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Brief Title: Explaining Innovative Activity in Service Industries

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Abstract

In earlier work we analyzed empirically the innovative behaviour of Swiss manufacturing firms building on the wide consent in economic literature that demand prospects, type and intensity of competition, market structure, factors governing the production of knowledge (appropriability, technological opportunities), innovation and production costs as well as firm size are the main determinants of a firm's innovative activity. In this paper we applied the same model to analyze innovative activities in the service sector. Several innovation variables referring to the input as well as the output side of the innovation process served as endogenous variables of the innovation model.

For the empirical work we used firm data from nine service industries collected by the Swiss Innovation Survey 1999 which was based on a questionnaire practically identical with that of the Innovation Surveys of the European Community.

We obtained a pattern of explanation of the innovative activity which looked quite plausilble across the different types of innovation measures used (input-oriented and output-oriented innovation variables); it was also consistent to that found earlier for manufacturing. In general, the theoretical model captured rather the characteristics of the basic decision to innovate rather than those of the desicion to choose some level of innovative activity.

1. Introduction

In earlier work we analyzed empirically the innovative behaviour of Swiss manufacturing firms building on the wide consent in economic literature that demand prospects, type and intensity of competition, market structure, factors governing the production of knowledge (appropriability, technological opportunities), innovation and production costs as well as firm size (as a variable controlling for futher unspecified influences) are the main determinants of a firm's innovative activity (see Arvanitis/Hollenstein 1994, 1996). In this paper we applied the same model to analyze innovative activities in the service sector. Several innovation variables referring to the input as well as the output side of the innovation process (seven indicators covering both product and process innovation) served as endogenous variables of the innovation model. Mostly due to lack of appropriate data at the firm level, innovative activity in the service sector remains still a rather underexplored area of research. In view of the increasing significance of this growth-leading sector more insights in the mechanism of the innovation process in this sector are needed in order to better undestand the specific character of its growth process.[1]

In his study we used firm data from nine service industries (including also growth sectors like banking, insurance, software and other business services) collected by means of the Swiss Innovation Survey 1999 which was based on a questionnaire practically identical with the one used in the 2nd Innovation Survey of the European Community. Our sample considered firms with more than 5 employees. The final data set contained usable data for 595 service firms. Owing to the nature of our dependent variables (ordinal measures of innovation) we mostly used a probit model for the econometric estimations.

The set-up of the paper is as follows: section 2 sketches briefly the underlying theoretical background and gives the necessary information with respect to the specification of the innovation equations respectively used in the empirical part of this study. In section 3 we present some descriptive information on various types of innovation indicators by industry and firm size class. Section 4 gives some information on data and method. In section we present the empirical results. Finally, in section 6 we draw some conclusions.

2. Framework of Analysis

Theoretical Background

The theoretical setting builds on a simple static deterministic model of a firm optimizing its innovation output separately for new products and new processes under monopolistic competition in a market of N identical firms; the model comprises the most important determinants of innovative activity as seen in the literature.[2] The formal exposition contains constant-elasticity functions for production costs and product demand complemented by a linear innovation cost function and a linear knowledge production function with intra- and extramural knowledge as inputs; in this context the extent of the appropriability of knowledge - or viewed the other way round - the existence of know-how spillovers can be taken into account. The innovation output is conceptualized as cost-reducing in the case of new processes or demand-creating for new products.

On the basis of the first-order conditions of the usual optimization calculus with respect to production output q and intramural knowledge x and after performing the necessary comparative statics, we obtain equation (1) which is interpreted as a causal relationship between innovation output k and the factors on the right side:[3]

$$k = k\,(\underset{+}{\sigma},\ \underset{+/-}{\varepsilon},\ \underset{+}{1/N},\ \underset{+}{\lambda},\ \underset{-/+}{\beta},\ \underset{+}{\alpha},\ \underset{-}{\varphi},\ \underset{-}{c'}) \qquad (1)$$

with

σ : shift parameter of a firm’s demand schedule representing pure income effects;

ε : price elasticity of a firm’s demand;

1/N : inverse number of N (identical) firms in the market (market concentration);

λ : degree of appropriability of a firm’s own knowledge;

β : shift parameter of the knowledge production function (cost and quality shifts);

α : elasticity of costs (demand) with respect to innovation output;

φ : unit costs of innovation;

c‘ : unit costs of production (relevant only for product innovation).

