attractors', i.e. firms that award contract research, make equity investments, or join technological developments started by others. Other strategic alliances having unidirectional technology flows are for instance joint ventures with OEM contracts, or the joint improvement of technology that one partner has originally developed. The *G/A* indicator was defined as the logarithm of the ratio between the total number of 'generative' strategic linkages and the firm's total number of 'absorptive' or 'attractive' linkages.

Economic performance This factor was represented by the average net income to sales ratio or profit rate (*PR*). Certain drawbacks characterize this indicator, in particular it is sensitive to the degree of vertical integration or sectoral differences (Davis and Kay 1990; Ansoff and McDonnell 1990). As the sample included just manufacturing companies and controls for industry differences these shortcomings are substantially meet.

According to the theoretical constructs underlying these variables first different models with more 'traditional' statistical techniques were tested before a decision was taken to use a LISREL model. The basic logic of the relevant relationships of the LISREL model is found in a path model that places strategic technology alliances, i.e. external linkages of firms, in a wider set of interrelated factors (Hagedoorn and

Schakenraad, 1994). The path diagram in Figure 1 presents the general explanatory framework. An arrow indicates an assumed direct effect of one factor on another.

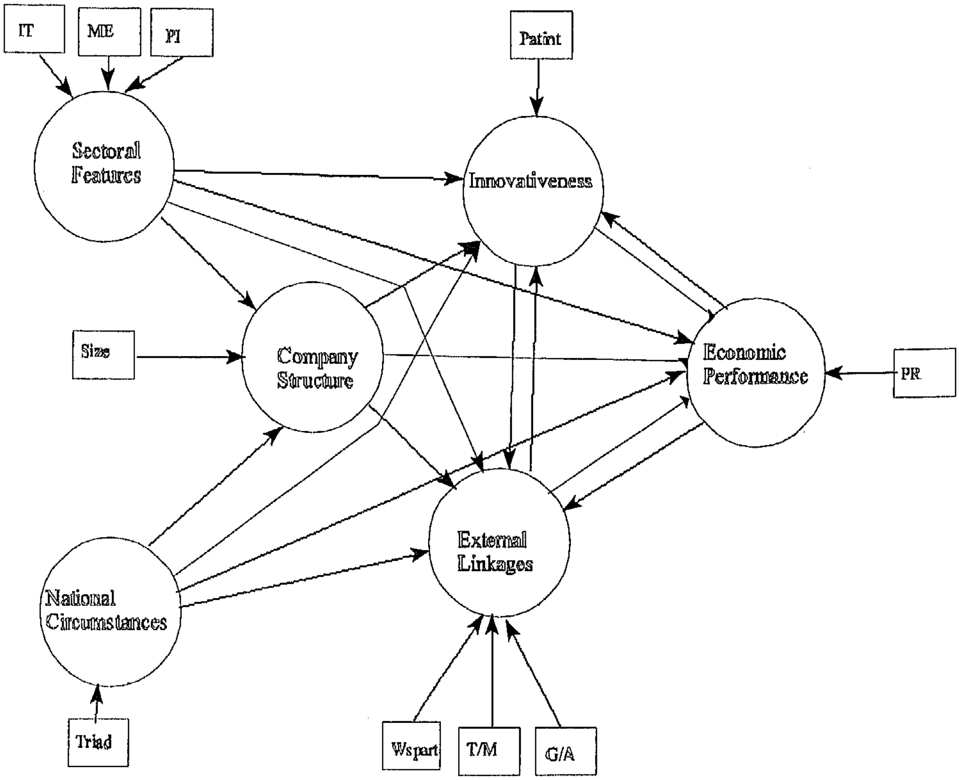

Figure 1. General outline of a path diagram for explanation of economic performance

In order to specify specification of cause and effect variables the interrelations of all variables in the model need some clarification about their strength and direction. In the effect matrix the expected direct effects of a number of variables on each other are indicated. The anticipated effects that were mentioned are due to either logical association, established knowledge in the literature, chronological consistency, or a combination of these. The path diagram in Figure 1 depicts a possible structure among five basic (groups of) factors that might effect the economic performance of companies. The expected effects of these different (groups of) factors are summarized in Table 1.

Table 1 Effect matrix of LISREL-model on strategic partnering

variables as effect	variables as cause							
	SECTOR	TRIAD	SIZE	PATINT	WSPART	G/A	T/M	PR
SIZE	?	?	*****	[]	[]	[]	[]	[]
PATINT	1	1	1	*****	0	[]	[]	0
WSPART	1	1	1	1	*****	[]	[]	0
G/A	?	?	1	?	1	*****	[]	[]
T/M	?	?	?	?	?	?	*****	[]
PR	1	1	0	1	1	?	?	*****

Legend:

SECTOR = dummy variables for IT/electronics, mechanical engineering, and process industries
TRIAD = dummy variables for European, American, and Japanese corporations
SIZE = size of company
PATINT = total number of assigned US patents, 1982-1986, set against average turnover 1982-1986
WSPART = weighted number of strategic linkages, 1980-1987
G/A = generation to attraction ratio, 1980-1987
T/M = technology to market ratio, 1980-1987
PR = average share of net income in total sales, 1984-1988

0 = no direct effect assumed
1 = direct effect hypothesized
? = direct effect open to question
[] = effect not explored

Sectoral features. It is assumed that the intensity of strategic partnering certainly is influenced by sectoral features. Previous research has shown that the number of strategic technology alliances does not follow an even distribution across technological fields. In addition, industries have been characterized by differences in profitability and patent intensity. Recent studies looking at the relationship between market structure and innovation have shown that technological opportunities differ across industries and explain to a large extent variations in innovative performance (Cohen and Levin 1989, Hagedoorn 1989).

