DO NETWORKS MATTER FOR INNOVATION? THE USEFULNESS OF THE ECONOMIC NETWORK APPROACH IN ANALYSING INNOVATION

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ABSTRACT
Economic network theory emphasises the importance of external resource mobilisation. In this paper, the relations between the mobilisation and use of internal and external resources in innovation processes, and the innovative performance of firms, are explored empirically, using an adapted version of Håkansson's (1987) economic network model. The main research question was: to what extent do network variables contribute to the innovative performance of firms? To answer this question, we assessed the explanatory power of economic network theory within the empirical study of innovation. Firms were found to engage in various configurations of internal and external resource bases, enabling them to innovate with better results. The relations in the estimated models are strongly influenced by moderating variables such as sector, and type and level of innovations produced. Our main conclusion is that models that include both internal and external resources explain the innovative performance better than models in which only internal resources are used.

Key words: Economic network theory, innovation, survey, North Brabant, regression models

INTRODUCTION

In the book *Networking in Dutch Industries* (Beije, Groenewegen & Nuys 1993) the economic network theory was adopted as a promising approach to the study of economic co-ordination. However, the members of the Dutch Committee on Industrial and Technology Policy (STIP) did not hesitate to emphasise both theoretical and methodological problems in the field of economic network research.

In a critical review Meeus and Oerlemans (1993) presented some very clear conclusions about the methodological state-of-the-art of economic network research and formulated various proposals for improving the research. In short, these authors concluded:

1. The theoretical development in economic network theory is only in its preliminary stages. The empirical support available is mainly descriptive and qualitative. In general, there is a general lack of hypothesis testing and explanatory designs.
2. The degree of control over research conditions and the research population is generally low.
3. As a consequence, the use of multivariate analysing techniques is very restricted.

The overall conclusion was that the scientific status of economic network research at that time was rather underdeveloped.

As a result of these conclusions, Meeus and

Tijdschrift voor Economische en Sociale Geografie – 1998, Vol. 89, No. 3, pp. 298–309.

Published by Blackwell Publishers, 108 Cowley Road, Oxford OX4 1JF, UK and 350 Main Street, Malden, MA 02148, USA

Oerlemans advanced some methodological proposals:

1. Extend theoretical models currently used in network research with variables deduced from other economic and sociological theories to facilitate analysis of the relations between economic structure and action.
2. Test these more sophisticated models under more controlled conditions.

This paper attempts to deal with some of these problems and proposals, and aims to assess the explanatory power of economic network theory within the empirical study of innovation.

THE ECONOMIC NETWORK APPROACH: A REVIEW

The economic network approach, especially as developed by Håkansson (1987; 1989; 1992; 1993) and Håkansson & Snehota (1995), provides a model to analyse the relation between economic networks and innovation.

Håkansson's economic network model contains three main elements: actors, activities, and resources. Actors perform activities and possess or control resources. They have a certain, but limited, knowledge of the resources they use and the activities they perform. Their main goal is to increase their control of the network. Actors in networks can be studied at different levels, from individuals to groups of firms. Two main types of activities are distinguished in the network model: transformation and transaction. Both are related to resources because they change (transform) or exchange (transact) resources through the use of other resources. Transformation activities are performed by one actor and are characterised by the fact that a resource is improved by combining it with other resources. Transaction activities link the transformation activities of the different actors. These exchanges result in the development of economic (network) relations between actors. There are several types of resources: physical (machines, raw material, components), financial, and human (labour, knowledge, relations). Furthermore, resources can be classified according to the degree of organisational control. In the case of internal resources the firm has a hierarchical control. External resources are controlled by external resource providers. As a consequence, resources are heterogeneous, i.e. their (economic) value depends on the other resources with which they are combined.