The signs of the determinants reported in (1) seem to be economically plausible, so we refrain here from a more detailed discussion; wherever two signs are given, the first one refers to process, the second one to product innovations. The most important feature of innovative activity which the model tries to capture is the interdependency of the generation processes of innovative knowledge among firms. According to the approach adopted here, at least two dimensions of such spillover effects have to be taken in consideration: first, the degree of absorption of extramural knowledge of a given firm (which is equal to one minus the degree of appropriability λ of a firm’s own, i.e intramural knowledge) and, second, the amount of knowledge which is available or is anticipated to be available to the firm. The shift parameter β measures the influence of the *amout* of available knowledge on innovation output, whereas the elasticity α reflects the *productivity* of used knowledge. The model is derived under the assumption of identical firms, therefore the influence of firm size is not considered explicitly. The number of firms on the market N is fixed in the short-term (no entry) and the effect of N on the short-term equilibrim (thus on innovative output k) is derived as a result of an exercise of comparative statics with respect to the equilibrium parameter N.

Empirical Model

Table 1 gives information on the measures of innovation output used as dependent variables in this study. These are, first, the two binary variables INNOPD (‚introduction of *product* innovations yes/no‘) and INNOPC (‚introduction of process innovations yes/no‘), second, two ordinal variables assessing the *technological* importance of introduced product and process innovations (intensity measures ININTPD and ININTPC resp.) and, third, a variable measuring the sales share of innovative products (SP). Alternatively to these variables, we also analyzed qualitative input-oriented innovation measures (RD: ‚R&D activities yes/no‘; DEVINT: intensity of development expenses).

Table 2 summarizes the relevant information with respect to the independent variables of the empirical model. This contains proxies for six out of eight theoretical variables in equation (1). We could not find in our data proxies for φ (unit innovation costs) and c‘ (unit production costs) in (1), so we were obliged to omit these variables in the specification of the empirical model; we assume that part of their impact can be captured by the control variables inserted in the estimation equations (firm size and industry dummies). We also included in the empirical model a proxy for *financing conditions* not explicitly considered in the theoretical model and a measure of the *follow-up investment expenses related to the innovation* (expenses for equipment needed for introducing new products and production techniques, acquisition of external knowledge, personnel training related to the introduced innovations and marketing for new products) which account for most of total innovation costs in service sector. These two variables capture the effects of the magnitude and type of financial resources dedicated to innovative activities. Finally, we also used some additional variables referring to *information technology aspects* of the innovations, which is a particular feature of innovative activities in the service sector.

We used asessments of firm-specific demand expectations (D) as a measure of (expected) demand shifts. As proxy for the price elasticity of demand we used assessments of the intensity of the price competition on a firm’s (global) product market (IPC); in addition, we also included in our empirical equation a measure of the intensity of non-price competition (INPC). Market concentration CONC is represented by four dummy variables related to the firm-specific number of principal competitors on the (world) market; this specification of CONC seems to be more appropriate for an open economy than traditional measures such as the concentration ratio or the Herfindahl index referring exclusively to the home market.

The relevance of the appropriability of the benefits of introduced innovations as an incentive for a firm’s innovative activity (dummy variable: ‚relevance of appropriability for innovative activity yes/no‘) is a proxy for the theoretical variable degree of appropriability λ. The technological opportunities (represented through the parameters α and β in equation (1)) are proxied by two (sets) of variables: The first one (TPOT) reflects the general technological potential characterizing the fields of activity relevant to the firm and leading to substantial quality and cost shifts. The second variable measures more specifically the contribution of external knowledge to the firm's own innovative activity (elasticity of innovation output with respect to external knowledge). This specific impact is proxied by the factor values of five factors extracted from information on a set of 14 single external knowledge sources (assessments of the importance of these sources for a firm’s own innovative activity) by means of a pricipal component factor analysis. The first factor (KS1) refers to science-related external knowledge from universities, private and public research institutions as well as information from patent disclosures, the second one (KS2) to knowledge on information technology from software suppliers, computer-based networks and consultancy, the third one (KS3) to know-how stemming from suppliers of materials, components and equipment, the fourth one (KS4) to knowledge from users of products, firms of the same firm conglomerate and competitors and the fifth one (KS5) to information from fairs, exhibitions as well as professional associations and professional journals.

As a measure of total follow-up investment expenses we used the ordinal variable FOLINT (‚intensity of total follow-up costs‘); the qualitative variable FIN (‚extent to which introduced innovations have been financed through internal funds (cash flow, reserves, etc.)‘) is considered to cover the effects of financing conditions.

Firm size was proxied by the number of employees; we included a linear and a quadratic term in order to investigate the type of quantitative relation between innovation variables and firm size.