National circumstances. In the literature it is proposed that there are differences in patenting behaviour according to country of origin and association with a certain 'Triad' block. For Japanese companies, for example, the growing technological competence has been indirectly measured by the rising number of assigned US patents. The literature on strategic partnering has increasingly stressed the importance of the 'Triad' in order to explain the co-operative behaviour between companies within blocks but also between blocks of the Triad (Ohmae, 1985). Across these blocks the distribution of alliances has, however, been assumed to be uneven.

For European, American, and Japanese companies, in addition, it has been assumed that there are differences in the profit rates. Relative lower rates of profits have been expected with Japanese companies in contrast to for instance US firms. These differences have frequently been explained using reasoning with respect to currency issues, Japanese attitudes with respect to dividends and profits, their preoccupation with growth strategies, the almost absence of a highly profitable pharmaceuticals industry in Japan and the short-run profit maximizing behaviour of US firms.

The effects of size of the firm on innovation and patent intensity, cooperation and profitability. It was expected that the intensity of strategic partnering is directly effected by size. The literature apparently confirmed the existence of a positive relationship between joint venture participation and size (Berg et al. 1982). For example, the concept of economies of scope has been used to explain this relationship, i.e. with scope technological opportunities are increasing and external linkages are fostered. Moreover, large firms might also serve as an attractive or even indispensable partner in an alliance. Small high-tech firms, in contrast, could also possess desirable characteristics as a partner. Thus, for some sectors a J-shaped distribution between size and strategic partnering has been expected (Hagedoorn and Schakenraad 1990a).

Furthermore, a direct impact of company size on innovation has been assumed. This effect has been further specified. According to the classical Schumpeterian and Galbraithian theory it has been postulated that with size of the firm research output (patent-intensity) increases more than proportionally. Bain (1956) stated, in contrast, that small companies are more innovation-efficient than larger firms due to 'creative backwardness' of the latter. Other authors (Freeman 1982) proposed that industry-specifics matter and postulated a positive relationship between size and innovation in R&D intensive industries and/or industries where economies of scale are decisive such as in the pharmaceutical, aerospace or vehicles sector. In the literature, the proposition held by Scherer (1965) seems widely accepted that once a threshold has passed both R&D input and output (patents) tend to rise less than proportionally. According to his view, the distribution of size and innovation followed an 'inverted U-shaped' curve. With the exception of the chemical industry where a linear relationship has been found, empirical studies undertaken by Mansfield (1984), Philips (1971), Mueller (1986) found ample support for the non-linearity of the relationship between R&D input and output. Later research by Scherer (1984) suggested that there are diminishing returns in the relation between firm size and patent-activity.

In recent years authors began to stress the relevance of technological opportunities as an intermediary factor (Kamien and Schwartz 1981, Cohen and Levin 1989). The dynamics in the relation between innovation, market structure and size of firms were emphasized by Dosi (1984). He suggested that innovativeness is positively related to technological opportunities in the industry as well as firms size. Market concentration, in contrast, has been negatively related to technological opportunity but positively to past innovativeness. In addition, the relationship between size of firms and innovation apparently has been considered to be dependent on the inter-sectoral pattern of technological opportunities. In analysing these pattern Pavitt et al. (1987) confirmed the U-shaped relation between size and innovation but found considerable variation among sectors.

Despite a decreasing propensity to patent with increasing firm size (Schmookler 1966, Pavitt et al. 1987, Soete 1979) a direct effect of the size of companies on their patent intensity has been assumed.

Despite some evidence in the literature (Berg et al. 1982) a direct effect of firm size on profitability of companies has not been anticipated. In general, it seems, however, that such direct relationship between both variables does not exist (Schmalensee 1989, Devine et al. 1986, Hay and Morris 1979).

The effect of patenting on cooperation and profitability. Innovative firms have been assumed to be attractive partners for strategic partnering. A positive effect of patent intensity of companies has therefore been expected on the intensity of strategic alliances of companies in the years 1980-1987. In addition, patent intensity in the years 1982-1986 should positively effect the intensity of strategic alliances from 1980-1987 because most alliances have been formed since 1984. A number of characteristics of inter-firm cooperation apparently supported an expected high correlation between patent intensity and the intensity of alliances. Important motives for forming strategic alliances have been technological complementarity of partners, concrete development of innovations and the need for technology monitoring (Hagedoorn 1994, Hagedoorn and Schakenraad 1990a). It was therefore expected that technologically capable companies achieve a higher degree of 'courtship' than less innovative companies. In support of this proposition, Hladik (1985, 1988) argued that there are positive effects of innovation on successful cooperation in joint ventures. Moreover, he proposed that the similarity of partners with respect to technical assets is among others a factor that explains the occurrence of cooperation. In explaining this relationship Link and Bauer (1989) argued that in more innovative industries the funds for cooperative endeavours are larger.

A moderately positive effect of patent intensity of firms in the years 1982-1986 on the rate of profit for companies in the years 1984-1988 has been expected. In this context, patent intensity as an indicator of innovativeness was expected to generate 'Schumpeterian' short-term monopoly-rents which enable the innovating company to raise the rate of profit (Scherer 1984).

