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Sectoral Patterns of Interactive Learning: An Empirical Exploration of a Case in a Dutch Region

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ABSTRACT *This paper pursues the development of a theoretical framework that explains interactive learning between innovator firms and external actors in both the knowledge infrastructure and the production chain. The research question is: What kinds of factors explain the interactive learning of innovator firms with distinct external actors? Our theoretical framework extends the resource-based perspective, which is predominant in network theory, with both an activity-based and a structural account of interactive learning. We contend basically that higher technological dynamics induce more complex innovative activities. But, more complex innovative activities increase the probability of internal resource deficits/shortages in the innovator firms. The lower the alignment of the innovative activities with the quality of the internal resource base, the higher the resource deficits/shortages and the more likely the search for complementary resources externally, which increases the likeliness of external relationships.*

In order to test the generality of our theoretical claims we analyse our models in four sectors with distinct technological dynamics as distinguished by Pavitt. For each sector we explore five models of the level of interactive learning of innovator firms with: (1) the public knowledge infrastructure (difficult to access, demands high internal competencies to utilize scientific knowledge), (2) the production chain (easy to access), (3) their users, (4) their suppliers, (5) their competitors. These analyses allow for a comparison between interactive learning with different external actors and give deeper insights into the differentiated interaction patterns involving innovation.

Our findings show that patterns of interactive learning between sectors differ. Some are more resource based and others are more affected by the complexity of innovative activities. Particularly the patterns of interactive learning between, on the one hand, firms and the knowledge infrastructure, and on the other hand of firms with the production chain show important differences.

Introduction

Interaction and learning are critical constituents of the innovation process. Innovation requires the ability of a firm to recognize the value of new, external information, assimilate it, and translate it into the procurement and allocation of facilities, materials,

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components and knowledge. The firm's interaction with its environment determines its access to a diversity of resources, whereas the learning enables firms to transform these resources, both financial and informational, into innovations. Both interaction and learning contrast sharply with notions of lonely innovators with invariable resource bases and stress the dynamic features of innovator organizations.

Despite the theoretical importance of these dynamic features, if given the option, most organizations would prefer to establish a minimum number of interorganizational relationships inasmuch as these relations can constrain their subsequent action (Galaskiewicz,[1] Alter and Hage,[2] and Hage and Alter[3]). Given managers' preference for autonomy and maximum discretionary power one could call this an autonomy–dependency dilemma. Moreover, Lam[4] argues that a large part of human knowledge is context bound, highly firm specific and tacit in nature; and that there are limits to which knowledge can effectively articulated, transferred and utilized. Hence, the triumvirate of innovation, interaction and learning is anything but automatic, and raises the issue of the causes of interactive learning in innovation networks.

In this paper we argue that particularly the complexity of innovative *activities* impels firms to exploit external knowledge and to build external relations despite the stickiness, firm specificity, and social embeddedness of human knowledge, and despite the limited governance opportunities. Following Alter and Hage[5] and Lundvall,[6] the complexity of innovative activities is by and large determined by the discontinuous nature of social, sectoral, technological and market developments (Tushman and Anderson[7]) to which firms try to respond, whether reactively or proactively. In such a context, the preservation of an up-to-date internal knowledge base is virtually impossible, which on its turn explains the attractiveness of building external relationships. The organizational form of networks is considered as an effective organizational strategy because it enables firms to avoid risks and uncertainties (Håkansson[8] and DeBresson and Amesse[9]) associated with innovative activities, either in the field of strategic positioning, or in the field of technical innovation (Boisot[10]). Simultaneously, networking allows firms to exploit heterogeneous external knowledge bases, and makes firms more aware of external capabilities, offers opportunities to adapt and learn and to develop new competences.[11] To explore the validity of our argument we develop a theoretical model for the interactive learning in networks extending the resource-based network approach in economics and sociology[12] as well as the knowledge based theories on learning.[13] In contrast with the resource-based theory of networks and learning where firms' activities are taken for granted we add the *complexity and structuring of innovative activities inducing the search and utilization of external resources.* Both, the nature of innovative activities and the coherence of internal innovative activities determine the extent in which innovator firms have to draw upon external knowledge bases and hence develop external relations. The complexity perspective implies on the one hand that growth of knowledge yields more elaborate production and innovation processes, whereas on the other hand the growth of the number of monitored external environments exponentially augments information flows. In tandem this induces the rise of the awareness of both threats and opportunities. Inherent in complexity is the dilemma of co-ordination and co-operation, the need to build external linkages and control many discrete activities.

Because technological dynamics and accordingly the complexity and embeddedness of the innovation process vary strongly between lines of business, we have build in our analyses a sectoral approach which controls for the pace and level of technological dynamics. Pavitt's[14] taxonomy of sectoral patterns of technological change is one of the few that clarifies the distinctions between sectoral technological dynamics and patterns of innovation, and it also reveals distinct patterns of interaction. The advanced theoretical framework will be explored at the level of firms within Pavitt sectors, and the patterns of interactive learning within these sectors will be explored for five different types of external actors (universities/research laboratories, the production chain, users, suppliers and competitors).

Our paper adds to the growing body of literature on innovation systems, interactive learning and networks and performs several functions. First, whereas the bulk of the empirical literature focuses on dyadic relations of innovator firms with its competitors, universities, or its customers or suppliers, we concentrate on the interaction of innovator firms with actors differing with respect to their accessibility. There are only a few empirical studies available that address patterns of interaction and relationship between innovator firms and a broad variety of actors (e.g. Håkansson, van der Knaap and Tortike, Krolis and Kamann, Cooke *et al.* and Meeus and Oerlemans).[15] Second, most network research applied in innovation studies does not develop theoretical accounts for the existence of networks, or the level of interactive learning (Meeus and Oerlemans[16]), nor tests their theoretical accounts. Hence we advance an alternative theoretical explanation for the external linkages between innovator firms and external actors based on several explicit theoretical frameworks.

The structure of our paper is as follows. We describe the components of our theoretical framework in the first section and define one general hypothesis. Next we qualify this by taking into account two contingencies: the accessibility of external actors, and sectoral technological dynamics. This yields a research model and a set of three hypotheses on the relation between levels of interactive learning and the complexity of innovative activities, the quality of the internal resource base and the structuring of innovative activities. The next section describes the research design including the sample, measurement and analyses. Subsequently, our results are described. Finally, we discuss these results and derive some theoretical and policy inferences, complemented with some ideas about future research.

Theoretical Framework

Toward a Research Model

Four constructs form the basis of our synthetic model: interactive learning, resources, the complexity and structuring of innovative activities. Each of these is described and then combined, which yields our first and general hypothesis.

