Supplier and Buyer Market Power, Appropriability, and Innovation Activities

Evidence for the German Automobile Industry

by

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Abstract

Recent econometric studies only emphasize the role of long-term demand expectations and technological capability. They neglect the impact of buyer market structure on innovative efforts of input suppliers. This paper deals with the effects of supplier and buyer market concentration, and appropriability conditions on the innovative behavior of suppliers within the German automobile industry. The data set contains firms from all size classes and measures of innovation input as well as innovation output. It can be shown that a) innovation and R&D-employment intensity will decline (increase) in buyer concentration if supplier markets are low (high) concentrated, b) buyers' pressure on input prices reduces suppliers' innovation expenditures and their incentive to develop new products, c) a small number of competitors in domestic and foreign suppliers markets and a large stock of customers stimulates innovative behavior, d) small and medium sized suppliers invest more in their innovation activities but have lower probabilities to realize innovations than larger firms, and f) higher technological capabilities lead to a higher innovation input and output.

Key words: Innovation; Buyer Market Power; Appropriability; Market Structure; Firm Size; Automobile Industry

JEL classification: O31; L13; L62

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I. Introduction

In the past, the empirical literature had concentrated primarily on the effects of market concentration, technological opportunities, demand and appropriability conditions on the innovation activities of firms (Cohen 1995). The results were heavily discussed (Acs and Audretsch 1990; Frisch 1993). While in the 60's and 70's market power and firm size in the tradition of Schumpeter (1948) were said to have a significant impact on innovation activities (Cohen et al. 1987; Geroski 1990), in the last few years the recognition rose that it is the technological opportunity of markets and technological spillovers which influence innovative behavior significantly (Arvanitis and Hollenstein 1994; Geroski 1992; Klevorick et al. 1995; König and Licht 1995; Levin 1988). Other studies confirm that long-term demand expectations positively influence the innovation investments of firms (Cohen et al. 1987; Schmookler 1966).

But one issue has not yet been thoroughly explored in the econometric innovation literature. In some industries, such as electronics, chemicals, synthetics, and automobiles, also the conditions on vertically related markets determine the innovation activities of firms. Because firms' cost of production, time of development and/or quality of new products depend on the innovation activities of firms operating in vertically related markets, they have incentives to control the development process on these markets (Geroski 1992). The empirical case studies of von Hippel (1988) show that innovation efforts as well as appropriability conditions of input suppliers are influenced by firms on buyer markets. On the one hand, the buyers pass relevant technological information on to suppliers (Robertson and Langlois 1995). But on the other hand, they have an incentive to limit the appropriability of their suppliers by price discrimination, short-term contracts or by restricting property rights (Williamson 1975).

This paper deals with the effects of buyer concentration and demand power on the innovation activities of automobile suppliers, in view of the structure and the technological opportunities and technological capabilities on the supplier markets. On this issue only Farber (1981) provides insight into the impacts of buyer concentration on the R&D efforts of input suppliers. He considers several effects of buyer concentration on suppliers' expected profits of innovation (e.g. royality appropriability, speed of invention adoption). By estimating a simultaneous equation system for market concentration, advertising intensity, and R&D intensity, he finds significant effects of buyer concentration on R&D efforts for fifty U.S. four-digit industries. The data support his hypothesis, that sellers' R&D activities decline with buyer concentration for unconcentrated seller industries, and may increase with buyer concentration for concentrated seller industries.

In this paper we estimate the effects of market power of buyers on the innovation input (R&D employment intensity and innovation expenditure per unit of sales) and on the innovation output (realization of product and process innovation) of German automobile suppliers. In this sector market power of buyers is a traditional problem (Mendius 1991). We use indicators representing the structures on the supplier and buyer markets as well as the behavior of buyers influencing the appropriability of the suppliers' innovation rents. The data are derived from a sample survey conducted in the German automobile industry in 1995, representing 401 automobile suppliers out of sixteen four digit industries.

The paper is organized as follows. In section II some peculiarities of the (German) automobile industry are briefly mentioned with special attention to buyer-supplier relationships. Next, some relevant theoretical implications are made regarding the effects of demand power on innovation rent expectation and appropriability conditions. In section IV the data are described with consideration of the innovation indicators used. The estimation methods and results are depicted in section V. Section VI summarizes the main findings.

II. Market Power of Buyers in the German Automobile Industry

All over the world, the automobile industry is very heterogeneous because automobiles consist of *"as many as 20,000 parts that must all work together as an integrated unit"* (Liker et al. 1996, p.60). The automobile industry comprises a variety of buyer and supplier markets according to different business units (e.g. motors, tires, electronic components, plastics, glasses, forging dies). Most of the supplier markets are operated by small and medium sized firms. For example, in 1995, about 60 percent of the German automobile suppliers had less than 500 employees, wheras most of the smaller suppliers have only few buyers of their products (Peters 1996; Scientific Consulting 1995). In average, buyers of automobile parts (automakers or other large automobile suppliers) are larger than their input suppliers and have a high share of suppliers' sales. But in the German automobile industry also smaller suppliers which are exposed to a low market power of large buyers can be found.

The view demand power is a traditional problem in the (German) automobile industry (Mendius 1991) is supported by the fact that suppliers have to make transaction-specific investments in developing and producing automobile parts. The high degree of asset-specifity often implicates monopsonistic market relationships between automobile suppliers and their buyers. In addition, because amongst variables such as functional performance of new automobiles, the price is one of the most important factors on which automakers compete worldwide, automakers attempt to minimize the costs of their inputs. As a result, buyers on monopolistic or oligopolistic markets often use their bargaining power to lower prices or to change the regularity of delivery when dealing with small automobile suppliers operating in competitive markets (Nagel et al. 1989).

In recent years, automakers have changed their strategies in developing and producing new automobiles (Dyer 1996; Womack, Jones and Roos 1990). Most of the R&D- and production-activities formerly done in-house have been outsourced to external suppliers. In the early 90's, up to 70-75% in the case of Japan, up to 50-70% in Germany, and up to 35% of the automobiles in the US are developed and manufactered by suppliers (Clark und Fujimoto 1991; Meissner et al. 1994; Smitka 1991). Nowadays, German automakers buy more parts from outside. Suppliers have more responsibilities for product development (e.g. for designing, R&D, prototyping and testing) which seems to have positive impacts on their innovation efforts. But because of global sourcing, the bargaining power of automakers haver further increased.

