Why Do Scientists Engage in R&D Co-operations With Industrial Partners?

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Abstract

Existing literature has mainly focused on firms' incentives to engage in research cooperations with academic partners. In this study we empirically investigate the attractiveness of such cooperations from the *scientists' point of view*. Our empirical analysis is based on a survey of scientists working at the research institutes of the Max Planck Society in Germany. The dataset used contains information about scientists' attitudes toward commercialization activities in general and research cooperations with private firms in particular. Our results suggest that scientists face trade-offs. On the one hand, cooperations are attractive since they increase scientists' reputation and allow for sharing costs of commercialization. On the other hand, reduction of time for own research and reduced dissemination of scientists' research results make cooperation less attractive. We found that attractiveness does indeed increase probability of being engaged in cooperations. Moreover, scientific environment, like the "commercialization culture" as well as personal characteristics, like career stage and experience, are important factors driving a scientist's decision to cooperate with private firms.

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"*Knowing is not enough; we must apply. Willing is not enough; we must do.*"
Johann Wolfgang von Goethe

1 Introduction

Although Goethe certainly did not have in mind the innovation process of the 21st century, this quotation describes pretty well a prevailing economic problem of this process – at least in Europe. Recent European innovation data show that "the link between publicly financed science and innovative industry is rather weak". [1] It is often complained that Europe has large investments in knowledge generation but is comparatively weak in transforming it into innovations and economic growth. This is sometimes called the *European Paradox*. Hence, it is important to understand the factors that influence the decision of private firms and scientists to engage in joint commercialization activities.

This paper analyzes the factors that influence the decision of scientists to engage in research cooperation with private firms. The latter is a very important knowledge transfer channel between public science and the private sector and is therefore essential of the commercialization of scientific knowledge. In particular, potential advantages and disadvantages of commercialization activities from the scientists point of view are analyzed and it is empirically investigated how these affect the attractiveness of cooperations with private firms and in turn the decision to cooperate.

While the incentives of private firms to engage cooperation with public science institutions have been analyzed in empirical studies, our knowledge why scientists are interested to engage in research cooperations is limited (Lööf & Broström, 2008). As previous research on firm incentives indicates, firms pursue cooperative agreements with scientific partners for two main reasons. Firms either intend to share invention costs (Veugelers & Cassiman, 2005) or try to open up new technological fields based on radical innovation (B. H. Hall, Link, & Scott, 2003; Monjon & Waelbroeck, 2003).

However, despite firms' interest in joint research with public science institutions, cooperation may not occur due to scientists lack of interest in participation. Public science institutions are obliged to freely disseminate knowledge (Henderson, Jaffe, & Trajtenberg, 1998), but we know little about scientists' in-

[1] See Parvan (2007) who reports the results of the fourth Community Innovation Survey.

centives to share their knowledge with private firms and potential benefits for scientists that result from it. Scientists might have incentives to restrain from joint R&D projects with private firms due to obstacles associated with cooperation. Some of these obstacles might be intellectual property right issues (B. Hall, Link, & Scott, 2001), the value of scientific freedom or simply the preference to do scholarly work (Dasgupta & David, 2002) or the perception that science is a public good. Moreover, scientists often aim at signaling excellence in research while firms focus on applicability of results. Thus, the scientific 'winner-takes-all', reward structure as depicted by (Stephan, 1996) may well deter scientific cooperation with private partners.

Our study contributes to the literature on cooperations between scientific and private actors by investigating the incentives and motives of scientists to engage in research cooperation. We focus on several trade-offs associated with cooperative R&D from a scientists' perspective. In contrast, existing empirical studies either investigate cooperation from the firms' perspectives or regard scientific incentives using data on an institutional level. We fill this gap by investigating which factors determine whether or not an individual scientist makes the decision to joint research with private firms. We distinguish between scientists' perceived advantages and disadvantages of commercializing research, their scientific environment and personal demographic characteristics that determine scientists' incentives to engage in such cooperations. This allows us to identify to what extent high expected costs and expected monetary rewards, social scientific rewards and personal opinions on the role of science as well as scientific background impede on the cooperation behavior or incite to it.

Our empirical analysis is based on a sample of scientists working at the research institutes of the Max Planck Society in Germany. Max Planck research institutes doing basic research in various fields of life science, natural science, mathematics, technology and computer science as well as social science. The advantage of surveying Max Planck scientists is that all scientists work under the same institutional setting which allows us to examine determinants of cooperation behavior at an individual level, unbiased by potential institutional influences.

Our results suggest that expected reputational rewards as well as peer influences are key stimuli to cooperation attractiveness while expected time costs and the personal opinion that research cannot or should not be commercialized significantly reduce cooperation attractiveness. Cooperation attractiveness as well as the scientific environment and personal characteristics shape scientists' decisions to actually cooperate with private firms.

The rest of this paper is structured as follows. Section 2 discusses the determinants of scientists' R&D cooperations with private firms and derives testable hypotheses. Section 3 describes the the institutional background of the Max Planck Society, the Max Planck Scientists Survey (MPSS), definition of variables and presents descriptive statistics. The empirical analysis and estimation results are presented in Section 4. Section 5 discusses the results and Section 6 concludes.

2 Determinants of R&D Cooperations with private firms

Innovations and novel applicable research results are often the result of research cooperations between scientists working in public science institutions and private firms. Therefore, managers, the society, and policy makers have a common interest in fostering these cooperations. Seen from a firm perspective, cooperations with scientific partners is a tool of sharing invention costs and an opportunity of increasing the chance to invent something radically new with the help of the expertise of scientific partner. This paper deals with scientists' incentives to engage in such cooperations, since successful cooperations requires both partners, the scientists and the private firms, to benefit from the joint work. We present and test different stimuli and obstacles that determine whether or not an individual scientist cooperates with private firms. In this section we will first discuss the advantages and disadvantages of cooperations with firm s from the scientists' point of view. We will then discuss the role of the scientific environment and the relevance of scientists' personal characteristics, like career stage and age.

2.1 Advantages of commercialization activities - the scientists' point of view

Science is under increasing pressure to translate research results into appropriable knowledge for the private sector. In the last decades a shift of science toward more commercialization has already become evident. Several studies explored the explosion of university patenting in the U.S. as a result of the law changes and increasing competition for federal resources. Jaffe and Lerner (2001) have shown that patent policies can incentivize the commercialization of federally funded research if this is wanted by policy makers. In line with their study are the findings by Azoulay, Ding, and Stuart (2007), who have shown that the number of patent applications and patent grants have significantly risen after the Bayh-Dole act, enacted in 1980. This act made it significantly easier for universities to retain the property rights to federally funded inventions. As Henderson et al. (1998) pointed out, this change in law was associated with a shift toward more commercialization in universities as commercial revenues are sought by universities in order to increase the research budget. New technology transfer offices were established to actively pursue industrial support. Thus, bridging innovative research results to private firms has become an important focus of research organizations. Inside and outside the U.S. the mediation of scientific innovations between researchers and firms was facilitated.

This shift toward more commercialization of research requires scientists to fulfill two tasks: to perform excellent scientific research and to contribute to develop innovations, based on these new research results, that firms are willing to pay for. In order to find out to what degree these tasks contradict each other, several studies (Breschi, 2007; Van Looy, Callaert, & Debackere, 2006) have analyzed the relationship of patents and publications. Both mentioned studies provided evidence that there is a positive relationship between a scientist's number of patents and the number of publications. However, Gittelman and Kogut (2003) have shown that while scientific knowledge and patents are related, good publications and good patents are not. They analyze publications and patents of 116 biotechnology firms and show, that selection mechanisms in markets for valuable scientific papers and valuable patents are different. Though, as a common pattern, they detect that collaboration choices are influenced by status in a scientific community. Firms choose scientific partners with a reputation of performing excellent science. A similar result has been shown by Audretsch and Stephan (1996) who detected that firms even form around star scientists in the biotechnology industry. Thus, the development of the biotechnology indicates that scientists are capable of extracting monetary rents from their knowledge by jointly working with private firms. Scientists are financially rewarded by firms, when they work on inventions leading to potential market products. We consequently predict, that monetary rewards stimulate scientists' engagement in cooperative research with the private sector.

