Harabi, Najib

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Vertical Relations Between Firms and Innovation: An Empirical Investigation of German Firms

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Najib Harabi

Non-technical summary

Joint ventures between firms as part of innovation projects can be seen as a strategy to deal with market failure and other insufficiencies of technology markets. It is the objective of this paper to examine empirically the occurrence and significance of types of joint ventures between innovative companies, customers and suppliers within the German industry. The analysis is based on a written survey of 3.122 enterprises, carried out by ZEW in 1994. The most important results can be summarized as follows:

- 84% of those surveyed state that as part of innovation projects they cooperated either with customers or suppliers or both. This percentage is even higher (99%), when only companies with a formal R&D department were taken into account.

- „Informal exchange of technical knowledge“is regarded to be the most significant form of cooperation between innovative firms, customers and suppliers, followed by formal types such as „joint development teams“ and „R&D-cooperation by contract agreement“. „Joint ventures“and „R&D orders“ on the other hand are regarded as the least important types of cooperation.

- The occurrence and significance of different types of vertical cooperation between innovative firms, customers and suppliers vary from one industry to the other.

- The different forms of vertical cooperation can - in accordance with multi-variate statistical methods - be reduced to two subgroups: While one subgroup includes formal cooperation types, the other group includes informal types of cooperation. The latter form of cooperation is of more importance to those surveyed than the former.

Vertical Relations Between Firms and Innovation: An Empirical Investigation of German Firms

by

Najib Harabi

Institute of Economics, University of Zurich

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Abstract:

The surge in interfirm cooperative agreements can be seen as expressing a way for firms to respond to and to organize market failure, especially in technology markets. The incentives of firms to internalize activities are to avoid the disadvantages, or capitalize on the advantages, of imperfections or disequilibria in external mechanisms of resource allocations. The purpose of this paper is to investigate empirically the occurrence and importance of different modes of vertical relations between innovating firms, suppliers and users, using data from Germany. The analysis is based on a survey conducted by the "Center for European Economic Research" (Mannheim, Germany) among 3122 firms

representing 378 different lines of business, mainly in the manufacturing sector. The main results can be summarized as follows:

- 84 % of all innovating firms responded that they have had R&D cooperation agreements with either suppliers or customers or both. This percentage is even higher (99 %) if we consider only those innovating firms that have also had formal R&D departments. The phenomenon of vertical R&D cooperation is therefore widespread among German firms.

- Informal exchange of technical knowledge was perceived as the most important mode of R&D cooperation between innovating firms on one hand and customers and suppliers on the other, followed by formal methods of cooperation such as joint development teams and contractual R&D cooperation. Joint ventures and direct R&D orders to either customers or suppliers were seen as the least important modes of vertical cooperation.

- The occurrence and importance of cooperative agreements between innovating firms, users and input suppliers vary across industries.

- Results of multivariate statistical analysis (correlation, principal components and cluster analysis) suggested that the various modes of R&D cooperation between innovating firms on one hand and customers and suppliers on the other could be reduced to two subgroups: the first one includes formal modes of cooperation, the second one includes only informal exchange of technical knowledge. On this basis patterns of cooperative agreements could be established for firms operating in different industries and for firms using different product and process technologies.

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1 Introduction

A great deal of intellectual and political energy has been spent around the issue of horizontal R&D cooperation between firms. Politicians both at national and regional level propagate this idea as an important part of their national and regional technology policy[1]. This political debate has been preceded and accompanied by extensive economic research on the question of the importance of horizontal R&D cooperation for innovative activities and international competitiveness of firms, industries and nations (or blocks of nations). This research has highlighted the benefits and costs of policies aimed at enhancing horizontal R&D cooperation between firms.

The expected main benefits of such policies are: (i) overcoming R&D financial constraints of individual firms (costly research projects can be realized due to cost-sharing); (ii) exploitation of economics of scale and scope in R&D; (iii) reduction of wasteful duplication in R&D; (iv) internalization of technological spillovers and other forms of externalities[2]; (v) better use of synergies due the fact that each firm can contribute distinct capabilities to a common research project; and finally, reduction of investment risks due to demand uncertainties. In short, horizontal R&D cooperation has been seen as a panacea for solving important aspects of market failures and other deficiencies in technology markets (for a survey of the literature on this subject see Katz/Ordover 1990, Geroski 1995)[3].

Policies aimed at enhancing horizontal R&D cooperation between firms through government subsidies are, however, in practice problematic: they create costs for the economy at large. The major problem with these policies is that " ... they can

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[1] For Europe see, for instance, Commission of European Communities (1993) "White Paper" and the Cecchini Report (1988).

[2] In addition to technological spillovers, two other externalities have been featured prominently in the literature: pecuniary externalities and environmental externalities. The former "arise when the actions of some firm *i* directly affect the competitive position or profits of one of ist rivals, *j*. They occur when an action by *i* directly affects *j*'s costs or the damand which it faces, or when R&D undertaken by firm *i* retards or blocks the innovative efforts of *j*. Some pecuniary externalities are positive (e.g. those arising from risk-sharing), while others are negative (pre-emptive R&D can prevent rivals from realizing a positive return on their R&D). Environmental externalities occur when the actions of firm *i* affects the attitudes or expectations of *j* in a way which affects how it reacts to *i*'s actions. A classic example of this type of externality arises when cooperation between firms in one line of activity (say, in R&D) affects their willingness and ability to cooperate in other lines of activity (say, in pricing)." (Geroski 1993 :59)

[3] For individual country studies on R&D cooperation see König/Licht/Staat (1993) and Licht (1994) for Germany, Kleinknecht/Reijnen (1992) for the Netherlands, Arvanitis et al. (1995) for Switzerland.

undermine incentives to conduct R&D (and other) operations efficiently, and may lead to cozy pricing arrangements for the products embodying that R&D. What is more, while monopolists may have the resources and opportunities to innovate, they lack the incentives to do whenever the innovation threatens to displace any of their existing activities. In a sense, these horizontal strategies set one type of market failure against another, and it is not surprising that a "cure" of this type has some side effects. Broadly speaking, the empirical evidence can be read as suggesting that such strategies do not often work very well. Innovation is almost a product of active rivalry, frequently occurring simultaneously with waves of entry" (Geroski 1995:140).

All these reservations regarding the efficacy of horizontal collusion - either it can lead to the exploitation of market power or it may simply be misdirected, or both - have led different scholars to advocate an alternative policy. This policy should be aimed at enhancing vertical relations between innovating firms on one hand and suppliers and users of innovations on the other. Such a policy would be based on the theoretical insight and empirical evidence that innovation often requires coordination between those agents that are operating at different stages of the innovation process, that is between innovation producers, innovation users and input suppliers.

The purpose of this paper is to investigate empirically the occurrence and importance of different modes of vertical relations between innovating firms, users and suppliers, using data from Germany.[4] The paper proceeds in three steps. I start in section 2 by reviewing the motivations of innovating firms to embark on different modes of vertical R&D cooperation with either suppliers or customers or both. In section 3 I present briefly the data and the related results. I conclude with a brief summary of the paper, some reflections on the results and a few brief observations on the implications they carry for public policy towards vertical R&D cooperation between firms (section 4).

2 Vertical Relations Between Firms and Innovation: Theoretical Background

In this section two questions will be asked: first, why innovating firms seek to cooperate with input suppliers and product users; second, what is the economic rationale behind the choice of different modes of cooperation. In order to answer the first question I will be looking at the body of theoretical and empirical industrial

[4] In an upcoming paper I will be looking at the effects of vertical relations on the R&D Intensity of innovating firms, using the Mannheim Innovation Panel (MIP) data for Germany.

organization literature concerning the economics of technological innovation.[5] For the second question I will be using the insights of transaction costs economics.[6] The theoretical perspective that would help us to explain the reasons behind vertical relations between innovating firms, suppliers and customers and those behind the choice of different modes of vertical relations is what is now called "the New Industrial Economics."[7]

2.1 Reasons for Vertical Relations Between Innovating Firms, Suppliers and Customers

In the most general terms, private profit-seeking 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 technological opportunities; if they expect that there will be a market for their new products and processes, and, finally, if they expect some economic benefits, net of the incurred costs, deriving from the innovations. These three major determinants of technological innovations mentioned here are summarized in the literature under the headings of "technological opportunities", "appropriability conditions" and "market demand". In other words, technological innovations, like many other economic phenomena, are determined both by supply factors (the first two factors) and by demand factors.

