Financing Constraints and the Timing of Innovations in the German Services Sector

Martin Kukuk and Manfred Stadler

University of Tübingen
Department of Economics
Mohlstr. 36
D-72074 Tübingen

Abstract: Using newly available data at the firm level, this study provides convincing evidence of the importance of financial constraints in explaining the timing of innovations in the German services sector. Based on a dynamic model of firms' optimal R&D behavior under financial constraints, we estimate various versions of an econometric specification of the model with dichotomous innovation data by using a univariate ordered probit model. Our results are consistent with the theoretical view that, because of capital markets imperfections, internal finance should be an important determinant of innovative activities by private firms in the manufacturing sector as well as in the services sector.

JEL Classification: G30, O31, C4

Keywords: Innovation, Financial Constraints, Ordinal Regressors, Indirect Inference Estimation

1. Introduction

Since Schumpeter's (1942, Ch. 8) seminal conjectures about the importance of internal finance for innovation, much effort has been devoted to theoretically and empirically investigating the influence of financial constraints on the innovative behavior of firms. Modern theoretical models suggest that R&D expenditures must be funded primarily by internal finance due to the existence of information asymmetries between innovative firms and the suppliers of external funds.

Stiglitz, Weiss (1981) analyze the effects of moral hazard and adverse selection in debt markets and explain why lenders may deny a loan agreement even if the project is profitable. Adverse selection problems arise because of asymmetric information about the risk characteristics and the default probabilities of firms' investment projects. Lenders may ration credit rather than accept a higher interest rate to clear the market because increases in the interest rate induce the low risk borrowers to exit the pool of applicants first. In addition, borrowers whose actions cannot be monitored by lenders, have an intrinsic incentive to invest in riskier, higher-return projects that increase the probability of bankruptcy. It is primarily for this moral hazard problem that equity rather than debt is considered the natural source of external finance for firms investing in risky R&D projects.

Like debt markets, however, equity markets are also characterized by serious adverse selection problems. Myers, Majluf (1984) analyze the effect of adverse selection on the market for new share issues and explain why firms may be forced to sell equity at a discount if they can sell it at all. If in addition, no venture capital is available, firms are forced to self finance their R&D projects.

There is a large empirical literature on internal finance and physical investment.[1] However, there are only few attempts to investigate the influence of financial constraints on R&D investment (see, e.g., Hao, Jaffe 1993, Himmelberg, Petersen 1994, Harhoff 1998, Bond, Harhoff, Van Reenen 1999). All of these studies are concerned with the manufacturing sector. Since the importance of the services sector is continuously increasing, it seems worthwhile to investigate the role of financial constraints on the innovative behavior of firms in this sector.

Using newly available data at the firm level, this paper provides some evidence of the importance of financial constraints in explaining the timing of innovations in the German services sector. The remainder of the paper is organized as follows: In Section 2 we present a

1 See, e.g., Fazzari, Hubbard, Petersen (1988), Devereux, Schiantarelli (1989), Hoshi, Kashyap, Scharfstein (1991), and, for excellent surveys Schiantarelli (1996) and Hubbard (1998).

dynamic model of innovation, explaining the timing of an innovation in terms of financial constraints, technological opportunities, profit expectations, and current profits. In Section 3 we derive a tractable econometric specification which can be estimated using qualitative dependent variable models. A description of the data is given in Section 4. Section 5 presents the empirical results. Finally, Section 6 concludes.

2. The Theoretical Model

Following Kamien, Schwartz (1982, Ch. 4), we consider a firm investing in a new technology or in a new product to replace its current technology or product, respectively. The firm has to calculate whether the R&D project is worthwhile and, if so, has to determine the innovation date and the R&D expenditure spending plan that will maximize the present value of profits. We assume that the firm realizes a profit stream at the constant rate $v>0$ per unit of time. This profit stream continues until the product or the process in use is displaced by the firm's innovation at time T. From this time on, the further profit stream is assumed to have the gross capitalized value V when discounted with the constant interest rate r to the innovation time.