The effect of strategic alliances on innovation and patenting. Theory would predict that the degree of cooperation affects the innovativeness of large groups of companies because the improvement of innovative performance is a major objective of strategic inter-firm collaboration. A testing of these direct effects was, unfortunately, not possible because a periodization of both variables cannot be done. Firstly, with respect to strategic alliances most of them have been forged since the mid-eighties and secondly with respect to patents, patent approval requires, in general, an average period of two years

The relation between strategic alliances and rate of profit. With a time-lag of 1- 4 years a high intensity of strategic partnering, in particular for 'attractors' during 1980-1987, was expected to transform into an increase in turnover. Strategic alliances can provide companies with new skills, access to new markets and might improve their overall performance which generates, in turn, a growth in turnover. As has been said previously, no effect of the profit rate on other variables was expected because the different time intervals do rarely allow for such relationship.

In the literature, 'traditional' statistical techniques to explain profitability have been regression equations. It has been argued that most cause variables specified in regression models stand for broader underlying constructs or concepts. Theoretical problems emerged, however, if the number of significant cause variables specified in the model remained relatively low. Additional problems could arise if the specification of a large number of cause variables did not necessarily increase the proportion of variance explained. Another consideration that was taken into account was that the use of a standard regression analysis would assume a one-way causal relation between cooperative activity and other measures of external linkages and economic performance. As shown in the path diagram in Figure 1, it was, in contrast, proposed that the causality among our three different (groups of) factors could run in both directions. Based on these theoretical considerations, a reexamination of more 'traditional' statistical techniques in their use to explain our theoretical model was undertaken.

In order to examine the structure of the relationships in the path diagram (Figure 1) a LISREL approach, instead of multiple regression analysis, was chosen because of the following three reasons. Firstly, problems of multicollinearity could arise making it rather difficult to assess the significance of the effect parameters and of the model as a whole. Problems of multicollinearity can be circumvented in using factor analysis in order to create a set of fully independent variables. The use of factor analysis would, however, reduce not only the number of statistically significant parameters but also would alter the concepts underlying our theoretical model. Another potential statistical problem in multiple regression is heteroscedasticity which negatively effects the precision of the estimated relationship and weakens its significance level (Gujarati 1992, 1988). LISREL breaks the error term in two parts, a disturbance term which indicates the effect of variables not in the equation, and a measurement error term which specifies random measurement errors. This splitting up of the error term provides a possible corrective for heteroscedasticity. Thirdly, in multiple regression no distinction is made between direct and indirect effects. LISREL offers the possibility to decompose a total effect into direct and indirect effects. In addition to quantifying direct effects, the LISREL model allows to measure indirect effects via intermediary variables (Long 1994a, 1994b). For example, in the model the effects of sectoral features on company performance are directly as well as indirectly measured via their effects on innovativeness, company structure and external linkages.

2. General outline of LISREL

The path diagram in Figure 1, that pictures the general outline of the assumed relations between relevant variables, can be expressed as a set of structural equations. Based on the LISREL approach the parameters of this set of linear equations could be estimated. In the general form the covariance structure of LISREL consists of three well-known equations (Long 1994: 341). In the measurement part of the model LISREL offered a data reduction technique comparable to factor analysis, i.e., it explained the variation and covariation in a set of observed variables in terms of a set of unobserved factors. In factor analysis, the latent variables were defined as factors (constructs), the manifest variables are called indicators. LISREL distinguished two types of factors: common factors that may directly affect more than one of the observed variables, and unique or residual factors that may directly affect just one observed variable. In addition, it is assumed that exogenous variables act only as independent variables, whereas endogenous variables are dependent variables, or act as both dependent as well as independent variables. In the first measurement model the relationships between 'unobserved' (latent) variables and 'observed' (manifest) variables is specified by the matrix equation (1) :

$$\underset{(q \times 1)}{x} = \underset{(q \times n)(n \times 1)}{\Lambda_x \xi} + \underset{(q \times 1)}{\delta} \qquad (1)$$

where x is a (q x 1) vector of observed exogenous variables, Λ_x is a (q x n) matrix of coefficients, or factor loadings of the observed x-variables, x is a (n x 1) vector of common factors and δ is a (q x 1) vector of residual or unique factors. Unobserved exogenous variables are designated as ξ *'s*. In the equation, q describes a number of indicators of n exogenous latent variables. Errors in the measurement of x are contained in δ . In the equation, it is assumed that q is greater than n, i.e. that the number of observed variables in *x* is greater than the number of common factors in **x**.

In the second measurement model, the observed *y*-variables are linked by the loading matrix Λ_y to the latent η -variables in the following way:

$$\underset{(p \times 1)}{y} = \underset{(p \times m)(m \times 1)}{\Lambda_y \eta} + \underset{(p \times 1)}{\varepsilon} \qquad (2)$$

where y is defined as a (p x 1) vector of observed endogenous variables , Λ_y denotes a (p x m) matrix of the observed y-variables on the latent variable η and ε is a (p x 1) vector of errors of measurement of y. The latent variable η is described by a (m x 1) vector of unobserved variables measured without error. In the equation, p designates indicators of m-endogenous variables.

The relationships among exogenous and endogenous variables are defined in the structural equations part of the model:

$$\underset{(m \times 1)}{\eta} = \underset{(m \times m)(m \times 1)}{B\eta} + \underset{(m \times n)(n \times 1)}{\Gamma\xi} + \underset{(m \times 1)}{\zeta} \qquad (3)$$

where B refers to a (m x m) coefficient matrix relating the m-endogenous variables to one another, Γ denotes a (m x n) coefficients matrix relating the n-exogenous variables to the m-endogenous variables and ζ describes a (m x 1) vector of errors in the equation. The measurement equations (1) and (2) in conjunction with the structural equation (3) describe the covariance structure model of LISREL.