In linking networks and innovation, the heterogeneity of resources and resource mobilisation are the key concepts. According to Håkansson (1993), the effects of heterogeneity are that knowledge and learning become important. How should the firm handle these heterogeneous resources? In answer to this question, Håkansson cites Alchian and Demsetz (1972, p. 793), who state that 'efficient production using heterogeneous resources is not a result of having better resources, but knowing more accurately the relative performance of these resources'. In other words, it is not only necessary to have resources, but to know how to use them.

This knowledge can be acquired in two ways: internally and/or externally. Learning to use internal resources can be accomplished in several different ways, for example through R&D activities or learning by using or doing. The external mobilisation of resources can be labelled 'learning by interacting' (Lundvall 1988, p. 362), i.e. firms can use the knowledge and experience of other economic actors.

In order to make use of external resources, firms need to exist within structures that make these learning processes possible and efficient. According to Håkansson, economic networks produce these structures characterised by stability and variety. First, scarce external resources are more easily mobilised through stable relations with other economic actors. Second, stable relations in networks enable innovating firms to gather knowledge and to learn from other actors how to use heterogeneous resources innovatively and efficiently. Third, the stability of economic network relations provides a basis for variety. This variety offers new opportunities for innovation.[1]

The economic network approach makes it clear that firms can supplement their innovation process by using external resources as well. They can also acquire knowledge through the use of their economic network relations. But Håkansson's model does not provide a clear picture of innovative activities in firms. These problems are dealt with in the next section.

FROM A DESCRIPTIVE MODEL TOWARDS AN EXPLANATORY MODEL, RESEARCH QUESTIONS AND HYPOTHESES

After this review of Håkansson's descriptive economic network model and its usefulness for analysing innovation, some critical remarks are in order. These remarks allow us to partially reformulate the network model for our empirical purposes, aiming at an illustration of the explanatory power of network variables in the context of innovation.

Our comments can be divided into two parts. The first discusses the lack of theoretical maturity of the economic network approach in general and of Håkansson's network model in particular. Two problems are addressed: the conceptualisation of innovation in the economic network model and the classification of heterogeneous resources. The second part deals with problems regarding the degree of control on research conditions and population in economic network research.

Håkansson overemphasises an interorganisational approach to organisational processes. As a consequence, even innovation processes are primarily conceptualised as a product of external factors. In our view, innovation in firms is primarily internal in nature. External (f)actors can play a role in this process (Von Hippel 1988), but the innovator initially uses his internal capabilities. If the process runs into problems, external resources are sought (Oerlemans 1996). We therefore have to find a balance between an internal and external view of innovation.

As Dosi stated (1988, pp. 1120–1):

> agents will plausibly allocate resources to the exploration and development of new products and new techniques of production if they know, or believe in, the existence of some sort of yet unexploited scientific and technical opportunities; if they expect that there will be a market for their new products and processes; and finally, if they expect some economic benefit.

Dosi stresses the knowledge, beliefs, and expectations of the innovating actor.

As a consequence, we have to define the technological innovation processes in Håkanssonian terms. Technological innovation is a transformation activity where an actor, through the (re)combination of heterogeneous resources, develops and introduces new or improved products or production processes with the expectation of better economic performance. Within firms, innovation is conceptualised as an open system (Katz & Kahn 1966), where inputs (heterogeneous resources) are transformed into outputs (results of innovations). This process is related to several economic actors which, through their transformation and transaction activities, use resources in order to produce innovations.

Despite Håkansson's claim that resources are heterogeneous, and internal and external, he does not systematically identify which heterogeneous resource bases he is referring to. If we assume that innovation is a knowledge-intensive process, we must determine which 'knowledge bases' (Dosi 1988, p. 1126) can be used by innovators. Smith (1995, pp. 78–81) systematises the attributes of, what he calls, a 'modern view' on technological knowledge. One of these attributes is that technological knowledge is differentiated and multi-layered. At least three different resource bases can be discerned. First, there is the general (scientific) resource base. This base is highly differentiated internally and is of varying relevance for industrial production and innovation. Second, resource bases exist at the level of the industry or product field and entail shared understanding of the technical functions, performance characteristics, use of materials, etc., of products and processes. This knowledge and practice shape the performance of firms in an industry. Third, the resource bases of firms are highly localised. They tend to have one or more technologies and practices that they understand well and that are the basis of their competitive position. This firm-specific resource base is not only technical, but also concerns the way in which technical processes are interwoven with other firm activities. These include identifying market opportunities, financing, and marketing new products and processes.