Interactive Learning

The concept of learning is not new.[17] Learning is conceived as a set of activities in which all kinds of knowledge are (re-)combined to form something new. Jin and Stough[18] define the learning capability of an agent as its 'capacity to create, acquire, and transform knowledge and thereby upgrade its skills, expertise and competencies . . .'. Lundvall[19] has introduced the notion of interactive learning in the innovation literature. The notion of interactivity performs several functions. First, it applies to the dependency of learning on the communication between people or organizations that possess different types of required knowledge. Second, it allows for feedback loops between 'upstream' activities like R&D and external actors like user communities or the basic science infrastructure.[20] The dependent variable in our research model is defined as the level of interactive learning between the innovator firms and external actors and is indicated by the frequency of external actors' active participation in or contribution of ideas to the innovation process of the innovator firm in the period between 1988 and 1993.[21]

Resources

Several researchers on learning convincingly showed the association between learning and resources. Post-Fordist conditions for competition rest more on the superior capacity to learn rapidly to improve products and processes than simply on cost advantages in the production and distribution of standardized goods. The strategic definition of a business firm has shifted from being a profit maximizer or transaction cost avoider to being a learning organization of knowledge creating company.[22] Our research model includes three distinct indicators for the quality of the internal knowledge base:[23] R&D intensity,[24] percentage of higher educated workforce[25] (a proxy for the depth of the available human capital) and size of the firm.[26]

The innovation process draws on a large number of heterogeneous resources, which are not easily acquired.[27] The acquisition of such resources is enabled by the interaction between the involved actors. In the context of innovation these resources are primarily defined in terms of money enabling investments, a physical and technological infrastructure, a stock of knowledge, information and human skills enabling an organization to transform inputs into outputs and decision-making.

The central tenet of the resource-based approach is that the higher the environmental dynamics, the more a firm has to draw on its internal and external environment to develop the strategic (knowledge) resources conducive to innovation. Consequently firms have to monitor actively their resource bases, particularly their knowledge base (embodied and disembodied) as well as their financial position and decide how to solve their resource deficits. In that context the intensification of existing relationships or the formation of new linkages with other firms, institutional actors like universities, or competitors are considered as behavioural alternatives enabling innovation strategies. Each external actor can be evaluated with regard to its competencies to complement the resource base of the innovator firm. So the interaction between innovator firms and a broad variety of firms and institutional actors is the corollary of their needs for heterogeneous resources.[28] Cohen and Levinthal[29] argue that the ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge. This suggests that firms with a comparatively stronger resource base are less inclined to develop external relations. This yields our first resource-based proposition:

> P1a: *A higher quality of the internal knowledge base reduces levels of interactive learning with external actors.*

However, the discontinuity of technological development calls for a qualification of this resource-based argument. Due to the nature of technological evolution firms' abilities to sustain their internal knowledge base without incurring high costs are severely limited. Leonard-Barton and Doyle[30] expect the occurrence of resource deficits particularly in case of disruptive or fast technological changes, when existing competencies become obsolete in such a pace that no firm can anticipate. Hence they suggest that although the core competencies of a firm are often an aid to its innovative performance, the very same core technical capabilities that have made a company great can constitute core rigidities and hinder new product development in subtle ways. The second resource-based proposition on interactive learning is as follows:

> P1b: *Higher environmental dynamics create a higher probability of internal resource deficits, which on its turn fosters levels of interactive learning with external actors.*

Clarifying the effects of the quality of the resource base on a firm's monitoring capacities enhances a second qualification of the resource-based proposition. A higher quality of the internal resource base allows firms to monitor a larger set of external environments more in depth. This implies a rise of the probability of defining a larger number of opportunities that cannot be met with the internal resource base, which on its turn invokes a higher probability of developing external relations. Therefore the following proposition reads:

> P1c: *A higher quality of the internal resource base enables in-depth monitoring of a larger number of external environments, increasing the chance of interactive learning.*

Complexity

Whereas the resource-based perspective takes firms' activities for granted, several activity-based theories emphasize firms' activities as the major cause for the emergence of external relationships (Lundvall, and Alter and Hage[31]). This allows for a further qualification and extension of the resource-based perspective of interaction and learning.

Lundvall explains levels of interactive learning primarily with the variable complexity of innovative activities. Lundvall's starting point is twofold. First, he conceptualizes innovation as an informational commodity (Cohendet *et al.*[32]), and he interprets innovation profits in a Schumpeterian way as transitory. Therefore the acquisition and protection of information is essential in order to innovate and to profit from the innovation, which explains the emergence of linkages as well as the importance of control. Secondly, Lundvall contends that a broader range of technological opportunities and a higher changeability of user needs cause a higher rate of innovation. Since innovation is by definition the creation of qualitatively different, new products and technologies involving new knowledge, the chances and threats of technological opportunities, as well as changing user needs have to be evaluated in order to know whether they can be translated into new product/process features. Particularly when a firm plans process or product innovations, this feasibility check demands close co-operation between users and producers, since users provide the required information for the producers. This has two related consequences: (1) a higher rate of innovation causes more intense patterns of interaction between users and producers, and (2) a higher level of innovation (incremental/radical) affects the complexity of the knowledge exchange. It is especially radical innovations that erase existing communication codes between user and producers. New codes have to be developed on a trial and error basis, which requires intensive interactions between users and producers compared to incremental innovations. Hage and Alter[33] stress another aspect—basically the growth of knowledge—which causes more elaborate production and innovation processes. In tandem, both dimensions of complexity generate the dilemma of co-ordination and co-operation, the need to build external linkages and control many discrete activities. The general proposition derived from the assumptions of Lundvall, and Hage and Alter is as follows:

> P2: *More complex innovative activities induce higher levels of interactive learning.*

In innovation research, the nexus between complexity and external linkages is often indicated with the contrast between incremental and radical innovation.[34] Lundvall and Maillat gave similar accounts for the relation between the level of innovation and the emergence of linkages. Maillat[35] argues that the importance of the local environment for the innovation process is dependent on the type of innovation, on the one hand, and on the innovation strategies of the firms on the other. For incremental innovators, the local production environment is of little importance. According to Maillat, the resources necessary for incremental innovation can in many cases be found in the firm itself. Radical innovators, however, develop more relations with the local production environment if they have an insufficient supply of internal resources to realize this type of innovation. Therefore, we hypothesize that innovator firms implementing radical innovations have a higher probability of internal resource shortages and face higher uncertainties and hence they are more inclined to exploit external knowledge and build external relationships.

Complexity has different meanings in different stages of the innovation process and also impacts in different ways on the formation of linkages. In the pre-innovation stage, complexity pertains to innovative search activities.[36] Following Mezias and Lant,[37] firms' innovative search aims at the monitoring of innovation possibilities for their products or processes either looking at new technical findings, or at new market needs. Uncertainties exist as to markets and technologies. These uncertainties induced by both types of information trigger an internal and external assessment as to the capabilities needed to absorb these new technical findings into an efficient process or product. If the internal resource base is insufficient, the alternative option is to draw on external resources. Because innovative search deals with the processing of relatively new and unused knowledge, it probably evokes more processing problems and therefore increases the chance of internal knowledge shortages, which in turn enlarges the probability of the emergence of external linkages. Hence, innovator firms with lower levels of innovative search activities interact less frequently with the actor set than firms with higher levels of innovative search activities.