In contrast with the perceived tendency of the competitive market to achieve static efficiency, it is generally agreed among economic theorists that the market mechanism is likely to fall short of optimality in innovation. Many analysts

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5 For the theory see Tirole 1988, for a survey of the empirical literature see Dosi (1988), Cohen/Levin (1989) and Cohen (1995)

6 See Coase (1937), Williamson (1975, 1985 and 1989).

7 Of course, there are other theoretical traditions, especially in the management science literature, that one may pursue for looking at the issues discussed here: First, the "Resource-Dependency" approach (see Pfeffer/Nowack 1976); second, the "Exchange-theoretic" approach developed by Thibaut and Kelley (see Anderson/Narus 1990 and Schrader 1990); third, the "strategic behavior" approach, or (fourth) the "organizational knowledge and learning" approach (for a brief survey of the last two approaches regarding the explanation of joint ventures see Kogut 1988). In addition, the different theoretical approaches have different units of analysis: transaction costs economics looks at single transactions, industrial economics analyses firms and industries, exchange theoretic approaches looks at single persons (see the various papers by Schrader), while some management science scholars look at functional firm divisions (for a recent empirical study in the last tradition see Kirchmann 1994).

conclude that there is a propensity to underinvestment in R&D (see, e.g., Katz 1986:527-528)[8], first because spillovers mean that a substantial proportion of the benefits of an innovation are apt to go to an entity other than the one that bore its cost - and benefits may even flow to the innovator's competitors. Second, even in the absence of externalities, the innovator will not capture all the benefits if it cannot achieve perfect price discrimination, since the innovation will then enhance consumers´ surplus. Third, imperfect information impedes sale of the rights to an innovation at its full value because it ´... is hard to evaluate before it is transferred from the buyer to the seller, and information that has been "loaned" to the buyer for evaluation is difficult to recover' (Katz 1986:528). In other words, this third problem "refers to the difficulties that buyers have in trying to value an innovation, and that sellers have in helping them without giving away crucial secrets. As knowledge is a public good, any successful sale automatically creates potential competition for the original seller, since the seller and the first buyer are both capable of selling to a second buyer, and so on." (Geroski 1992: 139).

All these problems - appropriability problem, imperfect price discrimination, imperfect information and the related problems of demand valuation and resale - may cause market failure in technology markets. Since innovating firms cannot always rely on market forces to solve their problems, they seek ad hoc nonmarket solutions, such as cooperative agreements with other firms, specially those between them on one hand and suppliers and customers on the other. "The surge of interfirm agreements cannot be seen as expressing an improvement in the efficiency of markets, or a reassertion of their effectiveness, but on the contrary represents the full emergence of a new way for firms to respond to and to organize market failure. The incentives of firms to internalize activities ... 'are to avoid the disadvantages, or capitalize on the advantages, of imperfections or disequilibria in external mechanisms of resource allocations'"(Chesnais 1988:83).

Since cooperative agreements between innovating firms on one hand and suppliers and users on the other affect the supply and demand facing them, they thus influence major forces behind the innovation process. One of these major forces is the issue of how innovators solve the "appropriability problem". Consequently, a major motivation for innovating firms to seek R&D cooperation with input suppliers and users is the expectation to solve this problem"[9]. Problems of

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8 However, see Dasgupta and Stiglitz (1980) for a case in which firms have an incentive to overinvest in R&D.

9 Classic discussion of the appropriability problem includes Arrow (1962) and Hirschleifer (1971). In addition to R&D cooperation between innovating firms, suppliers and customers, there are other solutions to the appropriability problem: government subsidies; horizontal R&D cooperation between innovating firms, fostering of national champions in key technology areas; strengthening the patents system (see, for instance, Geroski (1995)).

appropriability affect both the amount of R&D that firms undertake and the location of innovation. In both cases, vertical cooperation between innovating firms, suppliers and users plays an important role.

With respect to the first case - appropriability conditions affecting the amount of R&D - the following observations can be made: At base, the problem of appropriability is that innovators are not protected by sufficiently high barriers to entry, very often even in the presence of patents or other intellectual property rights (see Cohen 1995, Harabi 1995b), to insure that they get a reasonable return for their R&D efforts. If , however, a technological innovation must be packaged with other assets to be commercially successful (such as specialized inputs, manufacturing or marketing capabilities, see Teece 1986), then any artificially created shortages in the supply of critical complementary assets effectively acts as a barrier to entry into the market where the packaged technological innovation is sold. This, in turn, allows the innovator to reap monopoly profits in that market to use in setting against the costs of its R&D program. The innovator can gain control over the supply of critical complementary assets through vertical cooperation with other firms or through vertical integration of firms providing those complementary assets.[10]

Turning to the second case of how problems of appropriability can affect the location of innovation, one can point to the following mechanism: If the returns of new knowledge are difficult to appropriate, then it is likely to be the case to be embodied in output if an innovator is to realize any revenue. According to von Hippel (1982) two hypotheses follow from this observation. First, independent innovators (for instance independent R&D labs) are less likely to innovate than agents operating in the value chain involving the innovation (as suppliers, manufacturers or users of the innovation) because they have only non-embodied knowledge to sell. Second, differences in the ability of different agents in the value chain to appropriate the rewards of innovation may give rise to incentives to innovate which translate into systematic differences in the functional source of innovation (i.e. whether it is user, supplier or manufacturer led). This second hypothesis is consistent with evidence suggesting that users play a major role in the innovative process in some sectors, while manufacturers (or suppliers) play a major role in others (see von Hippel, 1976 and 1978). Von Hippel, for example, examined 111 basic, major and minor innovations in four families of scientific instruments, and discovered that users dominated the innovation process in about 80% of the sample innovations. The users perceived the need for a new instrument, invented it, built and applied the prototype, and spread knowledge about it. Manufacturers mainly performed product engineering work to improve manufacturability. Other

[10] For a discussion of these issues, see Perry (1989),Thorelli (1986), Monteverde and Teece (1982), Kogut (1988), Klein et al. (1978), Ayal and Izraeli (1990)

researchers have emphasized the crucial role of users and suppliers for the innovation process in other industries. Clark et al (1987) is a particularly clear illustration of the important role played by the suppliers in giving Japanese automobile producers a comparative advantage in developing new products. They found that early supplier involvement in product design was a key part of Japanese automakers´edge in introducing new models both faster and with fewer total labor hours than their US and European counterparts.[11]

The supply of technological innovations in an industry depends, as mentioned, on the various opportunities of the innovators to obtain economically-usable technical knowledge. Empirical researchers have identified different sources of those technological opportunities (for a recent survey see Cohen 1995). They can be grouped into market- and non-market sources. The first subgroup consists of the contributions of firms within the same line of business, of material and equipment suppliers and of product users. The second subgroup encompasses the contributions of university research, of government research labs, of other government agencies, of professional or technical societies and of independent inventors. A voluminous literature documents the contribution of these different sources. The case studies of Jewkes et al. (1958) contain instances of virtually every type of those sources. Specially important for this paper is von Hippel´s (1976, 1977, 1988) treatment of the contributions of users to technological development in a variety of industries, including scientific instruments and semiconductor process equipment. Other researchers have on the other hand documented the contributions of input suppliers to the innovation process in specific case studies (see Harhoff 1996a)[12]. Klevorick et al. (1993) offer the first broad, cross-industry empirical examination of the contributions to technical advance made by different sources of embodied and

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[11] Other researchers have studied other industries: for a study on biotechnology, see Pisano (1991), for another one on robotics (and other examples) see Porter (1990).