The restructuring of the development and production process along the value-added line changes the structure and competition on the supplier markets. First, automakers reduced the number of suppliers to which they maintain direct transactions to realize returns of scale. They integrate less suppliers in the product development and (in some cases) have formed vertical corporate networks with first-tier, second-tier and third-tier suppliers. There is evidence that first-tier suppliers are involved earlier in product development, receive more technical information, use longer-terms contracts, and are supported more intensively by their buyers in the generation of new products than other suppliers (Becker and Peters 1997). Other suppliers are further used predominantly as low-cost subcontractors under short terms, arm's length contracts which handle blue-prints.

Second, the restructuring caused a process of cooperations and mergers among suppliers, producing substitutionary or complementary inputs. By acquisition of other firms, suppliers tried to enlargen their inhouse capacities in developing subsystems (rather than parts) to get first-tier suppliers and to build up a countervailing power position against the automakers.

In summary, it can be stated that at the beginning of the 90's, the buyer-supplier relationship in the German automobile industry, and especially the organizational structure of the automobile supply industry have changed remarkably. But the question, which implications does the vertical organization of structural dependencies and especially the demand power of buyers have on the innovation activities of input suppliers, is still unanswered.

III. Buyer and Supplier Market Power and Conditions of Appropriability

In the literature, the effects of demand conditions on innovation and R&D activities are mostly treated in the light of the *demand-pull* hypothesis in the tradition of Schmookler (1966). Contrary to the *technology-push* hypothesis the firms' evaluations regarding future sales and marketing expectations of new products and processes affect their innovation activities. Both the introduction of innovations and the firms' willingness to carry out innovation activities depend on the expected profitability. Apart from the demand conditions which are determined by the product life cycle, and therefore, by the degree of saturation of markets (Utterback and Abernathy 1975) profit expectations of suppliers in intermediate good sectors seem to be influenced by the structure of the buyer markets and by the behavior of the buyers of innovations (von Hippel 1988). Both aspects describe the market power of buyers.

As no specific theoretical frameworks to handle the impact of buyer concentration on innovation efforts of firms exist, we present some theoretical explanations to the role of buyer market power for the innovation behavior on input markets.[1] There is particular emphasis on the interaction between supply and buyer market structure. It is assumed that the incentive to innovate is entirely driven by profit expectations, and that most of the innovations are custom-tailored.

Expectation of Demand Changes

For sellers of innovations it is easier to evaluate future changes in demand and to address customers' needs, if they transact to high-concentrated buyer markets because they have to satisfy only the needs of few large buyers. Regarding to the life-cycle hypothesis of Utterback and Abernathy (1975), the diversity of competing versions of products and the number of (major) innovations declines with higher concentration (Klepper 1996). Thus, the risk of innovation failure for suppliers decreases, if only a small number of buyers operate in high-concentrated markets. Christensen and Bower's (1996) study on the influence of relevant buyers for a successful introduction of technological innovations in the world disk drive industry gives evidence for this argument. They find that *"when a proposed innovation addresses the needs of small customers in remote or emerging markets that do not supply a significant share of the resources a firm currently needs for growth and survival, firms will find it difficult to succeed even at innovations that are technologically straightforward"* (Christensen and Bower 1996, p. 199).

[1] Some of the arguments are derived from the investigation of Farber (1981).

Order Size

Large firms in high-concentrated buyer markets are more able to demand products of higher order sizes than small firms on low-concentrated buyer markets. If the realization of returns of scale in the production of new inputs is most important (e.g. in the automobile industry) buyers share their factor demand on one large supplier rather than on several small suppliers. Given the schedule of delivery, larger order sizes give suppliers more certainty in their output of the new products and higher incentives to invest in R&D. In addition, large order sizes seem to stimulate firms' efforts to engage in R&D for process innovations. Based on the theory of industry evolution, Klepper (1996) states that the value of a unit cost reduction achieved through new processes is proportional to the level of output sold by the firm.[2]

Diffusion Rate of Innovations

The potential of innovation returns is also determined by the speed of adoption whereas the seller of innovation prefers low (high) rate of adoption on the seller (buyer) markets. Regarding the positive interactions between seller (supplier) and buyer concentration, Farber (1981) points out the inverse relationship between seller and buyer power on the rate of diffusion of new knowledge. Firms in monopolistic markets have higher abilities to errect entry barriers, which reduce the rate of diffusion (Geroski 1990; Gilbert and Newberry 1982). In addition, Leibenstein (1969) argues that monopolists face X-efficiencies in form of inflexibilities in the adoption of new technologies. The time-lag between imitation and innovation increases with higher concentration, which implicates a lower speed of diffusion and a lower rate of imitation. A lower rate of adoption on the supplier market has a positive impact on firms' innovation efforts because it leads to a reduction of the discount rate and to increasing returns. A lower rate of imitation on the buyer market reduces the expected profit stream of innovation and therefore reduce the innovation activitities of suppliers. But Farber (1981, p.338) believes: *"If the speed of adoption declines with the concentration of buyers, buyer market concentration may have a negative effect on inventive and innovative activity where the seller's market is more competitive."*

Licensing Contract Design and Royalty Appropriability

The effects of buyer market structure on the innovative efforts of suppliers may be explained by following the theory of efficient licensing contracts. Farber (1981) remarks that the licensor's choice of the optimal compensation schedule (fixed or variable fees) depends on the structure on the licensee markets, which has certain effects on the profit expectations of the supplier (Shapiro 1985). The literature of efficient licensing puts strong emphasis on fixed

[2] But Klepper (1996, p. 365) further assumes that the incentive for product innovation is conditioned by the demand of *new* buyers. Thus, the number of (major) product innovations tends to increase in the number of buyers. But it has to be remarked that Klepper looks at major innovations rather than incremental innovations.

fees. A royalty will affects firms' behavior since it increases the marginal costs of using the innovation. A fixed fee has no effect on the decision of the licensee and avoids the need to monitor the use of the innovation by the licensee. But under certain conditions (risk sharing) it may be optimal for the supplier to choose royalties for innovations (Kamien 1992). But in a simple formal model of linear demand, Demsetz (1969) shows that in the case of innovations, which reduce the production cost of buyers, the optimum rent potential is at least as great for a monopolistic buyer industry as for a competitive buyer industry of the same size and cost assumptions. Therefore, the potential for licence fees from cost-reducing innovations is higher, the more concentrated the buyer markets. In the case of innovations which are demand-improving for the customers, the topic is more complex and ambiguous (Farber 1981, p. 337). Only with constant costs, imperfect licence discrimination, and sufficiently high demand improvement on the buyer markets coming from suppliers' innovations, licence fees on monopolistic buyer markets exceed licence revenues on low-concentrated buyer markets.[3]