The variables INFORM (‚extent to which introduced innovations are applications of information technology‘; this output-oriented variable was used in the estimates for ININPD, ININTPC und SP) and INFOEXP (qualitative measure for the expenditures for information technology; this input-oriented variable was used in the estimate with DEVINT) were added to the model to capture the specific influence of information technology on the innovative activity.

Most variables shown in table 2 reflect assessments of the surveyed firms on a five-point Likert scale, which were introduced into the model either directly in their original form or indirectly as the outcome of a factor analysis; these assessments are assumed to be measurements on an interval scale. The sign expectations as given in the last column are derived partly from the theoretical model (for the variables D, IPC, INPC, CONC, APPR, TPOT), partly from the theoretical and empirical literature (for the variables FIN, INTF, INFORM, INFOEXP). The effects of each specific knowledge source and particularly of each single variable used in the model (variables KS1 to KS5) is not a priori given. However, there is a restriction stemming from the theoretical model that the overall effect of all five variables should be non-negative. For some variables (KS1, KS2 and KS1 for product innovations) we postulate a sign expectation based on evidence from earlier empirical work (for example Cohen and Levinthal, 1989, 1994 for the USA; Arvanitis and Hollenstein, 1994 for Switzerland). The impact of firm size is also not a priori given.

In sum, we used following three (slightly) different model specifications depending on the type of innovation indicator considered as the dependent variable:

INNOPD, INNOPC, RD = f (D, IPC, INPC, CONC, APPR, TPOT, KS1, KS2, KS3, KS4, KS5, L, L2, industry dummies) (4)

ININTPD, ININTPC, SP = f (D, IPC, INPC, CONC, APPR, TPOT, KS1, KS2, KS3, KS4, KS5, FIN, FOLINT, INFORM, L, L2, industry dummies) (5)

DEVINT = f (D, IPC, INPC, CONC, APPR, TPOT, KS1, KS2, KS3, KS4, KS5, FIN, INFOEXP, L, L2, industry dummies) (6)

Equation (4) can be interpreted as containing the determinants of the basic firm decision ‚to innovate or not‘ (variables INNOPD; INNOPC) or ‚conduct R&D or not‘ (in the case of the variable RD). In the equations (5) and (6) are then found the explanatory factors for the follow-up firm decision ‚to choose a certain level of innovation (R&D) activity‘ (ININTPD, ININTPC with respect to innovation output; DEVINT with respect to innovation input). Finally, the variable SP, which is actually more related to the *outcomes* of the innovation process with respect to the marketplace, is also explained by equation (5).

3. Innovative Activities in Swiss Service Industries: Some Descriptive Information

The level of innovation activity varies considerably across service industries. Table 2 gives a picture of the range of innovative activities in nine industries of the Swiss service sector for the period 1997-1999. The frequency of product *versus* process innovations is almost the same across industries with the notable exceptions of hotels and catering (as a ‚traditional' industry) and computer and research services (as a ‚modern' industry) both of them having a significantly higher propensity to product than to process innovations (columns 1 and 2 in the upper part of table 2). Intensity indicators referring only to innovating firms tend to reduce the differences among the industries (columns 3 and 4; once more is the industry of computer services an exception with a considerably above-average share of firms with high intensity of product innovation). Input-oriented activities demonstrate clearly the dominant position with respect to innovative activities of the three ‚modern' industries computer and research services, business services, banking and insurance (columns 5 and 6). These industries are responsible for practically all of R&D expenditures of the service sector which amounted to about 22% of R&D expenditures of the Swiss business sector in 2000 (see SFSO, 2001).[4] Finally, we find the highest sales shares of innovative products in computer and research services as well as in business services (column 7; in this case banking and insurance show only an average performance).

Tabel 2 also demonstrates that there is a tendency for a higher frequency of product as well as process innovation in larger firms (columns 1 and 2 in the lower part of table 2). This size effect almost disappeares in the case of the intensity indicators (only innovating firms; columns 3 and 4) and also for the sales share of new products (column 7). Nevertheless, size differences seem to be of considerable importance for R&D activities (columns 5 and 6). The missing firm size effects with respect to the output-oriented variables and to the input-oriented variable DEVINT are at odds with the strong size dependence of innovative activity usually observed in manufacturing (see Arvanitis, 1997).