[12] Input suppliers were identified as major innovators in several industries: aluminum and fiberglass (see Corey 1956); thermoplastics forming and modeling; application of industrial gases (see WanderWerf 1992). The economic history literature has also shown the importance of vertical relations for innovations in certain industries. As Rosenberg has remarked in his treatise on technology and American economic growth, the machine tool industry in the 19th century played a unique role both in the initial solution to technical problems in user industries, such as textiles, and as the disseminator of these techniques to other industries, such as railroad locomotive manufacture. Rosenberg´s description suggests that the users played a role in the development of new equipment. He notes that before 1820 in the United States, one could not identify a distinct set of firms that were specialists in the design and manufacture of machinery. Machines were either produced by users or by firms engaged in the production of metal or wooden products. Machinery-producing firms were thus first observed as adjuncts to textile factories. However, once established, these firms played an important role as the transmission center in the diffusion of new technology (Rosenberg 1972: 98-102).

disembodied knowledge in the US manufacturing sector. They found that what they call sources "within the industrial chain", such as buyers and materials and equipment suppliers, apparently contribute much more to most industries‘ technical advance than non-market sources such as universities and government labs. Similar results have been found for Switzerland (see Harabi 1995 and Arvanitis el al. 1995), for Germany (see "Zentrum für Europäische Wirtschaftsforschung" (ZEW) and infas 1994) and for France (see Lhuillery 1996)[13].

Finally, establishing vertical relations with either buyers or suppliers may also solve problems arising from uncertainty in R&D or from indivisibilities in R&D (or other) production processes to the extent that it creates a market in circumstances where one would otherwise have been poorly defined. Furthermore, a captive market can have the advantages of creating a pocket of demand for a product with certain well defined characteristics, and this may serve to focus R&D efforts and stimulate innovation.

2.2 Reasons for the choice of different modes of vertical relations

I now turn to the second question concerning the economic rationale behind the choice of different modes of vertical relations between an innovating firm on one hand and suppliers and users on the other. A transaction cost explanation for this choice involves the question of how an innovating firm should organize its boundary activities with other firms. Simply stated, Williamson proposes that firms choose how to transact according to the criterion of minimizing the sum of production and transaction costs. Production costs may differ between firms due to the scale of operations, to learning, or to proprietary knowledge. Transaction costs refer to the expenses incurred for writing and enforcing contracts, for haggling over terms and contingent claims, for deviating from optimal kinds of investment in order to increase dependence on a party or to stabilize a relationship, and for administering a transaction.

The principal dimensions on which transaction costs economics presently relies for purposes of transactions are (1) the frequency with which they recur, (2) the degree and type of uncertainty to which they are subject, and (3) the condition of asset specificity (Williamson 1989:142)[14]. In addition, transaction cost theory

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[13] All the surveys mentioned - Harabi (1995), Arvanitis et al. (1995), ZEW/infas (1994) and Lhuillery (1996) - have used broad cross section studies based upon mail surveys.

[14] In addition to these three dimensions, Williamson emphasizes the role of behavioral factors, such as "bounded rationality"and "opportunism" for choosing different forms of governance structures.

distinguishes between basically three transaction coordination mechanisms: markets, hierarchies (firms) and hybrid coordination mechanisms[15]. In market relationships, transactions take place between independent entities and are mediated by a market mechanism. Exchanges that are straightforward and nonrepetitive and that require no transaction-specific investments will take place between firms, that is, across a market interface. In hierarchical relationships, the transaction partners are part of one corporate body which somehow mediates the relationship through such mechanisms as surveillance, evaluation, and direction. Transactions that involve uncertainty about their outcome, that recur frequently and require substantial transaction-specific investments - of money, time, or energy that cannot be easily transferred to interaction with others - are likely to take place within hierarchically organized firms[16].

Hybrid forms - lying somehow "in between" markets and hierarchies - include cooperation agreements between the transaction partners (see Richardson 1972); they capture core benefits of markets while enjoying some transaction cost advantages of hierarchies.

Interfirm cooperation agreements are agreements between two or more companies that provide for a certain degree of collaboration between them and involve equity participation or the creation of new companies as well as no-equity agreements. Interfirm cooperation agreements can be formal or informal and have in general a long-term character. A one- time purchase of goods and services is not a cooperative agreement, but an agreement to purchase all inputs from one supplier over the next ten years is a cooperative agreement.

From the standpoint of innovation Freemann (1991) distinguishes ten different categories of cooperative arrangements: (1) joint ventures and research corporations; (2) joint R&D agreements; (3) technology exchange agreements; (4) direct investment (minority holdings) motivated by technology factors; (5) licensing and second-sourcing agreements; (6) sub-contracting, production-sharing and

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[15] In its early development, transaction costs economics distinguished between two ideal types of transactions only: markets and hierarchies. Later on, Williamson himself and other authors have extended and refined this typology (see for instance Williamson (1985), Ouchi (1980), Jarillo (1988) and MacNeil (1978))

[16] According to transaction costs economics, transactions are moved out of markets into hierarchies for two reasons. The first is "bounded rationality": the inability of economic agents to write contracts that cover all possible contengencies. When transactions are internalized, there is little need to anticipate such contengencies; they can be handled within the firm’s "governance structure". The second reason is "opportunism", that is, the rational pursuit by economic agents of their own advantage, by every means at their disposal, including guile and deceit.

supplier networks; (7) research associations; (8) government-sponsored joint research programmes; (9) computerized data banks and value-added networks for technical and scientific interchange; (10) informal agreements (vgl. Freemann 1991:502).

For illustration, some of these cooperative agreements can be defined as follows[17]: Joint ventures are operations whereby a legally independent and autonomously managed business enterprise is set up by two or more parent companies to run a clearly defined set of activities in the common interest of the founding firms. Joint R&D agreements cover agreements that regulate R&D sharing and/or transfer between two or more companies. Joint R&D refers to agreements such as (1) joint research pacts which establish joint undertaking of research projects with shared resources and (2) joint development agreements. Research contracts regulate R&D cooperation in which one partner, usually a large company, contracts another company, frequently a small specialized R&D firm, to perform particular research projects. R&D orders are normal market transactions between two or more firms covering R&D and/or R&D-related services.

Each of the three basic transaction coordination mechanisms - markets, firms and hybrid modes, including interfirm cooperation agreements- can be efficient, depending on the expected amount of transaction costs involved. Knowing when to integrate vertically, when to collaborate, and when to use the market is a major task of transaction costs economics. In the area of innovative activities the following examples clarify this central task of transaction costs economics: Vertical integration - meaning the creation of a hierarchical relationship - is , on one hand, more likely to predominate where the innovation chain is characterized by uncertain property rights, transaction-specific assets, and complex technology transfer (see Pisano 1991). On the other hand, "the complexity of scientific and technological inputs, the uncertainty of economic conditions and the risks associated with uncertain technological trajectories, appear to have reduced the advantages of vertical and horizontal integration and made hierarchies a less efficient way of responding to market imperfections. But the need to respond to and exploit market imperfections in technology has also increased, and has thus pushed interfirm agreements to the forefront of corporate strategy" (Chesnais 1998:84). Furthermore, interfirm agreements bearing on technology are preferable to arm’s-length market transactions for two reasons: First, "because long-term relationships are generally vital in technology exchange", and second because in this way "technology is kept out of the open market, preserving both entry and mobility barriers" (Chesnais 1988:84).

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[17] The definitions are borowed from Chesnais (1988:56) and Hagedoorn/Schakenraad (1990: 6).