Since firms are attracted by 'star scientists', scientific reputation and cooperation experience are mutually complementary. On the one hand, scientific reputation is essential for researchers to be chosen by firms as private partners. On the other hand, scientific reputation increasingly depends upon cooperation experience. Scientists may even be capable of signaling scientific excellence by being chosen as a cooperation partner by an important industrial partner. This picture of science is in line with Etzkowitz (2003), who drew the picture of modern scientists performing research in both, federal laboratories and private firms' research units with mutually beneficial synergies. By working with various partners with different goals of outcome, star scientists increase their knowledge stock and potentially their reputation. Thus, scientific reputation of commercialization efforts is assumed to be a key driver of R&D cooperations with private firms. However, studies revealing a positive relationship between star scientists and attraction by industry mostly regard the biotechnology industry. Thus, the positive effect on reputation may not be true for all scientific disciplines. Therefore, we predict that scientists are more likely to partake in joint R&D projects with private firms when they perceive it to be reputation increasing within their scientific community to commercialize research findings.

2.2 ***Dis*advantages of commercialization activities - the scientists' point of view**

Several studies have emphasized that scientists value the freedom of academic work and that they are willing to pay a (monetary) price for it. Stern (2004) analyzed the relationship between wages and scientific orientation of researchers and disentangled two effects, the preference effect and the productivity effect. The preference effect describes that some scientists have a taste for scientific freedom and for possible discovery of new insights and and are less interested in pursuing commercial applications. As potential commercial applications are often unrelated to the associated knowledge produced by science, some scientists simply prefer creating knowledge to working existing knowledge into applicable products or processes. The productivity effect denotes the motivation to undertake R&D to gain earlier access to scientific discoveries with commercial application. When commercialization is successful, scientists are able to extract a certain rent when firms recompense the scientists that have contributed to the idea.

Despite the possibility of extracting monetary rents, Jensen, Thursby, and

Thursby (2003) observed that for many university inventions there is a moral hazard problem with inventor effort. At the time a scientist discloses or licenses an invention, the most interesting research related to that invention has already been completed. Thus, a certain disutility of effort in development must be overcompensated through monetary rewards, a royalty rate or a share in equity. Unless this rate is high enough to at least compensate for the scientist's disutility to do less interesting research, the scientist will restrain from proceeding work on the invention. We therefore predict that scientists are faced with costs, when cooperating with private partners, as this reduces their time for their own research. Such costs equal the aforementioned perceived disutility of not performing the research they would like to do.

A common point of the aforementioned studies is that scientists, involved in commercializing research, often perform research in early stages of the commercialization process. A theoretical explanation for this empirical regularity has been derived by Aghion, Dewatripont, and Stein (2005). They assume that wages are always higher in firms than in academia. Thus, innovative firms face lower wage costs in each stage of the commercializing process when their research is conducted through academia. On the contrary, the probability of successfully generating payoffs is lower when research is performed externally. Given these conjectures, they prove that it cannot be value-maximizing for both firms and researchers to have academia operate in later stages of the commercialization process. Academic research can only be beneficial for firms and society at the beginning of the commercialization process, which usually is a (radical) innovation. Aghion et al. (2005) further derive an optimal transition point at which a firm should proceed with the research that an academic researcher from universities has started.

Proceeding with novel, but early-stage results often requires costly protection of results. Protecting new research findings may result in either applying for a patent or searching a potential partner or investor, interested in improving this research. Thus, both, firms and researchers need to bear financial as well as time costs when seeking commercialization of joint findings. We predict that researchers are less likely to engage in joint research with private partners if they perceive high costs when commercializing research.

In order to exploit the gained knowledge from such cooperations financially, firms have an incentive to write contracts that guarantee the firm to appropriate the knowledge. Reasoning that knowledge spillovers to other market actors may occur, firms often intend to protect their knowledge and consequently prohibit scientists to publish research results. Thus, intellectual property right issues can play a role as scientists must delay publication of new findings. However, B. Hall et al. (2001) show that when research results are uncertain, intellectual property rights and hence appropriation are less likely to be an insurmountable issue. When research outcome is uncertain, there is also a certain probability of finding fundamentally new results. In spite of the risk of getting no new result at all, this attracts some scientists as they are seeking for radically new results. Cooperation may also be valuable for scientists as they may learn new methods or techniques from firm employees that they can apply in their work. Nevertheless, scientists may restrain from R&D cooperations due to concerns about the appropriability. Stephan (1996) has analyzed the economic value of scientific discoveries which clearly shows that in science a 'winner takes all'-reward structure is common. The first one to publish gets credited for the new result. Therefore, scientists are incentivized to publish as soon as possible.

Scientists might also be motivated to diffuse their knowledge, as they regard the creation and diffusion of knowledge as the main task of scientific work. As many universities and research organizations are publicly funded, scientific research results are often seen as a public good. Such a view on the role of science may keep scientists from cooperating with private firms even if they feel that their results have commercial potential. B. Hall (2004) points out that there are two worlds of science. On the one hand, research is assigned to support regional firms, while on the other hand, research excellence is often evaluated in publication record. Regarding the different incentives of fast publication and free diffusion, we predict that scientists are less likely to engage in research cooperations when they want their research results to be made available to anyone.

2.3 Scientific environment

Peer effects, scientists' field of research and the applicability of results may also influence cooperation behavior. Science is often divided into basic and applied science. Jensen et al. (2003) model it as a strategic decisions by scientists to allocate time to perform basic or applied science. Performing basic science accumulates to a greater extent to the knowledge stock and the prestige of scientists, whereas applied science as patent licensing increases income in the given time period. Thus, at a given time, some scientists may chose to accumulate knowledge at some career stages while others use existing knowledge and try to commercialize it.

With respect to cooperation behavior, the nature of science and the preference to do applied science may effect scientific cooperation behavior. If scientists work in research groups concentrating on basic science, their research may not be applicable for industrial needs. While it is difficult to measure to what extent research is applied or basic, it is possible to identify to what extent scientists believe that their research is applicable. We predict that scientists find cooperation less attractive and are less likely to engage in research cooperations if they identify their own research as too basic to be commercially valuable.

Apart from individual scientist's personal assessment of their research, commercialization efforts of peers working in the same research field can also affects scientists cooperation decision. Scientists may adjust their own commercialization and cooperation behavior to the degree other researchers within their scientific community partake in commercialization efforts. Azoulay et al. (2007) show that magnitude of patenting is positively related to patent output of coauthors. This indicates that scientists adapt a commercialization attitude that is common among peers working in the same field. Our prediction is that scientists find cooperation more attractive and are more likely to engage in research cooperations if they perceive commercialization to be common in their field of research.

Peer pressure to cooperate with private partners may also stem from institutional culture. Previous research indicates that scientists are more likely to be entrepreneurial if peers within their field are entrepreneurial (Stuart & Ding, 2006). Peers can function as role models, stimulating commercialization by setting examples. Several studies point out that researchers are more likely to start companies or disclose inventions if they trained at institutions with a history of successful commercialization efforts (Bercovitz & Feldman, 2008). Our assumption is that this role model effect does not only hold for entrepreneurship and patenting output, but also for the cooperations with private firms. Therefore we predict, that scientists cooperation behavior is adapted to colleagues behavior at the same institute.

