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# Technology Transfer and the Internet: A Chance for Outsiders at Public Science to get Into the Business?

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## Non-technical summary

The Internet is expected to change technology transfer between public research and the private enterprise sector in many ways. From a technology perspective, it offers new methods for joint research, but it also enlarges the knowledge base available by providing ease of access to the world's research capabilities and competencies. Today, both public research institutions and firms have full Internet access and widely use it for information search, communication, and presentation of their activities, products and services. The Internet offers new possibilities for market interactions which also affect technology transfer: It reduces transaction costs by easing the establishment of contacts and making the exchange of information cheaper. It removes information asymmetries by widening the information base, shortening time lags in information provision and increasing the transparency of knowledge supply at public research. Hence, the Internet may expand the reach of technology transfer offers by public research. Especially public research units not involved in transfer activities with firms so far may use the Internet as a way to enter the business. Low costs for offering their services and competencies, direct access to potential customers, and equal opportunities to be considered by them significantly reduce the barriers to entering the transfer market.

In this paper, we examine to what extent this chance is seized using empirical data from the German public research sector. A recent survey of state universities, polytechnic colleges and public research laboratories in the fields of natural sciences and engineering provides information on interactions with firms in the field of knowledge and technology transfer, including Internet activities and contacts to firms established via the Internet. We test whether research units with few or no firm interactions in the past have a higher propensity to establish new firm contacts via the Internet. Four types of variables are expected to determine the firm profitability of establishing a contact with a certain research unit: the attractiveness of the knowledge supplied by the research unit, the relative price of research services offered by the unit, firms' demand for the unit's knowledge supply , and the orientation of the unit's Internet presentation.

Treating the effect of firm orientation of homepage design as endogenous, i.e. depending on the level of existing contact with firms and the knowledge supply characteristics, we found that the Internet is mainly used by research units already well positioned in the transfer business. They attempt to expand, deepen and/or maintain their transfer network to the enterprise sector by the means of Internet technology. In this case, the Internet seems to act as

a complementary medium for establishing contacts with firms. Especially those research units specialised in direct co-operation with firms show a high probability of establishing further contact with firms via the Internet. There is no contacts are successfully using Internet technologies as a convenient way to enter the business.

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## Abstract

The Internet is receiving increasing attention as a medium for technology transfer between public research and the enterprise sector. Based on a survey of public research units in natural sciences and engineering in Germany, we analyse the determinants of firm contacts established via the Internet. Special attention is paid to the effect of experiences in firm interaction in the past. Econometric estimation results suggest that Internet contact to firms is more likely to be established by public research units which are already well established in the transfer market. Research units which orientate their homepage design towards the business sector are more likely to build Internet-based contact with firms. There is no evidence that public research units which were market outsiders in the past use the Internet more intensively to get into the transfer business.

**Keywords**: Technology transfer, Industry-science interaction, Internet use, Simultaneous equation Probit

**JEL Classification**: C35, O31, L14, L86

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## 1 Introduction

The Internet is expected to change technology transfer between public research and the private enterprise sector in many ways. From a technology perspective, it offers new methods for joint research, e.g. collaboration over time and space, sharing of computing facilities (see Chien, 1999), but it also enlarges the knowledge base available by providing ease of access to the world's research capabilities and competencies. Today, in most parts of the world both public research institutions, i.e. universities and public sector research establishments, and firms have full Internet access and widely use it for information search, communication, and presentation of their activities, products and services. The Internet offers new possibilities for market interactions (see Varian, 2000, Shapiro and Varian, 1999) which also affect technology transfer: It reduces transaction costs by easing the establishment of contacts and making the exchange of information cheaper. It removes information asymmetries by widening the information base, shortening time lags in information provision and increasing the transparency of knowledge supply at public research. Hence, the Internet may expand the reach of technology transfer offers by public research. Especially public research units not involved in transfer activities with firms so far may use the Internet as a way to enter the business. Low costs for offering their services and competencies, direct access to potential customers, and equal opportunities to be considered by them (compared to those research institutions already in the market) significantly reduce the barriers to entering the transfer market. Thus, the Internet should give a special chance to outsiders of the technology transfer market to get into the business.

In this paper, we examine to what extent this chance is seized using empirical data from the German public research sector. A recent survey of state universities, polytechnic colleges and public research laboratories in the fields of natural sciences and engineering provides information on interactions with firms in the field of knowledge and technology transfer, including Internet activities and contacts to firms established via the Internet. We test whether research units with few or no firm interactions in the past have a higher propensity to establish new firm contacts via the Internet while controlling for other variables affecting the probability that a firm and a research unit get in contact via the Internet.

In section 2, we present a model used in this study to analyse the determinants of Internet-based contact with firms between firms and research units. In section 3, we describe the data base and give some descriptive results on Internet use in public research institutions in Germany. Section 4 discusses the model estimation and the results achieved. The major findings of our study are summarised in Section 5.

## 2 The Model

We model the probability that a research unit at public research, i.e. universities and public research laboratories, has established at least one Internet-based contact with a firm. An Internet-based contact is one which is established as a result of the Internet presentation of a research unit. The modelling of Internet-based contacts between research units and firms assumes that

- research units offer their services and competencies (type of research carried out, research facilities, reference projects) passively on the Internet but do not actively contact firms via the Internet;
- firms scan and evaluate the Internet presentation of research units on their search for external knowledge which is relevant to their innovation activities;
- firms decide to get in contact with a research unit if the expected returns from a co-operation exceed the costs of establishing and maintaining a contact, at least to a certain extent, i.e. there is a minimum level of profitability to be achieved.

We only take Internet-based contacts between firms and public research units that are related to knowledge transfer into account. This means that a firm's purpose for contacting a research unit is to acquire and exchange knowledge available at that research unit. The knowledge transfer between both parties may take a variety of forms, such as research contracts, direct collaboration in R&D projects, purchase of technology, informal knowledge transfer via personal contacts etc. (see Bonaccorsi and Piccaluga, 1994, Mansfield, 1997, Schmoch, 1999, Schartinger et al., 2001). We neither look at the medium used for establishing an Internet-based contact nor at the type of interaction that follows the initial contact, but solely at the fact whether a research unit could establish such a contact or not.