Innovating firms can, in addition, choose between different modes of cooperative agreements. Contractual R&D cooperation, for instance, is more likely to be chosen when R&D tasks are more routine and require less on-going interaction with the client firm’s other manufacturing and non-manufacturing functions (see Mowery 1989). The situational characteristics best suited for a joint venture are high uncertainty over specifying and monitoring performance, in addition to high degree of asset specificity. It is uncertainty over performance which plays a fundamental role in encouraging a joint venture over a contract (see Kogut 1988).

2.3 Summary

There is sufficient theoretical insight and empirical evidence suggesting the crucial importance of cooperation between innovating firms, users of innovation and suppliers. In the words of Geroski: "Indeed, so important are vertical associations between suppliers and users on the one hand and innovation producers on the other, that the innovation process is often user or supplier led and not producer led" (Geroski 1992:142). These vertical relations are important for the successful development and commercialization of innovations for three reasons: In general terms, they provide innovators with technological opportunities that can enhance their technological capabilities, they help innovators to solve the appropriability problem and, finally, they help to reduce uncertainties about market demand. To reap those benefits, innovators have to bear (transaction) costs. According to their specific cost/benefit analysis, which can vary across industries, innovators choose between different modes of vertical relations with suppliers and users. The choice ranges from total integration, to tapered integration, to no integration, and from long-term contracts, to short-term contracts, to no contracts. The purpose of the next section is to investigate empirically the occurrence and importance of some of these different modes of vertical relations between innovating firms, suppliers and users, using data from Germany.

3 Vertical Relations Between Firms and Innovation: An Empirical Investigation of German Firms

3.1 Data

During 1994 experts working in German industry were asked to answer questions related to the issue of the occurrence and importance of different modes of relations between innovating firms on one hand and suppliers and users on the other. These questions are only a small part of a much larger survey called "Mannheim Innovation Panel" (MIP) that started in Germany in summer 1993. The data were collected by the "Zentrum für Europäische Wirtschaftsforschung" (ZEW) and the

"Institut für angewandte Sozialforschung" (infas). This project was financed and supported by the German Ministry of Education, Science, Research and Technology (BMBF). The first wave was part of the Community Innovation Survey of the European Commission. The questionnaire follows the guidelines proposed by the OECD (1992) and is a somewhat extended version of the harmonized questionnaire for innovation surveys developed by EUROSTAT (for more details see Smith 1992).

The data used in this paper were gathered during the second wave of the MIP in 1994. Since an adequate completion of the questionnaire required solid knowledge of the technology as well as of the market conditions in a certain line of business, the experts questioned were mainly R&D executives of selected firms. The sample frame for the survey was formed by R&D experts working in 12576 firms. Of the 12576 experts included in the survey, 3122, or 25 percent, completed the questionnaire. These 3124 experts were active in 378 different lines of business (4- or 5-digit-level industries, as defined by the German Federal Office of Statistics, 1979). Taking the industrial structure of their activities at the 2-digit level, 3.81 % of the respondents worked in mining and energy, 9.41 % in foods and textile, 8.13 % in lumber and paper, 8.13 % in chemicals and petroleum, 6.82 % in synthetics and rubber , 4.16 % in glass and ceramics, 4.26 % in basic metals processing, 7.68 % in fabricated metals processing, 17.38 % in machinery, 7.81 % in office machinery, computer and electrical machinery, 6.24 % in medical, precision and optical instruments, 4.00 % in motor vehicles and 5.25 % in construction industries. The remaining experts (6.91 %) were active in technical services. (See Felder el al. 1994 for a detailed description of this survey.)

According to the statistical tests conducted, the sample described above is statistically representative neither of the distribution of industries in the German manufacturing sector nor of firm size[18]. Proportionally more R&D experts from large firms in innovative industries participated in the survey than experts from small and medium-sized firms in less innovative industries.

A final point concerning the data should be kept in mind while reading and interpreting the results listed below: All the survey-data used in this paper were derived from subjective judgments based on imperfect information.

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[18] This statement applies only to the data used in this paper which are the original ones; they have not been weighted according to the usual statistical techniques. The ZEW has, however, conducted these techniques, such as the non-response analysis, and applied them to its different datasets.

3.2 Results

3.2.1 Overall Results

Graph 1 shows the experts' responses to the question : "Cooperation with customers might have a special importance for your innovative activities. Which of the following modes of cooperation with your customers have you had in your firm (or line of business) in the years 1991-1993:

1 Joint ventures

2 Joint development teams

3 Contractual R&D cooperation

4 R&D order to customers

5 Informal exchange of technical knowledge" (Questionnaire, P. 12)

The same question was asked with respect to the occurrence of the same modes of R&D cooperation with suppliers. Before presenting the overall results, it is important to make the following three remarks: First, the different modes of interfirm cooperation listed above were not defined in the questionnaire[19]; there is a risk that the surveyed experts could have had different definitions of these concepts in mind. Second, the list of possible modes of R&D cooperation was not exhaustive; cooperative arrangements like equity participation of innovating firms in suppliers´ and users´ firms and vice versa or technology exchange agreements were not listed. Third, R&D order to either customers or suppliers is strictly speaking a normal market transaction and not a mode of interfirm cooperative arrangements.

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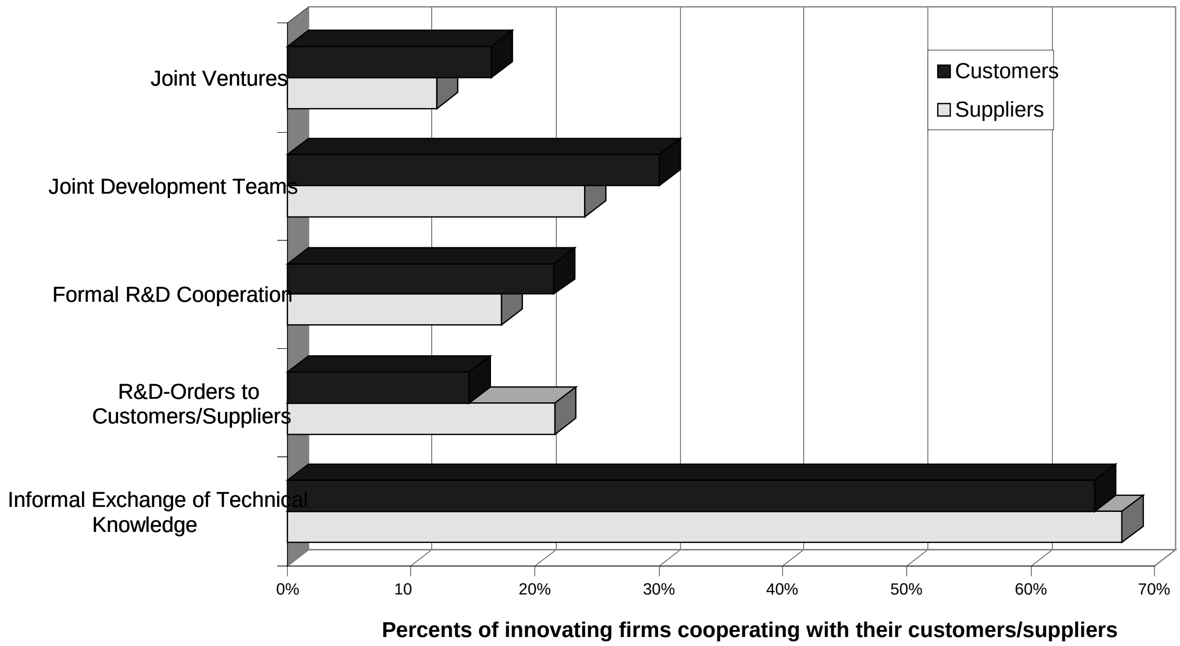
[19] For a brief discussion of some of the major features of the different modes of cooperation see section 2.2 above.