In comparing equations (1), (2) and (3) four matrices of coefficients can be distinguished: Λ_x, Λ_y, B and Γ. In addition, four covariance matrices can be defined. The covariance matrix of latent exogenous variables is called Φ. The other three matrices are related to residuals and measurement errors. The covariance matrix of the residuals ζ is called Ψ. The covariance matrices of the errors of measurement of y and x are designated with Θ_ε and Θ_δ respectively.

In the eight coefficients and covariance matrices of the model, there are fixed parameters with assigned given values, constrained parameters which are unknown but equal to one or more other parameters, and free parameters that are also unknown but not constrained to be equal to any other parameter. In the LISREL model it is assumed that the following propositions hold:

1. ε is uncorrelated with η;
2. δ is uncorrelated with ξ;
3. ζ is uncorrelated with ξ;
4. ζ, ε, and δ are mutually uncorrelated;
5. The diagonal elements of B are zero (Jöreskog and Sörbom 1993).

Using these assumptions the covariance matrix of observed variables (S) can be defined as a function of the eight matrices of coefficients and covariance. Listing the **y** variables first, followed by **x** variables, the covariance matrix of observed variables is:

$$\Sigma = \begin{bmatrix} \Sigma_{yy} & \Sigma_{yx} \\ \Sigma_{xy} & \Sigma_{xx} \end{bmatrix} \qquad (4)$$

In the analysis, a special case of LISREL, a structural equation model with observed variables, has been used. In these models it is assumed that the endogenous and exogenous variables are directly observed with no measurement error. Allowances for measurement errors can be made if they occur in endogenous variables that do not serve as explanatory variable in any equation (Bollen 1989: 80). These models have generally been presented in the following way:

$$\underset{(px1)}{y} = \underset{(mxm)(px1)}{By} + \underset{(mxn)(qx1)}{\Gamma x} + \underset{(px1)}{\zeta} \qquad (5)$$

In these models it is proposed that with a few exceptions, the observed *y* and *x* equal the corresponding ***h*** and **x**. The implicit measurement model for the structural equations with observed variables is therefore:

$$y = \eta$$
$$x = \xi \qquad (6)$$

According to Bollen (1989), the implied covariance matrix of *y* and *x* for these kind of LISREL models can be characterized in the following way

$$\Sigma = \begin{bmatrix} (I-B)^{-1}(\Gamma\Phi\Gamma' + \Psi)(I-B)^{-1'} & (I-B)^{-1}\Gamma\Phi \\ \Phi\Gamma'(I-B)^{-1'} & \Phi \end{bmatrix} \qquad (7)$$

There are three different iterative methods to arrive at estimates of elements of the matrices: unweighted least squares (ULS), general least squares (GLS), and maximum likelihood (ML) estimation. Jöreskog (1977) suggested to use starting values produced by either the specification of instrumental variables or a two-stage least squares (TSLS) method. In estimating the elements in the matrices in theoretical model the ML estimator was used because of its properties: scale invariance and scale freeness (Bollen 1989: 110).

Based on the LISREL program the parameters can be estimated using the information provided by the observed covariance matrix, which can also be a correlation matrix. There might be, however, no unique solution for the values of the parameters because of the problem of identification. In this context, identification refers to the problem whether or not the set of parameters is uniquely determined by the observed data. The coefficient can not be identified if there is more than one way to calculate a particular parameter, which in general will lead to different values. In order to solve for unknowns in equations a necessary condition is that the number of unknowns should be equal or less than the number of distinct equations. Differently stated, the degrees of freedom should be equal or larger than zero. Assuming there are ½ k (k+1) equations in the case of k observed variables, a necessary condition for identification is as follows,

$$s < \frac{1}{2}k(k+1) \qquad (8)$$

where **s** is the number of unknown elements. There are also rules for sufficient conditions for identification, but their formulation is rather complex. Based on a first rule of thumb it can be assumed that if the model is identified, the input matrix will have positive values. An increasing literature has been dealing with more complex issues with respect to the identification problem (Bollen 1989, Saris and Stronkhorst, 1984, Hayduk 1987, Gujarati 1988, Jöreskog 1977, Jöreskog and Sörbom, 1977).

The significance of the model and its parameters was assessed after the procedures for testing identification have been followed. The LISREL program provided some indicators for the goodness of fit of the measurement model and structural model, the overall model as a whole, as well as the individual parameters.

In the LISREL model, the well-known chi-square χ^2 has been used to measure the overall fit of the model. Based on the differences between observed and predicted values, in this case covariances or correlations the χ^2 can be computed. Given sufficient degrees of freedom, relatively small χ^2 values indicate that the model closely fits the observed data. Relatively large values suggests, in contrast, that the model is empirically inadequate. It is assumed that all observed variables should have a multinormal distribution and the sample size must be fairly large. In order to accept a model the analysis has to show that there is no real difference between the observed S and predicted Σ. In this case, p-values above 0.05 indicate that the model can be accepted.

The coefficient of determination (R^2) reports furthermore the squared multiple correlation coefficient for each endogenous variable. It has been used to check whether the endogenous variables in the model have sufficiently been accounted for. The LISREL models specified, in addition, critical ratios called t-values for all coefficients. These critical ratio have been calculated in dividing an estimated parameter by its standard error. In order to arrive at a more parsimonious model coefficients associated with small t-values were deleted. Tables of normal probabilities were used to create confidence intervals of any desired accuracy. The null hypothesis of a zero parameter with an error type I risk of 0.05 could be rejected if the absolute t-value was higher than 1.96. In interpreting the parameters, it can be said that they represent a direct effect of a one unit change of the cause, given all other variables in the model are held constant. The analysis of the direct effects between variables is insufficient when interpreting the LISREL solution. In order to disaggregate the total effect of a cause on an effect variable, the indirect effects between variables have to be measured as well (Saris and Stronkhorst 1984).