2.4 Changing Incentives Over A Scientist's Life Cycle

Scientists' incentives to engage in cooperations with private firms are likely to change over the a scientist's life cycle. When scientists begin their academic career they primarily strive to write and publish articles. The more papers a scientist manages to publish in highly ranked journals, the higher is her or his reputation within the scientific community. In order to be able to publish as many articles as possible, scientists often build up a scientific network as research collaborations with other scientists help to increase scientific productivity (Lee & Bozeman, 2005). Focusing on publication output and building a network within the scientific community is pivotal for young scientists to establish prestige and to become acknowledged by leading researchers.

Over the life cycle of their academic career scientists' incentives may change and scientific productivity becomes less important. Levin and Stephan (1991) analyzed the publication output of researchers in different disciplines over time and identified aging effects in all fields save particle physics. Thus, despite of having a comprehensive network of coauthors and potentially interdisciplinary knowledge, older scientists publish less than younger ones. As prestigious researchers are more likely to extract rents from their intellectual capital, they may use other channels to transfer their knowledge. They may found new companies as depicted by Zucker, Darby, and Brewer (1998) in the case of biotechnology to extract such monetary rents. Apart from starting new firms, prestigious researchers may also collaborate with existing firms. As collaborative research with prestigious scientists increases the probability of firm success (Zucker, Darby, & Armstrong, 2002), it is profitable for firms to pay high remunerations for star scientists. Thus, once a researcher has managed to build up a reputation, there are possibilities of financially exploiting the knowledge gained in science. Therefore we predict that scientists in high positions are more likely to cooperate with private firms.

Scientists' attractiveness of research cooperations is predicted to reach two peaks with respect to career positions, as directors and Ph.D. students be highly attracted for different reasons. The aforementioned possibility for directors to financially exploit their knowledge and their star status it is intuitive to predict that directors are also highly attracted to cooperating with private partners. Since we analyze scientists in Germany, Ph.D. students are also predicted to be highly attracted to partake in cooperative research with private firms. This prediction is due to the fact that in Germany a Ph.D. degree often implicitly helps getting high positions in private firms. Only about one tenth of awarded doctorates become professors (Schomburg & Teichler, 2006). Many young scholars take on jobs in the private sector after they finished the doctorate degree. For this reason we predict that doctoral students are highly attracted to cooperations with private firms as those firms possibly constitute potential employers.

2.5 Summary of Predictions

Table 1: Scientists' incentives to perform cooperative research with private firms

- Predictions how Scientists Incentives relate to their cooperation behavior

Scientific perception	Cooperation Attractiveness	Cooperation Experience
Cooperation Attractiveness		+
Advantages of Commercialization		
Commercialization increases scientific reputation	+	
Commercialization activities are financially beneficial	+	
Disdvantages of Commercialization		
Starting commercialization activities is associated with high costs	-	
Commercialization activities reduce time for own research	-	
Commercializing research reduces diffusion of knowledge	-	
Scientific Environment		
Group's research is too basic to be commercially successful	-	-
Within research field it is common to commercialize research	+	+
Institutes share of cooperators	+	+
Personal characteristics		
Holding *director* position	+	+
Being *Ph.D. student*	+	

3 Data

3.1 The Max Planck Society: Institutional Background

The dataset is based on a survey of scientists working at research institutes the Max Planck Society (MPS) in Germany. The latter plays a special role in the German innovation system. Research institutes of the MPS focus on basic research and they are fully (100%) government-financed. In contrast, other scientific institutions, like the research institutes of the Fraunhofer Society are engaged mainly in applied research and are partly financed by contract research. The German universities have a middle position. Thus, in principle unlike scientists from other scientific institutions, MPS scientists do not rely on external financing and are therefore not forced to cooperate with industrial partners.

Academic freedom of researchers is emphasized by MPS and supported by the institutional design of MPS institutes. In order to promote scientists, the Max Planck Society follows the so-called Harnack Principle.[2] MPS institutes are established only where the world's leading researchers are found and directors of MPS institutes are free to choose their research topics and make decisions about resource allocation. This may explain why MPS scientists have a lion's share in Germany's Nobel prizes awarded after World War II.

MPS institutes further promote scientific excellence by taking up particularly new and innovative research fields. Science in these fields is pursued independently, regardless of whether or not special resources are required, be they of a financial or temporal nature. Thus, the MPS complements German universities which do not yet have the requisite organizational structure necessary to undertake such research. The range of MPS research topics is constantly being refined, with new institutes being established to find answers to seminal scientific questions. To maintain a desirable balance, other institutes are closed when appropriate, for example, when their field of research matures enough to be taken up by the universities. This continuous process of renewal provides the Max Planck Society the scope it needs to respond quickly to new scientific developments.

The MPS currently maintains more than 9,000 scientists working at 80 institutes in various research fields. Each institute has a special statutory task be it

[2]This principle dates back to theologian Adolf von Harnack who was the first President of the Kaiser Wilhelm Society, the predecessor of the Max Planck Society.

to research the structure of matter, the function of our nervous system, or the birth and development of stars and galaxies. Max Planck Institutes work largely in an interdisciplinary setting and in close cooperation with research institutions in Germany and abroad to generate cutting-edge knowledge and technological breakthroughs and to produce highly qualified, internationally competitive junior scientists and researchers. The Max Planck Institutes are classified by the Society in three different sections: the Biology and Medicine Section, the Chemistry, Physics and Technology Section and the Humanities Section. Research fields within the Biology and Medicine Section include genetics, infection biology, cognition research and neuroscience among others. Astrophysics, material sciences, climate research and energy and plasma physics are the core fields of the chemistry, physics and technology section. Humanities research within the MPS mainly focuses on cultural studies, jurisprudence and social sciences.

Although the MPS consists of many very different institutes, the institutional setting is the same throughout. All institutes select and carry out their research autonomously and independently within the aforementioned scope of the MPS. Each institute administers its own budget which can be supplemented by third-party funds. Leading researchers from outside the MPS are appointed as directors of MPS institutes, the majority coming from abroad. Research results are made public and accessible to all enabling an external committee of experts to regularly (usually once in two years) evaluate the research going of MPS institutes.

The identical structure of MPS institutes allows us to analyze the cooperation behavior of scientists working in various field of basic research but under a similar institutional setting. Moreover, MPS institutes are funded entirely through government and therefore scientists of the Max Planck Society are not forced to engage in cooperative research to finance their research budget but can decide whether they want to cooperate with firms or not.

3.2 The Max Planck Scientists Survey (MPSS)

In order to survey the scientists of the Max Planck Society, we contacted the executive directors and heads of administration of the 80 MPS institutes and asked for permission to survey the scientists in their institute. Out of the 80 institutes, 67 allowed us to perform our survey at their institute and provided us with the contact phone numbers of their scientists. Our population for the survey consisted of 7,808 scientists working for 67 different MPS institutes. Included in the population were scientists with and without doctoral degrees.

The survey was conducted by TNS Emnid GmbH, a professional opinion research institute. The survey questions were given in German and English. To check for possible interpretation errors and mistakes, a pilot study was conducted with randomly contacted scientists of other research organizations in Germany. Additionally the survey was proofread and controlled by several scientists and non-scientists fluent both in English and German. After completing the pilot studies, TNS Emnid GmbH performed the survey by conducting phone interviews with the scientists. Every scientist was contacted by phone three times over a period of eight weeks. If a scientist was not reached after the third call, she or he was dropped from the study. As participation in the survey was voluntary a contacted scientist could either refuse to participate at all or skip specific questions. Questions on the survey covered four topics: commercialization activities, entrepreneurial activities, perceptions of commercialization activities and the role of science in general as well as individual demographic information.