The probability that a research unit *i* establishes an Internet-based firm contact *a* with at least one firm is basically modelled as a function of the information available to firms regarding *i*'s knowledge supply and transfer experiences, the returns firms expect from contact with *i*, given the information available, the expected costs of establishing and maintaining a contact with *i*, and the demand for i's knowledge supply at the enterprise sector.

*Expectations on returns* will heavily depend on the excellence of research carried out at research unit *i* as well as on the relevance of the knowledge available at *i* with respect to a firm's knowledge stock and technology specialisation (see Foray, 1997). A firm's demand for external knowledge from *i* will thus increase with the congruence of technological orientation of *i*'s knowledge supply with the firm's own knowledge stock, and with the novelty of the knowledge produced at *i*. The probability of establishing a firm contact in order to exchange knowledge is therefore modelled by knowledge supply characteristics of *i* and the demand for this knowledge among firms. Knowledge supply characteristics of *i* cover variables such as research orientation (with respect to the type of research carried out), the quality and innovativeness of research, and the (scientific) reputation of the research personnel. The demand for *i*'s knowledge supply depends on the size of the potential firm target group of *i*, i.e. the number of firms specialised in markets and technologies that require scientific knowledge produced at *i* to some extent. As the size of these target groups will vary by fields of sciences, the affiliation of a research unit *i* to a certain scientific field may be used as a proxy for variations in knowledge demand.

The *expected costs of establishing and maintaining contact* to a research unit *i* refer to transaction costs and the relative price of research services carried out by *i*. Transaction costs are assumed to depend on the experience a research unit has in knowledge transfer to firms, i.e. the level of learning (see Cohen and Levinthal, 1990, Saviotti, 1999). Experienced research units will have developed efficient transfer routines, be familiar with firm demands in transfer activities (e.g. project organisation), and will be able to transfer scientific results into innovation oriented outcomes. Thus, experience will increase the reputation of *i* with respect to transfers. The relative price of research services offered by a public research unit *i* mainly depends – given the institutional setting of the public research sector in Germany (see Beise and Stahl, 1999) – on its institutional affiliation, i.e. the type of university or public research lab a research unit belongs to, and its size, which allows the utilisation of economies of scale in transfer activities.

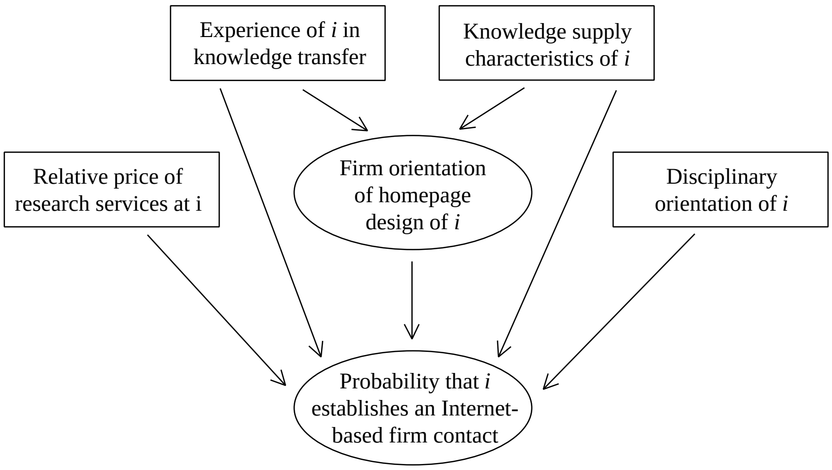
The *information available to firms* on the above mentioned characteristics of *i* shape firms' decision on establishing a contact. In this paper, we are especially interested in the Internet as a medium for acquiring this information. The content, quality and user orientation of the Internet presentation of a research unit *i* is assumed to significantly affect a firm's decision to contact *i*: The Internet is viewed as an efficient search tool for firms as it enables a comprehensive screening of supply, it is cheap and allows for anonymity for the searching firm. The information value of a research unit's Internet presentation will increase with the orientation towards firm needs. A strong firm orientation may be achieved by using a firm-oriented language, offering competence and knowledge with regard to its commercial potential, stressing transfer experiences, and presenting this information in an easily accessible way.

By directly addressing firm needs these research units can utilise specific advantages of Internet economies: First, the Internet provides direct access to all firms in the target group as long as they use Internet technologies in information search, which is highly common today. Thus it diminishes barriers to market access which are especially common in the transfer market, which is often characterised by "closed networks" of public research institutions and firms. Secondly, there are equal opportunities for all hosts to be perceived by the target group. Information asymmetries at the firm side often result in biased search processes and a pre-selection of potential co-operation partners at public research out of institutions with which contacts already have been established in the past. Thirdly, investment in establishing an attractive Internet presentation is low compared to other marketing strategies. Therefore small research units with a low budget may also try to enter the transfer market via the Internet. Hence, knowledge supply characteristics such as size, research orientation and thematic research topics may affect the firm’s orientation in homepage design.

Figure 1 shows the basic outline of our conceptual model. A major element of the model is endogenity among exogenous variables: Research units will show different levels of transfer activities with firms in the past and therefore have different transfer experiences. As such experiences will lower transaction costs, experienced research units can exploit a reputation advantage and should show a higher probability of establishing new contact with firms via the Internet than research units which are not or only minorly involved in knowledge transfer to firms. In order to catch up, the latter may try to use the Internet as a strategy for market entry. A promising method is to build up a strongly firm-focussed Internet presentation and thus increase the quantity and quality of information on the homepage relevant to firms. By doing this, they can compensate for low reputation and other disadvantages for market outsiders in establishing new contacts to firms.