During the implementation of an innovation specific operational deficiencies are detected. This implies that problemistic search[38] begins. The notion of problemistic search (Cyert and March[39]) indicates search that is stimulated by a problem (usually a rather specific one) and is directed toward finding a solution to that problem. Problemistic search increases with the amount by which performance is below aspiration level. Firms with this type of search consider those changes that alter the status quo only slightly, since the solution of product deficiencies pertains to an existing product it probably regards codified knowledge. If the problems are well defined and the required knowledge is not internally available a higher level of interaction with external actors can be expected. However it is well known that the solution of operational technical problems is often very troublesome and relies on untraceable tacit knowledge and tinkering. If the problems are ill defined, knowledge deficits cannot be defined either. In that case we expect that problems be tackled in a trial and error mode internally, because building links outside the firm is not very effective. Hence we expect that innovator firms with lower levels of problemistic search activities interact less frequently with the actor set than firms with higher levels of problemistic search activities only under the condition that problems to be solved are well defined.

Structure of Innovative Activities

There are many structural accounts explaining the outcomes of innovation processes.[40] The alignment and conduciveness of internal departments' innovative activities becomes more important in case of a higher complexity of innovative activities. It has become generally accepted that complementary functions or departments within organizations (e.g. R&D, sales and marketing, purchase, production) ought to be tightly intermeshed, recognizing that some amount of redundancy in expertise may be desirable to create what can be called cross-function absorptive capacities.[41] To the extent that an organization develops a broad and active network of internal relationships, individual awareness

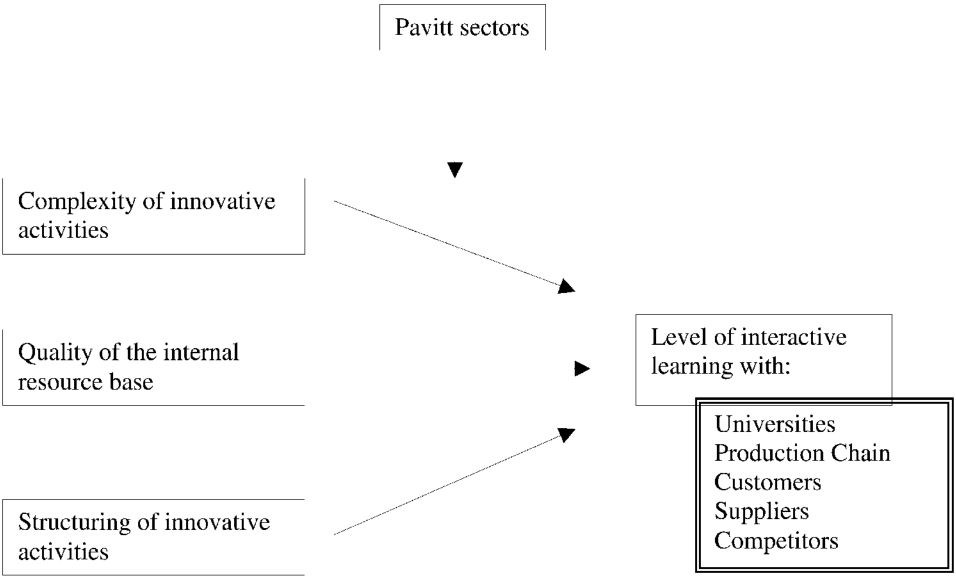

Figure 1. A research model of the relation between interactive learning of innovator firms with divergent actors, the complexity of innovative activities, the quality of the internal resource base and the structuring of innovative activities and the moderator effects of sectoral technological dynamics.

of others' capabilities and knowledge will be strengthened. Inward (production, engineering) and outward looking (R&D, sales/marketing) departments enable a comparison of the internal and external opportunities for co-operation in innovation projects. In our research model the structural variable indicates the integration of internal innovative activities.[42] The following proposition is explored:

> P3: *Higher integration of internal innovative activities creates a higher awareness of external as well as internal knowledge bases and therefore induces both lower and higher levels of interactive learning with external actors dependent on the evaluation of the quality of the internal resource bases.*

Our major hypothesis is based on our finding that the level of interactive learning cannot be explained only with the quality of the internal resource base of innovator firms and needs to be extended with the complexity and structuring of a firm's innovative activities:

> H1: *Higher levels of interactive learning are associated with the quality of the internal resource base, the complexity of innovative activities and the structuring of innovative activities.*

The Generality of Theoretical Claims

We expect the relations advanced in hypothesis 1 to be contingent upon divergent sectoral technological dynamics as well as on the type of actors involved in the innovator firm's interactive learning. This assumption asks for a test of the generality of our hypothesis, more specifically for a search for contingencies. To test the generality of our claims, we shall explore our hypotheses within the four sectors derived from Pavitt.[43] Within these sectors our hypothesis will be specified for five different types of external actors:

universities/research laboratories, the production chain, and users, suppliers and competitors separately.

The first specification of our hypothesis pertains to the external actors with which innovator firms interact.[44] The key interactions involved are between component and system producers, upstream and downstream firms, universities and industry, and government agencies and universities and industries.[45] Pavitt and Von Hippel[46] stressed the role of suppliers and users. There is ample evidence that innovator firms co-operate with institutional actors in the knowledge like universities and higher professional education.[47] This also applies to relationships amongst competitors.[48]

The access to and transfer of the resources between these external actors and innovator firms is determined on one hand by the nature of the knowledge provided by external actors, and on the other hand by the capabilities of the innovator firm to assimilate such knowledge. Universities and applied research laboratories produce complex, partially codified knowledge, of which the larger part has not been tested in industrial large scale or highly firm specific conditions. The utilization of such scientific knowledge in innovation processes requires strong engineering capabilities and production experience, which is unevenly distributed among firms. This implies that a number of firms are unable to assimilate such knowledge and consequently co-operation with universities is not likely. The empirical research of Nelson[49] stressed the linkage between basic science and innovation. The strength of the linkage between firms and other technology-generating institutions in the US appeared to be strongly differentiated. From the questioning of research managers in 650 firms it was found that all industries in the sample claimed a strong dependence on at least one field of basic or applied science while a small number of industries—drugs, semiconductors, instruments—were very dependent on a single science. However this did not mean that they had strong links with university-located research. In fact, only nine industries claimed close links with academic science. Meeus *et al.*[50] found that the interaction frequency of innovator firms with the universities and applied research laboratories in the Netherlands was very low. However, in other research projects, we found that in specific technical fields (image processing, human–system interaction), Dutch universities were perceived as very important knowledge bases for the innovator firms, which also resulted in regular interaction (Meeus *et al.*,[51] Oerlemans and Meeus[52]).