The dataset includes data from 2,604 conducted interviews. Institutes vary greatly in size, and consequently the number of responses per institute also varies. The number of potential interviewees per institute ranges from eleven to 465 while the number of completed interviews ranges from four to 139. The response rate per institute ranges from 7% to 61%.

3.3 Definition of variables

3.3.1 Attractiveness of Cooperations with firms

In the questionnaire cooperative research with firms was defined as either joint research ventures, contract research or cooperative research on research projects. The attractiveness of research cooperation with private firms is measured by the answer to the following question: "*To what degree is cooperative research with private firms an attractive idea to you? Would you say 1: not attractive at all, 2: not attractive, 3: neutral, 4: attractive, 5: highly attractive?*,".

Moreover, the surveyed scientists were asked the following question: "*Have you ever cooperated or are you currently cooperating on research with or for private firms in the private sector.*" In the second step of our analysis we use as our dependent variable a dichotomous variable, indicating experience in cooperative research with private firms (coded as 1) or not (coded as 0). In order to create indicators for a "cooperation culture" for each of the Max Planck Institute in our sample, we computed the institutional means of the cooperation attractiveness score and additionally the share of cooperators at each institute.

3.3.2 Advantages and Disadvantages of commercialization activities from Scientists' point of view

In order to analyze the factors that may influence the attractiveness of cooperations with private firms, we use the scientists' assessment of several statements concerning commercialization activities. Before scientists were asked whether they agree or disagree with these statements the following explanation was provided: "*We would like to consider factors influencing commercialization activities of research. By commercializing we include patenting results, research collaboration with the private sector, consulting activities and starting businesses. In case you have experience with such activities, please give a general answer and do not evaluate a specific research project. In case you do not have any experience, please indicate your personal presumption. For the following statements please indicate to what degree you agree or disagree with the statements on a scale from 1 to 5; 1 meaning "strongly disagree", 2 "disagree", 3 "either", 4 "agree", and 5 "strongly agree"."*' These 5-point Likert-scales are used as indicators. Note that scientists with and without experience in the commercialization of research results assessed the statements. Hence the statements do reflect the scientists' opinions about commercialization activities which may not necessarily match with "'the reality"'. However, for the attractiveness of cooperation scientists' subjective perceptions are relevant and not more "'objective"' measures. Hence, the scientists' answers to these questions allow us to analyze the perceived magnitude of benefits and costs from commercialization activities.

Advantages of commercialization activities: According to the literature reputation effects of commercialization activities may influence the attractiveness of cooperation with private firms. The measure of *reputation & recognition effects* of cooperations with private firms are measured by might be a major benefit from cooperation. We used the scores of the following question to compute an indicator for the reputation effects of commercialization activities:"Commercialization activities increase the reputation of a scientist in my scientific community". High values imply that relevant benefits from cooperation may be the 'scientific reward' of a higher reputation. Moreover, *financial benefits* from commercialization activities may be relevant. The scores of the following question are used as an indicator for such benefits:t "There is little, if any, money to be made from commercialization" . We rescaled the score so that a higher value means that financial benefits from commercialization activities are high.

Disadvantages of commercialization activities: Two statements in the questionnaire directly reflect costs associated with commercialization efforts: 1) "The costs of commercialization, such as time costs, patent application fees, or fees associated with starting a business, are very high" and 2) "Commercialization activities are time consuming and reduce time for my research". While the first indicator measures potential costs of commercialization, the second indicator reflects a possible negative impact of commercialization activities on time for own research. In addition, firms may find cooperation less attractive because cooperation may inhibit the diffusion of their research results. In order to measure their preference for open science and diffusion of knowledge the score of the following question is used: "Your research results should be freely available to any other researchers and businesses". The higher the score the higher the costs of cooperation in terms of loss of a scientist's utility due to less knowledge diffusion.

3.3.3 Scientific environment

A scientist's the attractiveness of cooperations with private firms and the decision to cooperate with them might be influenced by the scientific environment and "'commercialization culture"' in a scientist's field of research, at the respective Max Planck Institute or within the research group. As the measure of addition to potential costs the nature of research and the work environment of scientists might also partly determine her or his research cooperation behavior.

Group environment: An scientist's assessment of the following statement is used to measure the effects of the scientific environment of a research group: "My research group focuses on basic research which is not suitable for commercialization" It does not matter whether the answer reflect the objective this statement

Field environment: In order to control for effects scientific community we used the score of this question: " Commercialization activities are common in my scientific community[7].

Institute environment: We computed two indicators for the environment at each of the Max Planck Institutes in the sample. The first indicator is the mean of the attractiveness scores at the institute level. Since this measure is corrected for the attractiveness of the respondents it reflects the attractiveness of cooperation for the other scientist working at the same Max Planck Institute. The second indicator was computed in the same way. It is the an institute's share of scientists with cooperation experience. Again it corrected and does therefore only reflect the cooperation behavior of other scientists at the same institute.

3.3.4 Personal characteristics

The questionnaire does also contain information about the personal characteristics of scientists. These demographic variables include age, former work experience in industry, gender, and section and position at the Max Planck institute. The latter control is measured by distinguishing between Ph.D. students, postdoctoral research fellows and directors of research groups with the help of three binary variables indicating whether a respondent is a PhD student, a group leader or a director. Our gender and citizenship variables are binary, taking a value of 1 if the respondent is female and 0 if not; 1 if German and 0 if not. Work experience in industry is measured as a binary variable indicating experience in the private sector (coded as 1) or no experience (coded as 0). Moreover, section dummies are used. Two binary variables indicate by a code of 1 that a scientists belongs to the Biology and Medicine section or the Chemistry, Physics and Technology section. Additionally, we constructed a variable which measures the number of years a scientist has worked for the Max Planck Society divided by the scientist's age.

3.4 Descriptive Statistics

The scientists in our sample represent different career stages: about 40% are doctoral students, 27% are postdoctoral students, 15% are either group leaders or professors, and 2% are a director of a research department or institute. Additionally, the Max Planck Society employs scientists from many different countries. While 60% are German, 15% have citizenship of a different European country, 3.5% originate from China and 2.8% are from India. U.S. Americans or Russians each account for 2.5% of the sample.

In regards to the attractiveness of cooperation with firms we distinguish between scientists with and without cooperation experience. Figure reffigure reports the distributions of cooperation attractiveness for scientists without cooperation experience (upper figure) and for scientists with cooperation experience (lower figure). These figures show that for scientists with cooperation experience, the attractiveness of such cooperations is higher. Mean attractiveness is 3.23 for the scientists without cooperation experience and 43.2 percent of them answered that cooperation is either "highly attractive" or "attractive". Mean attractiveness is 3.72 for scientists with cooperations and 59,1 percent find cooperation "highly attractive" or "attractive".