Graph 1: Percents of Innovating Firms Having Cooperative Agreements with Customers/Suppliers



Of all innovating firms, 84 % indicated they had had cooperative relations with customers. If we only consider those innovating firms that also had formal R&D departments, 99 % of them responded that they had done so[20]. The phenomenon of vertical relations between innovating, specially R&D performing, firms and customers is therefore widespread in German industry.

The most cited mode of these cooperative arrangements between innovating firms and their customers was informal exchange of technical knowledge (over 65 % of all respondents), followed by joint development teams (around 25 %) and contractual R&D cooperation (20 %). The least cited mode of cooperation was R&D order to customers, followed by joint ventures.

The survey results concerning the occurrence of cooperative relations between innovating firms and suppliers and those concerning cooperative relations between the former and their customers are similar in some respects and different in others. They are similar regarding the results that (1) the percentage of innovating firms having cooperative arrangements with either customers or suppliers was equally

[20] If we take the weighted figures, we obtain the following statistics: 78 % of all innovating and 99% of all innovating firms that also had R&D departments indicatd they had cooperative arrangements with either customers or suppliers or both (for a description of the weights used see Felder et al. 1994).

high (in both cases they are around 84%) and that (2) informal exchange of technical knowledge and joint development teams were the two most cited modes of cooperation between both innovating firms and customers and between the former and users. The empirical results differ with regard to the ranking given to the remaining three modes of vertical relations. It seems that innovating firms had given R&D-orders more often to suppliers than to customers and that they had more contractual R&D cooperation with customers than with suppliers. Finally, joint ventures were assumed to take place more frequently with customers than with suppliers.

So far, the reported results have related to questions concerning the mere occurrence of vertical cooperation between innovating firms and their customers or suppliers. More significant, however, is the question of how important those cooperative modes are for the innovative activities of the firms surveyed. The answers to these questions were to be given on a scale from 1-5 (1=not important at all, 5=very important) and are summarized in Table 1. The first two columns of this table indicate the unweighted averages of the answers and the standard deviation (in parentheses). Columns 3 and 4 indicate the distribution of these averages. Q1 stands for the first quartile; similarly, Q3 represents the third quartile. That means the middle 50% of all the answers lies between these two values.

Table 1: Importance of Different Modes of Cooperation between Innovating Firms and either Customers or Suppliers (1 = not at all important, 5= very important;)

	Mean (Std. Dev.)		Q1 - Q3	
	Customers	Suppliers	Customer	Suppliers
Joint Ventures	2.33 (1.45)	2.40 (1.51)	1-4	1-4
Joint Development Teams	3.33 (1.43)	3.36 (1.36)	2-5	2-4
Contractual R&D cooperation	3.24 (1.37)	3.25 (1.36)	2-4	2-4
R&D-Order to Customers/Suppliers	2.46 (1.47)	3.14 (1.26)	1-4	2-4
Informal Exchange of Technical Knowledge	3.80 (1.11)	3.83 (1.06)	3-5	3-5

Q1: First quartile; Q3: Third Quartile

Informal exchange of technical knowledge was perceived on one hand as the most important mode of cooperation between innovating firms and their customers, followed by formal methods of cooperation such as joint development teams and contractual R&D cooperation. Joint ventures and direct R&D order to customers were seen, on the other hand, as the least important modes of vertical cooperation with downstream users. Although the results seem to be very similar to those concerning the importance of the five modes of vertical relations between innovating firms and upstream suppliers, the numerical results relating to suppliers are slightly higher than those relating to customers. On average, the vertical relations between innovating firms and their suppliers were perceived as being slightly more important than their relations with customers.

Comparing the overall results of our survey with those of other country studies, the following observations can be made: First, the phenomenon of cooperative associations between innovating firms and other firms is widespread.[21] Second, the result that informal exchange of technical knowledge is the most cited mode of cooperation between innovating firms, customers and suppliers is confirmed by a similar survey conducted in Switzerland (see Arvanitis et al. 1995:168). Finally, the

[21] This phenomenon seems to be more important in Germany than in France or Switzerland, however: In the latter country, only 43 % of the innovating firms surveyed responded that they had cooperated with other firms (see Arvanitis el al. 1995:167). Comparable figures for France are 55% and for Germany 78 %.

ranking of "contractual R&D cooperation" and "joint ventures" is similar in the two studies. Of all formal modes of cooperation mentioned above "joint development R&D" seems to be the most important one in the Swiss, the German and Merit studies (for the latter see Hagedoorn/Schakenraad 1990:7)

3.2.2 Interindustry Differences

The overall results presented so far should not obscure the fact that there are interindustry differences with respect to the occurrence of the different modes of cooperation between innovating firms, suppliers and users. Statistical tests, such as for example analysis of variance, show that there are significant interindustrial differences (significance level 0.05) regarding the occurrence of modes of vertical relations such as "joint development teams", "contractual R&D cooperation", "direct R&D-orders". These interindustrial differences are further examined below.

The general empirical finding that informal modes of cooperation between innovating firms and their customers are on average more important than the formal ones is confirmed when results are disaggregated at lower levels of industry classification. Viewing the results at the 2-digit level, the following observations can be made (see Table 2):

Table 2: Importance of Different Modes of Collaboration between Innovating Firms and their *Customers* in 14 (2-Digit) Industries (5 = very important; 1 = not at all important)

	Joint Ventures		Joint Development Teams		Contractual R&D cooperation		R&D-Order to Customers		Informal Exchange of Technical Knowledge	
	AM*	S*	AM*	S*	AM*	S*	AM*	S*	AM*	S*
Mining/Energy	**3.00**	1.73	3.33	1.86	3.00	1.41	2.20	1.30	3.77	1.19
Foods/Textile	2.06	1.34	3.27	1.52	2.50	1.47	**2.89**	1.75	3.53	1.10
Lumber/Paper	2.05	1.57	3.02	1.52	2.33	1.46	2.24	1.70	3.57	1.14
Chemicals/ Petroleum	**2.79**	1.47	**3.61**	1.41	**3.38**	1.39	**2.69**	1.40	3.73	1.21
Synthetics/Rubber	2.00	1.36	**3.52**	1.34	**3.26**	1.46	**2.68**	1.49	**3.96**	1.06
Glass/Ceramics	1.62	1.19	3.14	1.53	2.85	1.57	1.86	1.35	3.71	1.29
Basic Metals Processing.	2.27	1.35	**3.96**	1.11	**3.71**	1.16	**2.77**	1.48	**3.91**	1.11
Fabricated Metals Processing	2.05	1.32	3.24	1.48	3.00	1.53	2.05	1.36	**3.86**	0.99
Machinery	2.22	1.50	3.08	1.46	3.20	1.27	2.42	1.42	**3.93**	1.08
Office Machinery and Computers / Electrical Machinery	2.17	1.44	3.18	1.47	**3.38**	1.34	1.87	1.25	3.77	1.20
Medical, Precision, Optical Instruments	**2.77**	1.43	**3.37**	1.39	**3.38**	1.21	**2,69**	1.31	3.77	0.98
Motor Vehicles	**2.56**	1.58	**3.86**	1.15	**3.26**	1.41	**2.57**	1.66	**3.89**	1.11
Construction	**2.83**	1.27	3.07	1.49	2.80	1.40	**2.50**	1.52	3.63	1.28
Technical Services	**2.59**	1.58	3.32	1.40	**3.80**	1.24	**2.77**	1.63	**3.87**	1.11
Overall Industry Mean	**2.33**	**1.45**	**3.33**	**1.43**	**3.24**	**1.37**	**2.46**	**1.47**	**3.80**	**1.11**

* AM: Arithmetic Mean; S: Standard Deviation

The highlighted figures indicate above average responses, compared with the overall industry mean

Informal exchange of technological knowledge was perceived in all 14 industries as an important mode of vertical relations. It was given, however, a score above average in the synthetics/rubber, basic and fabricated metals processing, machinery, motor vehicles and technical services industries, and below average in the remaining industries.