Up to this point, only the effects of the buyer market power on the potential of innovation profits are described. Apart from the size of the innovation returns the *actual realization* (the appropriability) of innovation returns is influenced by the behavior of buyers. Assuming the ability to licence new technological knowledge and assuming the suppliers' ability to discriminate licences, demand power of buyers not only determines the choice of an appropriate compensation scheme but also - given the type of the licence fee - the size of the innovation returns. For example, negotiation power of buyers can spoil the size of the fixed quantity fee. Farber (1981, p. 338) remarks: *"The relative bargaining powers of buyer and seller of the innovation will determine the share of the rent which is appropriable by the innovator. As the relative bargaining power of the buyer increases, the appropriability of the rent declines."*

Countervailing Power

Within the automobile industry *price* discrimination plays an important role. According to Lustgarten (1975) monopsonistic buyers can discriminate prices more easily between their suppliers than buyers who act on lowly concentrated markets. This does not only effect the price evaluation of short-term market transactions, but also the design of *incomplete* long-term contracts (Klein et al. 1978; Williamson 1975). So, after the completion of customer specific

3 The theoretical framework of efficient licensing contracts is of minor relevance for the German automobile industry, because patents are an inefficient appropriability mechanism of innovation rent (Greif and Potkowik 1990). More often, automakers formally or informally insist on a sole right of disposal for their suppliers' developments, giving the suppliers a temporal right of producing the new inputs. Also, in some cases, certain parts of the suppliers' developments have to be done directly on the blue prints of the buyers (Nagel et al. 1989). This does not allow patenting on the supplier side any more as well as certainty on future delivery of the own-developed products is not assured either. However, the probability of such a behavior of buyers may decrease with the market power of suppliers.

innovations, long-term contracts cannot prevent powerful buyers from pushing through *ex-post* price negotiations, leading to price reductions despite constant contract periods. But rational acting suppliers will anticipate the opportunistic behavior of the buyers, reducing their R&D-investments to a level by which the marginal return of R&D equalizes the marginal cost of R&D. Because the marginal return of R&D declines with market power of buyers, the innovative efforts of suppliers will be reduced.

In general price discrimination requires to a certain degree incomplete competition on the supplier markets. Only then, factor prices can be pushed towards marginal costs via demand power, deteriorating the conditions to appropriate for the innovators. But the negative effects of opportunistic behavior of buyers seems to be higher for low-concentrated seller markets rather than for high-concentrated seller markets. High concentrations on both related markets implicate a *countervailing power* situation (Galbraith 1956; Soldatos 1994) or a double-sided *small number* situation (Williamson 1975), which reduce the incentives of buyers to behave opportunistic and to carry out price discrimination.

Vertical Corporate Networks

Surveys on the role of corporate networks in the innovation process, controlled and lead by dominant buyers, emphasize the influence of positive interactions in concentrated markets (Jarillo 1995, McMillan 1990). Most of the networks reveal a decentralized and pyramidal structure, showing large firms in concentrated markets on the last stages of production. Due to this market constellation of a double-sided small number situation suppliers seem to have the necessary security to carry out risky and technologically complex innovations. The network theory emphasizes that on the basis of rational and economical confidence between sellers and buyers long-term contracts are established, favoring the exchange of information between the partners and promoting innovation activities (Freeman 1991; Robertson and Langlois 1995). In examining the role of R&D-spillovers within vertical networks in the German automobile supply industry, Becker and Peters (1997) find support for this view. Buyers of automobile parts share more R&D-stimulating information with suppliers which are members of corporate networks than with suppliers to which they have only loose relationships. In addition, they observe that members of corporate networks operate in higher concentrated markets and focus their activities on less customers than non-members.

In summary, the various theoretical explanations suggest positive as well as negative impacts of buyer market power on innovative efforts of suppliers. The sign of the influences depends on the rate of concentration in the supplier markets. As Farber (1981, p. 338) argues: *"In the case where seller market power is low, increased buyer market power may reduce appropriability and discourage R&D by the selling industry. This is not likely to be the case* *when seller market power is high*". Next, we want to find empirical evidence for this statement.

IV. Empirical Model and Data Description

The econometric estimations are based on data of an empirical survey for the German automobile industry carried out in 1995 (Peters 1996). The survey aimed at measuring the effects of the conditions of competition and technological capabilities on automobile innovation behavior in general and specifically the effects of appropriability conditions and supplier-buyer relationships. Out of an initial sample of 1,306 automobile suppliers, 460 firms returned the questionnaire. After having excluded firms in the fields of engineering, consulting and tuning, 401 suppliers of automobile parts remained.[4]

Innovative Activitiy

Our survey evidently shows quite a number of indicators for the innovative behavior of firms. Four of these indicators are used in this paper. They refer to innovation input as well as innovation output, giving a more sophisticated picture of the effects of buyer market power on the innovative behavior of automobile suppliers.

The input of innovation processes is measured by the *R&D employment intensity* (R&D_INT) as well as the *innovation intensity* (INNO_INT) of suppliers. The R&D employment intensity relates to the percentage of employees performing R&D tasks within or outside R&D departments. As our survey does not operate with full-time equivalents, using the R&D intensity can lead to an overestimation of the R&D input in small firms. As Felder et al. (1996, p. 132) remark, in small firms „R&D tasks and non-R&D tasks are often assigned to the same employee" which is not taken into account here.

The innovation intensity captures further characteristics of firms' innovation input. Herewith criticism is refuted that firms not only need to perform R&D for a successful introduction of new products and processes, but also in related fields, such as design and conception, construction, engineering and fabrication of prototypes, as well as trial production and pilot plants, which are only under some circumstances part of R&D, in the sense of the Frascati Manual (OECD 1993; Kleinknecht and Bain 1993). The innovation intensity used in our paper are based on those financial means the automobile suppliers raised in 1994 for R&D and the other activities described.[5] To evaluate the innovation intensity the innovation

[4] We define automobile suppliers as firms producing parts, components, subsystems, materials or tools, which enter directly or indirectly in an automobile.