Compared to universities, customers and suppliers have lower access thresholds. There is ample evidence that innovator firms interact frequently with them in innovation projects and that they contribute significantly to innovation outcomes. Freeman and Soete[53] report SPRU research that tested 200 measures explaining the patterns of success of innovation projects in chemicals and instruments. The single measure that discriminated most clearly between success and failure was 'user needs understood'. Teubal[54] found the same 'market determinateness' in the Israeli medical electronics industry. In his seminal paper, Von Hippel[55] presented empirical findings stressing the importance of external sources for innovation. Of a total of 44 innovation projects in scientific instruments 36 (81%) were user dominated. He found that it was the user who perceived that an advance in instrumentation is required, invents the instrument, builds a prototype, proves the prototype by applying it and diffuses detailed information on the value of his invention. Only when all of the above has transpired does the instrument manufacturer enter the innovation process. Typically, the manufacturer's contribution is then to perform product-engineering work on the user's device to improve its reliability, convenience of operation, etc., and to manufacture, market and sell the innovative product. Interestingly, this user-dominated pattern appeared typical for innovations that were more 'basic', as well as for the minor and major improvement innovations. The user-dominated patterns described by Von Hippel also appeared to hold independent of the size—and thus, presumably, of the internal R&D potential—of the commercializing company. Finally, Von Hippel observed that the pattern of a user-dominated innovation process appears to be true for companies who are established manufacturers of a given product line—manufacturers who 'ought to know' about improvements needed in their present product line and be working on them—as well as for the manufacturers for whom a given innovation represents their first entry into a new product line. Gregersen and Johnson[56] reported that the Nordic Innovation Survey shows that customers are an important source of product-innovation ideas in Scandinavian firms. Universities and R&D institutions are also frequently mentioned.

Pavitt[57] extended the 'customer active paradigm' to a broader actor set, inside and outside the firm. Compared to Von Hippel, Pavitt refined the ideas on linkages with customers to linkages within the firm stressing the role of internal departments, and between firms stressing the role of suppliers, public R&D, etc. Pavitt[58] found that for supplier dominated sectors (e.g., agriculture, housing, private services, traditional manufacture) the sources of technology were suppliers, big users and research extension services. For the scale intensive sectors (e.g., bulk materials, assembly) he found that the production engineering department and (in-house) suppliers as well as the R&D department sourced innovation processes. Innovation among the specialized suppliers (e.g. machinery and instruments) was supported by the design and development department, in-house customers and users. Innovations in the science based industries (e.g. electronics/electrical, chemicals) originated in the R&D department, public science and production engineering and in-house suppliers. Over 40% of US firms questioned claimed that suppliers of capital equipment and components were important sources of innovation inputs.[59] These empirical findings allow for a first qualification of hypothesis 1, which yields hypothesis 2:

> H2: *Effects of the quality of the internal resource base, the complexity and structuring of innovative activities on interactive learning differ dependent on the type of external actor(s) involved.*

Pavitt's[60] sectors differ strongly as to the nature of the process of technological change and the embeddedness of the innovation process. He showed convincingly that innovation rates differ strongly between different sectors due to distinct technological dynamics. Following Lundvall[61] this implies a different level of complexity of innovative activities in these sectors. Pavitt also described the variety of relationships of the innovator firms with external actors as well as the contributions of internal departments to their innovative activities. His findings indeed confirm that the firms in the sector with the highest innovation rates had the largest variety of actors involved in their innovations. Empirical research confirmed the differences as to R&D participation, R&D spending and innovation outcomes between Pavitt sectors in the Netherlands. Vossen and Nooteboom[62] report a ranking of sectors from low to high is equal for both indicators: (1) the supplier dominated, (2) scale intensive, (3) specialized suppliers, and (4) science based industries. Oerlemans *et al.*[63] found that patterns of interaction with distinct external actors yield different innovation outcomes between Pavitt's sectors. In other words, technological innovation is a process that occurs differently across industries.

The *supplier dominated firms* can be found in traditional sectors of manufacturing, and in agriculture, construction and many professional, financial and commercial services. They are generally small and their in-house R&D and engineering capabilities are weak. Consequently these sectors make only a minor contribution to their process or product technology and have relatively low innovation rates. Especially linkages with their suppliers are important sources of technology, as well as big users. The *scale intensive* *producers* are found in food products, metal manufacturing, shipbuilding, motor vehicles, and glass and cement. They produce a relatively high proportion of their own process technology, to which they devote a high proportion of their innovative resources. Innovator firms are relatively big and have a relatively high level of vertical technological diversification into equipment related to their own process technology. Scale intensive firms acquire their technology from external and in-house suppliers and some internal departments. The *specialized suppliers*—mechanical and instrument engineering firms—produce a relatively high proportion of their own process technology too, but the main focus of their innovative activities is the manufacturing of product innovations for use in other sectors. Innovator firms are relatively small. Specialized suppliers acquire their technology from their users and product design. The *science-based industries* can be found in chemicals, oil, and electronics. These firms are relatively large, have a high R&D intensity, which is done in-house. They produce a high proportion of their own process technology, as well as a high proportion of product innovations that are used in other sectors. Science based firms have their internal R&D, production engineering, in-house suppliers and public science as technology sources. Empirical research in the chemical industry revealed that radical innovations indeed improve market success. Radical innovation has been identified as the kingpin for the evolution of technologies in both the micro- and macro-economic context, not only because it provides a model for imitation, but also because it turns out to be more profitable.[64] These empirical findings allow for a second qualification of hypothesis 1, which yields hypothesis 3:

> H3: *Effects of the quality of the internal resource base, the complexity and structuring of innovative activities on interactive learning are moderated by sectoral differences in technological dynamics.*

Research Design

Sample

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

The data gathering was performed in a region with typical features. This region is one of the most industrialized regions in the Netherlands. In 1992, the total number of jobs in manufacturing was roughly 210,000, i.e. the manufacturing sector's share of employment in the region was 28.8% (the average in The Netherlands is 19.5%). The population of firms in the region consists of a mix of small, medium-sized and large enterprises. About 84% of the responding firms have 100 or less employees. Furthermore, the manufacturing sector has shown a relatively high R&D and export performance.[65] Because technological activity is an important issue in this article, industrial firms were grouped according to Pavitt's taxonomy.[66]

Our sample is a reliable representation of the population of industrial firms in North Brabant, in which sample strata and population strata deviated within boundaries of 8%. The mean deviation between the percentages in the sample and in the response is 6.4%.

Measurement

In our theoretical explanations we have described the indicators used to measure our variables. In Table 2 for each variable, the items, calculations and transformations are described in detail.