Joint development teams as the second most important means of cooperation between producers and users of innovations was considered more important in some industries (for instance, in basic metals processing, motor vehicles, chemicals/petroleum and synthetics/rubber industries) than in others (lumber/paper, construction, machinery industries etc.).

Contractual R&D cooperation between producers and users of innovation was viewed on average as moderately important. Its importance varies across industries, however: it was given an above-average score in, say, basic metals processing, technical services and chemicals/petroleum industries, and below-average in the foods and textile, lumber/paper and construction industries.

Giving R&D-orders to customers was seen by innovating firms as moderately important, especially by firms from the following industries: foods/textile, chemicals/petroleum, synthetics/rubber and motor vehicles. Experts from office machinery and computers, or glass and ceramic products industries rated the importance of this method of cooperation as very low.

Joint ventures were perceived, as already mentioned, as being the least important mode of vertical relations between innovating firms and their customers. As to the industry-specific importance of this method of cooperation, the following observation can be made: Joint ventures were rated above average in the industries "mining/energy", "chemicals/petroleum" "medical, precision and optical instruments", "motor vehicles", "construction"and "technical services". In all the remaining industries they were rated below average.

Finally, Table 2 can also be read horizontally and thus answers the following question: "For a given industry, which are the most important modes of cooperation between innovating firms and users?" The answer for the mining and energy industries, for instance, is that"informal exchange of technical knowledge" is the most important mode of vertical cooperation with its customers, followed by "joint development teams".

As to the industry-specific differences concerning the importance of the different modes of cooperation between innovating firms and their suppliers**,** the following observations can be made (see Table 3):

Table 3: Importance of Different Modes of Cooperation between Innovating Firms and their *Suppliers* in 14 (2-Digit) Industries (1 = not at all important; 5 = very important)

	Joint Ventures		Joint Development Teams		Contractual R&D cooperation		R&D-Order to Suppliers		Informal Exchange of Technical Knowledge	
	AM*	S*	AM*	S*	AM*	S*	AM*	S*	AM*	S*
Mining/Energy	1.00	0.00	**3.67**	2.31	2.00	1.41	2.50	2.12	3.83	1.47
Foods/Textile	2.18	1.47	**3.47**	1.25	3.05	1.27	3.03	1.31	3.80	1.06
Lumber/Paper	2.40	1.68	3.27	1.43	**3.32**	1.64	2.95	1.27	**3.89**	0.98
Chemicals/ Petroleum	**2.95**	1.54	**3.62**	1.32	3.13	1.40	**3.50**	1.11	**3.87**	1.03
Synthetics/Rubber	2.20	1.57	**3.57**	1.20	3.12	1.51	**3.23**	1.41	**3.99**	1.08
Glass/Ceramics	1.75	1.42	2.77	1.45	2.50	1.69	2.79	1.40	3.68	1.28
Basic Metals Processing	**2.57**	1.40	**3.69**	1.25	**3.88**	1.22	**3.18**	1.40	4.17	0.82
Fabricated Metals Processing	2.28	1.53	3.17	1.42	2.73	1.44	2.53	1.22	3.78	1.04
Machinery	**2.61**	1.61	**3.54**	1.40	**3.42**	1.24	**3.28**	1.23	**3.88**	1.07
Office Machinery and Computers/ Electrical Machinery	2.19	1.44	2.96	1.44	3.22	1.38	3.00	1.25	**3.92**	1.00
Medical, Precision, Optical Instru-ments	2.09	1.28	3.14	1.32	**3.34**	1.22	**3.28**	1.14	3.72	1.06
Motor Vehicles	**2.46**	1.51	**3.80**	1.13	**3.65**	1.29	**3.47**	1.18	3.68	1.03
Construction	**3.50**	1.31	3.29	1.20	**3.39**	1.04	3.18	1.33	3.64	1.10
Technical Services	**2.75**	1.87	3.20	1.61	3.12	1.40	2.68	1.38	3.73	1.27
Overall Industry Mean	**2.40**	**1.51**	**3.31**	**1.36**	**3.25**	**1.36**	**3.14**	**1.21**	**3.83**	**1.06**

* AM: Arithmetical Mean; S: Standard Deviation

The highlighted figures indicate above average responses, compared with the overall industry mean

Informal exchange of technological knowledge was perceived in all 14 industries as an important mode of vertical relations. It was, however, given a score above average in the industries "lumber/paper", "chemicals/petroleum", "synthetics/rubber", "machinery", and "office machinery and computer/electrical machinery" and below average in the remaining industries.

Joint development teams as the second most important means of cooperation between innovating firms and input suppliers was considered more important in some industries (for instance, in the mining/energy, foods/textile, chemicals/petroleum, synthetics/rubber, basic metals processing, machinery, and motor vehicles industries) than in others (lumber/paper, construction industries, etc.).

Contractual R&D cooperation between innovating firms and inputs suppliers was viewed on average as moderately important. Its importance varies across industries, however: it was given a score above average by experts from the lumber/paper, basic metals processing, machinery, medical, precision, optical instruments, motor vehicles, and construction industries, and below average by experts form the mining/energy, foods/textile, and remaining industries.

Giving R&D-orders to suppliers was seen by innovating firms as moderately important, especially by experts from the following industries: chemicals/petroleum, synthetics/rubber and motor vehicles. Experts from office machinery and computers or glass and ceramic products industries rated the importance of this method of cooperation as very low.

Joint ventures were perceived, as already mentioned, as the least important mode of all vertical relations between innovating firms and their suppliers. As to the industry-specific importance of this method of cooperation the following observation can be made: Joint ventures were rated above average in the industries "lumber/paper", "chemicals/petroleum" "synthetics/rubber", "machinery", and "office machinery and computer/electrical machinery. In all the remaining industries they were rated below average.

Finally, Table 3 can also be read horizontally and thus answers the following question: "For a given industry, which are the most important modes of cooperation between innovating firms and suppliers?" For the food and textile industries, for instance, "informal exchange of technical knowledge" is the most important mode of vertical cooperation with input suppliers, followed by "joint development teams".

3.2.3 Vertical Relations Between Firms and Innovation: The Patterns

So far, the different modes of cooperation between innovating firms and either customers or suppliers have been analyzed and the empirical results concerning their existence and importance have been presented separately. Now, two questions can be raised: first, do dependencies between these different modes of vertical cooperation exist? and second, - based on these dependencies - can clusters of firms related to their cooperation patterns be constructed? In order to answer these two questions empirically, the usual methods of multivariate statistics, above all correlation, principal components and cluster analysis, were used.

The results of the correlation analysis are summarized in Tables 4 and 5. These tables show correlations among the five different modes of cooperation between innovating firms and their customers (Table 4) and between innovating firms and their suppliers (Table 5). In each cell of the two matrices the entry indicates correlation coefficients of individual responses. The results can be interpreted as follows: The different modes of cooperation between innovating firms and either customers or suppliers correlate with each other. A statistically significant correlation between almost all the different modes of cooperation exists. Certain patterns of dependencies among the different modes of cooperation emerge, however. On one hand there is a statistically significant correlation between the formal modes of cooperation (the four variables 33B.1- 33B.4), on the other hand there is first no statistically significant correlation between the variable "informal exchange of technical knowledge" and the other modes of vertical cooperation (specially "joint ventures" in Tab 4), and second , if there is a correlation between informal exchange of technical knowledge and the other four variables, the correlation coefficients are lower than those of the four formal modes of cooperation.

The results of the correlation analysis suggest that the five modes of vertical relations between producers, suppliers and users of innovations can be reduced to two subgroups: the first one includes formal methods of cooperation (the first four methods), the second one includes informal ones, summarized under the rubric "Informal exchange of technical knowledge".