Each innovation requires a certain amount of technological knowledge z which can be accumulated by investing in R&D expenditures x according to the concave function

(1) $$\dot{z}(t) = x(t)^{\alpha}, \ \ 0 < \alpha < 1.$$

The firm specific parameter α reflects the decreasing returns to faster spending at each point in time. At the beginning of the project, the knowledge necessary for the innovation is assumed to be negligible. The project is finished as soon as the critical knowledge level Z is reached. These assumptions correspond to the fixed endpoint conditions

(2) $$z(0) = 0, \quad z(T) = Z.$$

Liquidity b is augmented by the stream of interest earnings $r \cdot b$ and the current flow profits v, but is reduced by R&D expenditures x. This results in the differential equation

(3) $$\dot{b}(t) = rb(t) + v - x(t).$$

Due to the discussed adverse selection and moral hazard problems in the equity and debt markets, the firm is financially constrained if it is not able to internally finance its research project. Thus, the liquidity conditions are given by

(4) $$b(0) = B \geq 0, \ \ b(t) \geq 0 \ \ \forall \ \ 0 < t \leq T.$$

The optimal innovation date and the optimal time path of R&D are determined by the maximization of the discounted innovation profit function

$$\text{(5)} \qquad \pi(x(t)) = \max_{x(t)} \left\{ e^{-rT}V + \int_0^T e^{-rt}(v - x(t))\,dt \right\} - v / r .$$

subject to the constraints (1) to (4). The maximization problem can be solved in two steps. We first determine the time path of R&D, depending on the innovation date, and then calculate the optimal timing of an innovation. The Hamiltonian of the control problem with *T* fixed is given by

$$H = e^{-rt}(v - x(t)) + \psi_1 x(t)^{\alpha} + \psi_2 (rb(t) - x(t)),$$

where Ψ_1 and Ψ_2 are the costate variables of the state variables *z* and *b*. The necessary first order conditions are given by

$$\text{(6)} \qquad H_x = -e^{-rt} + \psi_1 \alpha x(t)^{\alpha-1} - \psi_2 = 0$$

$$\text{(7)} \qquad H_z = 0 = -\dot{\psi}_1 \;\Rightarrow\; \psi_1 = \overline{\psi}_1$$

$$\text{(8)} \qquad H_b = r\psi_2 = -\dot{\psi}_2 \;\Rightarrow\; \psi_2 = \overline{\psi}_2 e^{-rt}$$

with $\overline{\psi}_1$ and $\overline{\psi}_2$ constant. The transversality condition for b is given by

$$\text{(9)} \qquad b(T) \geq 0, \qquad \psi_2(T) \geq 0, \qquad b(T)\,\psi_2(T) = 0.$$

Since the Hamiltonian is concave in x and b, these necessary conditions are also sufficient for optimality. Substituting from (7) and (8) into (6) yields

$$\text{(10)} \qquad x(t) = \left[\alpha\,\overline{\psi}_1 e^{rt} / \left(1 + \overline{\psi}_2\right)\right]^{1/(1-\alpha)}$$

and thus the constant growth rate

$$\text{(11)} \qquad \dot{x} / x = r / (1 - \alpha),$$

regardless of whether a financial constraint is binding or not. It follows from the result that the growth rate of R&D expenditures exceeds the interest rate that in an optimal R&D program, liquidity will never become zero before the project is completed, i.e. $b(t)>0 \;\forall\; 0<t<T$.

