A Comparison of Information-Sharing between Scientists in Academia and the Industry

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Abstract

This paper investigates how scientists decide whether to share information with their colleagues or not. Detailed data on the decisions of 1,694 bio-scientists allow us to detect similarities and differences between academia-based and industry-based scientists. In both realms, we find that the likelihood of sharing decreases with the economic value of particular information. Social factors, i.e., expected reciprocity and the extent to which a scientist's community conforms to the norm of communalism, either directly affect information-sharing or moderate considerations of economic interest on information sharing. The effect depends on the system to which a scientist belongs.

Keywords: information-sharing; reciprocity; social norms; bio-sciences; IP protection mechanisms

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1. Introduction

In the normative literature, it is well established that distinct norms, customs and institutions govern academic science on the one hand, and industrial science on the other (Dasgupta and David, 1994). One behavioral aspect in which academic science is expected to differ to a large extent from industrial science is the sharing of information. According to Merton (1973) scientists working for universities are supposed to be guided by the ethos of the unconditional sharing of knowledge. This norm is referred to as "communism" or "communalism". It postulates the common ownership of scientific discoveries, according to which scientists give up IP rights in exchange for recognition and esteem. In contrast, scientists working for companies are expected to be secretive in order to protect the economic gains of research results (Rosenberg, 1990; Dasgupta and David, 1994). However, purposeful withholding of research advances and data has frequently been reported in academic science (Blumenthal et al., 1996; Campbell et al., 2000; Rhoten and Powell, 2007; Walsh et al., 2007), while other studies have documented that company-employed scientists regularly exchange information across organizational boundaries, including with direct competitors (e.g., von Hippel, 1987; Schrader, 1991; Henkel, 2006).

While these studies suggest that in both academic and industrial science there is information-sharing as well as withholding among scientists, the underlying mechanisms on which scientists in either area base their decisions to share or keep back such information are to a large extent unknown. This is surprising, as better knowledge would reveal insights into the tensions that are present in academia and the industry; specifically the tension between open innovation and protecting economic profit in the industrial system, and the tension between progress in public science and individual recognition in the academic system. As such this paper enhances our understanding of the general tension between individual/firm gains versus the public good or advancement of science through information sharing behavior. In addition, deeper insights into this topic would extend our understanding of the organizational culture differences between these two systems.

The few available empirical studies mostly focus on how individuals employed in firms behave with respect to information-sharing. Von Hippel (1987) and Schrader (1991) report that researchers in the specialized steel industry share information if it does not affect negatively the economic interest of their firm, i.e., if sharing is likely to harm the economic interest of their employer, they keep information secret. Criticizing the design of these studies and conclusions for being too mechanical and economically focused, Bouty (2000) presents a grounded theory framework which suggests that the social dimension is crucial to individual decisions on whether to exchange information. In her view, researchers are not mechanical actors but able to build strategies. With that in mind, she argues that personal considerations and the economic interests of scientists employed in firms are intertwined where interpersonal exchanges

are concerned. Analyzing knowledge flows in a multiunit company, Tsai (2002) reports that decentralization and social interaction are important in encouraging knowledge exchange among units that compete with each other in the marketplace. Analyzing the sharing of recipes among French chefs, Fauchart and von Hippel (2008) further support the notion of underlying social mechanisms. They find that French chefs are more likely to share their recipes with colleagues who they believe adhere to implicit social norms that have been established in the chef community, e.g., to credit the developer of a recipe as its author.

While some empirical studies investigate the sharing of information among company-employed scientists, there are fewer insights into what drives information-sharing in the academic system. An exception is the study by Walsh et al. (2007), which suggests that the cost of sharing, involvement in business activities, and scientific competition are the main factors influencing the likelihood of academics sharing information with their peers. So far, the role of the social dimension in information-sharing in academic science has not been investigated. While past research has revealed some interesting insights, these provide merely pieces of the puzzle of how scientists arrive to the decision to share or not to share information. A large number of questions are still unanswered. For instance: to what extent do scientists trade information? Does the extent to which the community of a scientist adheres to the norm of communalism affect the decision to share or withhold information? How are the economic and social dimensions of information-sharing interrelated? Are there organizational culture differences in the determinants of sharing behavior between university-employed and company-employed scientists?