The fact that resource bases of industrial firms are multi-layered has two important consequences for Håkansson's economic network model. First, it means that although individual innovating firms are competent in specific areas, their competence is nonetheless limited. In other words, innovating firms use

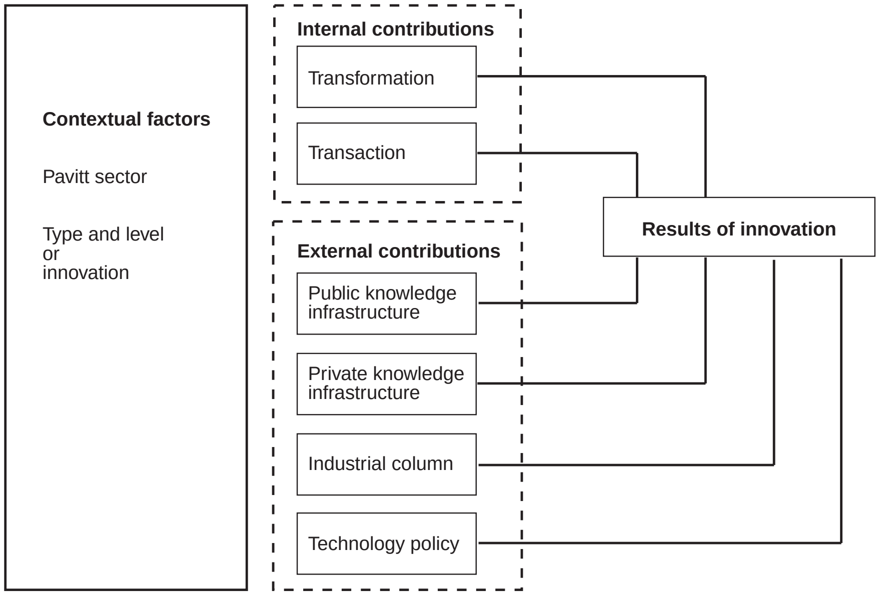

Figure 1. *Internal and external resources and results of innovation.*

their specific resources to innovate but they can easily run into problems. The solution to these problems may lay outside their area of expertise. Therefore, they must be able to access and use external knowledge. Second, the multi-layered and heterogeneous nature of resource bases makes it necessary to distinguish several actors and institutions inside and outside the firm in which resources are embodied.

Internal resources are embodied in the transformation (R&D, production) and transaction functions (purchase, marketing/sales) of the firm. Outside the firm, at least four groups of actors can be distinguished: the public and private knowledge infrastructure, the production column and intermediaries. The public knowledge infrastructure consists of organisations such as universities and colleges for professional and vocational training. Trade organisations and consultants can be found in the private knowledge infrastructure. The technological knowledge found here is mainly related to the industry or product field. The same is true for the third group, the production column. Suppliers, buyers, and other firms such as competitors are grouped in this category. Intermediaries such as Chambers of Commerce and regional Innovation Centres can be seen as information brokers. They are able to give general and specific information on innovation related issues, but they are also able to bring parties into contact with each other.

Figure 1 is based on our review of Håkansson's economic network model and enables us to formulate our first two research questions:

1. Do models including network variables explain the innovative performance of firms better than models without these variables?
2. To what extent is the use of internal and external resource bases associated with results of innovation?