Integrating (11) and using the accumulation function (1) together with the boundary conditions (2) yields the optimal R&D expenditure plan

(12) $\quad x(t) = (r\tilde{\alpha}Z)^{1/\alpha}(e^{r\tilde{\alpha}T} - 1)^{-1/\alpha} e^{[r/(1-\alpha)]t}; \quad 0 \le t \le T,$

with $\tilde{\alpha} \equiv \alpha/(1-\alpha)$. The discounted present values of R&D costs and rents of the new innovation are then determined by

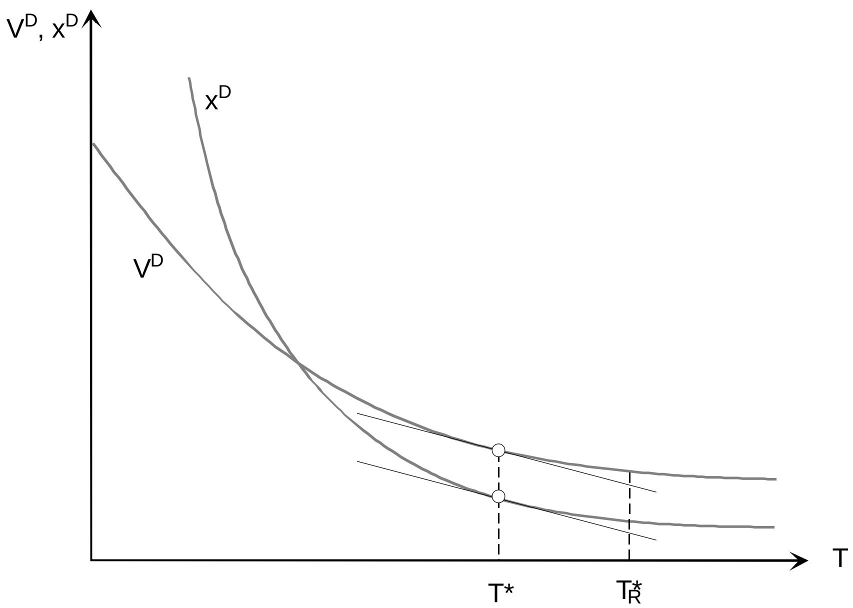
(13) $\quad x^D = Z^{1/\alpha}(r\tilde{\alpha})^{1/\tilde{\alpha}}(e^{r\tilde{\alpha}T} - 1)^{-1/\tilde{\alpha}}$

and

(14) $\quad V^D = (V - v/r)e^{-rT}.$

As can be seen from Figure 1, both discounted values are decreasing functions in time T.

Figure 1: Optimal Timing of Innovations with Non-Binding and Binding Financial Constraints



The time path of liquidity can be derived by integrating the differential equation (3) and inserting the starting condition b(0)=B from (4) and the starting value for R&D expenditures x(0) from (12) as

(15) $\quad b(t) = Be^{rT} + (e^{rt} - 1)v/r - (r\tilde{\alpha})^{1/\tilde{\alpha}} Z^{1/\alpha}(e^{r\tilde{\alpha}T} - 1)^{-1/\alpha}(e^{[r/(1-\alpha)]t} - e^{-rt}); \quad 0 \le t \le T.$

At the innovation date T, the liquidity function (15) takes the value

(16) $\quad b(T) = Be^{rT} + (e^{rT} - 1)v / r - e^{rT}(r\tilde{\alpha})^{1/\tilde{\alpha}}(e^{r\tilde{\alpha}T} - 1)^{-1/\tilde{\alpha}}$.

Let us first assume that the financial constraint is not binding, i.e. b(T)≥0 and hence $\overline{\psi}_2$=0. Then the firm will maximize its reduced profit function

(17) $\quad \pi = \max_T \left\{ e^{-rT}V + (1 - e^{-rT})v / r - Z^{1/\alpha}(r\tilde{\alpha})^{1/\tilde{\alpha}}(e^{r\tilde{\alpha}T} - 1)^{-1/\tilde{\alpha}} \right\}$.

Rearranging the first order condition $\partial\pi / \partial T = 0$ yields the solution function

(18) $\quad T^* = -(r\tilde{\alpha})^{-1} \ln\beta; \quad \beta \equiv 1 - (r\tilde{\alpha})^{1-\alpha} Z / [V - v / r]^{\alpha}$,

which is characterized by the comparative statics

(19) $\quad \partial T^* / \partial B = 0, \ \partial T^* / \partial Z > 0, \ \partial T^* / \partial V < 0, \ \partial T^* / \partial v > 0$.