Table 1. Population and sample divided in Pavitt sectors

Pavitt sector	**Population (%, *N*)**	**Total sample (%, *n*)**	**Sample of innovating respondents**
Supplier dominated	33.5% (1.028)	25.7% (149)	22.9% (92)
Scale intensive	41.1% (1.261)	36.1% (209)	34.1% (137)
Specialized suppliers	13.6% (478)	21.4% (124)	22.1% (89)
Science based	11.8% (363)	16.8% (97)	20.1% (84)
Total	100% (3.069)	100% (579)	100% (402)

Analyses

In this paper we restrict our analyses to descriptive, exploratory analyses. Five models, within four different economic sectors, were estimated. In order to test our hypotheses, OLS (ordinary least square) regression analyses were applied. Because our empirical model contains dichotomous (size) as well as numeric operations (R&D intensity) for resource indicators as predictor variables, the interpretation of our findings deviates from standard models containing numerical variables only.[67]

The interpretation of our findings is straightforward. For the dummy coded variable 'size' a significant positive beta means that large firms interact more frequently with an external actor, than do the small- and medium-sized firms. A negative implies the opposite. For the numerical variables the interpretation of research findings is slightly different. Positive betas for the complexity indicators imply that higher scores—so higher levels of radicalism of innovations—co-vary with higher levels of interactive learning. Significant negative betas would mean that higher levels of complexity are associated with lower levels of interactive learning.

In our analyses we controlled for collinearity, which means that different variables provide very similar information. The consequence is that the effects of individual variables are difficult to separate, which causes interpretation problems. Where collinearity occurred in the analyses, variables were excluded from the regression equation or deleted from the analysis. Control on collinearity was done using the variance inflation factor.[68]

Results

First we shall review the outcomes of our descriptive analyses. Next the results as to hypotheses 1–3 will be reviewed for the total sample of innovator firms supplying industrial users. Subsequently the outcomes of analyses within Pavitt sectors are reviewed separately. By comparing the outcomes of five models within one sector, the differences between modes of interactive learning can be revealed. Subsequently a cross-sectoral comparison is made between interactive learning with users, suppliers, competitors, universities and the production chain. This allows for an assessment of the moderating effects of sectoral dynamics on the relation of complexity, resource base and structure of innovative activities with the level of interactive learning.

Descriptive Statistics

As a general result (Figure 2) the innovation process of the firms seems to be affected most by internal departments, customers and suppliers. Neither the intermediary organizations, nor the public knowledge infrastructure seem to interact frequently with the innovator firms.

Table 2. Measurement of variables

Definition, name of dependent variable	**Indicators, range of scores**	
Level of interactive learning: the frequency in which external actors contributed to the innovation process(es) of the responding firm.	*Interactive learning with universities and research laboratories (IL1)*	IL1 pertained to contributions of Eindhoven University of Technology, Other Universities, and the National Centre for Applied Research
	Interactive learning within the production chain (IL2)	IL2 pertained to important buyers, important suppliers and competitors.
	Interactive learning with customers (IL3)	IL3 pertained to the contributions of 'important buyers' to the focal firms' innovations between 1988–1993.
	Interactive learning with suppliers (IL4)	IL4 pertained to the contributions of 'important suppliers' to the focal firms' innovations between 1988–1993.
	Interactive learning with competitors (IL4)	IL4 pertained to the contributions of 'competitors' to the focal firms' innovations between 1988–1993.
		The focal firms were asked to report the frequencies in which the internal and external actors contributed to the focal firms' innovation processes (1988–1993) by bringing up ideas, or participate actively. The respondents could score in terms of frequencies ranging from (1) never, (2) sometimes, (3) regularly, (4) often, (5) always. As far as multiple items were used raw scores were standardised into z-scores, which were averaged.
Definition, and name of independent variables	**Indicators, calculation of scores, range**	
Sector in which firm is active (control variable)	*Pavitt sectors*	1. Supplier-dominated: agriculture, housing, private services, traditional manufacture 2. Scale intensive: bulk materials, assembly 3. Specialised Suppliers: machinery and instruments 4. Science-based: electronics, electrical, chemicals
Complexity of innovative activities (CIA)	*CIA1 Problemistic search*: the extent into which firms innovate due to deficiencies in products and processes	Reasons to innovate were: 1. to solve technical product deficiencies 2. to solve technical production problems 3. Firms could respond to a 5-point scale of frequencies ranging from: (1) never, (2) sometimes, (3) regularly, (4) often, (5) always. Raw scores were averaged. Range 1–5.
	CIA2 Innovative search: the extent into which firms innovate due to technical or market opportunities	Reasons to innovate were: 1. discovery of new market needs 2. technical idea, invention Firms could respond to a 5-point scale of frequencies ranging from: (1) never, (2) sometimes, (3) regularly, (4) often, (5) always. Raw scores were averaged. Range 1–5.

Table 2. *Continued*

Definition, and name of independent variables	**Indicators, calculation of scores, range**	
	CIA3 Radicalness of innovations the extent into which firms alter product and/or process features	Firms could answer: 1. incremental improvement of product features 2. radical change of product features Range is 1 (incremental)—2 (radical). Firms could answer: 1. incremental improvement of process features 2. radical change of process features. Range is 1 (incremental)—2 (radical).
The quality of the internal resource base (QIR)	*QIR1 R&D intensity*	The number of employees working full-time on R&D as a percentage of the total workforce. Range 0–100.
	QIR2 % higher educated employees	The percentage of higher educated employees of the total workforce. Range 0–100.
	QIR3 Size	We applied a dummy coded variable: (1) small- and medium sized firms $\leqslant$100 employees, (2) larger firms $>$100 employees.
	QIR4 Number of innovation problems	A count of confirmative answers was made to items as to different types of innovation problems: exceeding time planning, product deficiencies, technical production deficiencies, exceeding budgets, bad timing, wrong partners, reaction of competitors, insufficient market introduction efforts. Range 0–8.
Structure of the innovative activities	*The level of integration of internal innovative* activities	An average score of the extent into which internal departments contributed to the firm's innovation projects. It concerned: the R&D, marketing and sales, purchase and production department. Firms could respond to a 5-point scale of frequencies ranging from: (1) never, (2) sometimes, (3) regularly, (4) often, (5) always. Raw scores were averaged. Range 1–5.

Interactive Learning in the Total Sample

Table 3 displays the findings on hypothesis 1 and 2 for the total sample of innovator firms. Hypothesis 1 is partially supported by our findings in Table 3. The explained variances of the five estimated models are relatively low (0.07–0.22), whereas no model contained significant betas for every type of independent variable (complexity, resource base and structuring indicators). By and large, resource indicators in combination with the structuring of innovative activities seem to affect levels of interactive learning.

Hypothesis 2 is confirmed partially. Interactive learning of innovators with their customers and suppliers did not differ and was significantly affected only by the structuring of innovative activities (Table 3, model 3 and 4). Model 1, 2 and 5 yielded a different set of indicators with significant betas. Higher levels of problemistic search induce the interactive learning of innovator firms with the universities and applied research centres (Table 3, model 1), a higher percentage of higher educated employees and large size firms. The number of innovation problems and the structuring of innovative activities affect the level of interactive learning within the production chain (Table 3, model 2). A higher level of integration of innovative activities and a lower number of higher educated employees affected the level of interactive learning of innovators with their competitors.