The effect of the knowledge transfer experience on *i*'s homepage design is ambiguous, however. On the one hand, experiences in knowledge transfer activities with firms provide information on the needs of firms and may make it easier to design a firm-specific homepage. This may be reinforced by knowledge supply characteristics that are attractive to firms, such as a focus on applied research and international renown. On the other hand, the Internet may be used primarily as a new technology by those research units which are not yet well established in the transfer market. Applying Internet technologies as a low cost entry, they may react by this strategy to the increasing pressure on public research to strengthen their links to industry.

**Figure 1: Variables affecting the probability of establishing an Internet-based firm contact by *i*-the public research unit**




Formally, the probability of a public research unit *i* establishing a technology transfer oriented firm contact $y_1$ is a function of (i) the relative price of its knowledge supply and the characteristics of the firm target group (represented by vector $x_1$), (ii) *i*'s knowledge supply (vector $x_2$), (iii) *i*'s experiences in transfer activities to firms (vector $x_3$), and (iv) the firm orientation of *i*'s Internet presentation $y_2$:

$$y_{1i} = a_0 + x_{1i}^{'}a_1 + x_{2i}^{'}a_2 + x_{3i}^{'}a_3 + y_{2i}^{'}a_4 + e_{1i} \qquad (1)$$

A contact will be established if the expected profitability exceeds a certain level $p^*$, otherwise no contact is established. We assume that all firms have the same minimum level of profitability when using public research institutions as a source of knowledge. The endogenous variable $y_1$ will take the value 1 if the expected profitability $p$ of co-operation with research unit *i* reaches or exceeds the uniform minimum level of profitability $p^*$, and the value 0 otherwise:

$$y_{1i} = \begin{cases} 1 & for \quad p_i \geq p^* \,, \\ 0 & for \quad p_i < p^* \,. \end{cases} \qquad (2)$$

The firm-specific orientation of *i*'s Homepage design $y_2$ is modelled on knowledge supply and transfer experience, $x_2$ and $x_3$:

$$y_{2i} = b_0 + x_{2i}^{'} b_1 + x_{3i}^{'} b_2 + e_{2i} \qquad (3)$$

$a_j$ with $j$=1,...,4 and $b_k$ with k=1,...,3 as the parameters to be estimated, $a_0$ and $b_0$ as constant terms, and $e_1$, $e_2$ as normally distributed error terms. A simultaneous estimation of equations (1) and (3) allows us to identify whether research units at public research institutions showing a low level of knowledge transfer experience with firms attempt to utilise the Internet as a new medium for establishing contact with firms. If $x_3$ negatively affects the firm-specific orientation of the Internet presentation $y_2$ in (3) but $x_3$ has a positive effect upon the probability of establishing contact with a firm in (1), we cannot not reject our hypothesis as stated at the beginning, i.e. the Internet then seems to be used successfully by less active research units to enter the transfer market with firms. Econometric details on the simultaneous estimation approach applied in our study are discussed in section 4.

## 3 The Data

The analysis is based on data collected by a survey of German research units in the field of natural sciences and engineering (NSE) at higher education institutions and public sector research establishments. Given the institutional structure of public research in Germany (see Rammer, 2001, Beise and Stahl, 1999), the survey is focussed on seven types of institutions (see also Table A.1 in the Appendix):

- General Universities (GUN) carry out both research and education within one organisational unit and represent about 45 % of total R&D expenditure on public research in Germany.
- Technical Universities (TUN) specialise in applied research and education in natural and technical sciences, representing about 7 % of total public research expenditure,
- Polytechnic colleges, also called "Universities of Applied Sciences" (UAS), offer practice-oriented education in technical and economic fields (ca. 2 % of total public R&D),

- the Max Planck Society (MPG) is devoted to carrying out top-level basic research based on international standards in selected areas and thereby completing research at universities (ca. 7 % of total public R&D),
- the Helmholtz Association (HGF) unites 16 large research centres performing long-term oriented basic research, as well as research in key technologies with public interest (ca. 16 % of total public R&D),
- the Fraunhofer Society (FHG) carries out R&D in technical sciences strongly oriented to industry needs (ca. 5 % of total public R&D),
- the Leibniz Association (WGL) comprises a heterogeneous set of research institutes from all fields of science (ca. 6 % of total public R&D).

Together, these institutions represent more than 87 % of total public research capacities in Germany (and 88 % of R&D expenditure within NSE). The unit of observation used in this study is a *research unit* within each institution. The organisational structure of research units varies according to institution and covers departments, sub-departments, institutes, working groups or sometimes individual professors (especially at polytechnic colleges which have no departmental structure). The survey considers only research units from natural sciences and engineering, i.e. physics, chemistry and pharmaceuticals, biology and life sciences, mathematics and computer science, geo-sciences, electrical and mechanical engineering, construction engineering and other natural and engineering sciences.

The survey was carried out in Spring 2000 by means of a standardised questionnaire posted to a total of 3,507 research units. The sample consists of a random selection of research units at general universities, technical universities and polytechnic colleges (stratified by regions). At the other four institutions, all research units in NSE were considered in the sample. At general and technical universities as well as PTCs, research units are defined as the smallest organisational unit, typically chaired by a full professor, but in some cases managed by a senior researcher (e.g. "working groups"). The number of staff at research units ranges from 2 to 40. At MPG, FHG and WGL, research institutes are considered as research units (typically consisting of 50 to 200 employees). At the HGF research centres we chose departments or working groups (with usually about 10 to 100 employees) as our units of observation. 857 questionnaires were returned, resulting in an average response rate of 24.4 per cent (see Table A1 in the Appendix).

The research units provided information on their staff (by qualification), their financing structure (basic and additional financing, including the share financed by industry), their research orientation, the level of personnel mobility by sector of destination, the significance of various sources of information used for directing research topics, the significance of various types of interaction with the enterprise sector both in the past (i.e. in the time period 1997 to 1999) and as expected for the following years, and the relevance of various barriers to co-operation with firms. Furthermore, they stated whether they run their own homepage on the Internet, which they orient to the target group through the content and design of their homepage (distinguishing science, students and firms), and if they recently established contacts to firms as a result of their Internet presentation.