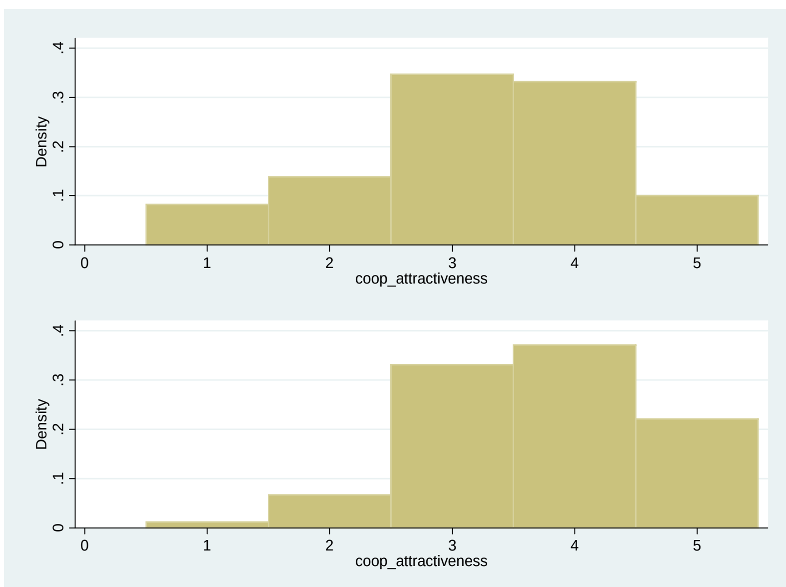

Figure 1: Attractiveness of Cooperations with private firms

4 Empirical Analysis

In this section we discuss the empirical model, used to analyze the determinants of cooperation behavior of scientists, and present the estimation results. As our empiricial approach consists of two stages of analysis, we first explain our model and estimating cooperation attractiveness of scientists and its results. We subsequently reason our model examining scientific engagement in research cooperation. Our analysis concludes with interpretating the results of the latter model.

4.1 Attractiveness of research cooperations with private firms

First, we analyzed the factors that may influence the attractiveness of cooperation with private firms. Since the dependent variable, the attractiveness of cooperation, is an ordinal variable (5 point Likert scale) we make use of an ordered probit model. Our explanatory variables include all of the aforementioned variables relating to advantages and disadvantages commercialization activities, scientific environment and personal characteristics.

$$\begin{aligned} Attractiveness_i^* \quad = \quad & \alpha + \sum_{j=1}^{J} \lambda_j Advantages_{ji} + \sum_{k=1}^{K} \gamma_k Disadvantages_{ki} \\ & + \sum_{l=1}^{L} \gamma_l Scientific\ Environment_{li} \\ & + \sum_{m=1}^{M} \delta_m Personal\ Characteristics_{mi} + \varepsilon_i, \end{aligned}$$

The estimation of the ordered probit model is based on the assumption that observations are independent across the scientists. However, scientists belonging to the same Max Planck Institute may share similarities which violate the assumption of independent observations. Hence, robust standard errors are reported which correct for clustering effects.

Estimation results of the ordered probit regression are reported in Table 2. As can be seen from the table the influence of reputation is positive and statistically significant at the one percent level. Scientists find cooperation more attractive if they think that commercialization activities tend to increase a scientist's reputation. In contrast financial benefits from commercialization do not increase attractiveness. Perceived costs of commercialization have a positive influence attractiveness and the estimated coefficient is also significant at the one percent level. This may suggest that cooperation is attractive since it allows for sharing costs with private firms. The negative impact of cooperation on time for own research makes cooperation less attractive although the estimated coefficient is only significant at the 10 percent level when controls for scientific environment and personal characteristics are included. The same is true for the indicator that reflects the preference for open science or diffusion of own research results. Scientist that prefer free diffusion of knowledge find research cooperations with private firms less attractive.

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insert table 2 about here

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Scientific environment plays an important role. The estimated coefficients of all indicators for scientific environment are highly significant. Scientists who report that the research of their group focuses on basic research which is suitable for commercialization find cooperations with private firms less attractive. If they report that commercialization activities are common in their scientific community cooperations are more attractive. Moreover, the scientist find cooperation more attractive if their colleagues at the same Max Planck Institute find cooperation more attractive which my point to the existence of a institute-specific "commercialization culture"'.

Personal characteristics do not have a strong impact on the attractiveness of cooperation. Only the estimated coefficients of age, the dummy of work experience in private firms, and the dummy for German scientists are statistically significant. The estimated of age is negative and weakly significant implying that older scientist, other things equal, find cooperations less attractive. Scientists who worked in private firms before they came to Max Planck Society find cooperation with firms more attractive than other scientists. Moreover, cooperation with private firms seems to be less attractive for scientists with German citizenship. The estimated coefficient is negative and statistically significant at the one percent level.

In order to check the robustness of the estimation results we investigated whether the results hold for sub-samples. The results are reported in Table 3.

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insert table 3 about here

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Column (1) reports on the results for scientist who do not have any cooperation experience whereas Column (2) reports on the results where only scientist with cooperation experience are included in the estimation. The sign of the estimated coefficient is the same for almost all of the variables. However, among scientists with cooperation experience the expected reduction of time for own research has a negative and statistically significant influence whereas this estimated coefficients of this variable is significant for the group of scientists without cooperation experience. This may imply that scientist with cooperation experience are better informed about this "negative" effect of cooperations with private firms. However, the fact that a scientist thinks that commercialization is common in his or her scientific field of research does only have a positive effect if scientists do not have any cooperation experience. Columns (3) and (4) report the estimation results for the sub-samples of PhD students and scientists who already have their PhD. Again, reputation effects of commercialization activities have a positive impact on attractiveness of cooperation for both groups of scientists. In contrasts, the estimated coefficients of variables reflecting disadvantages of commercialization activities have the same signs for both groups although the absolute values are higher for scientist with a PhD. Moreover, the estimated effects of disadvantages of commercialization activities are statistically insignificant for the group of PhD students, whereas these effects are statistically significant at the one and five percent level for scientists with a PhD.

The estimated coefficients of the variables reflecting scientific environment are statistically significant for all sub-samples which confirms the relevance of group, field and institute effects for the attractiveness of cooperations with firms. Among the personal characteristics work experience in industry and German citizenship seem to be important. The former has a positive and significant effect for the sub-sample of scientists with cooperation experience and scientists with having a PhD. Being German has a negative and statistically significant effect in three of four estimations.

4.2 Empirical analysis of engagement in research cooperation

Next we analyzed to what extent attractiveness of cooperation drives the actual participation in research cooperations. The following probit model was estimated:

$$
\begin{aligned}
I_i^* &= \mu + \beta\ Attractiveness_i + \sum_{l=1}^{L} \gamma_l Scientific\ Environment_{li} \\
&\quad + \sum_{m=1}^{m} \delta_m Personal\ Characteristics_{mi} + v_i, \\
I &= 1 if I_i^* > 0 \quad and \quad I = 0\ otherwise,
\end{aligned}
$$

where v_i ($\sim N(0, \sigma^2)$) is the error term and *Attractiveness* represents the attractiveness of a research cooperation with a private firm and β is the parameters which reflects the impact of attractiveness on a scientists's probability of cooperating. Again, we control the scientific environment and the personal characteristics of scientists. Hence, attractiveness of cooperation reflects the advantages and disadvantages of cooperation discussed in the previous section. Clustering (institutes) is taken into account to estimate robust standard errors.

Estimation results of probit regressions are reported in Table 4. The estimated coefficient of the variable of attractiveness is positive and highly significant. Comparison of columns (1) and (2) shows that the inclusion of this variable leads to a much better fit. The results suggest that scientist who find cooperation attractive do also have a higher propensity of being engaged in cooperations. In Column (3) the variables reflecting the focus of the scientist's research group and commercialization activities in her research field are included. The estimated marginal effects have the expected sign and are highly significant. Column (4) takes into account the effect of cooperation experience of other scientists working at the same Max Planck institute. The estimated marginal effect is positive and statistically significant which implies that a higher the share of colleagues with cooperation experience increases the probability of being engaged in cooperations. Hence, scientific environment at the group, field and institute level seems to be important for a scientist's decision to cooperate.