As can be seen in the left hand side of Figure 1, the relations in the model are supposedly susceptible to moderating contingencies. These assumptions are a consequence of our comments regarding the rather low degree of control over research conditions and population in economic network research and the lack of controlled research designs restricting the use of multivariate analysing techniques. This is certainly true for Håkansson's research. He generally uses descriptive statistics (Håkansson 1989) for analysis and the case study as a research type (Håkansson & Snehota 1995). In order to increase control of the research conditions, homogenised groups can be used in the research population and then compared using economic network features. Two conditions apply.

First, analyses are controlled for Pavitt's sector classification. It is well known that industrial sectors have different sources, paces, and rates of technological innovation. Keith Pavitt's seminal paper (1984) made this very clear. He categorised firms in sectors using the following criteria:

- The sources of technology used in a sector, particularly the degree to which it is created within the sector or is externally generated by purchasing production equipment, components, and materials.
- The nature of the technology produced in a sector, i.e., the relative importance of intra- and extra-organisational knowledge sources and of product and process innovations.
- The features of (innovating) firms, particularly their size, R&D efforts, and principal economic activities.

In this way, Pavitt systematically described innovation and networks on a sectoral level. Because sectoral patterns of technological innovation are different, one may expect that firms in specific sectors use specific internal and external resources in order to innovate successfully. Using this argument, we conclude that Pavitt's taxonomy can be used as a condition in our network model of innovation.[2]

Second, analyses are controlled for the type and level of innovation. According to Maillat (1991, p. 111), the resources in the external environment are of little use for firms with incremental innovations. Most of the time, the resources needed for these innovations can be found inside the firm. Firms with radical product and process innovations require more than the limited internal resources can provide. Intensive use of external resources can be expected in such cases.

This leads us to the third and last research question:

3. To what extent are empirical associations between the use of internal and external resource bases on the one hand, and results of innovation on the other hand, moderated by contextual factors such as sector and the type and level of innovation?

Our review of Håkansson's economic network model enabled us to hypothesise on relations between the use of internal and external resources and results of innovation.

Firms innovate on the basis of their internal, firm-specific, and limited resources. If the limits of internal competence are reached, we expect the results of innovation to be constrained. The acquisition and use of external resources can overcome these internal competence deficits, resulting in better performance. Hypothesis 1 addresses this issue:

1. Models that include network variables, i.e. external resources, explain the innovative performance of firms better than models which do not include these variables.

Industrial sectors have different sources, paces, and rates of technological innovation. Using Pavitt's taxonomy (1984, p. 355), we might expect that the innovation processes in the supplier dominated sector is mainly influenced by the production column, particularly by suppliers. According to Pavitt, the use of internal resources, especially production and R&D knowledge, is very important in the three other sectors. The scale intensive and science-based sectors combine the use of these internal resources with resources from suppliers (production column). Specialised suppliers generally use buyers as an external resource base. In the science-based sector, the main sources of technological innovation are internal R&D activities, based on the development of sciences in universities. Therefore, innovating firms in this sector use the public knowledge infrastructure. Hypothesis 2 addresses the moderating influence of industry dynamics:

2. Effects of the use of internal and external resources on results of innovation are moderated by industry dynamics.

Maillat claims that firms with radical process and product innovations experience reach the limits of their internal competences more quickly. In order to innovate successfully, they must overcome internal knowledge deficits by mobilising and using external resources.

3. Effects of the use of internal and external resources on results of innovation are stronger and more diverse for firms with radical product and process innovations.

METHOD

Sample – A survey was administered to industrial firms with five or more employees in the region of North Brabant (a province in the southern part of the Netherlands). The data gathering took place between December 1992 and January 1993.

The data was collected in one of the most industrialised areas in the Netherlands. In 1992, the total number of manufacturing jobs in North Brabant was roughly 210,000, 28.8% of total employment (in The Netherlands as a whole it was 19.5%).