Table 4: Correlation Matrix of the Importance of Different Modes of Cooperation between Innovating Firms and their *Customers*

	33B.1	33B.2	33B.3	33B.4	33B.5
33B.1 Joint Ventures	1.00	0.51*	0,48*	0.44*	0.09
33B.2 Joint Development Teams		1.00	0.62*	0.54*	0.36*

33B.3 Contractual R&D cooperation			1.00	0.59*	0.34*
33B.4 R&D-Order to Customers				1.00	0.27*
33B.5 Informal Exchange of Technical Knowledge					1.00

* Significant at the 0.01 level

Table 5: Correlation Matrix of the Importance of Different Modes of Cooperation between Innovating Firms and their *Suppliers*

	34B.1	34B.2	34B.3	34B.4	34B.5
34B.1 Joint Ventures	1.00	0.60*	0.53*	0.49*	0.29*
34B.2 Joint Development Teams		1.00	0.72*	0.58*	0.47*
34B.3 Contractual R&D cooperation			1.00	0.70*	0.40*
34B.4 R&D-Order to Suppliers				1.00	0.43*
34B.5 Informal Exchange of Technical Knowledge					1.00

* Significant at the 0.01 level

These findings will now be further analyzed using other statistical techniques: principal components and cluster analysis.

The principal components analysis generally transforms a given set of variables (here: the five modes of vertical relations) into a new set of compounded variables (principal components) that are mutually orthogonal (not correlated). The results of this analysis - using the individual responses of the survey - are summarized in Table 6. The first two columns show the weights associated with the first two principal components when the five questions relating to the importance of the modes of cooperation between innovating firms and their customers are analyzed. The next two columns report the results of a principal components analysis on the set of questions related to the cooperation modes with suppliers. In both cases, the results suggest that the five means of vertical cooperation can be reduced to two dimensions (principal components). The first principal component loads most heavily on formal means of cooperation (means no.1, 2, 3, 4). The second component loads mainly on informal exchange of technical knowledge (means no.5).

The interpretation of the results of the principal component analysis that the data do reduce the five modes of cooperation to two dimensions is statistically quite satisfactory. As Table 6 indicates, when the questions are analyzed for customers, the first two components explain 65 percent of the variance in the responses to five questions, and when the questions are analyzed for suppliers, the two components explain 70 percent of the variance.

The hypothesis that the five modes of vertical R&D cooperation can be reduced to two subgroups will further be pursued by means of cluster analysis. The cluster analysis classified in this case the 3000 surveyed firms (or business units of multidivisional firms) according to two principal components constructed above (see Table 6).[22] As reported in Tables 7 and 8, two clusters were found for both vertical relations with customers and for vertical relations with suppliers. In the case of vertical relations with suppliers the first cluster consists of 2407 innovating firms - or 89% of all innovating firms - that used exclusively informal methods of cooperation. The second cluster includes 299 - or 11% of all - innovating firms that used formal modes of vertical cooperation. The sectoral distribution of the two clusters is shown in Table 7.

Table 6: Principal Components Analysis of Different Modes of Cooperation with eitherCustomers or Suppliers

	Customers		Suppliers	
	Coefficients of 1st Principal Component	Coefficients of 2nd Principal Component	Coefficients of 1st Principal Component	Coefficients of 2nd Principal Component
1. Joint Ventures	**0.77**	-0.23	**0.83**	0.01
2. Joint Development Teams	**0.67**	0.31	**0.80**	0.19
3. Contractual R&D cooperation	**0.68**	0.42	**0.77**	0.33
4. R&D-Order to Customers	**0.75**	0.13	**0.65**	0.46
5. Informal Exchange of Technical Knowledge	0.07	**0.93**	0.14	**0.95**
Cumulative Variance Explained	0.46	0.65	0.56	0.72

Comparing the cluster assignment for modes of vertical relations with downstream customers to cluster assignment for modes of vertical relations with upstream suppliers, one can conclude that they are - apart from small nuances concerning the sectoral distribution - similar for both clusters. Again, only 12 % of all innovating firms (cluster 1) used formal modes of cooperative agreements with customers,

[22] The procedure used here is the SAS procedure called "FASTCLUS". It is a non-hierarchical method of determining disjunct clusters on the basis of Euclidean distances: The observations (here: the 1517 firms) are classified in such a way that each observation is attributed to one single cluster only (see SAS User's Guide: Statistics, version 5, 1985:377-402).

while the remaining majority, 88% of all innovating firms surveyed (cluster 2) relied exclusively on informal modes of cooperation (that is on informal exchange of technical knowledge). The sectoral distribution of the two clusters is again shown in Table 8.

To sum up, the results of multivariate statistical analysis (correlation, principal components and cluster analysis) suggest that the various modes of R&D cooperation between innovating firms on one hand and customers and suppliers on the other could be reduced to two subgroups: the first one includes formal modes of cooperation, the second one includes informal exchange of technical knowledge. On this basis patterns of cooperative agreements could be established for different industries and technological fields (see Table 9 & 10).

Table 7: Number of Firms in Clusters on the Basis of the Importance of Different Modes of R&D-Cooperation with *Suppliers* in 14 Different Industries. Cluster 1: firms using formal modes of R&D cooperation; Cluster 2: firms using informal modes of R&D-cooperation

	Cluster 1		Cluster 2	
	Frequency	Percent	Frequency	Percent
Mining/Energy	99	4,11%	4	1,34%
Foods/Textile	216	8,97%	15	5,02%
Lumber/Paper	212	8,81%	17	5,69%
Chemicals/Petroleum	174	7,23%	29	9,70%
Synthetics/Rubber	167	6,94%	15	5,02%
Glass/Ceramics	100	4,15%	12	4,01%
Basic Metals Processing	63	2,62%	15	5,02%
Fabricated Metals Processing	241	10,01%	21	7,02%
Machinery	375	15,58%	48	16,05%
Office Machinery and Computers/Electrical Machinery	172	7,15%	30	10,03%
Medical, Precision, Optical Instruments	152	6,31%	39	13,04%
Motor Vehicles	121	5,03%	25	8,36%
Construction	165	6,86%	7	2,34%
Technical Services	150	6,23%	22	7,36%
Total	**2407**	**100,00%**	**299**	**100,00%**

Table 8: Number of Firms in Clusters on the Basis of the Importance of Different Modes of R&D cooperation with *Customers* in 14 Different Industries. Cluster 1: firms using formal modes of R&D cooperation; Cluster 2: firms using informal modes of R&D-cooperation

	Cluster 1		Cluster 2	
	Frequency	Percent	Frequency	Percent
Mining/Energy	6	1,89%	98	4,09%
Foods/Textile	18	5,68%	241	10,07%
Lumber/Paper	19	5,99%	223	9,31%
Chemicals/Petroleum	29	9,15%	168	7,02%
Synthetics/Rubber	15	4,73%	159	6,64%
Glass/Ceramics	19	5,99%	99	4,14%
Basic Metals Processing	8	2,52%	66	2,76%
Fabricated Metals Processing	23	7,26%	244	10,19%
Machinery	49	15,46%	353	14,75%
Office Machinery and Computers/Electrical Machinery	32	10,09%	168	7,02%
Medical, Precision, Optical Instruments	45	14,20%	145	6,06%
Motor Vehicles	30	9,46%	118	4,93%
Construction	8	2,52%	166	6,93%
Technical Services	16	5,05%	146	6,10%
Total	**317**	**100,00%**	**2394**	**100,00%**

Table 9: Number of Firms in Clusters on the Basis of the Importance of Different Modes of R&D cooperation with *Suppliers in 11 Different Technological Fields.* Cluster 1: Cluster of firms using formal modes of R&D cooperation; Cluster 2: Cluster of firms using informal modes of R&D cooperation