4. Data and Method

The data used in this study came from the Swiss Innovation Survey 1999 which in its core questions was quite comparable with the ‘Community Innovation Survey' (CIS II) conducted in most European countries between 1996 and 1997. The survey was based on a (with respect to firm size) disproportionately stratified random sample (28 industries, 9 of them belonging to the service sector, and, within each industry, three industry-spesific firm size classes with fill coverage of the upper class of large firms). The firms were asked to fill in a questionnaire on several aspects of innovative activity and economic performance during the period 1997-1999.[5]

The present analysis is confined to the subsample of firms in service industries (2731 firms; nine industries). We received valid answers from 880 firms, i.e. 32.2% of the firms in the underlying sample. The response rates do not vary much across industries and size classes with a few exceptions (overrepresentation of business services and large firms in general, underrepresentation of hotels, catering). The non-response analysis (based on a follow-up survey of a sample of the non-respondents) did not indicate any serious selectivity bias with respect to the structure of the original sample. In the study we used two final data sets, one containing data for both innovating and non-innovating firms (N=595) and another with only data for innovating firms (N= 303) (see table A.1 in appendix for the structure of the used data set by industry and firm size class).

For binary independent variables (INNOPD, INNOPC, RD) a standard probit model was applied as estimation method. For polychotomous ordered variables (ININTPD, ININTPC, DEVINT) we used an ordered probit model. A Tobit estimation procedure was the appropriate method in the case of the censored variable SP.

5. Empirical results

Input-oriented Innovation Variables

Table 4 (columns 1 and 2) contains the model estimates for the input-oriented variables RD and DEVINT. According to the results reported in this table the probability to conduct R&D in the service sector is positively correlated to supply-sided explanatory factors such as the degree of appropriability of the gains of the innovative activity (APPR) and the technological potential (TPOT; i.e. the amount of available knowledge which can be utilized in new products and processes); in particular, know-how stemming from users and competitors (KS4) seems to be important in this case. For firms operating in highly concentrated market environments (up to 10 competitors) is significantly more probable to conduct R&D than for firms in less concentrated markets; we could not find any effects of the market structure at other concentration levels. Demand expectations (D) and competition intensity (IPC for price competition, INPC for non-price competition) do not exert any significant influence on the probability of conducting R&D.

There are two possible explanations for the result with respect to demand expectations: first, for firms which intend to conduct *permanently* R&D demand expectations are relevant presumably only for the determination of the level of the R&D activities, but not for the basic decision to conduct R&D. From earlier innovation surveys we know the firms conducting R&D *occasionally* are reluctant to report such activities, so we can reasonably assume that firms reporting R&D activities belong to the first category which opt for *permanent* R&D activities; such a decision we consider to be independent of demand level. Secondly, the demand expectations referring to the years 2000-2002, which are generally expected to be a boom period, may look almost equally favourable for most firms, thus generating too little variance in the data to show up in the estimates. The data do not allow to discriminate between these two explanations.

There is also a discernible effect of firm size on R&D activity: the coefficient of the linear term is positive and the coefficient of the quadratic one negative which means that there is an inverted U-shaped relation between the firm size and the probability to conduct R&D. This result can be interpreted as a hint that there are no positive scale effects with respect to R&D.

The probability to choose a certain level of R&D activity, particularly development activity (variable DEVINT for development expenses) depends partially on the same factors as the probability to conduct R&D, namely appropriability conditions, technological potential and, to some extent, market concentration (6-10 competitors). Competition conditions and, at first glance rather astonishingly, demand expectations seem to exert no influence on the level of development expenses; in this case only the second of the two possible explanations mentioned above, quite similar expectations across industries, looks plausible enough to interpret this result. There are also some important differences compared to the results for RD: science-related knowledge from universities, technical colleges, etc. (KS4) is now the relevant external knowledge source which looks quite plausible. Contrary to the estimates for RD, we found no effect of firm size on development expenses. We also do not find any influence of financing conditions (FIN), a rather unexpected result (but see next paragraph on the output-oriented indicators). There was no significant correlation of the variabel DEVINT to the expenses for information technology (INFOEXP), which we interpret as a hint that, for most firms in our sample not belonging to the computer services industry, R&D activities are not closely related to information technology, even if the resulting innovations need much information technology for their implementation, which takes the form of follow-up investments (see also next paragraph on the output-oriented indicators).