The population of firms in the region consists of a mix of small, medium and large enterprises. Furthermore, the manufacturing sector has a relatively high R&D and export performance (Meeus & Oerlemans 1995). Because technological network activity is an important issue in this article, industrial firms were grouped according to Pavitt's taxonomy (1984). These criteria were applied by Oerlemans (1996) to the responding firms.

Table 1 shows that the sample is a fairly reliable representation of the population of industrial firms in the region of North Brabant. The maximum deviation between the proportions in the population and in the usable response is within 8%. The mean deviation between the percentages in the sample and in the response is 6.4%.

Operationalisation of variables – Our interpretation of Håkansson's economic network model is summarised in the conceptual model presented in Figure 1. In this section, the operationalisation of the concepts in the model is described (Table 2).

Following Håkansson, two types of internal activities were distinguished: transformation and transaction. Because we were studying the influence of these activities on the innovation process, we asked the following question: How often in the last five years did the transaction function (purchase or sales/marketing), or the transformation function (R&D or production) suggest ideas for, or make an important contribution to, the realisation of innovations?[3] The contribution of the transaction function variable (CFT1) represents the mean score of the contributions of the purchase and sales/marketing function. The contribution of the transformation function variable (CFT2) was computed in the same way, using the contributions of the R&D and the production function.

The external economic actors that can contribute to the innovation process are divided into four main categories: public and private knowledge infrastructure, the production column, and intermediaries. Firms were asked how often in the last five years external organisations thought up ideas for, or made an important contribution to, the realisation of innovation.

The technology policy variable (TP) describes the total number of technology policy instruments used by the firm and can be interpreted as an external financial resource stimulating innovation provided by the Government.

The dependent variable in our model is a result of innovation. It contains a count of the number of performance improvements due to product and process innovations.[4]

ANALYSES

In order to test whether the mobilisation and use of internal and external resources influences the results of innovations (Hypothesis 1), two models were analysed. The first, the so-called 'with model' is a result of a multiple regression analysis using internal and external resources. In the second, the 'without model', only internal resources were used as criterion variables. The explanatory power of both esti-

Table 1. *Population and sample divided into Pavitt sectors.*

Pavitt sector	Population	% population	Sample (n = 579)
Supplier dominated	1,028	33.5%	25.7%
Scale intensive	1,261	41.1%	36.1%
Specialised suppliers	417	13.6%	21.4%
Science-based	363	11.8%	16.8%
Total	3,069	100%	100%

Table 2. *An overview of concepts and indicators used.*

Variables	Indicators
Pavitt sector	1. Supplier dominated; 2. Scale intensive; 3. Specialised suppliers; 4. Science-based
Type and level of innovation	Type of innovations: product or process Level of innovations: incremental or radical
Transaction (CTF1)	Contributions to the innovation process by the purchase or the sales and marketing function of the firm
Transformation (CTF2)	Contributions to the innovation process by the production or the R&D function of the firm
Public knowledge infrastructure (EI1)	Contributions to the innovation process by (technical) universities and colleges for professional and vocational education
Private knowledge infrastructure (EI2)	Contributions to the innovation process by trade organisations, TNO, and private consultants
Production column (EI3)	Contributions to the innovation process by important buyers, suppliers, and other firms
Intermediaries (EI4)	Contributions to the innovation process by Innovation Centres or Chambers of Commerce
Technology policy (TP)	Number of technology policy instruments used by the firm
Results of innovation	The extent to which process or product innovations resulted in: 1. Reduction of the cost price; 2. Quality improvement of a. processes and b. products; 3. Increase in production capacity; 4. Improvement in delivery time; 5. Increase in sales; 6. Increase in profits

mations is indicated by 'R^2 with' and 'R^2 without'. A comparison of the explained variances gives an impression of the additional explanatory power of the network model.

To test the hypotheses, regression analyses using the stepwise method were applied. All analyses were controlled for collinearity, which means that different variables provide very similar information. If collinearity occurs, the effects of the independent variables are difficult to separate, causing severe interpretation problems. Collinearity was controlled for using the variance inflation factor.[5] Collinearity did not occur in the analyses.