[5] In the OSLO-Manual activities for patenting and licensing as well as staff training are also part of the innovation process (cf. König and Licht 1995). These activities, however, are not taken into account here, because they do not refer to the course of the innovation process (Clark and Fujimoto 1991).

expenses were related to the sales the firms made in 1994 with automobile products only. As variables to measure innovation output, we use data on the successful *market introduction of product innovations* (PROD_IN) and on the successful *implementation of process innovations* (PROC_IN). An innovative supplier is defined as a firm which has introduced new or improved products or processes in 1993 or 1994. These indicators have the advantage of showing the actual realization of new products and processes as opposed to the patent indicator which only measures the registered patents (cf. Acs and Audretsch 1990; König and Licht 1995).

Our effort to control measurable inter-firm differences in buyer and market structure, appropriability conditions, and technological opportunity restrict the size of our sample. Data were available for only subsets of suppliers because some of them did not answer all questions. Further, in some models we restrict our attention to innovating firms only. The reduction of the entire sample led to some modifications to the innovation indicators (cf. Table 1). For example, the share of the non-innovative firms was reduced moderatly from 13.2 per cent to 12.1 percent. The drop in the variance of the innovation intensity can be explained by the exclusion of two firms which both invested 30.0 per cent of their sales in R&D.

INSERT TABLE 1 HERE

Market Structure, Appropriability and Technological Capabilitiy

For the empirical analysis we assume a causal relationship between the innovation input as well as innovation output and the factors on the right side as follows:

$$\textit{innovation input/output} = f(\underset{(+/-)}{SMC}, \underset{(+/-)}{BMC}, \underset{(+)}{AP}, \underset{(+)}{TCO}, \underset{(+/-)}{A})$$

where SMC = parameter of suppliers’ market structure, BMC = parameter of buyers’ market structure, AP = degree of appropriability of suppliers’ innovation rent, TCO = conditions of technological capability and opportunity, and A = conditions regarding firm size, degree of inter-industry diversity, demand schedules etc.). The expected signs of the determinants of innovation are in brackets.

Table 2 shows the exogenous variables used in the estimations, and Table 3 shows the descriptive statistics of these variables. Data on market structure were drawn from the survey as well as from a publication of the German Monopoly Commission for the year 1991. The concentration in the domestic supplier markets are measured by the Herfindahl index, computed for the lines of business (SCR). Where such a classification was not feasible, the

SCR of the respective two-digit industry was used. To describe the situation of suppliers in their home and foreign main market we use a dummy variable characterizing oligopolistically structured markets with 1 to 10 competitors (COMP_H).

INSERT TABLE 2 HERE

Special attention was paid to the inclusion of the demand conditions of the suppliers. On the basis of lines of business a sales weighted CR3-concentration index of the domestic markets was depicted (BCR). The weights of buyer concentration index relate to the shares of suppliers' output, made directly with car makers, commercial vehicles or with first- and second-tier suppliers in 1994. The advantage of BCR over comparable variables of demand power (cf. Farber 1981, Lustgarten 1975) is on the direct registration of firm related, monopsonistic buyer market power of the automobile suppliers. Further, a dummy was introduced to define all suppliers with more than 10 customers within the automobile industry (CUST_H). This variable does not only reflect the potential demand power of buyers (the possibility of opportunistic behavior declines with the number of customers), but also the size of the automobile specific markets. We therefore expect the coefficient of CUST_H to be positive. To measure the effects of interaction of the concentration in the (domestic) supplier and buyer markets we multiplicate the concentration indices. We suggest a positive sign of the coefficient of SCR*BCR but a negative sign of the individual coefficient of BCR.

Closely connected with the demand power of buyers are the appropriability conditions. In general, the conditions of appropriability are determined by the possibility of patenting innovations, the complexity of the design, the immediate introduction into the market, the secrecy of technological know-how, long-term work contracts, as well as contractual seller-buyer-relations (cf. Cohen 1995, Levin et al. 1985, König and Licht 1995). This list is far from being complete. Since automobile supplier products are usually custom-tailored, the design of supplier contracts is most important for innovation returns.[6]

A dummy variable was introduced, characterizing suppliers, which use long-term contracts (model life contracts over 3 to 5 years) to a higher extent than short-term contracts (APPROP_C). The firms were also asked to declare to which extent they were confronted with declining revenues in 1993 and 1994 due to price pressure of the buyers (APPROP_P). Here the assessment ranged on a a Likert-scale starting from 1 (not at all) to 7 (to a high degree). The respective scale values were used as regressors.

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[6] We have already mentioned that patents in the automobile sector are far less important than in other sectors. Moreover, only the innovative enterprises had to comment on the effectiveness of patents in the survey

Also variables were intended to capture dimensions of the technological *opportunity* of markets and of firms' technological *capabilities*. Unfortunately, no data were available about the closeness to science and the importance of external sources of technological knowledge (Arvanitis and Hollenstein 1994; Klevorick et al. 1995). Instead, industrial effects of technological opportunity were measured by the contribution of factor specific, technological know-how for industrial research. These data are taken from a publication of Meyer-Krahmer and Wessels (1989), in which they examined the intersectoral integration between the technology suppliers and takers in Germany using the industrial distribution of price adjusted stocks of R&D-capital. Using their classification, a dummy variable was intended to reflect the lines of business chemicals, automobile parts and automobile electronics as having above average stocks of R&D-capital (R&D_CAP).

Primarily, we measured the technological capabilities of firms with responses to questions concerning the share of sales of automobile parts, developed exclusively by the suppliers (TEC_SUPP) or custom-tailored (TEC_CUST). Custom-tailored products are also called black-box products, where the buyers only fix the successful characteristics of the intermediate products and leave the development as such to their suppliers (Clark and Fujimoto 1991). The features of the products reflected different aspects. First, according to Cusumano (1989), automobile suppliers with high technological capabilities should be able to make higher R&D efforts with their own developed and black-box products than firms with low technological abilities which mainly produce parts, which are controlled in all details by their customers. Second, the variables intended to reflect the contribution of buyers as an external information source for the suppliers' innovation activity and hence the locus of innovation (von Hippel 1988). Third, it should be mentioned that the various specifications of automobile parts other than technological opportunity also catch aspects of demand (Cohen 1995; von Hippel 1988). So, automobile parts produced through own supplier drawings may be less customer-specific than detail-controlled or black-box products. Consequently, they can be offered to a larger number of customers, reducing the potential opportunistic behavior of the buyers (Williamson 1989).