Output-oriented Innovation Variables

There are separate estimates for product and process innovations for both types of variables (probability of introducing new products and new processes respectively: INNOPD, INNOPC (table 4; columns 3 and 4) and probability of choosing a certain level of innovative activity for products and processes respectively: ININTPD, ININTPC (table 4; columns 5 and 6)). There are some differences between the estimates for product and process innovations for the first type of variables (INNOPD, INNOPC). The probability to introduce product innovations correlated also in this case positively with supply-sided factors such as the appropriability conditions, the technological potential and especially knowledge from suppliers of materials, components and equipment. There was a linear relation to firm size and a non-linear relation to market concentration (positive coefficients for high levels (less than 5 competitors, 6 to 10 competitors) as well as for rather low concentration levels (16-50 competitors)). As in the estimates for input-oriented indicators we could not find any influence of demand expectations and competition conditions (IPC, INPC) on the probability to introduce product innovations. The estimates for process innovations showed a rather weak positive effect of demand expectations and no impact at all for the variables related to the market conditions including the dummies for market concentration (IPC, INPC, CONC). Appropriability was also not important, whereas the technological potential remained a considerable explanatory factor also in the case of process innovations. We found positive effects for two categories of external knowledge, know-how related to information technology stemming from software suppliers, computer-based networks, etc. (KS2) and, rather unexpectedly, generally accessible information from fairs, exhibitions, professional associations and journals (KS5); for one type of external knowldge (KS3: information from suppliers) we obtained, contrary to our result for product innovations, a negative effect.

Firm size showed a parabolic relation to the probability to introduce process innovations similar to that found for R&D activities.

Some of the effects found for the estimates for the probability to innovate (variables INNOPD, INNOPC) became insignificant with respect to the probability to choose a certain level of innovative activity (variables ININTPD, ININTPC): market concentration showed no effect on product innovation and also the variable for the intensity of nonprice competition (INPC) had a statistically insignificant coefficient. In accordance to the theoretical model we obtained a negative effect for the variable measuring the intensity of price competition (IPC; a similar effect was also found in the estimates for the variable SP; see below). In the estimates for the variables ININTPD and ININTPC the variables measuring technological opportunities (technological potential, specific knowledge sources with the exception of KS4 for process innovations) lost their explanatory power. Firm size also became statistically insignificant. On the other hand there was a discernible positive effect of the financing conditions (FIN) in the case of product innovations and, as expected, a strong positive influence of the variable INTF (measuring the follow-up investment expenses) on process innovation. Further, INFORM (measuring the extent to which introduced innovations are applications of information technology) was strong positively correlated to the probability to choose a certain activity level for both types of innovation (product innovations and process innovations). This result demonstrates clearly that most innovation activity in the service sector is closely related to applications of information technology.

For the outcome-oriented indicator SP we found a negative effest of the variable of price competition (IPC) and a positive one for the variable for non-price competition (INPC); both effects are in accordance with the theoretical predictions. Financing conditions seem to be also important for the sales share of new products. The influence of supply-sided factors such as appropriability and technological opportunities were only weakly correlated to SP (positive effect of users knowledge SP4, negative effect of know-how from general accessible information sources KS5). The variables for follow-up investments FOLINT and for information technology content of the introduced innovations (INFORM) were of no importance for this innovation variable. Further, the sales share of new products is not size-dependent. Rather unexpectedly, we could not find a significant demand effect. On the whole, it looks quite plausible that demand-sided factors such as market competition conditions together with financial resources exerted a stronger influence on this outcome-oriented variable than supply-sided factors such as appropriability and technological opportunities.

Relation between Input-oriented and Output-oriented Innovation Measures

In order to investigate the influence of various kinds of innovation *inputs* on innovation *output* we inserted seven variables measuring different types of innovation costs alternatively as regressors in the equations for the output-oriented innovation indicators ININTPD, ININTPC and SP. These additional estimates are reported in table 5. To make the table more comprehensible, we omitted all other variables and kept only the coefficients for the seven cost variables: expenses for research, development and total follow-up investment as well as four components of follow-up costs: expenses for equipment, acquisition of external knowledge, personnel training and marketing of new products. R&D expenses have no significant impact on innovation output in the service sector on the whole (which is does not exclude that a positive effect does exist in more R&D-intensive industries such as computer and business services). Follow-up investment expenses seem quite relevant for innovations in the service sector, especially in the case of process innovations: all four cost components showed positive effects on the output-oriented variable ININTPC, the strongest effect stemming from human capital investment (training costs). In the case of product innovations only expenses for equipment (presumably for computers, etc.) were of relevance.

6. Conclusions

We obtained a pattern of explanation of the innovative activity which looked quite plausilble across the different types of innovation measures used (input-oriented and output-oriented innovation variables); it was also consistent to that found earlier for manufacturing. In general, the theoretical model captured rather the characteristics of the basic decision to innovate rather than those of the desicion to choose some level of innovative activity. Supply-sided factors such as appropriability and technological opportunities seem to be more important for the decision to introduce innovations than demand-sided variables like demand-perspectives and intensity of price and non-price competition. These results are similar to those found in earlier work for manufacturing. There is a stronger influence of market structure in the service sector than in manufacturing. However, we also find some differences from our previous results. For example, contrary to manufacturing sector firm size seems to be less important in explaining the intensity of innovative activity in the service sector. Follow-up costs are important for the level of innovative activity, especially for process innovations. The high information technology content is a particular feature of the innovative activity in the service sector.