RESULTS

Four groups of actors that influence the innovation process were distinguished on theoretical grounds (see Table 2). Subsequently, the question of whether these theoretical dimensions also exist empirically was addressed. In order to answer this question, factor analysis was applied which resulted in the four factors presented in Table 3.[6]

Factors EI1–EI4 represent contributions to the innovation process by the public and private knowledge infrastructure, the production column, and intermediaries. In short, we can conclude that the results of this factor analysis empirically confirm the initial categorisation. Factors EI1–EI4 were used as independent variables in further regression analyses.

Sectoral patterns – In order to test Hypotheses 1 and 2, five OLS models were estimated, one for the total population and four for the Pavitt sectors. As can be seen in Table 4, all models are significant as indicated by the F-values. The percentages of variance explained using the 'with' models varies between 16% for the scale intensive model and 33% for the specialised

Table 3. *Results of factor analysis on the external influences on the innovation process.*

Factors and items	Factor coefficients	Labels
Factor 1: (EI1)		
Technical University	0.80	Contributions of the public
Other universities	0.78	knowledge infrastructure
Colleges	0.66	
MBO	0.47	
Factor 2: (EI2)		
Trade Organisations	0.73	Contributions of the private
National Centre of Applied		knowledge infrastructure
Research (TNO)	0.65	
Consultants	0.61	
Factor 3 (EI3)		
Important buyers	0.73	Contributions of the
Important suppliers	0.72	production column
Other firms	0.67	
Factor 4 (EI4)		
Chambers of Commerce	0.77	Contributions of
Regional Innovation Centres	0.75	intermediaries

Table 4. *OLS estimates with innovation results as the dependent variable and the internal and external contributions to the innovation process as independent variables: a comparison between Pavitt sectors.*

Independent variables	Pavitt sectors				TP
	SD	SI	SS	SB	
CTF1	n.s.	n.s.	n.s.	n.s.	n.s.
CTF2	n.s.	n.s.	.58****	.33**	.26****
EI1	n.s.	n.s.	n.s.	.28**	n.s.
EI2	n.s.	.20*	n.s.	n.s.	.12*
EI3	.34***	.22**	n.s.	.31**	.24**
EI4	n.s.	n.s.	n.s.	n.s.	.13**
TP	.26*	.27**	n.s.	n.s.	n.s.
R^2 with	.22	.16	.33	.25	.19
R^2 without	.14	.05	.33	.13	.13
Difference	+8%-p	+11%-p	0%-p	+12%-p	+6%-p
F-value	6.76***	4.82***	16.83****	5.34***	12.06****
N	50	78	36	52	216

SD = Supplier dominated; SI = Scale intensive; SS = Specialised suppliers; SB = Science based; TP = Total population
Significance levels: * $p < .10$; ** $p < .05$; *** $p < .01$; **** $p < .001$, n.s. = not significant

suppliers sector. If we compare the 'with' and 'without' models, it appears that, in four of the five cases, the R square is higher for the 'with' model.

The addition of external contributions to the innovation process increases the percentage of variance explained by 6 percentage points for the model of the total population to 12 percentage points for the science-based sector. In other words, the network models have a higher explanatory power.[7]

The model that includes all firms shows that both internal and external contributions are positively related to results of innovation. The higher the contributions of the transformation function (internal) and the contributions of the private knowledge infrastructure, the production column, and intermediaries (external), the more positive the results of innovations. Therefore, the analysis shows that an additive combination of internal and external resources results in better innovation results.

Furthermore, it becomes clear that Pavitt sectors differ strongly regarding the use of internal and external resources. In the supplier dominated sector, better results were achieved with the contributions of the production column and the use of instruments of technology policy. The same is true for firms in the scale intensive sector, though in this sector the contributions of the private knowledge infrastructure are also important. For the specialised suppliers only the contributions of the transformation function are positively related to innovation results. The firms in this sector can be called 'lonely innovators'. In addition to the transformation function, firms in the science-based sector use external resources from the public knowledge infrastructure and the production column. It can be concluded from these analyses that the transformation function and the production column are important resource bases in the innovation process.