Hence, the discounted present value of R&D costs in (13) can be expressed by $x^D = (V - v / r)\beta^{1/\tilde{\alpha}}(1 - \beta)$, the discounted present value of innovation rents in (14) by $V^D = (V - v / r)\ \beta^{1/\tilde{\alpha}}$, and finally the discounted present value of innovation profits in (17) by $\pi = (V - v / r)\ \beta^{1/\alpha}$. Since superiority of new innovations generally imply V>v/r, the necessary and sufficient condition for undertaking the R&D project at all is β>0, i.e.

(20) $\quad V > v / r + (r\tilde{\alpha})^{1/\tilde{\alpha}} Z^{1/\alpha}$.

If condition (20) holds, the R&D project is undertaken, independent of whether the financial constraint is binding or not. This can be seen from Figure 1, where the functions of the discounted costs and discounted rents are graphically presented. Obviously, the only impact of financial constraints is to postpone the optimal timing of the innovation from T* to T_R*. The optimal innovation time T_R* is then determined by b(T_R*)=0 in (16). Unfortunately, this equation cannot be explicitly solved for T_R*. Nevertheless, the comparative statics

(21) $\quad \partial T_R^* / \partial B < 0, \ \partial T_R^* / \partial Z > 0, \ \partial T_R^* / \partial V = 0, \ \partial T_R^* / \partial v < 0$

are unambiguous. If the starting point of the research project and unobserved heterogeneities of firms determining α are treated as random, condition (20) and the comparative statics in (19) and (21) indicate that the probability of a planned innovation within a specific time interval from the present depends negatively on technological difficulties as measured by *Z*. The impacts of liquidity *B*, the value of the innovation *V*, and the current profit stream *v* on the innovation probability depend on whether the firm is financially constrained or not. If there is no liquidity constraint, *B* does not matter, but the innovation probability increases with increasing *V*. In addition, the larger the profit stream *v* is, the smaller is the innovation probability since a further innovation would destroy the rents realized from the existent goods and services. However, if there is a financial constraint, the innovation probability increases with liquidity *B* and with the profit stream *v* since the constraint becomes less binding, but it does not depend on innovation profits *V*.

3. Econometric Specification

According to the theoretical model, each firm decides on the optimal time of an innovation $T^{**} = \max\{T^*, T_R^*\}$, depending on whether the financing constraint is binding or not. In our data set, the firms´ decisions on the timing of their innovations cannot be observed directly. Instead, we only observe the firms as to answer whether or not they intend on introducing an innovation within the next one and a half years, implying whether or not *T*** falls into this given time interval, i.e. $T^{**}<1.5$. Therefore, we treat the optimal values of *T*** as continuous latent variables and define

$$(22) \qquad T^D = \begin{cases} 1, & \text{iff} \quad T^{**} \le 1.5 \\ 0, & \text{iff} \quad T^{**} > 1.5 \end{cases} .$$

The structural equation for the latent variable is specified as

$$(23) \qquad T^{**} = \gamma' y + u ,$$

where the exogenous variables are summarized in the vector *y* and the stochastic error term *u* is added to account for the unknown starting points of the R&D projects and other unobserved heterogeneities. This implies for our econometric model that a firm's probability of introducing an innovation within this given time period is a function of the explanatory variables *B*, *Z*, *V* and *v*.