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Notes

1 For recent studies analyzing, some of them descriptively, the innovative activity at the firm level based on survey data for the service sector see Gellatly, 1999, Gellatly and Peters, 1999 for *Canada*, Licht et al., 1997 and Janz and Licht, 1999 for *Germany*, Brower and Kleinknecht, 1996, 1997 for *Holland* and Sirilli and Evangelista, 1998 for *Italy*. For some earlier exploratory work for *Switzerland* see Arvanitis et al., 1998 and Donzé and Lenz, 1999.

2 See e.g. Dasgupta (1986), Dosi (1988), Cohen and Levin (1989) and Cohen (1995) for reviews of theoretical and empirical literature in general. There are relatively few studies dealing theoretically with the specific features of the innovative activity in the service sector, thus innovation in the service sector does not (yet) build a distinctive branch of theoretical reasoning (see e.g. Barras, 1986, Quinn, 1987, Sunbo, 1997

(strong oriented to the management literature), Galloux and Weinstein, 1997, Gallouj, 1999 and Tether et al., 2001).

[3] For a detailed description of the model see Arvanitis (1999), ch. 2. A preliminary version of this model was used in an earlier investigation of the innovative behaviour of manufacturing firms (see Arvanitis and Hollenstein 1994).

[4] The R&D share of services in Switzerland is higher than that in Germany (5.1%), France (12.3%), Italy (16.2%), Japan (5.5%) and the United Kingdom (19.6%), but lower than the corresponding share for Canada (36.7%) and the United States (28.8%); the figures for the G-7 countries are cited in Jankowski, 2001 and refer to the period 1996-1998.

[5] There is a German, a French and an Italian version of the questionnaire which is available at request.

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TABLE I
Specification of the Innovation Variables

Variable	Definition	Measurement Scale
RD	R&D activities yes/no	nominal (1, 0)
DEVINT	Development expenditures	ordinal; measured on a five-point Likert scale
INNOPD	Product innovations yes/no	nominal (1, 0)
INNOPC	Process innovations yes/no	nominal (1, 0)
ININTPD	Assessment of the importance of the introduced *product* innovations from a *technical* point of view	ordinal; measured on a five-point Likert scale
ININTPC	Assessment of the importance of the introduced *process* innovations from a *technical* point of view	ordinal; measured on a five point Likert scale
SP	Sales share of ‚highly improved' products or ‚entirely new' products	metric (%)

TABLE II
Specification of the Explanatory Variables of the Innovation Equation

Variable	Description / Economic Interpretation	Sign
1. Demand		
D	Medium-term expected change of demand 2000-02	+
2. Market Conditions		
IPC	Intensity of price competition in the product market; (negative (positive) sign expected for product (process innovation)	-/+
INPC	Intensity of non-price competition in the product market	+
CONC	Concentration measure based on the number of competitors in the product market (four dummies: 16-50 competitors, 11-15 competitors, 6-10 competitors, less than 5 competitors; reference group: more than 50 competitors)	+
3. Appropriability		
APPR	Relevance of property rights protection for a firms's innovative activities (dummy variable)	+
4. Technological Opportunities		
TPOT	Technological potential, i.e. scientific, technological and organizational knowledge relevant to the firm's innovative activity	+
External knowledge sources:		
(Factor values of five factors extracted through a principal component factor analysis of ordinal data (measured on a five-point Likert scale) referring to the importance of fourteen external knowledge sources)		
KS1	Universities, technical schools, research laboratories, patent disclosures	+
KS2	Software suppliers, consultancy, computer-based information networks	+
KS3	Suppliers of materials, components, equipment	?
KS4	Users of a firm's products, firms of the same conglomerate, competitors	(+)
KS5	Fairs, exhibitions, professional associations and journals	?
5. Other variables		
FIN	Extent to which introduced innovations have been financed through a firm's *internal* resources (cash flow, reserves, etc.)	+
INTF	Follow-up investment related to product and process innovations (equipment, acquisition of external knowledge, training, marketing)	+
INFORM	Extent to which introduced innovations are applications of information technology	+
INFOEXP	Expenditures for information technology	+
Firm Size:		
L	Number of employees	?
L	Square of number of employees	?
(8 industry dummies; reference group: personal services)		

Note: Unless otherwise specified, the variables reflect assessments of the surveyed firms measured on a five-point Likert scale for the period 1997-1999.