Type and level of innovations – In Hypothesis 3, we assumed that the type and level of innovations moderated the relations in our model, i.e. firms with radical innovations use internal and external resources more intensively.

Table 5 reveals that the level and type of innovations indeed have a strong influence on the relations in the model. Contrary to our

Table 5. *OLS estimates with innovation results as the dependent variable and internal and external contributions to the innovation process as independent variables: a comparison between types and levels of innovation.*

Independent variables	Type and level of innovation			
	Incremental process	Radical process	Incremental product	Radical product
CTF1	n.s.	n.s.	n.s.	.26**
CTF2	.18**	.23*	.25***	.25**
EI1	n.s.	n.s.	n.s.	n.s.
EI2	.13*	n.s.	n.s.	n.s.
EI3	.19**	.50****	.21***	n.s.
EI4	.16**	n.s.	.18**	n.s.
TP	.13*	n.s.	n.s.	.20*
R^2 with	.16	.35	.16	.24
R^2 without	.09	.21	.10	.21
Difference	+7%-p	+14%-p	+6%-p	+3%-p
F-value	6.20****	11.48****	8.69****	6.15***
N	164	45	146	61

Significance levels: * $p < .10$; ** $p < .05$; *** $p < .01$; **** $p < .001$, n.s. = not significant expectations, firms with incremental innovations use more internal and external resources than firms with radical innovations. If firms have incremental process innovations, an extensive use of all resource bases, with the exception of the transaction function and the public knowledge infrastructure, yields better results. If firms have incremental product innovations, results are positively related to the contributions of the transformation function, the production column, and the intermediaries.

The patterns found in firms with radical innovations tend to reflect the lonely innovator perspective. The results of innovations of radical process innovators are, besides the contributions of the transformation function, only influenced by the production column. This is stronger for firms with radical product innovations that use their internal resource bases intensively and use only technology policy instruments as external resources.

A comparison of the 'without' and 'with' models reveals that the latter perform better. The increase in the percentage of variance explained varies between +3 percentage points for the model of firms with radical product innovations and 14 percentage points for the model using firms with radical process innovations. These results again confirm Hypothesis 1.

CONCLUSIONS AND DISCUSSION

Using an adapted version of Håkansson's economic network model, the relations between the use of internal and external resources in innovation processes and the innovative performance of firms were empirically explored. In this last section, our conclusions are formulated and discussed.

Our main question was whether economic networks influenced innovation processes. The answer to this question is, in view of the results of our analyses, a clear 'yes'. In nearly all estimations, the addition of external resources increases the explanatory power of the models. These results show that innovation processes are embedded processes. To paraphrase Richardson (1972, p. 883), innovating firms are not islands of planned co-ordination in a sea of market relations. Contrary to this rather atomistic view, our results indicate that firms not only mobilise internal resources, but also use their environment in order to innovate with better results. This mobilisation of external resources by economic actors is as a form of interorganisational co-ordination of innovation.

It also became clear that the use of internal and external resource bases was positively associated with results of innovation. An overall view of the results reveals that the contributions of buyers and suppliers to the innovation process are of particular importance. In 10 out of 12 estimations, there was a statistically significant, positive relation between the influence of the production column and the results of innovation. The contributions of the internal transformation functions were also important (8 out of 12).

This indicates that the regular flow of goods in the firm is accompanied by a stream of ideas for and contributions to the realisation of innovations. Buyers and suppliers on the one hand, and the R&D and production function on the other hand, influence the results of innovation. All are directly connected to the primary economic activity of industrial firms: the transformation of resources into economic value.