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insert table 4 about here

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According to the estimation results, personal characteristics are relevant, too. Moreover, cooperation is more likely the longer a scientists worked for Max Planck Society relative to her age. Work experience in industry has a positive and significant effect. A scientists who worked in industry has a more than 30 percent higher probability of having cooperation experience with private firms. Furthermore, career stage is important. Group leaders and Max Planck directors have a (20 percent) higher probability of having cooperation experience with private firms. Females are less likely to have cooperation experience. Surprisingly, German citizenship has now a positive statistically significant effect on the probability of having cooperation experience whereas the effect of German citizenship on attractiveness was negative. This implies that Germans are more likely to be engaged in cooperation with firms although they find them less attractive.

As a check of robustness, we performed additional regression where we used a dummy variable of attractiveness which takes the value one if a respondents reports that the cooperation with a firm is attractive or very attractive and zero otherwise. Moreover, we performed regressions based on sub-samples. The estimations results of these regressions are reported in Table 5. Again the estimated coefficient of the dummy variable of attractiveness is positive and highly significant in the regression based on the whole sample (column (1)).

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insert table 5 about here

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Note that the table reports the marginal effects the estimated coefficient of the attractiveness variables which implies that the probability of being a cooperator is 12,2 percent higher for scientists who find cooperation attractive or very attractive as compared to scientist that find cooperation less attractive. Estimation results based on regressions using sub-samples, only PhD students (Column (2)), exclusion of PhD students (Column (3)), and exclusion of scientist's without working experience in industry (Column (4)) show that the marginal effect of "high attractiveness" is of positive and statistically significant. However, the order of magnitude of the estimated effect differs between sub-samples. The marginal effects is higher for the group of scientists with a PhD than for the group of PhD students. The difference is also statistically significant. The estimated effects of variables reflecting scientific environment and personal characteristics are similar.

A problem of our approach might be the potential endogeneity of the attractiveness of cooperation with respect to cooperation. One might consider the dependent binary variable “cooperation” as simultaneously determined with the variable “attractiveness” or the dichotomous regressor “attractiveness high”. Scientists with cooperation experience, for instance, may find cooperation more attractive than other scientist. If this were the case our estimates would be biased because of endogeneity of variables.

To deal with this problem we estimated an instrumental variable probit. Therefore, we make use of two additional instrumental variables that do not have a direct influence on the probability of having cooperation experience but do affect the attractiveness of cooperation. The first variable is the attractiveness of cooperation at the institute level which we used as an explanatory variable in the ordered probit regressions for the attractiveness of cooperation. The second instrumental variable we used is the risk attitude of scientist. We argue that the attractiveness of cooperation is related to scientists’ risk attitude. The more riskaverse a scientist is, the lower is her perceived attractiveness of cooperation with firms. Our measure of risk is adopted from the Social Economic Panel in Germany. Respondents hypothetically won in a lottery and were confronted with a financially risky yet lucrative investment. They can either invest nothing, 20 %, 40 %, 60 % or 80 % or 100 % of their lottery winnings. We created a dummy for each of the answers.

Estimation results of the instrumental variable regression (second stage) are reported in Column (1) of Table 6. As can be seen from the table, the estimated coefficient of the attractiveness variable is still positive and statistically significant. Moreover, a Wald test of exogeneity suggests that the null hypothesis of exogeneity is rejected. However, this estimation is based on the assumption that the endogenous variable is continuous, whereas the measure of attractiveness is a ordinal variable.

We therefore performed an additional analysis based on the potentially endogenous dummy variable “high attractiveness”. Recently, (Monfardini & Radice, 2008) have proposed a test of exogeneity of a dichotomous regressor which is based on the estimation of a recursive bivariate probit model. In our case this model consists of a reduced form equation for the potentially endogenous dummy variable “attractiveness high” and a structural form equation for cooperation with private firms. It is tested whether the correlation between the residuals of these equations is zero which is the null hypothesis (exogeneity). In principle, formal identification of the recursive bivariate model does not require additional exogenous regressors (instruments) if there is sufficient variation in the data Wilde (2000). However, (Monfardini & Radice, 2008) show that instruments are important because they preserve the validity of the LR testing approach in the presence of misspecification.

The results are reported in Column (2) of Table 6. Test of exogeneity do again suggest that endogeneity of attractiveness might be a problem since the Likelihood ration test rejects the null hypothesis of exogeneity. However, estimation results show that the estimated effect of the dummy variable "attractiveness high" is still positive and statistically significant even if one takes into account endogeneity. Hence, the results of instrumental variable estimations are in line with our previous results.

5 Discussion

Our analysis suggests that scientists carefully appraise costs and benefits of engaging in research cooperations with private firms. Both, perceived advantages and disadvantages of commercialization activities significantly influence to what extent cooperative research is attractive from scientists' point of view. Cooperation attractiveness is a key determinant of cooperations. Therefore, scientists perceptions on advantages and disadvantages moderate their actual decision to pursue joint research with industrial partners. Peer effects within the scientific community and on an institutional level are crucial influences on both, the attractiveness as well as the actual engagement in research cooperations. Personal characteristics are found to have a significant influence on magnitude of cooperations, while only age and German citizenship impact its attractiveness.

Interestingly, regarding advantages and disadvantages of commercializing research, non-monetary costs and benefits significantly influence cooperation behavior, while monetary rewards do not. Our indicator for *reputation & recognition* effects is a positive and highly significant factor explaining cooperation attractiveness in the total sample, and also in all tested subgroups. In subsamples of experienced scientists, indicators on time effort and concerns about constraints on knowledge diffusion are found to reduce research cooperation attractiveness. This is result holds for scientists experienced in cooperations, as well as scientists holding a Ph.D. degree. In both groups, researchers find cooperations the less attractive the more they perceive that commercialization activities reduce their time for own research. In the subsample of all post-doctoral researchers we also find that the more scientists intend to diffuse their knowledge, the less attractive they find cooperations. Financial benefits have no significant relation to cooperation.

The finding that scientists are more likely to engage in research cooperations, if they value costs of commercialization as high. We interpret this finding as an indicator, that scientists with cooperation experience find it attractive to do joint research with private firms in order to share the high cost of commercialization activities. Note that the measure of the cost of commercialization does not only reflect cost of cooperation but also scientists' perception about cost of other commercialization activities, like cost of patenting or cost of starting a business. Hence, cooperations with firms may be viewed as a less costly way to commercialize knowledge as compared to own patenting activities or starting a business. This interpretation fits the result that high costs have the strongest positive relation in the the subsample of experienced researchers. As existing literature indicates, the cost sharing motive is also one of the most important incentives for private firms to engage in cooperation with public science institutions. Hence, interests of firms may be here in line with those of scientists.

Cooperation behavior of peers is found to have a striking influence on scientists' own cooperation behavior. All three variables representing the scientific environment are highly significant determinants of cooperation engagement and its attractiveness. As predicted, scientists are less likely to value cooperations as attractive and to partake in joint R&D, if they view the research their research group as too basic to be commercialized. Our indicators of institutional attractiveness and the common use of commercialization activities in scientists' research community positively drive cooperation behavior. Theses findings stress the high influence of peer groups. Scientists seem to transfer their knowledge in similar ways as their peers do and the "commercialization culture" at the level of Max Planck institutes seems to be very important.

Further, our results suggest that experience and research expertise explain the extent of cooperation engagement. Various variables measure of expert knowledge and experience, namely age, being director or group leader, work experience in the private sector as well as the share of lifetime they were employed by their MPS Institute. All measures are positive and highly significant indicators of research cooperations. Thereby, our analysis shows that 'expert knowledge' is a better predictor of successful commercialization than the standing as a 'star scientist'. The positive and significant effect of expertise is not limited to directors, it also includes other experienced scientists. This opens up a new research window as it rephrases the question of the relation of star scientists and commercialization success.