The technological capability/opportunity established *internally* by the suppliers is included by a dummy variable (TEC_INT). It subsumes those firms doing regular basic research or experimental development in formal R&D departments. In addition, they call themselves *development suppliers*.

The estimations are also controlled by differences in business unit size. As a proxy variable for business unit size the sales of automobile parts (in logs) is chosen (SIZE). This catches the effect of the *automobile sector specific* firm size (cf. Cohen et al. 1987). Using the logged number of employees, which relates to the entire firm, led to similar results. As the literature does not offer a standard economic interpretation of size effects, business unit size can be used as a proxy for various economic effects and therefore can have ambiguous effects on suppliers' innovation activities (Arvanitis and Hollenstein 1994; Felder et al. 1996). In order to control intersectoral synergy effects with the development of new products and processes, the dummy DIVERS was included, reflecting all suppliers having made less than 40% of their sales with automobile parts in 1994. Highly diversified suppliers should have better opportunities to make use of know-how coming from other sectors for the realization of automobile specific innovation.

V. Estimation Issues and Results

Two statistical problems arose as we estimated our specification of the innovation input. First, some of the automobile suppliers had no expenditures on R&D and other innovation activities even if they had successfully introduced new products or processes in 1993 or 1994. An estimation of the intensities, containing firms with positive innovation expenses only, would lead to a truncation of the error terms and to biased parameter values. Accepting a misspecification of the model, the problem can be solved by using a Tobit model. The possible misspecification lies in the fact that independent parameters simultaneously determine the probability as well as the expenditures of innovation activities (Cohen et al. 1987; Arvanitis and Hollenstein 1994).

A second statistical problem arose since after using a likelihood-ratio test the hypothesis of homoscedasticity in the error terms had to be rejected. Moreover, it became evident that a certain structure of multiplicative heteroscedasticity in the restricted as well as in the unrestricted sample can be found. Here the log of the variance of error terms could be depicted as a linear function of business unit size as well as the concentration indices of domestic markets. A binary Probit model was used for estimating innovation outputs (PROD_INN and PROC_INN). The determination of maximum-likelihood values was done by implementing the numerical Newton-Raphson procedure.

Innovation Expenditure and R&D Employment

Our estimation strategy is to fit regression models for two different samples containing innovative as well as non-innovative suppliers yet with the same set of parameters. The Tobit estimates of the effects of supplier and buyer market concentration, appropriability conditions, technological capability/opportunity, and other characteristics on automobile supplier's innovation intensity and on their R&D-employment intensity are shown in Table 4.

The coefficients of the variables representing the supplier and buyer market structure on the innovation intensity are individually and jointly significant at the 0.05 resp. 0.1 level across both models. The expectation that buyer market power has a negative effect on innovative efforts is supported by the estimation of the innovation intensity, but only weakly. The signs of the coefficients for BCR and SCR*BCR show that the innovation expenditures per unit of sales will fall with rising buyer markets concentration, if automobile supplier markets are low-concentrated. But the innovation intensity will rise with an increasing buyer concentration, if supplier markets are highly concentrated. The effect of the supplier concentration on the innovation intensity is as well dependent on the concentration of the buyer markets, as the sign of the coefficients for SCR and the interaction term SCR*BCR shows. A high supplier concentration reduces (stimulates) the firms' innovation intensity, if the buyer markets are lowly (highly) concentrated. These effects are more evident for the larger sample containing innovative as well as non-innovative firms than for the smaller sample containg only innovative firms.

INSERT TABLE 4 HERE

The data also give information about the effects of competition on the domestic and foreign markets. German automobile suppliers acting on oligopolistically structured domestic and foreign markets seem to invest more in their innovation process than other suppliers. There is a significant positive influence of COMP_H in the estimation of the innovation intensity of innovative as well as non-innovative firms (model 1) but not for the sample of innovative firms (model 2).

The estimations suggest that the market structure variables SCR and COMP_H reflect different aspects of supplier competition. While the Herfindahl index on an aggregated level only measures the general conditions in the *domestic* good sectors, the dummy variable which reflects suppliers acting on tight oligopolistic markets relates to the market constellations both at home *and* abroad. In addition, suppliers in lowly concentrated four-digit industries may only have a small number of rivals in their main markets if they produce differentiated inputs.

A large stock of customers influences the innovative efforts positively. Suppliers operating with many customers are faced with a lower opportunistic behavior of their buyers, improving their ability to appropriate sufficiently high innovation returns. As expected, the potential utilization of the innovation and the speed of adoption new technologies seems to be higher, the more potential buyers are available. This, however, requires implicitly low costs for suppliers to switch among buyers (Riordan and Sappington 1989; Williamson 1989).

In principle, the estimation results of the suppliers and buyer market structure (concentration) on the R&D employment intensity follow a similar pattern to that of the innovation intensity but with lower statistical significance. The signs of the coefficients of the variables which capture the effects of market concentration are conformable in all models. But in all estimations of the R&D employment intensity the coefficient of the buyer concentration was not significant. Thus, buyer concentration gains only a *weak* positive impact in interaction with a high seller concentration. Contrary to the findings in the estimations on the innovation intensity neither a positive effect of competition on the domestic and foreign suppliers markets nor of a large stock of customers was found in the models of the R&D employment intensity.

As a provisional outcome, the estimations on the R&D employment intensity and on the innovation expenditures per unit of sales for the German automobile supply industry confirm the results of Farber (1981) who found the same effects of supplier and buyer concentration on R&D employment intensity for fifty U.S. four-digit industries. In our data however, the impacts of buyer concentration are stronger in the models of explaining the innovation intensity than the R&D efforts, as well as for the sample containing innovative and non-innovative suppliers than for the sample containing innovative suppliers only. The latter finding suggests that supplier and buyer market structure may affect the probability to realize an innovation to a larger extent than the intensity of innovation activities.[7] In addition, the Wald Test shows that the explaining power of the variables representing buyer and seller market structure is only moderate in the sample of innovative suppliers.