LISREL requires endogenous variables to be measured at least on an interval scale. In measuring ordinal variables, specific correlation coefficients can be used to reflect the strength of their relationships. If the following two conditions hold a specification of variables at the nominal level is possible: Firstly, the variables are specified as exogenous, coded dummy variables. In this case, LISREL is then only concerned with conditional distributions for given x. Secondly, all exogenous variables are manifest, i.e. each exogenous variable is measured by one single indicator without specifying error of measurement (Hayduk 1987).

3. The results of the LISREL analysis

For the empirical analysis the sample comprised of 346 corporations from the USA, Japan and Europe in the following sectors: information technologies and electronics, mechanical engineering and process industries (see Appendix II). In order to display the effects of the variables in the theoretical model discussed in the Introduction two LISREL path diagrams are used (Figures 2 and 3)[1]. According to the overall statistics

[1] Two path diagrams have been defined because the specification of all dummy variables in a single model was expected to generate perfect linear dependencies. In order to measure the dummy variables and dummy codings sectoral and 'Triadic' features have been included. In the diagrams normal lines represent direct effects that are significant at the .05 level. Next to te lines the estimated coefficients have been put. If there have been indirect effects in the model, their total effects has been presented in brackets. In order to

both LISREL models fit the data reasonably well.

With respect to the above mentioned hypotheses the following empirical results have been obtained. It became apparent that patent intensive *(PATINT)*, i.e. innovative, corporations are heavily involved in strategic partnering (*WSPART*). In addition, firms in information technology had a higher cooperation intensity than firms in process industries. In the model, patent intensity (*PATINT*) acted as an intermediary variable between sectors (*IT, PI*) and cooperation intensity (*WSPART*).

Moreover, US firms had on average a larger size but they had not been more inclined to engage in cooperative strategies than Japanese and European firms. Despite the average intensity of strategic partnering in Europe, the USA and Japan apparently differed, these differences became insignificant at the multivariate level when controlling for size. With respect to size Japanese firms in the sample were on average smaller and, therefore, less cooperation intensive than their counterparts.

The empirical analysis confirmed, in addition, that European firms have been more 'absorption'-oriented. In contrast to popular beliefs, empirical results showed that on average Japanese firms appeared to have more 'generative' than 'absorptive' strategic linkages.

In Table 2 the major findings from LISREL path diagrams have been summarized with respect to separate economic blocks and industrial branches. According to the empirical analysis the following conclusions can be drawn. In general, there was a strong positive relationship between intensity of strategic partnering and size of firm. With increasing firm size, enterprises 'absorb' more technology. This relationship did hold in particular for European information technology firms and Japanese process industries.

In information technology and all process industries where European and Japanese firms have actively been involved a strong positive impact of patent intensity on the propensity to establish strategic alliances was observed. In information technology and mechanical engineering US corporations that have heavily been engaged in strategic partnering were more inclined towards R&D cooperation. European firms in information technology that have heavily been involved in strategic partnering were more inclined to attract than generate technological knowledge through their alliances.

More disaggregated analyses showed divergent patterns with respect to the relationship between strategic technology partnering and profitability. In particular for US firms in mechanical engineering, the generation to attraction ratio showed an influence on profitability. For European and American firms in process industries a positive relationship between R&D-driven cooperation and profitability could be observed.

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generate a parsimonious and statistically acceptable overall model, some insignificant or 'marginally significant' (at the .10 level) effects have been included. Dashed lines indicate these effects. In addition, for each effect variable the multiple determination coefficient (R^2) has been presented. Multiple determination coefficients insignificant at the .05 level have been placed in brackets.

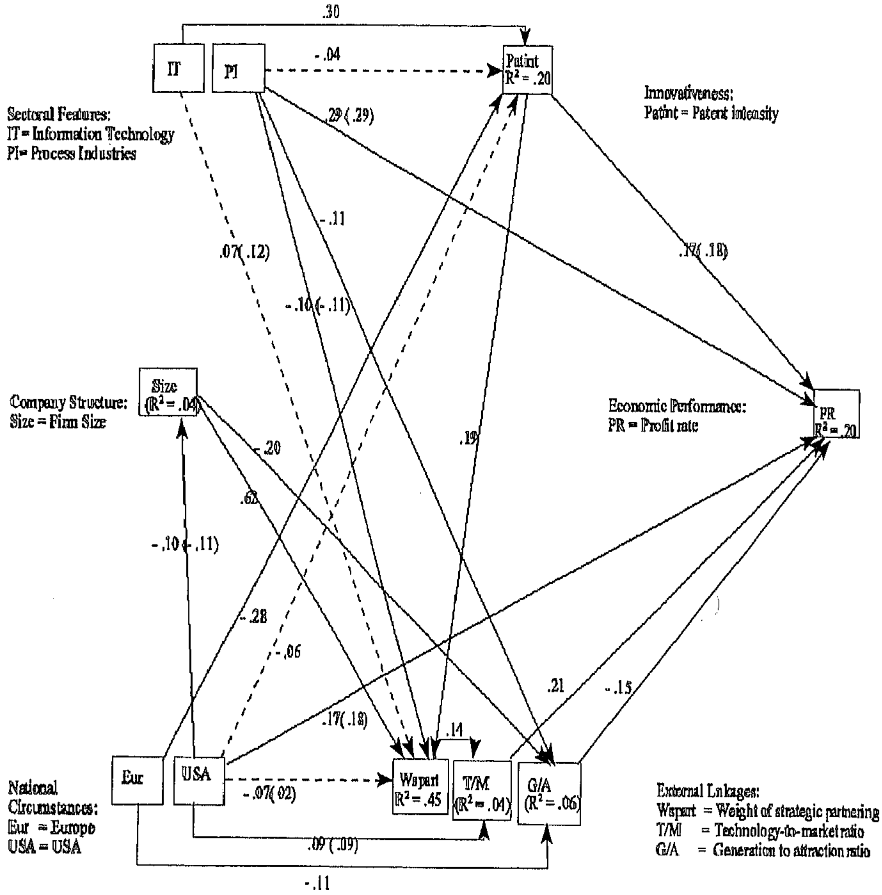

Figure 2. LISREL path diagram for the largest industrial corporations in the TRIAD, across industries (overall statistics: $n=346$, $\chi^2=30.20$, $df=19$, $p=.11$)