Using this information source, we construct the following indicators for the model variables in (1) and (3) (abbreviations for independent model variables as used in the subsequent sections are given in parentheses):

a. *Firm contact established via the Internet* ($y_1$): Dummy variable which takes the value 1 if a research unit states that contact with firms has been established as a result of its Internet presentation, and 0 otherwise (INTCON).

b. Relative price of research services offered and disciplinary orientation ($x_1$):

- Differences in the price of research services are assumed to occur mainly between types of public science institutions, reflecting differences in the efficiency of transfer activities, which result from different organisational structures, resources available for transfer activities, incentive schemes, equipment with research facilities, employment regulations and wage levels. The *institutional affiliation* is measured through dummies for each of the seven institutions covered by the survey: general universities (I_GUN), technical universities (I_TUN), polytechnic colleges (I_UAS) ("universities of applied sciences"), the Max Planck Society (I_MPG), the Helmholtz Association (I_HGF), the Fraunhofer Society (I_FHG) and the Leibniz Association (I_WGL).

- *Dummies for disciplinary orientation*: We distinguish 10 knowledge fields within NSE, assuming that each field is oriented towards a different group of firms with respect to the production technology employed by these firms, the structure of the market within which these firms are active and the corresponding demand for scientific knowledge. The fields are general physics, astronomy, space research and geo-sciences (D_PHY), chemistry, pharmaceutics, biology and life sciences (D_CHE), mathematics (D_MMT), computer science (D_COM), mechanical engineering (D_MEC), electrical engineering (D_ELE), material sciences (D_MAT), environmental sciences and engineering (D_ENV), process engineering (D_PRO), and other engineering sciences such as food technologies, instrumental engineering, construction engineering, logistics and transportation engineering (D_OTH).

c. Knowledge supply characteristics relevant to expected returns ($x_2$):

- Share of resources devoted to either *basic research* (BASIC), *applied research* (APPLIED) or *technology development* (TECDEV).

- The extent to which staff *is financed by project-based financing* (from both public and private funds) is used as a proxy for competition orientation of research and is measured as "additional funding" per researcher, i.e. in addition to institutional funding (ADFUND).

d. Experience in transfer activities with firms ($x_3$):

- *Direct contact with firms in the past*: Dummies that take the value 1 if a certain type of direct knowledge interaction with firms was of considerable significance to contact with firms in the period 1997 to 1999, and 0 otherwise, distinguishing two types of direct interaction: collaborative research (C_COL) and joint publication and/or patenting (C_PUB).

- *Experience in knowledge transfer with firms*: Number of interaction channels for knowledge transfer to industry which was of importance for contact with firms in the period 1997 to 1999, distinguishing 11 channels (collaborative research, commissioned research, joint publication and/or patenting, personnel mobility from science to industry, former jobs for scientists at the firm, new firm creation by scientists, training for firm members, joint supervision of thesis, lectures and presentations at firms, publication in scientific journals, publication in popular media), i.e. the variable values may range from 0 to 11 (CONT).

e. The quality of Internet presentation with respect to firm needs ($y_2$) is measured using two types of variables:

- The significance of *firms as a target group for a research unit's homepage design* is assessed by the research unit and is measured on a four-stage scale with the value 0 if a target group is not considered when designing a homepage and 3 if it has a high relevance for the homepage design (H_FIRM). This indicator is used to represent the dependent variable in (3).

- In order to control for competing homepage orientation towards the scientific community and students respectively, research units were asked to assess the *significance of science and students as target groups for their homepage design* on the same four-stage scale. This information is used to construct dummy variables taking the value 1 if a research unit states that science (students) are of high relevance for designing the homepage, and 0 otherwise (H_SCIE, H_STUD). Both variables are used in (1) as control variables.

Furthermore we control both in (1) and (3) for size effects, using the log of the number of personnel (both scientific and administrative) at a research unit *i* (LNSIZE). Table A2 in the Appendix shows descriptive statistics for all variables used in the model.

Today, all institutions of public research in Germany, i.e. each university, college, research centre etc, run their own homepage in the Internet. These central homepages typically provide general information on organisation, services, databases and study-related topics. For more detailed information on research topics and activities one has to refer to departments, working groups or individual professors/researchers who run their own homepages and often use their own design. If firms look for knowledge transfer related contacts to public research using the Internet as an information source, they primarily refer to the information provided at these decentralised homepages.

By mid of 2000, the vast majority of research units for public research in Germany was equipped with its own homepage (see Table 1). At polytechnic colleges and HGF research centres there are some research units without their own Internet presentation. These are mainly individual professors or small working groups obviously reluctant to invest in this information activity up to now.

There are significant differences in the target group orientation of homepage design among the seven public research institutions considered. While research units at the Fraunhofer Society are primarily oriented to firms, most other institutions consider other scientists as the main target group for their Internet presentation. At technical universities and polytechnic colleges, research units strongly focus their homepage design on students' needs, reflecting their mission as higher education institutions.

As a result of their Internet presentation, a considerable share of a research units could establish contacts to firms. There are statistically significant variations among the seven institutions, but at each institution at least about 30 % of all research units in NSE have established contact with firms via the Internet. High shares of research units which used the Internet to contact companies are reported by Fraunhofer Institutes and by research units from technical universities.

**Table 1: The use of Internet by research units at public research in Germany, differentiated by institution (share of research units in %)**

| | GUN | TUN | UAS | MPG | HGF | FHG | WGL |
|---|---|---|---|---|---|---|---|
| Own homepage | 98 | 99 | 91 | 100 | 94 | 100 | 100 |
| High significance of **firms** as homepage target group (*) | 19 | 28 | 21 | 0 | 27 | 100 | 21 |
| High significance of **science** as homepage target group (*) | 65 | 59 | 13 | 94 | 70 | 24 | 82 |
| High significance of **students** as homepage target group | 63 | 63 | 63 | 76 | 54 | 52 | 57 |
| No. of contacts to firms established via the Internet (*) | 29 | 49 | 31 | 29 | 33 | 95 | 43 |

(*) Variation among institutions is significant at the 1 % level (Pearson's $\chi^2$).