Next we will comment on appropriability and buyer power. In the empirical models for innovation intensity the coefficient of the variable reflecting the contractual appropriability shows neither a significant influence nor do the coefficients of APPROP_C have the positive signs expected. However, the realization of long-term contracts strongly stimulates a supplier's decision to invest in R&D. Thus, for the German automobile industry, the data find no unambiguous support for the findings of recent case studies which suggest that long-term contracts should improve the relationship between suppliers and their customers (automakers), and thus, the appropriability of *innovation* returns (Dyer 1996; McMillan 1990). Only, the less firms fear that the time of amortization of *R&D* costs is too short the more they will invest in their (formal) R&D activities. Also Felder et al. (1996) found no effect of their appropriability

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[7] Instead of a Tobit model we can also use a Heckman-type model which can identify the parameters of suppliers' participation in the innovation process and the intensity of their efforts separately. But the firms' participation refers to the decision to *invest* in the innovation process or not (independently, if they had realized an innovation in 1993 or 1994) but not to the probability that suppliers will be innovative. Thus, also non-innovative suppliers can unsuccessfully invest in the innovation process or innovative suppliers do not have to spend on R&D.

measure on innovation intensity but on R&D intensity although they use other specifications of their appropriability measures.

In other estimations, not reported in Table 4, we replace APPROP_C by a dummy, characterizing all suppliers using balanced shares of short- and long-term contracts. By this we tested the hypothesis of the OECD (1983) that by using long-term contracts the dependence on buyers increases for suppliers, especially for smaller suppliers. This market power may give buyers incentives for opportunistic behavior which reduces the willingness of suppliers to invest in R&D. Our data for German automobile suppliers gives us only little support for this hypothesis. Indeed, automobile suppliers having balanced shares of short- and long-term contracts, show higher innovation intensities but this impact is only significant at the 0.12 level. Using a dummy, which characterizes all suppliers using more short-term contracts compared to long-term contracts, also yields negative (insignificant) signs of the coefficients in the estimations of the innovation expenditures per unit of sales. Thus, the data cannot confirm a *strictly* positive impact of using long-term contracts on the innovation input, allowing for a better appropriability of innovation returns.

There is, however, a stronger indication in the data that price-related buyer power (APPROP_P) has negative effects on innovation expenditures, and especially on the R&D employment intensity. A current adverse business situation reduces the financial potential to carry out R&D and innovation activities. If the profit expectations are also coupled with the current business situation, price pressure of buyers will reduce innovative efforts because of worse (financial) demand expectations which confirm Schmookler's hypothesis. This relationship, however, is weaker for the models in the estimation of the innovation intensity than for the models in the estimation of the R&D employment intensity.

Now we look at the technological capability of firms and at the technological opportunity of markets. The estimates show that the suppliers' technological capability associated with the degree of supplier integration into the development of new products (TEC_CUST and TEC_SUPP) as well as with the capacities established internally (TEC_INT) determines their innovation expenditure as well as their R&D intensity significantly. Higher shares of automobile parts which are developed supplier-own or custom-tailored as well as higher internal R&D-capacities stimulate the suppliers' innovative efforts. But the positive impact of internal R&D capacities is weaker in explaining the variances in the innovation input for innovative suppliers (model 2). The coefficient estimates of the technological opportunity R&D_CAP have insignificant effects in all models. Automobile suppliers operating in lines of business with above average R&D capital stocks seem to have no higher innovative and R&D efforts than other firms.

Finally, the effects of business unit size (SIZE) and intersectoral diversification (DIVERS) are mentioned. While DIVERS is not significantly positive in the estimations of the innovation input, there is a highly significant influence of suppliers' firm size in automobile parts. We observe a strongly negative impact in the investment in innovation and R&D activities with growing business unit size. But we have not controlled the non-linearity of the intensity and firm size relationship whichwas found by Felder et al. (1996) in the (West) German manufacturing industries.

The Probability of Realizing an Innovation

Table 5 presents the binary Probit estimates of the same determinants discussed so far on the realization of product and process innovation. Contrary to the findings in the estimations of the innovation input, the coefficients of the concentration variables are individual and jointly insignificant at the 0.1 level across the Probit estimation of the probability of product and process innovations. Only the seller concentration affects the probability of realizing a *process* innovation. Remarkably, in this model the terms of the seller and buyer concentration have the opposite signs than in the empirical models for innovation and R&D employment intensity but in principle have lost their statistical significance. Domestic seller and buyer concentration does not explain inter-firm differences in the probability of realizing an innovation. Thus, the lower significance of the interaction of buyer/supplier concentration in the estimations of the intensities for the sample containing innovative suppliers (model 1 in Table 4) compared to the sample of innovative and non-innovative suppliers (model 2 in Table 4) can not be explained by an larger impact of domestic market concentration on the probability of realizing an innovation.

INSERT TABLE 5 HERE

In summary, the regressions show that buyer (seller) concentration - in interaction with seller (buyer) concentration - affects the innovation input but the effect is lost when estimating the innovation output. But although the indicators of domestic market concentration lack on statistical significance, automobile suppliers acting on oligopolistically structured domestic and foreign markets seem to have higher probabilities of realizing an innovation than suppliers operating in markets with a large number of competitors. The results of other surveys, signalling insignificant effects of supplier market structures on innovation output, may therefore be biased due to measurement problems (Arvanitis and Hollenstein 1994; Felder et al. 1996; Geroski 1990). But, the data give no strong evidence for the Neo-Schumpeter hypothesis that firms with high market power are more innovative than other firms.

The probability of realizing a *process* innovation is larger for suppliers with a large stock of customers than for those with only few customers. However ths effect is lost when estimating the probability of realizing a *product* innovation. If we assume that the stock of customers is also an indicator for the suppliers' size of the automobile market, we can explain the positive effect of a large stock of customers by the suggestion of Klepper (1996). He states that the incentives of firms to invest in process innovations increase with the size of their output because innovation rents are connected to the current output if the innovator can use its generated knowledge inhouse only. Thus, it is more likely for firms with a larger stock of customers to realize a process innovation than for firms with only few customers.

Klepper's (1996) argument is also confirmed by the significant effects of the size of business units. Whereas larger firms invest less in their R&D and innovation process we observe an increasing probability for the realization of process (as well as product) innovation with growing business units. This is conformable to results of other empirical studies, signalling a lower probability of realization of product innovations for small and medium firms compared to large firms, but having higher innovation and R&D intensities (Cohen 1995; Felder et al. 1996; Kleinknecht and Bain 1993). The positive (negative) sign of the coefficient of the business unit size on the realization of new automobile parts (innovation input) is evident, although the share of small and medium sized firms is smaller in the subsamples compared to the entire sample.[8]

Now we want to consider the effects of appropriability. First, suppliers with long-termed contracts have higher probabilities of realizing process innovations but not of realizing product innovations or investing more in their innovation process. Second, a high price pressure reduces the suppliers' incentives to engage in the innovation process and to realize a product innovation. This relationship, however, cannot be observed with the estimation of the probability to realize a process innovation. Therefore, the estimations cannot confirm the results of some case studies that the demand of German automakers for high price reducement encourages suppliers to realize innovation returns by improving their production processes (e.g. Scientific Consulting 1995).