The conditional mean of the dependent variable is a linear function of the regressor variables *y*, which is comparable to regression models. However, the dependent variable *T*** is not observable. The only information we have is in which interval *T*** falls according to (22). Thus, if we assume the error term *u* to be independently and normally distributed we obtain the conditional probabilities of the random variable T^D given the exogenous variables *y*:

$$(24) \qquad P\left(T^D = 1 \middle| y, \gamma\right) = \Phi\left(\frac{1.5 - \gamma' y}{\sigma}\right),$$

where Φ denotes the standard normal distribution function. To identify the parameters the variance σ^2 has to be restricted to unity. In addition, the threshold value and the constant term need to be combined so that

$$P\left(T^D = 1 \middle| y, \gamma\right) = \Phi(-\gamma' y).$$

With available observations from individual firms on T^D and also on the regressor variables y, we can formulate a likelihood function and maximize it with respect to parameter vector γ (see, e.g. Ronning 1991, Ch. 2.4). Note, that common software packages estimate

$$P\left(T^D = 1 \middle| y, \beta\right) = \Phi(\beta' y),$$

implying that $\beta = -\gamma$. Thus, the opposite sign and significance of the parameter values can directly be related to the comparative statics results of our theoretical model.

4. The Data

The data set we use is one of the first attempts to gain information about firms' innovative behavior in the German private services sector. Comparable studies for the industrial sector have a much longer tradition. The OSLO manual (OECD 1992) gives guidelines for business surveys on this topic, especially designed for the industrial sector. Therefore, the Center for European Economic Research (ZEW) in Mannheim has designed a questionnaire in cooperation with infas (Bonn) and Fraunhofer ISI (Karlsruhe) to account for peculiarities of services sector innovations. The survey was conducted in the Fall of 1995 and most questions referred to 1994 or the time period from 1993 to 1995.

The survey contains responses of about 3.000 German service firms sampled from eight branches, including wholesale trade, retail trade, communication and transportation, banking and insurance, other financial services, software, technical counseling, and other private services. These covered branches employed about 32% of the workforce in 1994. Further service activities, which are not covered by the survey, employing another 25%, encompass public services, education, health and social work, and some other personal services (for a detailed description of the data refer to Licht et al. 1997).

One of the main topics in the survey is concerned with the realization of innovations in the time period from 1993 to 1995. The respondents had to distinguish between product, process, and organizational innovations. However, the examples the firms gave, point to the fact that this common distinction is not meaningful in the services sector (see also König et al., 1996). Therefore, for our purposes, an innovator is defined as a firm that introduced at least one of these three innovation categories. In our sample, 76.8% of the firms are innovators. The questionnaire also contains a question whether the firms intend to introduce an innovation over the next one and a half years. About 74.8% were planning to introduce at least one innovation. This question corresponds to T^D of (22) which will be treated as the dependent variable in our econometric estimation.

The firms were also asked to assess some obstacles hindering the realization of innovation projects in the past. A five-point Likert scale was provided in the questionnaire to indicate the degree of obstruction the respondents faced with respect to a given aspect. The categories of the Likert scale for a specific obstacle were ranked from *to be of little importance* (first category) until *to be of great importance* (fifth category). Two questions on this topic were concerned with the importance of financial constraints due to *lack of equity funds* and due to *lack of debt funds* for the realization of their innovation projects in the last three years. These two questions and four further obstacles are used in our empirical investgation to explain planned innovative activities. For the econometric analysis, the five point Likert-scale variables are transformed into dichotomous variables for which the means differentiated by branches are recorded in Table 1. More details of these variables are given in the next section.

Table 1: Descriptive Statistics for our Data Sample

Branches	No. of Obs	Innov. plan	Lack Equity Funds	Lack Debt Funds	Innov. in the Past	Diffic. in Realiz.	Lack Techn. Equip.	Demand Exp.	Demand in the Past
Wholesale Trade	411	71.3	17.6	13.6	70.2	8.5	3.4	49.9	43.8
Retail Trade	188	70.2	20.6	12.4	68.3	7.7	5.2	41.8	37.6
Communication,Transportation	316	67.7	27.6	15.7	74.8	10.7	4.4	52.9	53.5
Banking and Insurance	233	88.0	4.2	21.2	91.4	5.1	1.7	77.6	73.4
Other Financial Services	112	75.9	13.4	8.9	75.9	2.7	1.8	68.7	65.2
Software	133	90.2	33.6	23.1	87.9	11.9	2.2	78.8	57.6
Technical Counseling	246	72.8	26.5	20.7	81.0	10.0	3.2	46.7	54.5
Other private Services	796	74.6	18.3	10.9	75.6	7.0	3.5	58.9	59.1

5. Empirical Results

According to our theoretical model, we want to analyze the effects of financial constraints, technological opportunities, profit expectations and current profits on the timing of innovations. Therefore, we estimate univariate ordered probit models using the binary information whether a firm plans on introducing at least one innovation within the next one and a half years or not. The estimation results are recorded in Table 2. The two specifications differ in how financial constraints are modeled.