As expected, there is a statistically significant correlation between the degree of firm orientation of a research unit's homepage design and establishing contact to firms based on the Internet presentation (cf. Table 2). While 25 per cent of all research units regard firms as a highly important target group, this share is nearly 50 per cent for those research units which could establish Internet-based contact with firms. The relevance of other target groups (i.e. science and students, respectively) for the homepage design shows no statistically significant correlation with the establishment of Internet-based contacts to firms.

**Table 2: Contact with firms established via the Internet and target group orientation of homepage design (in %)**

| Contact with firms established via | High relevance of target group for homepage design | | |
|---|---|---|---|
| the Internet (INTCON) | Firms (H_FIRM=3) | Science (H_SCIE=1) | Students (H_STUD=1) |
| 0 (no) | 12.3 | 62.8 | 70.4 |
| 1 (yes) | 46.8 | 57.5 | 66.9 |
| Total | 25.8 | 60.7 | 69.0 |

# 4 Model Estimation Results

The theoretical considerations yield following econometric model:

$$y^*_{1i} = a\, y^*_{2i} + z'_{1i} g + e_{1i}, \tag{4}$$

$$y^*_{2i} = z'_{2i} b + e_{2i}. \tag{5}$$

The errors are normally distributed

$$\begin{pmatrix} e_{1i} \\ e_{2i} \end{pmatrix} \sim N\left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} s_1^2 & s_{12} \\ s_{12} & s_2^2 \end{pmatrix} \right) \tag{6}$$

where $s_1^2$ and $s_2^2$ denote the variances and $s_{12}$ the covariance respectively. The observed variables are

$$y_{1i} = \begin{cases} 1 & \text{if} \quad y^*_{1i} > 0 \\ 0 & \text{if} \quad y^*_{1i} \le 0 \end{cases}, \quad y_{2i} = \begin{cases} 0 & \text{if} \quad y^*_{2i} \le m_0, \\ 1 & \text{if} \quad m_0 < y^*_{2i} \le m_1, \\ 2 & \text{if} \quad m_1 < y^*_{2i} \le m_2, \\ 3 & \text{if} \quad y^*_{2i} > m_2. \end{cases} \tag{7}$$

The line vector $z'_{1i}$ contains the vectors $x_{1i}$, $x_{2i}$ and $x_{3i}$ and a constant term. The line vector $z'_{2i}$ contains the vectors $x_{2i}$ and $x_{3i}$. There is no constant term in $z'_{2i}$, because the three threshold values $m_0$, $m_1$ and $m_2$ to be estimated fit the four different categories of $y_2$.

Two problems occur if one wants to estimate the unknown parameter vectors α, β, and γ. On the one hand, the latent variable $y^*_{2i}$ which is a regressor in the first equation cannot be observed and the covariance $Cov(e_{1i}, e_{2i}) = s_{12}$ may be different from zero. This induces inconsistent estimates should both equations of (4) and (5) be considered separately. However, writing the reduced form of equation (4) solves the problem: Substituting $z'_{2i} b + e_{2i}$ for $y^*_{2i}$ yields

$$\begin{aligned} y^*_{1i} &= z'_{pi} p + h_i, \\ y^*_{2i} &= z'_{2i} b + e_{2i} \end{aligned} \tag{8}$$

with $h_i = e_1 + a e_2$. The error term of the reduced form equation is distributed as

$$h_1 \sim N\left(0, \left(1 + a^2 + 2ar\right)\right) \tag{9}$$

with the coefficient of correlation

$$r = \frac{s_{12}}{\sqrt{s_1^2 s_2^2}}.$$

The line vector $z_{pi}^{'}$ contains the variables $x_{1i}$, $x_{2i}$ and $x_{3i}$. The reduced form equations (8) can be estimated consistently using single equation estimators or, to gain efficiency, one can use a seemingly unrelated system method. The likelihood function of a bivariate probit model for one binary variable and one ordered variable is straightforward, but a little cumbersome, so that it is relegated to the appendix of this paper. Remember, for the probit case the estimable coefficient vectors are

$$\frac{p}{s_h} \text{ and } \frac{b}{s_2}.$$

To obtain estimates for the structural parameters of the first equation, we follow Gourieroux (2000)[2]: We compute the predictions of the latent variable $\hat{y}_{2i}^{**} = \frac{\hat{y}_{2i}^{*}}{s_2}$ and use this as a regressor. As the prediction $\hat{y}_{2i}^{**}$ is asymptotically uncorrelated with the disturbances, we can estimate the equation

$$y_{1i}^{*} = a\,\hat{y}_{2i}^{**} + z_{1i}^{'}g + e_{1i} \tag{10}$$

applying the probit technique. However, the estimated standard errors are biased because $\hat{y}_{2i}^{**}$ is an estimate itself. This problem can be solved by calculating bootstrap standard errors (see e.g. Efron and Tibshirani, 1993, Greene, 1997).

The model is estimated for those research units out of the total sample size of 857 which run their own homepage and provided information on the target group orientation of their homepage, whether they have established contact with firms via the Internet, and on all other exogenous variables of the model. The total number of valid observations is 762.

At first, we estimate the reduced form equations by FIML. The results are reported in Table 3. The dummy variables for different types of public research institutions, which are assumed to represent differences in relative prices for research services, and should therefore affect the probability of establishing contact with firms, have been ignored in the equation because they have proved to be statistically insignificant. This is rather surprising as these institutions are regarded as offering very different conditions for transfer activities due to differences in efficiencies, incentives and resources available for transfer activities (see Czarnitzki et al., 2000, Schmoch et al., 2000). Furthermore, descriptive analysis (Table 1) showed that there is significant variation among these types of institutions with respect to contact with firms established via the Internet. These variations obviously result from a different disciplinary specialisation, size differences and a distinctive research orientation.