	Cluster of firms using informal modes of R&D cooperation (Cluster 1)		Cluster of Firms using formal modes of R&D cooperation (Cluster 2)	
	frequency	in %	frequency	in %
New materials	179	18,80%	527	22,80%
Microelectronic and semiconductor-technology	81	8,51%	150	6,49%
Laser-technology, optoelectronics, displays	55	5,78%	104	4,50%
Software, simulation and arificial intelligence	136	14,29%	323	13,98%
Telecommunication and information-technology	69	7,25%	152	6,58%
Bio-technology	18	1,89%	34	1,47%
Medicine and health care-technology	33	3,47%	66	2,86%
Flexible integrated manufacturing (FIT)	122	12,82%	354	15,32%
Transport, traffic and logistic	80	8,40%	196	8,48%
Transformation and storing of energy	44	4,62%	92	3,98%
Environment-technology and resource saving technology	135	14,18%	313	13,54%
Total	**952**	**100,00%**	**2311**	**100,00%**

Table 10: Number of Firms in Clusters on the Basis of the Importance of Different Modes of R&D cooperation with Customers *in 11 Different Technological Fields.* Cluster 1: of firms using informal modes of R&D cooperation; Cluster 2: Cluster of firms using informal modes of R&D cooperation

	Cluster of firms using formal modes of R&D cooperation (Cluster 1)		Cluster of firms using informal modes of R&D cooperation (Cluster 2)	
	frequency	in %	frequency	in %
New materials	543	22,29%	159	19,23%
Microelectronic and semiconductor-techno-logy	154	6,32%	68	8,22%
Laser-technology, optoelectronics, displays	114	4,68%	41	4,96%
Software, simulation and arificial intelligence	335	13,75%	127	15,36%
Telecommunication and information-technology	156	6,40%	63	7,62%
Bio-technology	45	1,85%	16	1,93%
Medicine and health care-technology	79	3,24%	28	3,39%
Flexible integrated manufacturing (FIT)	362	14,86%	108	13,06%
Transport, traffic and logistic	206	8,46%	64	7,74%
Transformation and storing of energy	102	4,19%	35	4,23%
Environment-technology and resource saving technology	340	13,96%	118	14,27%
Total	**2436**	**100,00%**	**827**	**100,00%**

4 Conclusions

I conclude the paper with a brief summary of the results, some reflections on them and a few brief observations on the implications they carry for public policy towards vertical R&D cooperation between firms.

The purpose of this paper was to investigate empirically the occurrence and importance of different modes of vertical relations between innovating firms, suppliers and users, using data from Germany. The main results can be summarized as follows:

84 % of all innovating firms responded that they have had cooperative agreements with either suppliers or customers or both. This percentage is even higher (99 %) if we consider only those innovating firms that have also had formal R&D departments. The phenomenon of vertical R&D cooperation is therefore widespread among German firms.

Informal exchange of technical knowledge was perceived as the most important mode of cooperation between innovating firms on one hand and customers and suppliers on the other, followed by formal methods of cooperation such as joint development teams and contractual R&D cooperation. Joint ventures and direct R&D orders to either customers or suppliers were seen as the least important modes of vertical cooperation.

The occurrence and importance of cooperative agreements between innovating firms, users and input suppliers vary from one industry to another.

Results of the methods of multivariate statistical analysis (correlation, principal components and cluster analysis) suggested that the various modes of vertical relations between innovating firms on one hand and customers and suppliers on the other could be reduced to two subgroups: the first one includes formal modes of cooperation, the second one includes informal exchange of technical knowledge. On this basis patterns of cooperative agreements could be established.

The empirical results from German industry confirm by and large the overall a-priori predictions of the New Industrial Organization literature in the area of innovation. This literature emphasizes, as mentioned in section 2 above, the central role of suppliers and users in the innovation process. Accordingly, it is not surprising that the majority (84 %) of German innovating firms have had R&D cooperation agreements with either suppliers or users or both. The high percentage of German firms having this kind of vertical relations might be explained by the fact that the German economy is technologically highly developed and therefore the degree of the division of - innovative - labor is very high as well.

The empirical finding that informal exchange of technical knowledge was perceived as the most important mode of R&D cooperation between innovating firms on one hand and customers and suppliers on the other can be interpreted as follows: From the standpoint of transaction costs analysis one can pinpoint two central dimensions of such transactions: uncertainty and asset specificity. Both dimensions are important in the interactions between innovators, suppliers and customers, and thus make trust an important element of their relations. Informal exchange of information can be seen as trust-building steps towards more formal modes of cooperation[23].

From the perspective of the New Empirical Industrial Organization one can add that some of the informal exchange of technical knowledge between innovating firms, suppliers and users can be interpreted as "knowledge spillovers". According to Grilliches such knowledge spillovers are "both prevalent and important" (Grilliches 1992: 29). Nadiri goes even further: "As to the existence and magnitude of R&D spillovers, the evidence points to sizable spillovers both at the firm and industry levels. The spillover effects of R&D are often much larger than the effects of own R&D at the industry level" (see Nadiri 1993:35).

On the other hand one can argue that this interpretation is only partly true, due to the fact that much of this informal exchange of technical knowledge between innovating firms, suppliers and customers can be seen as "Informal Know-how Trading" between partners. This has been observed between engineers in competing steel minimill producers in the US, an exchange that often went well beyond simple exchanges of data to include free training and the exchange of personnel (see von Hippel 1988, Schrader 1991). Another quite interesting interpretation of the existence of informal networks has been put forward by Freeman: "Informal networks ... are extremely important but very hard to classify and measure. However, just because of this difficulty it is essential to notice that they have a role somewhat analogous to "tacit knowledge" within firms. It is very generally recognized that in the technology accumulation process within firms and other organizations, tacit knowledge is often more important than codified formal specifications, blue-prints, etc.." (Freeman 1991:503).

In sum, both formal and informal cooperative arrangements between innovation producers, innovation users and suppliers are important. Innovation does require informal or formal coordination between agents operating at different stages of the

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[23] Williamson has also seen the importance of trust in interfirm relations: "To be sure, trust is important and businessmen rely on it much more extensively than is commenly realized."(Williamson 1985:108)

innovative chain. The question now is, what are the public policy implications of this empirical finding. The answer to this question has to be differentiated. In the area of informal modes of R&D cooperation, public policy has no role to play: It is up to the innovating firms themselves to set up the kind of informal relations with users and customers that are most useful for them. In the area of formal cooperative agreements, public policy can affect microeconomic decisions concerning two major issues: first, can vertical relations between innovation producers, users and suppliers be formed at all, and second, are the right kinds of vertical relations formed. Three sets of public policies can be brought to bear on both of these issues: Anti-trust (or merger) policy , public procurement policies and regional policy (see Geroski 1992:143).

Anti-trust policy can be used to discourage horizontal mergers in sectors where horizontal collusion is unlikely to yield dividends, and to discourage vertical integration in sectors where less formal vertical relations are likely to be desirable. Public procurement can be used to mobilize and focus demand and therefore stimulate innovation through the creation of a "user market". Regional policy may also stimulate vertical relations between innovation producers, suppliers and users at a well defined location. "It has often been argued that regional policy ought to encourage industrial specialization to build up around regional growth points. This is effectively a strategy which involves attracting clusters of mutually supporting activities together at a particular location. Its appeal is that it enables firms to benefit from a range of external economies, facilitating interactions between suppliers, producers and users. Distance often magnifies problems created by market failures, and proximity often facilitates the emergence of the kinds of formal and informal alliances which are necessary to overcome them." (Geroski 1992:145)

In short - as Gerosski observs: "Markets are inter-related, and the emergence of new products and processes often requires that the activities of agents operating in several markets be coordinated. This network of inter-market relations opens up numerous routes into any particular market, and gives policyholders several levers with which to try to stimulate industrial innovation. Vertical strategies often involve trying to bridge specific market failures that separate two or more markets (or activities), and may, for this reason, prove to be more effective than horizontal strategies which neglect inter-market linkages." (Geroski 1992:146)

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