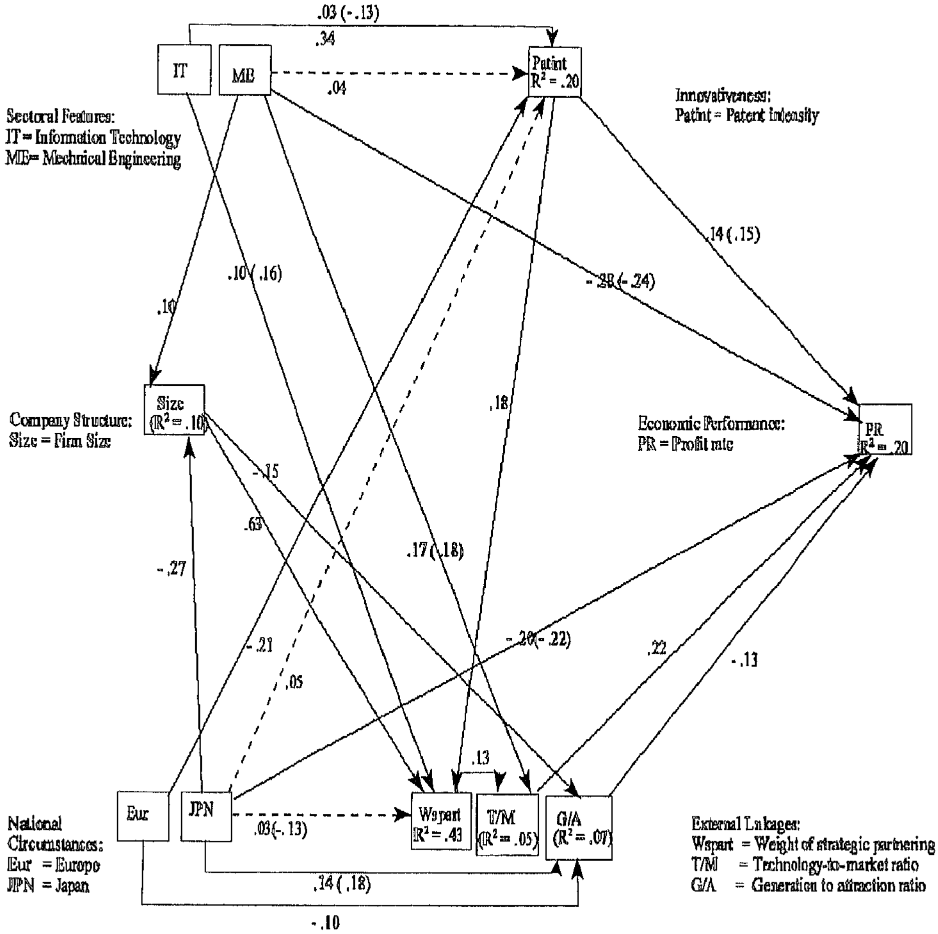

Figure 3. LISREL path diagram for the largest industrial corporations in the TRIAD, across industries
(overall statistics: n=346, χ^2=27.23, df=19, p=.12)

Table 2. Summary of findings from LISREL analyses according to economic blocks and industrial branches

		effect=PR					effect=T/M			effect=G/A			effect=WSPART		effect=PATINT	
		SIZE	PATINT	WSPART	G/A	T/M	SIZE	PATINT	WSPART	G/A	SIZE	PATINT	WSPART	SIZE	PATINT	SIZE
EUR	all	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+
	IT	0	0	0	0	0	0	0	0	0	(-)	0	(-)	+	+	+
	ME	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
	PI	0	0	(+)	0	+	0	0	0	0	0	0	0	+	+	+
USA	all	0	(+)	0	-	0	0	0	+	0	0	0	0	+	+	0
	IT	0	0	0	0	0	0	0	+	0	0	0	0	+	0	0
	ME	(+)	0	0	-	0	0	0	+	0	0	0	0	+	(+)	0
	PI	(-)	+	0	0	+	0	0	0	0	0	0	0	+	+	0
JPN	all	0	+	0	0	0	0	0	0	0	-	0	0	+	+	0
	IT	0	+	0	0	0	0	0	0	0	0	0	0	+	+	0
	ME	0	(+)	0	0	0	0	0	0	0	0	0	0	+	0	0
	PI	0	0	0	0	0	0	0	0	0	-	0	0	+	+	0
ALL	all	0	+	0	-	+	0	0	+	0	-	0	0	+	+	0
	IT	0	(+)	0	0	(+)	0	0	(+)	0	(-)	0	0	+	0	0
	ME	0	0	0	-	+	0	0	+	0	0	0	0	+	0	0
	PI	0	+	0	-	+	0	0	0	0	-	0	0	+	+	0

Legend:

0	= no relation
+	= significant positive relation (.05 level)
(+)	= marginally significant positive relation (.10 level)
-	= significant negative relation (.05 level)
(-)	= marginally significant negative relation (.10 level)

Conclusions

As it became obvious during the course of the paper, the application of the LISREL approach to the complex phenomenon of strategic alliances generated at least three major conclusions: Firstly, apparently there is no straightforward relations between strategic technology partnering and company performance, secondly, using the LISREL model certainly improved the general understanding of the effects of strategic technology alliances beyond more traditional statistical approaches, and thirdly, LISREL models have to be considered as a very versatile statistical technique that could be used in future research on strategic technology alliances at a more dis-aggregated level (e.g. the industry level).