In the first specification, a dummy variable for *lack of equity funds* is used which is equal to one whenever this hampering effect is of great importance to the firm. In the second specification, a dummy variable for *lack of debt funds* is used which is constructed in an analogous manner. In both specifications the parameter for the financing constraints variable is negative, but not significant in the second. According to our theoretical model, this implies that a firm which is restricted by liquidity, has to postpone its optimal innovation date T^{**}.

The parameter of past innovations is highly significant supporting the *success breeds success* hypothesis as discussed by Mansfield (1968) and empirically investigated by e.g. Flaig, Stadler (1994, 1998). Due to this hypothesis, successful innovations in the past confer advantages in the technological opportunities that make a further innovation success more likely.

The variables for the hampering effects, describing the technological opportunities, were constructed analogously to the lack of financial funds variables. If a firm indicates that a specific hampering factor was of great importance for the realization of innovation projects, the dummy variable is set equal to one. The results indicate that in situations where difficulties in the project realization occurred, technical equipment was lacking, the innovation costs were very high, or technologies were not yet mature, the planned innovation projects will be postponed. Not all parameters are significant, but they all show the expected sign. The assessment of hampering factors with Likert scales is often criticized since the answers for a certain question cannot be compared across firms. Respondents might be subjectively biased when answering, even though they objectively face the same economic conditions. Therefore, we calculated a mean variable from those hampering factors provided in the data set which are not used in our empirical model. This variable is included to control for the individual specific behavior when answering subjective assessment questions.

Table 2: Binary Probit Estimations

Dependent Variable: Planned Innovations				
	Specification (1)		**Specification (2)**	
Explanatory Variables	**Parameter**	**t-value**	**Parameter**	**t-value**
Lack of Equity Funds	-0.166 *	-1.76		
Lack of Debt Funds			-0.119	-0.86
Innovation in the Past	0.751 ***	11.09	0.757 ***	11.16
Difficulties in Project Realization	-0.243 **	-2.03	-0.265 **	-2.21
Lack of Technical Equipment	-0.278 *	-1.64	-0.299 *	-1.76
High Innovation Costs	-0.092	-1.02	-0.105	-1.18
Innovation Technologies not Mature	-0.170	-1.07	-0.160	-1.00
General Hampering Factors	0.274 ***	6.39	0.262 ***	6.17
Expected Demand	0.266 ***	3.38	0.242 ***	3.48
Expected. Demand*Lack of Equity F.	0.028	0.23		
Expected. Demand*Lack of Debt F.			0.234	1.26
Past Demand	-0.046	-0.58	-0.008	-0.11
Past. Demand*Lack of Equity Funds	0.031	0.25		
Past. Demand*Lack of Debt Funds			-0.147	-0.79
Log(Number of Employees)	0.178 ***	9.19	0.181 ***	9.39
Branches:				
Wholesale Trade	-0.318 **	-1.99	-0.322 **	-2.01
Retail Trade	-0.403 **	-2.24	-0.418 **	-2.33
Communication and Transportation	-0.520 ***	-3.15	-0.524 ***	-3.17
Banking and Insurance	-0.074	-0.40	-0.073	-0.39
Other Financial Services	Reference		Reference	
Software	0.338	1.56	0.323	1.49
Technical Counseling	-0.309 *	-1.81	-0.308 *	-1.80
Other private Services	-0.277 *	-1.81	-0.281 *	-1.84
East-Germany	-0.007	-0.11	-0.016	-0.25
Const.	-0.979 ***	-5.34	-0.977 ***	-5.34
Number of Observations	2426		2423	
Log-Likelihood	-1131.2		-1129.9	
R^2_{VZ}	0.305		0.306	

Note: ***,**, and * indicate significance on a 1%, 5%, and 10% level, respectively. R^2_{VZ} is a (pseudo-) coefficient of determination (Veall, Zimmermann 1996).