Citizenship and gender also influence the cooperation behavior. Females are less likely to engage in research cooperations, although they do not find cooperations significantly less attractive. This finding suggests that low female participation in commercialization activities has different reasons than preference. Interestingly, German researchers find cooperations significantly less attractive, while having a significantly higher probability of being engaged in cooperations than their non-German reference group. One explanation for the high share of German cooperators are networks effects. Germans simply do not have a language barrier, they may well have a better understanding about firm culture in Germany as well, and may therefore be better integrated in (local) research networks. This reasoning, however, does not explain why Germans find cooperations less attractive than their foreign peers. Seemingly, Germans focus on research and would like to distinguish research from potential application to a greater extent than foreigners.

In sum, our analysis shows that personal perceptions about advantages and disadvantages of commercialization activities, peer behavior and expertise predict scientists attractiveness of cooperations and cooperation behavior. Our prediction that financial rewards also drive cooperation attractiveness is rejected. From a R&D manager's point of view, these results are of high interest. From firms' perspective, working with prestigious scientists can serve as a role model attracting other scientists, while monetary rewards are less capable of doing so. This study also reveals, that researchers view on the nature of science and their preference to diffuse knowledge impede on cooperation behavior. Thus, in order to foster academic interest in joint R&D with private partners, scientific benefits from cooperations need to be institutionalized. The authors encourage further researchers in this agenda.

6 Conclusion

In this paper we analyzed the attractiveness of research cooperation with private firms from the point of view of scientists. We argued that attractiveness of cooperation is affected by potential advantages of commercialization activities, like reputation effects or monetary rewards, as well as by potential disadvantages of commercialization activities, like less time for own research or restriction on the dissemination of scientists' research results. We made use of a new dataset that contains information about scientists attitudes toward commercialization activities in general and research cooperation with private firms in particular. Our study is based on a sample of more than 2000 scientists working at the various institutes of the Max Planck Society in Germany.

Our results suggest, that scientists' face several trade-offs when deciding about engagement in such cooperations. On the one hand, research cooperations are attractive if they increase a scientists reputation. Our results suggest the expected reputation effects have a positive and statistically significant impact on attractiveness of cooperation. Moreover, we found some evidence that sharing costs of commercialization activities between firms and scientists makes cooperation more attractive. On the other hand, the reduction of time for own research due to engagement in cooperation and concerns about reduced dissemination of scientists' research results make cooperation less attractive. Our results are relevant for the design of research cooperation between firms and scientists. While there is no conflict of interest between firms and scientists with respect to reputation and cost sharing motives, there is surely a conflict with respect to the time demanded for cooperation and the restriction regarding the confidentiality of results of joint research.

Moreover, our results show that the probability of cooperating with private firms is indeed positively affected by the attractiveness of such cooperations. Besides the attractiveness, scientific environment as well as personal characteristics influence the probability of being engaged in cooperations. We identified effects of scientific environment at different levels, namely the level of a scientist' research group, Max Planck institute and field of research. Controlling for attitudes toward commercialization, personal characteristics, and effects of scientific environment, we found that scientists find cooperation more attractive and are more likely to be engaged in cooperations if their colleagues at the same Max Planck institute find cooperation more attractive, too. This my point to a "commercialization culture" at the institute level that encourages scientists to engage in cooperations.

Moreover, personal characteristics, like experience and career stage are important. One interesting find is that Germans don't like cooperation but have a higher probability of cooperating with private firms.

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7 Appendix

Table 2: Determinants of the Attractiveness of Research Cooperations with Private Firms: Results of Ordered Probit Estimations

	(1)	(2)	(3)	(4)
Advantages of commercial.				
Reputation & Recognition	0.251***	0.237***	0.235***	0.235***
	(0.0234)	(0.0242)	(0.0245)	(0.0247)
Financial benefits of comm.	0.0204	0.0185	0.00759	0.00691
	(0.0300)	(0.0299)	(0.0314)	(0.0314)
Disadv. of commercial.				
Costs of commercialization	0.0754***	0.0613**	0.0931***	0.0899***
	(0.0288)	(0.0292)	(0.0309)	(0.0307)
Less time for own research	-0.0697**	-0.0753**	-0.0597*	-0.0591*
	(0.0306)	(0.0316)	(0.0322)	(0.0324)
Less knowledge diffusion	-0.0604**	-0.0433	-0.0439*	-0.0442*
	(0.0269)	(0.0278)	(0.0259)	(0.0257)
Scientific Environment				
Group - basic research focus	-0.148***	-0.132***	-0.134***	-0.135***
	(0.0225)	(0.0215)	(0.0214)	(0.0213)
Field - commercial. is common	0.144***	0.117***	0.101***	0.0985***
	(0.0225)	(0.0240)	(0.0233)	(0.0237)
Institute - attractiveness of coop.		0.455***	0.475***	0.412***
		(0.0736)	(0.0704)	(0.0737)
Personal characteristics				
Log age			-0.186*	-0.181*
			(0.0998)	(0.0984)
Worked in industry			0.166**	0.171**
			(0.0716)	(0.0720)
German			-0.249***	-0.248***
			(0.0604)	(0.0617)
Female			-0.0110	-0.0109
			(0.0546)	(0.0551)
Post-doctoral fellow			-0.0305	-0.0332
			(0.0587)	(0.0590)
Group leader			-0.0617	-0.0656
			(0.0807)	(0.0808)
Director			0.0343	0.0414
			(0.163)	(0.163)
Section dummies	-	-	-	YES
Pseudo R	0.0618	0.069	0.0769	0.0777
Likelihood	(7) 356. 72	(8) 400.15	(15) 444.17	(17) 448.61

Notes: Robust standard errors which are adjusted for clusters (institutes) are reported in parentheses. The asterisks *, ** and *** denote significant at the 10, 5 and 1 percent level respectively.

Table 3: Detereminants of the Attractiveness of Research Cooperations with Private Firms: Results of Ordered Probit Estimations (sub-groups)

	(1)	(2)	(3)	(4)
Advantages of commercial.				
Reputation & Recognition	0.255***	0.182***	0.194***	0.272***
	(0.0282)	(0.0327)	(0.0335)	(0.0349)
Financial benefits from comm.	0.0188	-0.0138	-0.0260	0.0228
	(0.0345)	(0.0486)	(0.0442)	(0.0427)
Disadv. of commercial.				
Costs of commercialization	0.0703*	0.115*	0.0579	0.123***
	(0.0366)	(0.0632)	(0.0543)	(0.0413)
Less time for own research	-0.0235	-0.146***	-0.0167	-0.0984**
	(0.0349)	(0.0555)	(0.0465)	(0.0446)
Less knowledge diffusion	-0.0163	-0.0630	-0.0202	-0.0636**
	(0.0354)	(0.0388)	(0.0410)	(0.0296)
Scientific Environment				
Group - basic research focus	-0.120***	-0.111**	-0.0865**	-0.175***
	(0.0286)	(0.0473)	(0.0337)	(0.0346)
Field - commercial. common	0.0967***	0.0541	0.0841**	0.115***
	(0.0291)	(0.0458)	(0.0392)	(0.0293)
Insitute - attractiveness of coop.	0.385***	0.291**	0.542***	0.316***
	(0.0849)	(0.123)	(0.0982)	(0.0977)
Personal characteristics				
Log age	-0.165	-0.561***	-0.381	-0.0638
	(0.144)	(0.187)	(0.289)	(0.113)
Worked in industry	0.0153	0.310***	0.0855	0.245***
	(0.0952)	(0.106)	(0.107)	(0.0836)
German	-0.356***	-0.132	-0.258***	-0.277***
	(0.0798)	(0.110)	(0.0830)	(0.0779)
Female	0.0332	-0.0605	-0.0126	-0.000486
	(0.0659)	(0.123)	(0.0717)	(0.0930)
Post-doctoral research fellow	-0.126	0.117	-	-
	(0.0808)	(0.0988)		
Group leader	-0.239*	-0.0444	-	-0.0511
	(0.130)	(0.115)		(0.0797)
Director	0.0729	-0.0128	-	0.0321
	(0.308)	(0.219)		(0.160)
Section dummies	Yes	Yes	Yes	Yes
Pseudo R^2	0.0796	0.0640	0.0650	0.0953
Wald test	$\chi^2(17)$	$\chi^2(17)$	$\chi^2(14)$	$\chi^2(17)$
	630.6***	132.7***	332.9***	630.6***
Observations	1377	672	927	1122