TABLE III
Innovative Activities by Industry and Firm Size 1997-1999

Industry	Innovations product (1)	Innovations process (2)	Innovation Intensity product (3)	Innovation Intensity process (4)	R&D activities (5)	Intensity development activities (6)	Sales share new products (7)
				percentage			
Wholesale trade	36.2	32.4	50.7	58.3	19.6	23.7	17.5
Retail trade	33.3	30.3	38.3	30.3	11.5	8.3	11.1
Hotels, catering	51.2	40.5	36.8	44.8	15.7	8.9	15.8
Transport, communications	25.6	29.3	41.9	36.4	15.2	10.4	11.3
Finance, insurance	71.7	63.6	41.8	55.2	41.8	16.0	11.5
Real estate, leasing	14.3	35.7	0.0	0.0	7.1	0.0	4.0
Computer services, R&D	61.1	41.7	81.8	35.7	47.2	56.0	31.8
Business services	38.1	46.5	59.3	64.3	36.8	24.7	18.1
Personal services	35.0	35.0	42.9	66.7	15.0	0.0	6.6
Firm Size (number of employees)							
6-19	31.4	28.8	47.1	52.6	14.9	10.7	17.6
20-49	35.9	33.6	50.0	53.7	18.1	14.3	16.0
50-99	44.5	37.3	46.7	38.9	28.4	18.0	13.7
100-199	37.9	43.7	50.0	36.6	28.2	10.5	16.0
200-499	66.7	56.9	50.0	56.4	39.4	18.2	14.6
500-999	69.4	77.8	45.5	65.4	55.6	14.8	12.9
over 1000	65.5	79.3	52.6	55.0	44.8	31.8	11.2

Note: (1): firms with product innovations; percentage of all firms; (2): firms with process innovations; percentage of all firms; (3): firms with high intensity of *technically* important product innovations (intensity higher than 3 on a Likert scale of 1 to 5); percentage of innovating firms; (4): firms with high intensity of *technically* important process innovations (intensity higher than 3 on a Likert scale of 1 to 5); percentage of innovating firms); (5): firms with R&D activities; percentage of all firms; (6) firms with high expenditures for the *development* of new products and new processes (intensity higher than 3 on a Likert scale of 1 to 5); percentage of innovating firms; (7): sales share of ‚new‘ and ‚highly improved products‘ (%).

TABLE IV
Probit, Ordered Probit and Tobit Estimates with Input- and Output-oriented Innovation Measures

Explanatory Variable	RD 1	DEVINT 2	INNOPD 3	INNOPC 4	ININTPD 5	ININTPC 6	SP 7
D	0.005	-0.065	0.017	0.173*	0.029	-0.057	-0.469
	(0.072)	(0.080)	(0.067)	(0.068)	(0.085)	(0.096)	(1.270)
IPC	-0.011	-0.054	0.039	0.008	-0.154**	-0.028	-2.118**
	(0.053)	(0.063)	(0.050)	(0.049)	(0.074)	(0.070)	(1.017)
INPC	-0.006	-0.005	0.060	0.037	0.004	-0.092	2.102*
	(0.060)	(0.070)	(0.056)	(0.055)	(0.079)	(0.083)	(1.168)
CONC							
16-50 firms	0.297	0.246	0.522**	0.063	-0.275	-0.206	-5.147
	(0.191)	(0.219)	(0.183)	(0.180)	(0.239)	(0.242)	(3.701)
11-15 firms	-0.005	0.146	0.044	-0.232	-0.184	-0.335	-0.618
	(0.257)	(0.329)	(0.238)	(0.240)	(0.362)	(0.374)	(5.547)
6-10 firms	0.287*	0.439**	0.282*	0.091	0.107	0.135	0.082
	(0.172)	(0.201)	(0.164)	(0.163)	(0.231)	(0.226)	(3.359)
< 5 firms	0.331**	0.085	0.364**	0.102	0.086	0.228	-3.403
	(0.166)	(0.199)	(0.158)	(0.154)	(0.222)	(0.219)	(3.247)
APPR	0.475**	0.499**	0.396**	-0.033	0.389**	-0.115	2.592
	(0.141)	(0.156)	(0.141)	(0.140)	(0.176)	(0.190)	(2.752)
TPOT	0.220**	0.115*	0.192**	0.138**	0.074	0.074	0.892
	(0.057)	(0.066)	(0.054)	(0.053)	(0.073)	(0.075)	(1.074)
KS1	0.044	0.189**	-0.048	-0.103	0.099	-0.141	1.380
	(0.061)	(0.069)	(0.059)	(0.069)	(0.076)	(0.095)	(1.205)
KS2	0.026	-0.119	-0.107	0.188**	0.023	0.018	-0.751
	(0.064)	(0.078)	(0.072)	(0.062)	(0.087)	(0.095)	(1.295)
KS3	0.035	0.117	0.112*	-0.120**	0.043	0.134	-0.697
	(0.063)	(0.073)	(0.062)	(0.061)	0.082)	(0.087)	(1.231)
KS4	0.106*	0.028	0.068	0.057	-0.088	0.205**	2.003*
	(0.064)	(0.075)	(0.060)	(0.059)	(0.085)	(0.086)	(1.238)
KS5	0.018	-0.048	0.006	0.107*	-0.059	0.113	-2.216*
	(0.062)	(0.072)	(0.059)	(0.059)	(0.080)	(0.083)	(1.235)
INFOEXP		0.054					
		(0.057)					
FOLINT					-0.002	0.227**	0.449
					(0.075)	(0.078)	(1.078)
INFORM					0.210**	0.240**	0.156
					(0.061)	(0.068)	(0.910)
FIN		0.077			0.127**	-0.010	4.908**
		(0.053)			(0.060)	(0.060)	(2.052)
L	2.7E-4**	1.3E-4	3.1E-4**	8.0E-4**	-3.0E-5	4.0E-5	-2.2E-3
	(1.2E-4)	(0.9E-4)	(1.5E-4)	(2.1E-4)	(9.4E-5)	(9.7E-5)	(1.5E-3)
L^2	-7.2E-9**	-3.1E-9	-5.5E-9	-1.7E-8**	9.2E-10	-5.8E-10	6.1E-8
	(3.5E-9)	(2.5E-9)	(4.7E-9)	(0.6E-8)	(2.5E-9)	(2.5E-9)	(4.0E-8)
N	595	303	595	595	216	216	250
Left censored							22
McFadden R^2	0.139	0.110	0.151	0.131	0.081	0.121	
df	24	25	24	24	26	26	
LR statistic	100**	89**	124**	197**	50**	70**	66**