**Table 3: Determinants of contact with firms by public research units established via the Internet: results of reduced form estimation as illustrated in equation (8)**

| Exogenous Variables (abbreviations see Table A2) | | Endogenous Variable | | | |
|---|---|---|---|---|---|
| | | Binary Variable: Contact with firms via the Internet (INTCON) | | Ordered Variable: Firm Orientation of Internet Presentation (H_FIRM) | |
| | | parameter estimate | t-value | parameter estimate | t-value |
| Knowledge supply characteristics ($x_2$) | BASIC | -.08 | -.81 | -.77 *** | -5.63 |
| | ADFUND | -.000007 | -.00 | .002 | 1.14 |
| Experience in knowledge transfer ($x_3$) | C_COL | -.08 | 1.10 | / | / |
| | C_PUB | -.28 | -2.18 | / | / |
| | CONTACTS | .06 ** | 2.52 | .13 *** | 4.86 |
| Disciplinary orientation ($x_1$) (reference dummy: D_PHY) | D_CHE | -.07 | -1.07 | / | / |
| | D_MMT | .04 | .49 | / | / |
| | D_COM | .36 *** | 3.40 | / | / |
| | D_MEC | .28 *** | 2.75 | / | / |
| | D_ELE | .20 ** | 2.17 | / | / |
| | D_MAT | .13 | .76 | / | / |
| | D_ENV | .38 ** | 2.11 | / | / |
| | D_PRO | .29 ** | 2.12 | / | / |
| | D_OTH | .27 ** | 2.05 | / | / |
| Quality of Internet presentation ($y_2$) | H_SCIE | -.08 | -1.50 | / | / |
| | H_STUD | -.12 ** | -2.34 | / | / |
| | H_FIRM | / | / | / | / |
| Control variable size | LNSIZE | .10 *** | 4.35 | .09 ** | 2.47 |
| Constant term | | .16 | 1.43 | / | / |
| | $m_0$ | / | / | -.56 *** | 3.72 |
| | $m_1$ | / | / | .71 *** | 9.23 |
| | $m_2$ | / | / | 1.28 *** | 10.35 |
| Coefficient of correlation | $\rho_{12}$ | .59*** | | | |
| Number of observations | | 762 | | | |
| Log likelihood | | -1,235.34 | | | |

Note: *** (**,*) significant at the 1% (5%, 10%) level

The Internet presentation as aimed at the business sector (H_FIRM) is related both to knowledge supply characteristics and to the level of experience in interaction with firms.

[2] This approach was first proposed by Mallar (1977).

Research units that are engaged in basic research rather than in applied research or technology development are less likely to focus their Internet presentation on firm needs. The positive effect of the experience in knowledge transfer on the firm orientation of the homepage suggests that the Internet is used by "insiders" on the transfer market, who use the Internet as an additional marketing instrument to maintain their high level of business contacts. Furthermore, the size of a research unit positively affects the orientation of the homepage design towards firms. This result may reflect that fact that the larger amounts of resources available at these research units allow for a more differentiated homepage design, including a special presentation for firms. This is supported by the fact that large research units tend to give firms, the scientific community, and students a high significance as target groups for their Internet presentation.

To obtain estimates for $\alpha$ and $\gamma$, we predict H_FIRM by the regression shown in Table 3 and use this as a regressor in equation (10). The regular t-values calculated by the inverse of the ML information matrix are presented. However, as these may be biased because the prediction of H_FIRM was estimated before, additional bootstrap t-values are provided. For those, 200 random samples (with resampling) were drawn, with which the model has been re-estimated. The standard errors were calculated according to the parameter variation of these 200 replications. The results are given in the Table 4.

The main results of our analysis are as follows: First, as was expected, the probability of a research unit *i* establishing contact with firms via the Internet is strongly affected by the target group orientation of the homepage design. Research units that focus their Internet presentation on the business sector are more likely to set up contact with firms. Secondly, the disciplinary orientation among NSE, and thus the firms' demand for knowledge produced at *i*, is another main determinant of establishing contacts to firms. Public research units in computer science show the highest propensity, followed by process engineering, other engineering sciences, material sciences and electrical engineering. The effect of disciplinary affiliation seems to be the main factor behind the observed variation in the likelihood of public research institutions in Germany establishing contact with firms. Within a certain discipline, the research orientation to basic or applied research has no further statistically significant effect upon the probability of creating an Internet-based contact with firms. Thirdly, large research units ceteris paribus tend to have a higher probability of establishing an Internet-based contact with firms.

**Table 4: Determinants of public research units' contact with firms established via the Internet: results of estimation as illustrated in equation (10)**

| Exogenous Variables (abbreviations see Table A2) | | Endogenous Variable<br>Binary Variable:<br>Firm Contact via the Internet (INTCON) | | |
|---|---|---|---|---|
| | | parameter estimate | regular t-value | bootstrap t-value |
| Knowledge supply characteristics ($x_2$) | BASIC | .28 | .87 | 0,73 |
| | ADFUND | / | / | / |
| Experience in knowledge transfer ($x_3$) | C_COL | .18 | 1.23 | 1,10 |
| | C_PUB | -.06 | -.25 | -0,19 |
| | CONTACTS | / | / | / |
| Quality of Internet presentation ($y_2$) | H_SCIE | .12 | 1.04 | 1,03 |
| | H_STUD | -.20 | -1.79 * | -1,53 |
| Estimated according to regression in Table 4: | **H_FIRM** | 1.02 | 3.19 *** | 2,69 *** |
| Disciplinary orientation ($x_1$) | D_CHE | -.19 | -1.08 | -1,05 |
| (Reference dummy: D_PHY) | D_MMT | -.12 | -.38 | -0,34 |
| | D_COM | .82 | 3.83 *** | 3,69 *** |
| | D_MEC | .73 | 3.79 *** | 3,63 *** |
| | D_ELE | .55 | 2.78 *** | 2,52 ** |
| | D_MAT | .61 | 2.03 ** | 2,06 ** |
| | D_ENV | .54 | 1.75 * | 1,42 |
| | D_PRO | .75 | 3.16 *** | 3,06 *** |
| | D_OTH | .62 | 2.47 ** | 2,28 ** |
| Control variable size | LNSIZE | .16 | 2.95 *** | 2,16 ** |
| Constant | | -2.06 | -6.36 *** | -4,74 *** |
| Number of observations | | | 762 | |
| Log likelihood | | | -415.21 | |

Note: *** (**,*) represent significance levels at 1% (5%, 10%).