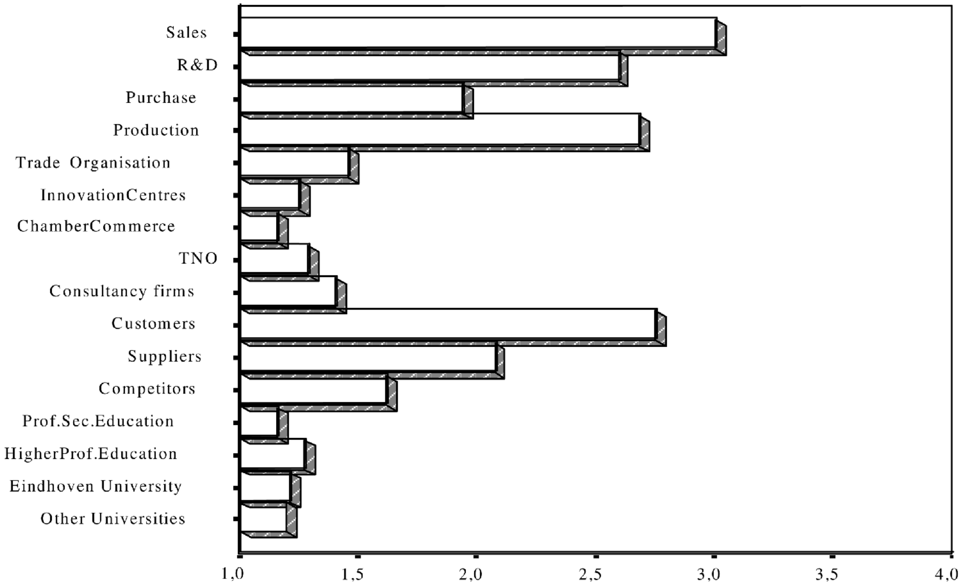

Figure 2. Mean level of interactive learning of innovator firms with external actors in North Brabant ($n = 402$). A five-point scale was used: (1) = never, (2) sometimes, (3) regularly, (4) often, (5) always.

Moderating Effects of Pavitt Sectors on Levels of Interactive Learning

The overall results displayed in Tables 4–7 show that hypothesis 3 is strongly confirmed. Sectoral technological dynamics indeed moderated the relation between complexity, the quality of the internal resource base, the level of integration and the levels of interactive learning. First, the R^2 in Tables 4–7 for the cross-sectoral OLS regression analyses are largely higher than in Table 3, displaying the analyses for the total sample. We estimated 20 models, and in 15 models the explained variance was higher. Second, compared to the predictors significantly contributing to the explanation of interactive learning for the total population (Table 3, models 1–5), the predictors affecting the levels of interactive learning differed in 17 of the 20 estimated models.

A closer inspection of the differences of sectoral patterns of *interactive learning with different actors* revealed the following patterns. The *level of interactive learning of innovators, universities and research centres (Tables 4–7, model 1)*, was affected by three resource-based indicators and two complexity indicators. In the supplier-dominated industries, size positively affected interactive learning with the knowledge infrastructure. The R^2 had a range between 0.08 (science-based firms) and 0.29 (scale-intensive firms). We expected that this model fitted best with Pavitt's findings on the science-based industries, which was not the case.

The level of interactive learning within the production chain (forward with customers/users, backward with suppliers and horizontal with competitors) was affected significantly by resource indicators (size, number of innovation problems, percentage higher educated employees), the complexity of innovative activities (twice radicalism in innovations, level of problemistic search), and the level of integration of innovative activities (four times) (Tables 4–7, model 2). The highest R^2 was found in the supplier-dominated firms (0.42), which fits the logic of Pavitt's findings. Though supplier-dominated firms are generally low-tech, they are strongly oriented towards their big users and suppliers.[69]

Table 3. OLS regression of interaction frequency of innovating firms with external actors on indicators of complexity of innovative activities (radicalness of innovation, innovative search, problemistic search), indicators of the firms knowledge base (R&D intensity, % higher educated employees, size, learning problems) and one structure variable (the level of integration) for the total sample of innovator firms supplying industrial users

Dependent variable	Independent variables	Model 1 Interaction frequency with universities and centres for applied research	Model 2 Interaction frequency with production chain	Model 3 Interaction frequency with customers	Model 4 Interaction frequency with suppliers	Model 5 Interaction frequency with competitors
Complexity of innovative activities	Radicalness of innovation	−0.03	0.01	0.01	0.04	0.04
	Level of innovative search	0.10	0.04	0.05	−0.00	0.10
	Level of problemistic search	0.19***	0.09	0.06	0.05	0.04
Quality of the resource base	R&D intensity	−0.02	0.01	0.12	0.00	−0.04
	%higher educated employees	0.16**	0.03	0.12	0.00	−0.14**
	Size	0.14**	−0.14[1]	−0.11[1]	−0.12[1]	−0.01
	Number of innovation problems	0.14**	0.14**	0.07	0.05	0.13[1]
Structure of innovation	Level of integration of inn. act.	0.10	0.40****	0.37****	0.38****	0.19***
	R^2	0.08	0.22	0.18	0.16	0.07
	F- value	5.77	18.99	15.45	19.79	5.39
	Sign.	0.001	0.000	0.000	0.000	0.001
	D.f.	3, 204	3, 205	3, 212	2, 211	2, 205
	Listwise N	208	209	216	214	207

*$p \leq 0.10$, **$p \leq 0.05$, ***$p \leq 0.01$, ****$p \leq 0.001$.
[1] All these variables were excluded from the regression equation.

Table 4. OLS regression of interaction frequency of innovating firms with external actors on indicators of complexity of innovative activities (radicalness of innovation, innovative search, problemistic search), indicators of the firms knowledge base (R&D intensity, % higher educated employees, size, learning problems) and one structural variable (the level of integration) in Supplier Dominated firms

Dependent variable	Independent variables	Model 1 Interaction frequency with Universities and Centre for Applied Research	Model 2 Interaction frequency with Production Chain	Model 3 Interaction frequency with Customers	Model 4 Interaction frequency with Suppliers	Model 5 Interaction frequency with competitors
Complexity of innovative activities	Radicalness of innovation	0.05	0.36****	0.48****	0.26*	0.00
	Level of innovative search	0.21	0.11	0.01	−0.06	0.20
	Level of problemistic search	0.12	0.04	0.01	0.15	−0.04
Quality of the resource base	R&D intensity	−0.02	−0.09	0.06	−0.03	−0.12
	% higher educated employees	−0.11	−0.13	−0.11	−0.06	−0.12
	Size	0.35**	−0.01	−0.07	−0.12	0.24*
	Number of innovation problems	−0.02	0.05	−0.09	−0.01	0.08
Structure of innovation	Level of integration of inn. act.	0.06	0.43***	0.17	0.35**	0.32**
	R^2	0.12	0.42	0.23	0.34	0.19
	F-value	5.18	14.53	13.17	7.32	4.72
	Sign.	0.021	0.000	0.001	0.000	0.014
	D.f.	1, 42	2, 40	1, 44	3, 42	2, 40
	Listwise *N*	44	43	46	46	43

*$p \leq 0.10$, *$p \leq 0.05$, ***$p \leq 0.01$, ****$p \leq 0.001$.