In this paper, we propose that economic and social factors influence the behavior of scientists with relation to information exchange in both systems but in different ways and to different degrees. We investigate two social factors: expected reciprocity and the extent to which the community of a scientist is perceived to conform to the norm of communalism, as defined by Merton.[1] Following the definitions of Mauss (1950), Blau (1964) and Bouty (2000), for our purposes *social exchange* is associated with feelings of "unspecific" personal obligation, gratitude and trust, while purely *economic exchange* is based on private interest, namely to profit monetarily or careerwise, and not on "personal feelings." We presume that company-based researchers are expected to act in line with their employers' interests and business objectives and thus place more emphasis on considerations of economic interest but also on reciprocity than university-based scientists. The former do not want to endanger their employers' competitive position by sharing information and when they do share, they wish to see some potential "quid pro quo."

[1] Merton (1973) introduced four norms: communalism, universality, disinterestedness, organizational skepticism. The norm of communalism is thought to be the most important scientific norm or "science's bedrock" (Ziman 2002, p. 315).

We also presume that social exchange mechanisms, i.e. reciprocity-based and norm-based mechanisms, moderate the effect of economic factors on sharing behavior.

No study to date applies the same survey instrument to a sample of university-based and company-based scientists in order to examine information-sharing behavior. Our analysis builds on a novel survey dataset of 1,353 university-based[2] and 341 industry-based bio-scientists who received a request for information within the 12 months preceding our survey. We find that the likelihood of sharing decreases with the economic value of the requested information and increases by the extent to which the scientist perceives that his or her community conforms to the norm of communalism. These effects are present among both groups. Furthermore, company-based scientists appear to be directly influenced by the expectation of reciprocity. Our results suggest that while the expectation of reciprocity does not have a direct effect on information-sharing in the group of university-based scientists, it does moderate the effect that the economic value of the requested information has on the likelihood of sharing in that group. This suggests that reciprocity has a subtle effect on the decision to share information or not, and that this effect depends on the system to which a scientist belongs.

Among the sample of company-based scientists, our results indicate that the extent to which the community is perceived to conform to the norm of communalism moderates the effect of the economic value of particular information on sharing. Hence, we find that expected reciprocity and conformity to the norm of communalism greatly increase the likelihood of highly valuable information being exchanged.

This study contributes to three main strands of literature. First, it adds to a large body of research in organizational management and sociology that focuses on the institutional differences that affect decision-making (e.g., Hitt et al. 2004). We find that the determinants of sharing show similarities as well as differences between the groups of company-employed and university-employed scientists, differing mainly in whether social factors have a direct or indirect effect. Second, we contribute to the literature on the transfer and sharing of information, a strand that is gaining increasing attention with the upsurge of knowledge-intensive industries. We support the findings of von Hippel (1987) and Schrader (1991) by documenting that information-trading occurs among bio-scientists working for firms, and extend their results by reporting that information-trading also takes place among university-based scientists. Additionally, we find that social factors related to reciprocity and the strength of the norm of communalism in the community of a scientist encourage the disclosure of precious information. This suggests that rules of conduct like reciprocity and the communitarian norm govern information exchange and are not separated from profiting from scientific advances. Thus, our results provide insights into the

[2] Scientists working in a non-university public research laboratory (e.g., the Max Planck institute in Germany or the Medical Research Council in the UK) were added to the sample of university-based scientists.

relationship between the economic and social dimensions of sharing and extend the findings of Bouty (2000).