There is no statistically significant effect from knowledge supply characteristics and the experience in knowledge transfer on establishing a firm contact via the Internet. Both variables obviously exert their influence through the orientation of the homepage design: Research units specialised in applied research or technology development and well experienced in contact with firms arrange their Internet presentation according to the specific needs of firms, which they seem to know well, both from former co-operations with firms and as a result of similar orientation of R&D activities. The homepage design attracts the attention of firms and yields new contact with firms based on the Internet presentation. There is no evidence that research units with little experience in knowledge transfer to the business sector can successfully compensate for this disadvantage in reputation by designing a highly firm oriented homepage.

## 5 Conclusion

The purpose of the paper was to examine the extent to which public research units with a low current level of contact and co-operation with firms are using Internet technology to expand their interaction with firms and to enter the transfer market. Based on a recent survey of research units at different types of universities and public sector research establishments in natural sciences and engineering in Germany, we analysed the probability that a research unit establishes a firm contact via the Internet. In our model, we distinguish four types of variables which determine the firm profitability of establishing a contact with a certain research unit: the attractiveness of the knowledge supplied by the research unit, the relative price of research services offered by the unit, firms' demand for the unit's knowledge supply, and the orientation of the unit's Internet presentation.

Treating the effect of firm orientation of homepage design as endogenous, i.e. depending on the level of existing contacts with firms and the knowledge supply characteristics, we found that the Internet is mainly used by research units already well positioned in the transfer business. They attempt to expand, deepen and/or maintain their transfer network to the enterprise sector by the means of Internet technology. In this case, the Internet seems to act as a complementary medium for establishing contact with firms. Especially those research units with firm interactions based on collaborative research and joint publication and/or patenting (i.e. research units specialised in direct co-operation with firms) show a high probability of establishing further contact with firms via the Internet. There is no empirical evidence that research units with no firm co-operation or a low current level of contacts are successfully using Internet technologies as a convenient way to enter the business.

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# Appendix

**Table A1:** Sample size, observations, and return rate of the survey of public research units in the fields of NSE in Germany by institutions

| | GUN | TUN | PTC | MPG | HGF | FHG | WGL | *Total* |
|---|---|---|---|---|---|---|---|---|
| Sample Size | 1,545 | 526 | 1,033 | 51 | 252 | 54 | 46 | *3,507* |
| Number of Observations | 401 | 172 | 151 | 17 | 67 | 21 | 28 | *857* |
| Return Rate (%) | 26.0 | 32.7 | 14.6 | 33.3 | 26.6 | 38.9 | 60.9 | *24.4* |
| Share of natural and technical sciences in total R&D expenditures at each institution (in %) | 43 | 78 | 63 | 70 | 82 | 92 | 60 | *61* |
| Weight of institution (share of total R&D expenditure in natural and technical sciences, in %) | 34 | 14 | 2 | 10 | 25 | 9 | 6 | *100* |

Source: Czarnitzki et al. (2000), own calculations based on BMBF (2000)

**Table A2:** Descriptive statistics for model variables, 762 observations (abbreviations see text)

| Variable | | Mean | Standard Deviation | Mini-mum | Maxi-mum |
|---|---|---|---|---|---|
| INTCON | Firm contact established via the Internet | 0.392 | 0.489 | 0 | 1 |
| BASIC | Share basic research in total R&D activities | 0.420 | 0.332 | 0 | 1 |
| APPLIED | Share applied research in total R&D activities | 0.405 | 0.260 | 0 | 1 |
| TECDEV | Share technological development in total R&D activities | 0.168 | 0.201 | 0 | 1 |
| ADFUND | Share of personnel financed by additional funds | 29.93 | 23.17 | 0 | 100 |
| C_COL | Contact with firms 1997-99: collaborative research | 0.377 | 0.485 | 0 | 1 |
| C_PUB | Contact with firms 1997-99: joint publication/patenting | 0.072 | 0.259 | 0 | 1 |
| CONTACTS | Experience in firm co-operation 1997-99 (index) | 2.070 | 1.799 | 0 | 10 |
| I_GUN | Institutional affiliation: general universities | 0.474 | 0.500 | 0 | 1 |
| I_TUN | Institutional affiliation: technical universities | 0.205 | 0.404 | 0 | 1 |
| I_UAS | Institutional affiliation: universities of applied sciences | 0.161 | 0.368 | 0 | 1 |
| I_MPG | Institutional affiliation: Max-Planck-Society | 0.022 | 0.148 | 0 | 1 |
| I_HGF | Institutional affiliation: Helmholtz-Association | 0.079 | 0.270 | 0 | 1 |
| I_FHG | Institutional affiliation: Fraunhofer-Society | 0.028 | 0.164 | 0 | 1 |
| I_WGL | Institutional affiliation: Leibniz-Association | 0.031 | 0.175 | 0 | 1 |
| LNSIZE | Size of research unit (log of number of personnel) | 2.884 | 1.229 | 0 | 7.49 |
| H_FIRM | Orientation of homepage design on firms' needs | 1.795 | 0.951 | 0 | 3 |
| H_SCIE | Orientation of homepage design on scientific community | 0.608 | 0.489 | 0 | 1 |
| H_STUD | Orientation of homepage design on students' needs | 0.690 | 0.463 | 0 | 1 |
| D_PHY | Discipline dummy: physics, astronomy, geo sciences | 0.125 | 0.331 | 0 | 1 |
| D_CHE | Discipline dummy: chemistry, biology, life sciences | 0.224 | 0.417 | 0 | 1 |
| D_MMT | Discipline dummy: mathematics | 0.045 | 0.207 | 0 | 1 |
| D_COM | Discipline dummy: computer science | 0.094 | 0.293 | 0 | 1 |
| D_MEC | Discipline dummy: mechanical engineering | 0.147 | 0.354 | 0 | 1 |
| D_ELE | Discipline dummy: electrical engineering | 0.135 | 0.342 | 0 | 1 |
| D_MAT | Discipline dummy: material sciences | 0.034 | 0.182 | 0 | 1 |
| D_ENV | Discipline dummy: environmental sciences/engineering | 0.030 | 0.171 | 0 | 1 |
| D_PRO | Discipline dummy: process engineering | 0.064 | 0.245 | 0 | 1 |
| D_OTH | Discipline dummy: other sciences and engineering | 0.055 | 0.228 | 0 | 1 |