Not surprisingly, we also observe a strongly increasing probability for the realization of product as well as process innovation with higher technological capabilities. It is striking, however, that the realization of process innovations is a negative function of the shares of sales of automobile parts developed exclusively by the supplier or developed custom-tailored. It seems that those suppliers who mainly produce automobile parts from customer drawings,

[8] It was tested, whether small and medium sized suppliers are under-represented in the subsample. Out of the initial sample of 401 firms, the share in the subsamples reduces from 8.5 % to 7-7.5 %.

specialize their innovative efforts on the development of new processes by trying to take the position as a cost leader.

VI. Summary and Concluding Remarks

For the first time, the effects of buyer and seller power, appropriability, and the technological capability/opportunity on the innovation behavior of German automobile suppliers have been estimated. Contrary to the econometric study of Farber (1981) we use variables representing firms' innovation input as well as innovation output, yielding a more sophisticated picture for the models estimated. It was shown that suppliers' innovation intensity may decline with buyer market concentration when the supplier market is of low concentration, but may increase with buyer market concentration when the supplier market is concentrated. In principle, these effects were also found in the estimations of the R&D employment intensity but with lower statistical significance. However, an impact of domestic buyer or seller market concentration was not observable by the estimations on the indicators of the innovation output. Further we found that automobile suppliers in oligopolistically structured domestic and foreign markets reveal higher innovation activities and that the size of the suppliers' stock of customers stimulates their innovative behavior.

Estimating the effects of buyers behavior regarding the appropriability conditions of innovation returns we confirmed that long-term contracts positively influence the R&D employment intensity and the suppliers' probability of realizing a process innovation. But they have negative (insignificant) effects on the innovation expenditures per unit sales and on the probability of realizing a product innovation. However higher price pressure of buyers reduces the incentives of suppliers to invest in innovation and R&D activities, and reduces the probability of realizing product innovations. In controlling the estimates for the suppliers' technological capability/opportunity we found that a higher technological capability stimulates the firms' innovative efforts. The data also revealed that there is a lower probability for small and medium automobile suppliers to innovate, but that they invest more heavily in their innovation and R&D activities than larger suppliers.

The data give an indication that in analysing innovation processes we have to bear in mind the vertical interaction of decisions and structures. Buyer market power and especially its interaction with seller concentration has an impact on the innovative efforts of suppliers. But it seems that buyer concentration can explain only a small fraction of inter-firm differences in innovation activities. Also, the effects of the conditions of competition on buyer and seller markets differ, depending on the innovation indicators used. So Farber's (1981) findings could be confirmed rather with the estimation of innovation intensity and - with some cuts - of

R&D employment intensity. On the other hand, the innovation output depends rather on the technological capability/opportunity and on the size of firms than on buyer concentration. However, to obtain a better understanding of the interaction between seller and buyer power on innovative behavior we have to use more sophisticated indicators representing these effects.

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Appendix: List of Tables

Table 1: Descriptive Statistics on Innovation Intensity and on the Realization of Product and Process Innovation by Samples

	Innovation Intensity			R&D Employment Intensity				Realization of new					
								Products and/or Processes		Products		Processes	
	Sample			Sample				Sample		Sample		Sample	
	352	286	248	*368*	300	268		*401*	314	*401*	314	*401*	314
Mean	*0.050*	0.049	0.054	*0.049*	0.051	0.055	**No**	*13.2%*	12.1%	*21.9%*	20.7%	*25.4%*	24.2%
Std. dev.	*0.043*	0.038	0.038	*0.049*	0.050	0.051	**Yes**	*86.8%*	87.9%	*78.1%*	79.3%	*74.6%*	75.8%
Minimum	*0.000*	0.000	0.000	*0.000*	0.000	0.000							
Maximum	*0.300*	0.200	0.200	*0.300*	0.300	0.300							

Remark: * Only 352 (368) suppliers out of the unrestricted sample of 401 firms gave responses to their innovation expenditures or automobile sales (R&D-employment or full size employment).

Table 2: List of Variables and Description

Variable	Short Description of the Variable	Value
	Conditions on suppliers markets	
SIZE	*Firm size*; Sales of automobile parts (in log)	Metric
DIVERS	*Inter-industry diversification*; Low shares of production of automobile parts regarding to the whole sales of suppliers (1 = shares smaller than 40%, 0 = otherwise)	Nominal
SCR	*Domestic supplier concentration*; Herfindahl index based on the level of business unit	Metric
COMP_H	*Supplier concentration in domestic and foreign markets*; Responses to a question concerning the number of Competitors home and abroad (1 = 1 - 10 competitors, 0 = otherwise)	Nominal
	Conditions on buyer markets	
BCR	*Domestic buyer concentration*; sales weighted CR3-concentration index of domestic buyer markets (lines of business)	Metric
SCR*BCR	*Interaction of domestic supplier and buyer concentration*	Metric
CUST_H	*Stock of Customers*; Responses to a question concerning the number of Customers home and abroad (1 = more than 10 customers, 0 = otherwise)	Nominal
	Appropriability conditions	
APPROP_C	*Contractural appropriation of innovation return;* Relative importance of long-term contracts (model-life contracts with a time of delivery of 3 and 5 years) regarding to short term contracts of one year or less; (1 = higher importance of long-term contracts; 0 = otherwise)	Nominal
APPROP_P	*Appropriation of innovation return by input prices;* Responses on a seven point Likert scale to a question concerning lower rates of returns because of high price pressures by buyers. (1 = not at all accurate to 7 = very accurate)	Intervall
	Suppliers' technological opportunities	
TEC_INT	R&D-capabilities established *internally* by the suppliers (1 = R&D-department, periodical activities in R&D, and evaluation as development supplier, 0 = otherwise)	Nominal
TEC_SUPP	Shares of supplier-own developed automobile products	Metric
TEC_CUST	Shares of automobile products which are developed by suppliers at customers specifications (*black-box* products)	Metric
	Technological opportunitiy of Industries	
R&D_CAP	Lines of business having above average stocks of R&D-capital (1 = chemicals, automobile parts and automobile electronics, 0 = otherwise)	Nominal