Notes: Column (1): only scientists without cooperation experience are included. Column (2) only scientists with cooperation experience are included. Column (3): only PhD students are included. Column (4) PhD students are excluded. Robust standard errors which are adjusted for clusters (institutes) are reported in parentheses. The asterisks *, ** and *** denote significant at the 10, 5 and 1 percent level respectively.

Table 4: Determinants of the Research Cooperations with private firms - Results of Probit Estimations (marginal effects)

	(1)	(2)	(3)	(4)
Cooperation Attractiveness		0.124***	0.102***	0.0942***
		(0.0108)	(0.0105)	(0.00980)
Scientific Environment				
Group - basic research focus			-0.0431***	-0.0391***
			(0.00860)	(0.00854)
Field - commercial. common			0.0547***	0.0497***
			(0.0116)	(0.0114)
Insitute - share of cooperators				0.383***
				(0.0726)
Personal characteristics				
Log age	0.231***	0.266***	0.271***	0.260***
	(0.0739)	(0.0758)	(0.0790)	(0.0757)
Worked in industry	0.303**	0.327***	0.350***	0.335***
	(0.127)	(0.126)	(0.129)	(0.127)
(Years worked for MPS)/ Age	0.119***	0.0867***	0.0734**	0.0721**
	(0.0286)	(0.0284)	(0.0297)	(0.0305)
German	0.0679***	0.0970***	0.107***	0.105***
	(0.0211)	(0.0212)	(0.0197)	(0.0193)
Female	-0.0518**	-0.0540**	-0.0511**	-0.0553**
	(0.0234)	(0.0253)	(0.0232)	(0.0230)
Post-doctoral research fellow	0.0396	0.0396	0.0303	0.0312
	(0.0274)	(0.0276)	(0.0268)	(0.0268)
Group leader	0.206***	0.218***	0.201***	0.196***
	(0.0383)	(0.0398)	(0.0416)	(0.0392)
Director	0.193***	0.188**	0.161**	0.173**
	(0.0738)	(0.0760)	(0.0735)	(0.0733)
Section dummies	Yes	Yes	Yes	Yes
Pseudo R^2	0.0959	0.1453	0.1693	0.1788
Wald test	$\chi^2(10)$	$\chi^2(11)$	$\chi^2(13)$	$\chi^2(14)$
	209.1***	376.8***	383.8***	510.7***

Notes: Robust standard errors which are adjusted for clusters (institutes) are reported in parentheses. The asterisks *, ** and *** denote significant at the 10, 5 and 1 percent level respectively.

Table 5: Determinants of the Research Cooperations with private firms - Results of Probit Estimations (marginal effects)

	(1)	(2)	(3)	(4)
High Attractiveness	0.122***	0.0984***	0.134***	0.114***
	(0.0196)	(0.0271)	(0.0309)	(0.0192)
Scientific Environment				
Group - basic research focus	-0.0428***	-0.0223*	-0.0593***	-0.0475***
	(0.00823)	(0.0123)	(0.0108)	(0.0104)
Field - commercial. common	0.0553***	0.0586***	0.0461**	0.0651***
	(0.0115)	(0.0129)	(0.0201)	(0.0122)
Insitute - share of cooperators	0.430***	0.185*	0.599***	0.500***
	(0.0728)	(0.108)	(0.0921)	(0.0774)
Personal characteristics				
Log age	0.183**	-0.0596	0.300***	0.259***
	(0.0775)	(0.136)	(0.0916)	(0.0998)
Worked in industry	0.301**	0.513*	0.252*	-
	(0.121)	(0.266)	(0.145)	
(Years worked for MPS)/ Age	0.0808***	0.0478	0.111***	0.302**
	(0.0312)	(0.0404)	(0.0416)	(0.151)
German	0.112***	0.0899***	0.125***	0.0839***
	(0.0187)	(0.0230)	(0.0318)	(0.0213)
Female	-0.0555**	-0.0538**	-0.0507	-0.0560**
	(0.0220)	(0.0239)	(0.0453)	(0.0270)
PhD student	-0.0681**	-	-	-0.0344
	(0.0275)			(0.0302)
Group leader	0.166***	-	0.165***	0.128***
	(0.0374)		(0.0368)	(0.0410)
Director	0.167**	-	0.147**	0.114
	(0.0681)		(0.0713)	(0.0775)
Section dummies	Yes	Yes	Yes	Yes
Pseudo R^2	0.1667	0.1018	0.1678	0.1739
Wald test	$\chi^2(14)$	$\chi^2(11)$	$\chi^2(13)$	$\chi^2(13)$
	396.1***	150.7***	358.5***	310.5***
Observations	2049	927	1122	1654

Notes: Column (1): all scientists included. Column (2) only PhD students are included. Column (3): PhD students excluded. Column (4) Scientists with work experience in industry are excluded. Robust standard errors which are adjusted for clusters (institutes) are reported in parentheses. The asterisks *, ** and *** denote significant at the 10, 5 and 1 percent level respectively.

Table 6: Results of an Instrumental Variable Probit Estimation and the Estimation of a Recursive Bivariate Probit Model

	(1)	(2)
Cooperation Attractiveness	1.011***	-
	(0.0837)	
High Attractiveness	-	1.364***
		(0.158)
Scientific Environment		
Group - basic research focus	0.0718	-0.0368
	(0.0487)	(0.0291)
Field - commercial. common	-0.0288	0.0906**
	(0.0464)	(0.0353)
Insitute - attractiveness	-0.274	0.846***
	(0.427)	(0.238)
Personal characteristics		
Log age	0.583**	0.708***
	(0.231)	(0.212)
Worked in industry	0.563*	0.597*
	(0.316)	(0.360)
(Years worked for MPS)/ Age	-0.0403	0.101
	(0.0899)	(0.0893)
German	0.358***	0.462***
	(0.0701)	(0.0645)
Female	-0.102	-0.144**
	(0.0665)	(0.0686)
Post-doctoral research fellow	0.0805	0.104
	(0.0667)	(0.0782)
Group leader	0.384***	0.539***
	(0.122)	(0.107)
Director	0.250	0.472**
	(0.185)	(0.205)
Section dummies	Yes	Yes
Test for exoneity	Wald-test: $\chi^2(1)$	LR-test $\chi^2(1)$
	9.87***	37.23***

Notes: Column (1) reports the (second stage) results of an instrumental variable probit estimation. Column (2)reports the results of a recursivee bivariate probit estimation. RRobust standard errors which are adjusted for clusters (institutes) are reported in parentheses. The asterisks *, ** and *** denote significant at the 10, 5 and 1 percent level respectively.