**Derivation of the likelihood function for the econometric model**

The likelihood function for a seemingly unrelated probit model with one binary and one category variable can be derived easily. For our data, we have to consider following eight cases for every possible combination of $y_1$ and $y_2$ (for convenience, we drop the index $i$).

Case 1:

$$P_{00} = P\left(y_1 = 0,\, y_2 = 0\right) = P\left(z_p^{'}p + e_1 \le 0,\, z_2^{'}b + e_2 \le m_0\right) = P\left(e_1 \le -z_p^{'}p\,,\, e_2 \le m_0 - z_2^{'}b\right)$$
$$= \Phi_2\left(-z_p^{'}p\,,\, m_0 - z_2^{'}b\,,\, r\right),$$

where $\Phi_2$ denotes the cumulative density function of the bivariate normal distribution.

Case 2:

$$P_{01} = P\left(y_1 = 0,\, y_2 = 1\right) = P\left(z_p^{'}p + e_1 \le 0,\, m_0 < z_2^{'}b + e_2 \le m_1\right)$$
$$= P\left(z_p^{'}p + e_1 \le 0,\, z_2^{'}b + e_2 \le m_1\right) - P\left(z_p^{'}p + e_1 \le 0,\, z_2^{'}b + e_2 \le m_0\right)$$
$$= \Phi_2\left(-z_p^{'}p\,,\, m_1 - z_2^{'}b\,,\, r\right) - \Phi_2\left(-z_p^{'}p\,,\, m_0 - z_2^{'}b\,,\, r\right)$$

Case 3:

$$P_{02} = P\left(y_1 = 0,\, y_2 = 2\right) = P\left(z_p^{'}p + e_1 \le 0,\, m_1 < z_2^{'}b + e_2 \le m_2\right)$$
$$= P\left(z_p^{'}p + e_1 \le 0,\, z_2^{'}b + e_2 \le m_2\right) - P\left(z_p^{'}p + e_1 \le 0,\, z_2^{'}b + e_2 \le m_1\right)$$
$$= \Phi_2\left(-z_p^{'}p\,,\, m_2 - z_2^{'}b\,,\, r\right) - \Phi_2\left(-z_p^{'}p\,,\, m_1 - z_2^{'}b\,,\, r\right)$$

Case 4:

$$P_{03} = P\left(y_1 = 0,\, y_2 = 3\right) = P\left(z_p^{'}p + e_1 \le 0,\, z_2^{'}b + e_2 > m_2\right)$$
$$= \Phi_2\left(-z_p^{'}p\,,\, -\left(m_2 - z_2^{'}b\right),\, -r\right)$$

Case 5:

$$P_{10} = P\left(y_1 = 1,\, y_2 = 0\right) = P\left(z_p^{'}p + e_1 > 0,\, z_2^{'}b + e_2 \le m_0\right) = P\left(e_1 \le z_p^{'}p\,,\, e_2 \le m_0 - z_2^{'}b\right)$$
$$= \Phi_2\left(z_p^{'}p\,,\, m_0 - z_2^{'}b\,,\, -r\right)$$

Case 6:

$$P_{11} = P\left(y_1 = 1,\, y_2 = 1\right) = P\left(z_p^{'}p + e_1 > 0,\, m_0 < z_2^{'}b + e_2 \le m_1\right)$$
$$= P\left(z_p^{'}p + e_1 > 0,\, z_2^{'}b + e_2 \le m_1\right) - P\left(z_p^{'}p + e_1 > 0,\, z_2^{'}b + e_2 \le m_0\right)$$
$$= \Phi_2\left(z_p^{'}p\,,\, m_1 - z_2^{'}b\,,\, -r\right) - \Phi_2\left(z_p^{'}p\,,\, m_0 - z_2^{'}b\,,\, -r\right)$$

Case 7:

$$\begin{aligned} P_{12} &= P(y_1 = 1, y_2 = 2) = P\left(z_p^{'}p + e_1 > 0, m_1 < z_2^{'}b + e_2 \le m_2\right) \\ &= P\left(z_p^{'}p + e_1 > 0, z_2^{'}b + e_2 \le m_2\right) - P\left(z_p^{'}p + e_1 > 0, z_2^{'}b + e_2 \le m_1\right) \\ &= \Phi_2\left(z_p^{'}p, m_2 - z_2^{'}b, -r\right) - \Phi_2\left(z_p^{'}p, m_1 - z_2^{'}b, -r\right) \end{aligned}$$

Case 8:

$$\begin{aligned} P_{13} &= P(y_1 = 1, y_2 = 3) = P\left(z_p^{'}p + e_1 > 0, z_2^{'}b + e_2 > m_2\right) \\ &= \Phi_2\left(z_p^{'}p, -\left(m_2 - z_2^{'}b\right), r\right) \end{aligned}$$

Consequently, for these eight cases, the likelihood function to be maximised is

$$L = \prod_{y_1=0, y_2=0} P_{00} \prod_{y_1=0, y_2=1} P_{01} \prod_{y_1=0, y_2=2} P_{02} \prod_{y_1=0, y_2=3} P_{03} \prod_{y_1=1, y_2=0} P_{10} \prod_{y_1=1, y_2=1} P_{11} \prod_{y_1=1, y_2=2} P_{12} \prod_{y_1=1, y_2=3} P_{13}.$$