Table 5. OLS regression of Interaction Frequency of innovating firms with external actors on indicators of complexity of innovative activities (radicalness of innovation, innovative search, problemistic search) , indicators of the firms knowledge base (R&D intensity, % higher educated employees, size, learning problems) and one structural variable (the level of integration) in scale Intensive firms

Dependent variable	**Independent variables**	**Model 1 Interaction frequency with Universities and Centre for Applied Research**	**Model 2 Interaction frequency with Production Chain**	**Model 3 Interaction frequency with Customers**	**Model 4 Interaction frequency with Suppliers**	**Model 5 Interaction frequency with competitors**
Complexity of innovative activities	Radicalness of innovation	−0.13	−0.25**	−0.13	−0.25**	−0.27**
	Level of innovative search	0.17	0.04	−0.08	0.06	0.10
	Level of problemistic search	0.22**	0.14	0.03	0.14	0.20*[1]
Quality of the resource base	R&D intensity	−0.05	−0.03	−0.04	−0.03	−0.12
	%higher educated employees	0.47****	−0.13	−0.11	−0.14	−0.11
	Size	0.07	−0.30***	−0.21	−0.19	−0.11
	Number of innovation problems	0.05	0.31***	0.16	0.12	0.24*
Structure of innovation	Level of integration of inn. act.	0.19	0.40****	0.30***	0.30***	0.26**
	R^2	0.29	0.35	0.09	0.16	0.14
	F-value	12.31	7.92	6.33	5.89	5.19
	Sign.	0.000	0.000	0.014	0.005	0.008
	D.f.	2, 61	4, 60	1, 63	2, 62	2, 62
	Listwise *N*	64	65	65	65	65

$*p \leq 0.10$, $**p \leq 0.05$, $***p \leq 0.01$, $****p \leq 0.001$.

[1]All these variables were excluded from the regression equation.

Table 6. OLS regression of Interaction Frequency of innovating firms with external actors on indicators of complexity of innovative activities (radicalness of innovation, innovative search, problemistic search) , indicators of the firms knowledge base (R&D intensity, % higher educated employees, size, learning problems) and one structural variable (the level of integration) in Specialised Suppliers.

Dependent variable	**Independent variables**	**Model 1 Interaction frequency with Universities and Centre for Applied Research**	**Model 2 Interaction frequency with Production Chain**	**Model 3 Interaction frequency with Customers**	**Model 4 Interaction frequency with Suppliers**	**Model 5 Interaction frequency with competitors**
Complexity of innovative activities	Radicalness of innovation	0.28**	0.14	−0.14	0.14	0.46****
	Level of innovative search	0.06	−0.11	0.01	−0.02	−0.04
	Level of problemistic search	0.13	−0.09	0.01	0.02	−0.01
Quality of the resource base	R&D intensity	−0.15	0.03	0.07	0.02	0.20
	%higher educated employees	0.01	0.32**	0.32***	0.35***	−0.22
	Size	0.31**	−0.22	−0.06	−0.17	−0.16
	Number of innovation problems	−0.01	0.08	0.01	−0.03	0.21
Structure of innovation	Level of integration of inn. act.	0.05	0.41***	0.66****	0.23	0.08
	R^2	0.27	0.31	0.43	0.12	0.21
	F-value	8.80	6.79	19.53	6.99	12.53
	Sign.	0.001	0.001	0.000	0.011	0.001
	D.f.	2, 48	3, 46	2, 52	1, 50	1, 48
	Listwise N	51	50	55	53	50

*$p \leq 0.10$, **$p \leq 0.05$, ***$p \leq 0.01$, ****$p \leq 0.001$.

Table 7. OLS regression of Interaction Frequency of innovating firms with external actors on indicators of complexity of innovative activities (radicalness of innovation, innovative search, problemistic search) , indicators of the firms knowledge base (R&D intensity, % higher educated employees, size, learning problems) and one structural variable (the level of integration) in Science Based firms.

Dependent variable	Independent variables	Model 1 Interaction frequency with Universities and Centre for Applied Research	Model 2 Interaction frequency with Production Chain	Model 3 Interaction frequency with Customers	Model 4 Interaction frequency with Suppliers	Model 5 Interaction frequency with competitors
Complexity of innovative activities	Radicalness of innovation	−0.27	−0.11	−0.18	−0.15	0.05
	Level of innovative search	0.15	0.18	0.17	0.07	0.11
	Level of problemistic search	0.28**	0.40***	0.42****	0.16	0.24
Quality of the resource base	R&D intensity	0.23	0.10	0.09	0.07	−0.04
	% higher educated employees	0.03	0.07	0.32***	−0.07	−0.16
	Size	−0.25	−0.15	0.01	−0.17	−0.05
	Number of innovation problems	−0.03	0.05	0.01	0.08	−0.01
Structure of innovation	Level of integration of inn. act.	0.17	0.30**	0.20	0.51****	−0.10
	R^2	0.08	0.33	0.29	0.34	0.11
	F- value	4.52	11.86	9.70	12.76	0.616
	Sign.	0.045	0.000	0.000	0.000	0.759
	D.f.	1, 49	2, 48	2, 48	2, 49	8, 42
	Listwise N	51	51	51	51	51

*$p \leq 0.10$, **$p \leq 0.05$, ***$p \leq 0.01$, ****$p \leq 0.001$.

The level of interactive learning between innovator firms and their customers (Tables 4–7, model 3) was associated with a higher quality of resource bases (twice the percentage higher educated employees), with more complex innovative activities (radicalism in innovation, problemistic search) and tight integration of innovative activities. The highest proportion of explained variance (0.43) was found in the specialized suppliers, which is indeed a sector where firms have to be specialists in customization. The lowest proportion explained variance (0.09) was found in the scale intensive firms producing bulk products, which do not rely on close and intensive contacts with customers, because customers are predominantly price sensitive.

Interactive learning between innovator firms and their suppliers (Tables 4–7, model 4) turned out to be associated with the quality of the resource base (percentage of higher educated employees), the complexity (twice radicalism in innovation) and structuring of innovative activities (three times). The models for the supplier-dominated and the science-based firms yielded the highest explained variance, an R^2 of 0.34. This is not consistent with Pavitt's findings, which suggests that this model should perform the best in the supplier-dominated industries.

Interactive learning of innovator firms and their competitors (Tables 4–7, model 5) was determined by the firms' resource base (size), the complexity of innovative activities (radicalism in innovation twice) and the structuring of innovative activities (twice). The range of the R^2 of these models varied between 0.11 (science-based firms) and 0.21 (specialized suppliers).