Despite the research brought at the empirical level some evidence about the effects of strategic technology partnering on profitability, some questions could not be answered based on the existing LISREL model. For example, the effects of success and failure of strategic technology partnering on profitablity have been rarely discussed in the literature and could not be analyzed with this model. Moreover, the choice of the particular LISREL model, a structural equation model with observed variables, was driven by considerations based on the conventional structure-conduct-performance paradigm in industrial organization. In order to investigate more complex relationships further research could apply measurement models with latent and observed variables.

Appendix I. Organizational modes of inter-firm co-operation, their underlying motives, and definitions of strategic alliances

Primary modes of cooperation are joint ventures and research corporations, joint R&D agreements, technology exchange agreements, direct investment, customer-supplier relations and one-directional technology flows. These modes of cooperation display different effects on the character of technology sharing, the organizational context and the possible economic consequences for participating companies (Contractor and Lorange, 1988, Hagedoorn 1990). *Joint ventures* and *research corporations* are defined as combinations of economic interests of at least two separate companies in a 'distinct' firm. In these firms, profits and losses are shared according to equity invested. *Joint research pacts* and *joint development agreements* are established in order to jointly undertake R&D projects with shared resources. Technology exchange agreements cover *technology sharing agreements, cross-licensing* and *mutual second-sourcing of existing technologies.* Equity investment is a form of cooperation between companies which in the long run could affect the technological performance of at least one 'partner'. In this context, *minority investments* refer to cooperations where the sharing of minority interests is coupled with research contracts. *Customer-supplier relationships* are agreements in which a contract-mediated collaboration in either production or research is established. These relationships comprise, for example, co-production contracts, co-makership relationships, and research contracts. They define a R&D cooperation in which one partner gives a contract to another company to perform particular research projects. *Unilateral technology flows* such as second-sourcing and licensing agreements are another category.

Furthermore, a distinction is made between cooperative agreements aimed at strategic, long term perspectives of the product market positions of the companies involved and cost-economizing agreements which are more associated with control of either transaction costs or operating costs of companies. Agreements have a mixed character if both strategic and cost-economizing motives seem applicable. In this case, a differentiation between cost and strategic arguments are inappropriate or partners might have alternating motives. Despite a strict correlation between organizational modes of cooperation and their strategic or cost-economizing content has not been found yet, some modes of cooperation are more strategically motivated than others that tend to be more oriented towards cost-economizing. Estimates show, for instance, that over 85% of all R&D joint ventures, research corporations, joint R&D agreements and equity investments are strategically motivated (Hagedoorn and Schakenraad, 1990a). In contrast, only a small portion of the technology exchange agreements, one-dimensional technology flows and customer-supplier relationships are strategically motivated. An exception in this group are research contracts which might at least partly be strategically motivated.

Each agreement is measured according to its strategic or cost economizing contents in order to assess its strategic implications for the companies involved. Furthermore, two broad groups of motives are distinct: a) motives directly related to basic and applied research; and b) motives directly related to market access and structure of the market. Based on this distinction a selection of strategic alliances according to their content can be made: whether it is predominantly research oriented, or primarily market oriented. The dichotomy between R&D and market motives is called the 'technology to market ratio', designated as T/M ratio.

Appendix II. List of samples per sectors and per region (Europe, United States, Japan)

Europe	=	138 companies	
of which in		IT	= 21
		ME	= 46
		PI	= 71
United States	=	249 companies	
of which in		IT	= 121
		ME	= 46
		PI	= 82
Japan	=	78 companies	
of which in		IT	= 27
		ME	= 17
		PI	= 34

References

Ansoff, I. and McDonnell, E. (1990), *Implanting Strategic Management*, London (Prentice Hall).

Bain, J.S. (1956), *Barriers to new competition*, Cambridge (Harvard University Press).

Berg, S.V., Duncan, J. and Friedman, P. (1982), *Joint Venture Strategies and Corporate Innovation*, Cambridge, Ma. (Oelgeschlager).

Bollen, K.A. (1989), *Structural Equations with Latent Variables*, New York (John Wiley and Sons).

Cohen, W.M. and Levin, R.C.(1989), 'Empirical studies of innovation and market structure', in: R.Schmalensee and R. Willig (eds.), *Handbook of Industrial Organization*, Vol. 2, Amsterdam (North Holland), pp 1059-1109.

Contractor, F.J. and Lorange, P. (1988), 'Why should firms cooperate? The strategy and economics basis for cooperative ventures', in: F.J. Contractor and P. Lorange (Eds.), *Cooperative Strategies in International Business*, Lexington (Lexington Books), pp 3-31.

Davis, E. and J. Kay (1990), 'Assessing corporate performance', *Business Strategy Review*, Vol. 1, no. 2, pp 1-17.

Devine, P.J., Lee, N., Jones, R.M., and Tyson, W.J. (1986), *An introduction to industrial economics*, Fourth edition, London (George Allen & Unwin).

Dosi, G. (1984), *Technical Change and Industrial Transformation*. London (Macmillan).