Table 3: Indirect Inference Estimations with Equity Funds

Dependent Variable: Planned Innovations				
	Specification (1)		**Specification (2)**	
Explanatory Variables	**Parameter**	**t-value**	**Parameter**	**t-value**
Lack of Equity Funds (ordinal)	-0.161 **	-2.48		
Lack of Equity Funds (nominal)			-0.244 **	-2.41
Innovation in the Past	0.518 ***	9.60	0.503 ***	14.35
Difficulties in Project Realization	-0.114 **	-2.33	-0.143 ***	-3.18
Lack of Technical Equipment	0.057 ***	3.21	0.068	1.12
High Innovation Costs	0.064	1.39	0.034	0.49
Innovation Technologies not Mature	-0.039	-0.78	-0.023	-0.44
General Hampering Factors	0.277 ***	3.90	0.276 ***	5.21
Expected Demand	0.128 ***	2.62	0.116 ***	4.05
Past Demand	-0.034	-0.86	-0.024	-0.64
Log (Number of Employees)	0.115 ***	5.94	0.138 ***	7.26
Branches:				
Wholesale Trade	-0.346 *	-1.74	-0.307 *	-1.75
Retail Trade	-0.351	-1.25	-0.353 *	-1.88
Communication and Transportation	-0.549 ***	-3.08	-0.479 ***	-3.03
Banking and Insurance	-0.101	-0.61	-0.075	-0.33
Other Financial Services	Reference		Reference	
Software	0.322 *	1.65	0.377 ***	2.62
Technical Counseling	-0.325 **	-2.17	-0.289	-1.54
Other private Services	-0.330 **	-2.27	-0.318 *	-1.91
East-Germany	-0.032	-0.50	-0.023	-0.42
Const.	-0.142	-1.38	0.023	0.08

Note: ***,**, and * indicate significance on a 1%, 5%, and 10% level, respectively.

Table 4: Indirect Inference Estimations with Debt Funds

Dependent Variable: Planned Innovations				
	Specification (1)		**Specification (2)**	
Explanatory Variables	**Parameter**	**t-value**	**Parameter**	**t-value**
Lack of Debt Funds (ordinal)	-0.091	-1.58		
Lack of Debt Funds (nominal)			-0.234 **	-2.10
Innovation in the Past	0.519 ***	8.50	0.494 ***	9.06
Difficulties in Project Realization	-0.118 **	-2.51	-0.141 **	-2.53
Lack of Technical Equipment	0.049 *	1.80	0.001	0.01
High Innovation Costs	0.038	0.86	0.023	0.56
Innovation Technologies not Mature	-0.023	-0.50	-0.017	-0.23
General Hampering Factors	0.258 ***	3.92	0.267 ***	2.91
Expected Demand	0.123 ***	2.65	0.188 ***	5.05
Past Demand	-0.017	-0.49	-0.012	-0.40
Log (Number of Employees)	0.122 ***	7.57	0.130 ***	5.31
Branches:				
Wholesale Trade	-0.346 *	-1.71	-0.217	-1.52
Retail Trade	-0.364	-1.30	-0.258 **	-2.16
Communication and Transportation	-0.564 ***	-3.15	-0.413 *	-1.85
Banking and Insurance	-0.091	-0.54	0.005	0.02
Other Financial Services	Reference		Reference	
Software	0.281	1.39	0.616 **	2.55
Technical Counseling	-0.319 **	-2.04	-0.186	-0.83
Other private Services	-0.334 **	-2.25	-0.142	-0.63
East-Germany	-0.063	-0.98	-0.028	-0.61
Const.	-0.108	-1.11	-0.043	-0.14

Note: ***,**, and * indicate significance on a 1%, 5%, and 10% level, respectively.