Table 3: Descriptive Statistics of Regressors

Variable	Innovation Intensity				R&D Employment Intensity				Innovation output			
	N=286		N=248		N=300		N=268		N=314			
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Minimum	Maximum
SIZE	6.28	1.72	6.25	1.70	6.27	1.69	6.43	1.66	6.25	1.70	1.10	12.04
DIVERS	0.20		0.21		0.20		0.18		0.21		0.00	1.00
SCR	0.69	0.74	0.71	0.77	0.70	0.76	0.73	0.78	0.71	0.77	0.04	2.81
COMP_H	0.70		0.71		0.72		0.75		0.71		0.00	1.00
BCR	0.64	0.12	0.64	0.12	0.64	0.12	0.65	0.11	0.64	0.12	0.40	0.88
CUST_H	0.56		0.56		0.56		0.59		0.56		0.00	1.00
SCR*BCR	0.44	0.48	0.45	0.49	0.44	0.49	0.47	0.49	0.45	0.49	0.02	2.21
APPROP_C	0.16		0.16		0.17		0.18		0.16		0.00	1.00
APPROP_P	5.76	1.57	5.73	1.61	5.75	1.58	5.67	1.61	5.73	1.61	1.00	7.00
TEC_INT	0.40		0.39		0.39		0.44		0.39		0.00	1.00
TEC_CUST	23.22	29.19	23.11	29.81	22.68	29.81	22.93	29.07	23.11	29.81	0.00	100.00
TEC_SUPP	33.44	36.17	33.67	36.71	34.27	36.71	36.99	36.89	33.67	36.71	0.00	100.00
R&D_CAP	0.43		0.43		0.44		0.47		0.43		0.00	1.00

Table 4: The Effects of Supplier and Buyer Market Power, Appropriability, Technological Opportunity, and Firm Size on the Innovation Input

Variables	**Coefficients (*Standard Deviation*)**			
	INNO_INT		**R&D_INT**	
	(1)	**(2)**	**(1)**	**(2)**
CONSTANT	0.1084*** (0.0219)	0,1195*** (0,0249)	0,0612** (0,0258)	0,0650** (0,0262)
SIZE	-0.0054*** (0.0017)	-0,0063*** (0,0017)	-0,0050** (0,0024)	-0,0040* (0,0022)
DIVERS	0.0046 (0.0062)	0,0068 (0,0071)	0,0045 (0,0073)	0,0087 (0,0081)
SCR	-0.0386** (0.0191)	-0,0364* (0,0205)	-0,0292* (0,0154)	-0,0370* (0,0214)
COMP_H	0.0117** (0.0052)	0,0094 (0,0060)	-0,0015 (0,0056)	-0,0010 (0,0065)
BCR	-0.0668** (0.0310)	-0,0696* (0,0362)	0,0157 (0,0357)	-0,0070 (0,0357)
CUST_H	0.0093** (0.0045)	0,0090* (0,0051)	0,0059 (0,0065)	0,0080 (0,0059)
SCR*BCR	0.0593** (0.0284)	0,0567* (0,0303)	0,0481** (0,0231)	0,0584* (0,0339)
APPROP_C	0.0015 (0.0052)	0,0001 (0,0052)	0,0206*** (0,0068)	0,0178** (0,0074)
APPROP_P	-0.0025* (0.0014)	-0,0022 (0,0014)	-0,0048*** (0,0015)	-0,0039** (0,0017)
TEC_INT	0.0123*** (0.0042)	0,0083* (0,0044)	0,0169*** (0,0062)	0,0151** (0,0059)
TEC_SUPP	0.0002** (0.0001)	0,0002*** (0,0001)	0,0005*** (0,0001)	0,0006*** (0,0001)
TEC_CUST	0.0002*** (0.0001)	0,0002*** (0,0001)	0,0004*** (0,0001)	0,0004*** (0,0001)
R&D_CAP	0.0042 (0.0049)	0,0022 (0,0050)	-0,0069 (0,0071)	-0,0076 (0,0068)
χ^2 market structure (5 d.o.f)	14.08**	9.35*	13.10**	3.64
Number of Observation	286	248	300	268
Degrees of Freedom	272	234	286	254
Log Likelihood	569.475	498.873	527.361	455.037
Model χ^2 (14 d.o.f.)	698.79***	688.67***	559.94***	492.12***

Remark: Level of significance: * significant at the 0.1 level, ** significant at the 0.05 level, *** significant at the 0.01 level.

Table 5: The Effects of Supplier and Buyer Market Power, Appropriability, Technological Opportunity, and Firm Size on the Realization of Product and Process Innovation

Variables	**Coefficients (*Standard Deviation*)**	
	PROD_INN	**PROC_INN**
CONSTANT	-1,1347 (0,8941)	-0,9112 (0,7812)
SIZE	0,1646** (0,0796)	0,1268* (0,0651)
DIVERS	0,1899 (0,2677)	-0,2267 (0,2351)
SCR	-0,3329 (0,7867)	1,1623* (0,6953)
COMP_H	0,5883*** (0,2160)	0,4520** (0,2018)
BCR	0,9708 (1,0594)	0,6765 (0,9883)
CUST_H	0,2362 (0,2126)	0,3687* (0,1937)
SCR*BCR	0,5902 (1,3018)	-1,4595 (1,0935)
APPROP_C	-0,0237 (0,3127)	0,4961* (0,2928)
APPROP_P	-0,1629** (0,0749)	-0,0368 (0,0575)
TEC_INT	1,1350*** (0,2931)	1,2816*** (0,2493)
TEC_SUPP	0,0115*** (0,0037)	-0,0080** (0,0032)
TEC_CUST	0,0102*** (0,0037)	-0,0061* (0,0033)
R&D_CAP	0,0674 (0,2718)	0,1363 (0,2337)
χ^2 market structure (5 d.o.f)	10.62*	12.32**
Number of Observation	314	314
Degrees of Freedom	300	300
Log Likelihood	-160.129	-173.773
Mc-Fadden R^2	0.3571	0.2455

Remark: Level of significance: * significant at the 0.1 level, ** significant at the 0.05 level, *** significant at the 0.01 level.