ESA test (df)		98**(75)			114**(78)	98*(78)
%-concordant	75	72	75	73	70	71

Note: Each column contains the estimated parameters and the standard errors in brackets; the statististical significance is indicated with ** and * representing the 5% and 10%-level respectively (Wald Chi-Quadrat). Intercepts have been throughout omitted. LR statistic: Likelihood Ratio Test (Chi-Quadrat test); ESA test: Score Test for Equal Slopes Assumption (Chi-Quadrat test); 8 industry dummies.

TABLE V

Relations Between Input-oriented and Output-oriented Innovation Measures (Model Estimates of ININTPD, INNINTPC and SP with *Alternative* Input-oriented Measures)

Input Measure	ININTPD 1	ININTPC 2	SP 3
R&D Expenses:			
RESINT	-0.163	-0.004	2.165
	(0.102)	(0.114)	(1.587)
DEVINT	-0.019	0.112	0.787
	(0.069)	(0.070)	(1.035)
Follow-up Investment:			
FOLINT	-0.002	0.227**	0.449
	(0.075)	(0.078)	(1.078)
EQUIP	0.114*	0.137**	1.348
	(0.065)	(0.066)	(0.959)
KNOW	0.000	0.130*	-1.576
	(0.075)	(0.079)	(1.105)
TRAIN	0.107	0.171**	0.658
	(0.071)	(0.071)	(1.044)
MARKET	0.030	0.108*	1.860**
	(0.063)	(0.063)	(0.915)

Note: RESINT: research expenses; DEVINT: development expenses; FOLINT: total follow-up investment linked to product and process innovations; EQUIP: follow-up expenses for equipment; KNOW: follow-up expense for acquisition of external know-how; TRAIN: follow-up expenses for personnel training; MARKET: follow-up expenses for marketing of new products (all variables are measured on a five-point Likert scale). This table contains the coefficients of the input measures being used as regressors in estimates of the full model with the output-oriented measures ININTPD, ININTPC and SP (see table 4); the standard errors are in brackets; the statististical significance is indicated with ** and * representing the 5% and 10%-level respectively.

Appendix

TABLE A1
Composition of the Data Set

Industry	N	%
Wholesale trade	140	23.6
Retail trade	90	15.1
Hotel, catering	39	6.6
Transport, communications	85	14.3
Finance, insurance	77	12.9
Real estate, leasing	9	1.5
Computer services, R&D	31	5.2
Business services	115	19.3
Personal services	9	1.5
Firm Size (number of employees)		
6-19	185	31.2
20-49	136	23.0
50-99	84	14.1
100-199	81	13.6
200-499	57	9.6
500-999	27	4.5
over 1000	24	4.0
Total	595	