Freeman, C. (1982), *The economics of industrial innovation*, London (Pinter Publishers).

Gujarati, D.N. (1988), *Basic Econometrics*, 2nd Edition, New York (McGraw-Hill).

Gujarati, D.N. (1992), *Essentials of Econometrics*, New York (McGraw-Hill).

Hagedoorn, J. (1989), *The Dynamic Analysis of Innovation and Diffusion*. London (Pinter Publishers).

Hagedoorn, J. (1990), 'Organizational modes of inter-firm co-operation and technology transfer'. In: *Technovation*, 10/1, pp 17-30.

Hagedoorn, J. (1993), 'Understanding the rationale of strategic technology partnering: inter-organizational modes of cooperation and sectoral differences', in: *Strategic Management Journal* 14 (5), pp. 371-386.

Hagedoorn, J. and Schakenraad J.(1990a), 'Inter-firm partnerships and co-operative strategies in core technologies', in: C. Freeman and L. Soete (Eds.), *New Explorations in the Economics of Technical Change*, London (Pinter Publishers), pp 3-28.

Hagedoorn, J. and Schakenraad J.(1990b), *Technology Cooperation, Strategic Alliances, and their motives: Brother, can you spare a dime, or do you have a light?*, Paper for SMS conference, Stockholm, September 24-27, 1990.

Hagedoorn, J. and Schakenraad, J. (1994), 'The effect of strategic technology partnering on company performance', in *Strategic Management Journal* 15 (1) , pp 291-309.

Hay, D.A. and Morris, D.J. (1979), *Industrial Economics: Theory and Evidence*, Oxford (OUP).

Hayduk, L.A. (1987), *Structural Equation Modeling with LISREL, Essentials and Advances*, Baltimore/London (Johns Hopkins University Press).

Hladik, K.J. (1985), *International Joint Ventures*, Lexington (Lexington Books).

Hladik, K.J. (1988), 'R&D and international joint ventures'. In: F.J. Contractor, P. Lorange (Eds.), *Cooperative Strategies in International Business*, Lexington (Lexington Books), pp 187-205.

Jöreskog, K.G. (1977), 'A General Method for Analysis of Covariance Structures', in: D.J. Aigner and A.S. Goldberger (eds.), *Latent Variables in Socio-Economic Models*, Amsterdam (North-Holland), pp 187-204.

Jöreskog, K.G. and Sörbom, D.(1977), 'Statistical Models and methods for Analysis of Longitudinal Data', in: D.J. Aigner and A.S. Goldberger (eds.), *Latent Variables in Socio-Economic Models*, Amsterdam (North-Holland), pp 285-325.

Jöreskog, K.G. and Sörbom D. (1993),*LISREL® User's Reference Guide, Chicago*, (Scientific Software International, Inc.).

Kamien, M.I. and Schwartz, N.L. (1982), *Market Structure and Innovation*. Cambridge (CUP).

Kleinbaum, D. (1994), *Logistic regression: A self-learning text*. New York (Springer-Verlag).

Link, A.N. and Bauer, L.L. (1989), *Cooperative Research in U.S. Manufacturing: Assessing Policy Initiatives and Corporate Strategies*, Lexington (Lexington Books).

Long, J. (1994a),'Confirmatory factor analysis: A preface to LISREL', in Lewis-Beck, M. (Ed), *Factor analysis and related techniques*. London (Sage Publications).

Long, J. (1994b),' Covariance structure models: An introduction to LISREL', in Lewis-Beck, M. (Ed), *Factor analysis and related techniques*. London (Sage Publications).

Mansfield, E. (1984), 'R&D and innovation: some empirical findings', in: Z. Griliches (ed.) *R&D,Patents, and productivity*, Chicago (University of Chicago Press), pp 127-148.

Mueller, D.C. (1986), *The modern corporation - Profits, power, growth and performance*. Brighton (Wheatsheaf Books).

Mueller, R. (1996), *Basic principles of structural equation modeling. An introduction to LISREL and EQS.* New York (Springer-Verlag).

Ohmae, K. (1985), *Traid power*. New York (Free Press).

Patel, P. and Pavitt, K. (1991), Large firms in the production of the world's technology: An important case of 'non-globalisation', in: *Journal of International Business Studies*, 22, no. 1, pp 1-21.

Pavitt, K., Robson M. and Townsend J. (1987), 'The size distribution of innovating firms in the UK: 1945-1983', in: *Journal of Industrial Economics*, 35, no. 3, pp 297-317.

Philips, A. (1971), *Technology and marketstructure*. Lexington (Lexington Books).

Saris, W. and Stronkhorst, H. (1984), *Causal Modeling in Nonexperimental Research, an Introduction to the LISREL Approach*. Amsterdam (Sociometric Research Foundation).

Scherer, F.M. (1965), 'Firm size, marketstructure, opportunity, and the output of patented inventions'. In: *American Economic Review*, 15, no.5, pp 1097-1123.

Scherer, F.M. (1984), *Innovation and growth: Schumpeterian perspectives*, Cambridge, Ma. (MIT Press).

Schmalensee, R. (1989), 'Inter-industry studies of structure and performance'. In: R.Schmalensee and R. Willig (eds.), *Handbook of Industrial Organization*, Vol. 2, Amsterdam (North Holland), pp 951-1011.

Schmookler, J. (1966), *Invention and economic growth*. Boston (Harvard University Press).

Scott, M. (1995), *Applied logistic regression analysis*. London (Sage Publications).

Soete, L. (1979), 'Firm size and inventive activity-the evidence reconsidered', in: *European Economic Review*, no. 12, pp 319-340.