However, general statements about the relations between the use of resources and results of innovation could not be made. The moderating effects of sectoral characteristics, and type and level of innovations produced made this impossible.

Table 6 summarises the expected and actual influence of sectoral dynamics on the relation between the use of resource and innovation results.

A comparison between the expected and empirically established use of resource bases reveals that the expectations are only partially confirmed. Only in the science-based sector were the resource bases consistent with expectations. The deviances can be explained by referring to the fact that, in our analyses, these bases are related to the innovative performance of firms. Pavitt only indicates the origin of the resources. Our approach reveals not only the origin of the resources, but also the actual contributions to the results of innovation.

Second, our results show that the innovative performance of firms having incremental innovations, as opposed to radical innovators, is strongly influenced by the use of external

Table 6. *Expected and actual influences of sectoral dynamics.*

Pavitt sector	Expected use of resource bases	Found use of resource bases
Supplier dominated	EI3	EI3, TP
Scale intensive	CFT2, EI3	EI2, EI3, TP
Specialised suppliers	CFT2, EI3	CFT2
Science based	CFT2, EI1, EI3	CFT2, EI1, EI3

CFT2 = transformation function; EI1 = public knowledge infrastructure; EI2 = private knowledge infrastructure; EI3 = production column; TP = technology policy instruments

resources, although we hypothesised the opposite. Explaining these findings in Håkanssonian terms, we could say that incremental innovators make better use of resource heterogeneity. The main characteristic of the incremental innovation is the gradual development of the (technical) features of products or processes. It is therefore relatively simple to connect the innovation with already existing technical products and systems inside and outside the firm. Because of this relatively small gap, it is easier to make use of external resources. Radical innovations imply a high proportion of newness. The probability that the internal resources can be combined with resource bases outside the firm is smaller. In conclusion, it can be argued that resource heterogeneity has its limits. If heterogeneity becomes too great, the ability to make use of external resources decreases.

Although our analysis stresses the relevance of including network variables in innovation research, a final remark must be made to put our findings in perspective. As can be seen in Tables 4 and 5, the addition of network variables indeed raises the explanatory power of the models, but at the same time, the contributions of internal resources are still most influential in terms of variance explained in most models. These findings support Dosi, who stressed that innovation is primarily a process built on internal capabilities. It is also clear that Håkansson's claims concerning the mobilisation and use of external resources are too strong. An approach in which the importance of internal and external resources are balanced proved to be more fruitful.

NOTES

1. The variety argument of Håkansson is a variation on Granovetter's weak ties. In his famous article 'The strength of weak ties' (1973, pp. 1360–1380), Granovetter argues that actors receive new information through their weak ties with other networks.
2. The taxonomy consists of four sectors:

Pavitt sector:	Typical industries:
Supplier dominated	Textiles, leather goods and footwear; furniture; paper and board; printing
Scale intensive	Food; metal products; glass, cement; transport vehicles
Specialised suppliers	Machinery; instruments, opticals
Science-based	Chemicals; plastics; electronics

3. Firms were asked to judge the impact of these functions on a Likert scale with the values 1: never, 5: always. Since a large part of our population of firms consists of SMEs, we distinguished functions instead of departments.
4. Firms were asked to judge these performance improvements on a Likert scale with values ranging from 1: 'very little' to 5: 'very much'. The highest possible score was 8, the lowest 1.
5. The variance inflation factor is defined as $VIF_i = 1/(1 - R_i^2)$.
6. The four factors were found using a varimax rotated principal components analysis. The KMO measure of sampling adequacy was 0.768. Bartlett's Test of Sphericity was 1011.75 (sign. 0.0000). The cumulative percentage of variance explained was 59.4%.

7. Although all responding firms are located in North Brabant this does not necessarily mean that their network relations cover the same region. The external actors may be located in this region, in other parts of the Netherlands or even in foreign countries. Oerlemans (1996, pp. 374–6) showed, however, that especially innovative network relations are spatially clustered.

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