The theoretical model also suggests that expected profits influence the optimal timing of innovations. However, our data set only offers information on firms' expected demand. This variable is measured on a five point Likert scale where the firms could indicate expected changes from a large decrease (first category) to a large increase (fifth category). We again constructed a dummy variables for increasing demand. The estimated parameter is positive and highly significant. As a proxy for the variable current profits we use the firms' responses on past demand. The corresponding parameter has the correct sign, but is insignificant. In order to distinguish the influence of expected and past demand in the different financial regimes, we included interaction variables each defined as demand variable times the lack of funds variable. However, we could not find any significant effect of these indicators.

Schumpeter (1942) already suggested our finding that firm size, measured by the number of employees, has a positive effect on firms' innovation behavior which was often observed in empirical studies in the industrial sector (see, e.g. the survey by Cohen 1995). In many other aspects of service sector innovations, East-German firms are significantly different than West-German firms. Surprisingly, this is not the case for the aspect we are focusing on.

The estimation strategy we followed so far is common practice in the sense that the scale of the dependent variable is handled properly, whereas regressors are handled differently. With regard to the left hand side of the econometric specification, the estimation method assumes a latent variable for the observed categorical indicator. The right hand side variables are treated differently. Although they are sampled in the same survey, it is common to construct dummy variables for the ordinal scaled variables. Therefore, we apply an estimation procedure developed in Kukuk (1998) which is based on the indirect inference method (Gourieroux et al. 1993). In this approach each ordinal variable on the right hand side of the specification is also seen as a manifestation of an underlying continuous variable which is unobservable. This method uses simulation techniques to estimate the econometric model formulated in continuous latent variables.

Therefore, in the next approach we are not using constructed variables for expected and past demand and the obstacle variables. Instead, we use the whole ordinal information. In a first step, we also used the ordinal information for the lack of funds variables but could not find reasonable results. In Table 3 and Table 4, estimation results are given for the model where we use the full ordinal information for the obstacles and the expected and past demand, but a dichotomous variable for the lack of funds as defined in our first specification of Table 2. The two specifications in Table 3 and Table 4 differ in the treatment of this dichotomous variable: in the first column this variable is treated as an ordinal indicator, whereas in the second column it is treated as a nominal indicator. The estimates for lack of technical equipment show the wrong sign in the first specification. However, regarding the second specification, all the variables are in accordance with our theoretical view. The lack of external funds variable is highly significant in these approaches, supporting and even strengthening our initial estimates in Table 2. However, the lack of funds variable should be seen as a nominal information in the sense that either a firm is financially restricted or not. The idea that there are differences in the degree of financial restriction is not supported by the data.

6. Summary

In the theoretical model, we considered a firm which is planning the introduction of an innovation. As a consequence, its old product and the implied profit stream is replaced by the new product. The introduction date also depends on the costs of R&D since it is assumed that the innovation requires a critical knowledge level to be accumulated over time. If R&D expenditures cannot be financed internally, the company is financially constraint due to adverse selection and moral hazard effects in the capital market. The model predicts a delay in the introduction date of the innovation if the firm faces a liquidity constraint.

The model is estimated for firms in the German services sector using a cross section survey, which was among the first to gain information on service sector innovations. Industrial innovations were always seen as technological innovations implying large investment in technical equipment and R&D knowledge. The service sector innovations might not all be technical and R&D is not as institutionalized as in the industry, but innovation projects show similarities in both sectors.

The empirical results show a significant effect of financing constraints on the timing of introducing an innovation as implied by the theoretical model. All the variables used to describe the knowledge level, which is necessary to innovate, show the predicted sign. Even the two variables concerned with the technological aspects of the innovation project, show parameter estimates underlining the similarity to industrial innovations. Other variables which are included to control for issues not addressed in our theoretical model, show the same results which are known from industrial innovation studies.

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