The comparison of the interactive learning with distinct external actors shows some interesting differences. The integration of innovative activities had no impact on interactive learning with universities and research centres, whereas it turned out to be the most consistent impact in the interactive learning with the other actors. The indicators predicting the levels of interactive learning between innovator firms, universities and research laboratories turned out to differ strongly from those in the other four models.

The extended resource-based model turns out to predict best the interaction of innovator firms with their production chain. It yielded the largest number of significant predictors, and the highest R^2s, whereas the interactive learning of innovator firms with their competitors was predicted worst with our predictors. It yielded the smallest number of significant predictors, one insignificant model (science-based firms, Table 7, model 5) and the lowest R^2s. Compared to the results achieved with the estimation for the total sample, the cross-sectional analyses for Pavitt sectors refined our ideas about interactive learning with different actors.

A Comparison of Pavitt Sectors

The most remarkable differences between the Pavitt sectors are:

- The interactive learning of specialized suppliers is determined the most by the quality of the internal resource base (three times the percent higher educated employees, and size one time).
- The interactive learning of scale intensive firms is negatively affected by the radicalism of innovation, whereas it impacted positively on interactive learning in the other sectors.
- The impacts of the quality of the internal knowledge base are very few in the science-based industries.

Discussion and Conclusions

Despite the numerous publications on networks, learning and interactive learning, the review studies of technological collaboration this study clearly shows that interactive learning is anything but automatic and turns out to be a multifaceted and complex phenomenon. The main conclusion from our exploratory analyses for the total sample is that:

- Our results showed that the resource- and structure-based perspective were confirmed for interactive learning with most actors, whereas the complexity-based perspective was only confirmed for the interactive learning between innovators and the knowledge infrastructure. So hypothesis 1 was partially confirmed.
- The comparison of interactive learning with distinct external actors revealed that patterns of significant predictors differed except for suppliers and customers. This implied a partial confirmation for hypothesis 2.

Our decomposition of the total sample in Pavitt sectors, controlling for divergent technological dynamics by and large confirmed hypothesis 3:

- The explanatory power of our models in general improved. This implies that at the sectoral level we found stronger support for hypothesis 1 than at the level of the total sample. Except for R&D intensity and innovative search, all the indicators included in the model contributed to the explanation of the level of interactive learning.
- Patterns of predictors explaining levels of interactive learning differed with distinct external actors involved. This implies that at the sectoral level we found stronger support for hypothesis 2 than at the level of the total sample.

Our findings indicate convincingly: (1) that the augmented resource-based model of interactive learning performed well, but (2) that the explanation of interactive learning should be done at the sectoral level, for distinct types of external actors. Controlling for differences in technological dynamics and divergent patterns of embeddedness also enhances interpretation of the results and improves results.

In general it is interesting that our findings confirm Cohen and Levinthal's[70] ideas on absorptive capacity. Firms with external linkages tend to have more prior related knowledge, a higher quality of internal resources in our terms. Conversely, resource deficits in general did not account for the level of interactive learning of innovator firms. It is interesting that interactive learning in some sectors (specialized suppliers) is determined particularly by the quality of internal resources, whereas interactive learning in the science-based firms is determined more by their problemistic search.

Probably the most robust finding is that greater internal integration of innovative activity leads to greater external integration. This finding holds for four out of four sectors, whereas it turns out to be robust for four out of five external actors. The fact that the integration of internal innovative activities did not affect the interactive learning with universities, whereas it does affect the interactive learning in the complete production chain, as well as with customers, suppliers and competitors separately may be interpreted in terms of the fit of the knowledge bases to distinct resource environments. The internal integration of innovative activities fosters primarily the knowledge exchange derived from market-based links needed to run the firm's production process and to monitor the activities in the production chain.

Our findings indicate several things. First, since moderation effects of Pavitt's sectors were prevalent future research should continue to make cross-sectional analyses. Second, except R&D intensity and innovative search, all the indicators included in the model contributed to the explanation of the level of interactive learning. It might be the case that these variables were excluded because there are non-linear relations with interactive learning. Future research should pursue non-linear analyses. Third, the mixed signs of radicalism of innovation—negative in the scale intensive firms, positive in specialized suppliers—shows that particularly lower levels of complexity invoke interactive learning in specific sectors. Fourth, similar indicators explain the interactive learning between innovator firms and customers, suppliers, and competitors within sectors. This suggests that there is a general logic underlying the interactive learning within the production chain. Here it would be helpful to include the reasons for choosing specific types of co-operation, which would allow for a further qualification of patterns of interactive learning. Fifth, the indicators predicting interactive learning with universities and research laboratories are distinct from those in the other four models. This implies that interaction within the production chain follows a different logic, compared to the interactive learning with universities and research laboratories. Again, our extended resource-based model would need further extension, particularly with respect to the types of knowledge needs that led to the search for and utilization of external knowledge bases.

Another important research direction is to compare regions with respect to their connectivity. By comparing external linkages of innovator firms within several comparable regions, we may tease out the effects of networking on regional competitiveness. Furthermore, given the low utilization of regional resources in this specific region, we suggest research focusing on the comparison of strategies for the acquisition of distinct resources and their relative contributions to innovative performance. This allows us to support the efficiency of network strategies, as well as the efficacy of regional innovation systems more solidly.

Although we contend that the results of this study provide a valuable addition to the micro-foundations of innovation and organization theory, several cautions should be noted. First, because we studied a specific region, with a specific population of predominantly small- and medium sized firms. Second, because the way we controlled for sectoral differences is multidimensional (size, embeddedness, technological dynamics) it is unclear how this precisely affects our outcomes. So, this demands further specification of control variables. Finally, we did not control for so-called interaction effects, and concentrated on the main effects of our independent variables.

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67. The least-square regression model can easily be extended to accommodate dichotomous predictors, including sets of dummy and numerical variables . With the dichotomous predictors for size, the intercept and the slope have a special interpretation compared to numerical variables measured at interval, or ratio level. It is still true that the intercept is the predicted value of the dependent variable when the independent variable is coded 1 (=100 employees) but with only two groups the intercept now is the mean innovation outcome for the group coded as 1. The slope is still the change in the dependent variable associated with one-unit change in the independent variable, but with only two categories; that value becomes the difference in the mean scores in the criterion variable (level of interactive learning) between the first (sme's =100 employees) and second group (large firms >100 employees.). The sum of the slope and the intercept is therefore the mean score the level of interactive learning for the second group (large firms). Adapted from: S. Menard, *Applied Logistic Regression Analysis* (London, Sage, 1995), p. 5, and D.L. Harnett, *Statistical Methods*, 3rd edn (Reading, MA, Addison-Wesley, 1982), pp. 571–577.
68. This quantity is called the variance inflation factor (VIF) since the term is involved in the calculation of the variance of the *i*th regression coefficient. The formula is: $VIF_i = 1/(1\text{-}R_i^2)$.
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