Our study also contributes to a third, emerging strand of research on alternate mechanisms, not based on the formal IP protection system, that support the disclosure of information. Fauchart and von Hippel (2008) suggest that in areas where formal IP rights are absent or difficult to establish, social norms may induce sharing behavior. We add to this idea by demonstrating that both in academia and the industry, scientists are motivated to share information with colleagues when their community is perceived to respect the communalist norm. In the academic system, where protecting research results by means of formal IP rights is not (or should not be) prioritized, scientists are more likely to be willing to share highly valuable than low-value information when the inquirer is perceived to reciprocate the gesture of disclosure. Moreover, we find that whether the norm of communalism is respected by members of a specific community has an effect on the impact that economic considerations related to protecting interests against competition have on the decisions of company-employed scientists to exchange information. This suggests that, as a result of social factors, scientists gain from sharing sensitive information, e.g., they may profit from being offered information in return at some future point, and gain respect among peers.

The remainder of the paper is organized as follows: in Section 2, we summarize the literature on differences between the incentives of university-based and industry-based scientists and develop our hypotheses. Section 3 presents our field of study, research design and data. In Section 4, we describe our analysis and report our results. Section 5 concludes with a summary and a discussion.

2. Conceptual framework and previous literature

2.1. The distinct worlds of academic and industrial science

Influenced by Merton (1973), a large normative literature has elaborated on the different missions to which academia and industry are committed and on how this affects the behavior of scientists employed in either system.

One aspect in which these worlds differ is the selection of projects. The objective of academic science is to generate new, fundamental, universal knowledge that is not necessarily immediately practical or profitable (Merton, 1973). In contrast, industrial science focuses on short-term projects which, when applied in practice, eventually generate financial rewards (Heller and Eisenberg, 1998; Rhoten and Powell, 2007). Furthermore, distinct incentives and output mechanisms guide scientists in the two institutional systems. Whereas university-based scientists publish their results, company-based scientists patent them in order to protect them. Where public research is concerned, there is a concept that university-based scientists are quick to publish research results in order to achieve recognition for getting there first (Merton, 1973; Dasgupta and David, 1994). In that area, the selection of research results for

publication involves a peer-reviewing process which subjects results to trials of replication and verification (David, 2004). Direct financial returns from publishing academic articles are typically nonexistent, but career advances and the desire for peer recognition and acclaim provide powerful incentives (Merton, 1988; Stephan, 1996; Lerner and Tirole, 2005). In contrast, industrial science is driven by the profit imperative, which is often reinforced through the protection of intellectual property.

The differences in incentives and output mechanisms between the worlds of academic and industrial science are also reflected in distinct behaviors where information-sharing is concerned. According to Merton (1973), the principle of openness, which is manifested in the norm of communalism, is considered an integral component of scientific ethos. It puts forward that "substantive findings […] constitute a common heritage in which the equity of the individual is severely limited" (Merton 1973, p. 273). Eamon (1985, p. 321) stresses that "secrecy is universally regarded as a dangerous enemy of the advancement of science." Scientific results present an unconditional contribution to the "scientific commons" (Nelson, 2004). Sharing them helps avoid the wasteful duplication of research efforts and increase the likelihood that research will contribute to further work. Industrial science, in contrast, is not committed to the principle of openness. As industrial research is a private endeavor, secrecy is an important element (Rai, 1999). The behavior of industry-based scientists is guided by requirements for commercial confidentiality and secrecy, to ensure returns from research investments.

While these normative considerations suggest that in academia there is unrestricted sharing of information among scientists, they point to a rationale of non-sharing among scientists in the industry. However, empirical evidence suggests that there is a large gray area between university-based and industry-based scientists. Campbell et al. (2000) and Walsh et al. (2007) document that university-based scientists withhold information to a significant degree. In the "republic of science," these findings indicate that scientific publishing is not synonymous with openness. University-based scientists may avoid sharing information, either entirely or in part, to safeguard planned publications. For example, the more time scientists are given to analyze exclusively datasets before they are made public, the more likely it is that they will be the first to publish several articles based on these datasets. In the realm of technology, scholars have documented that company-based researchers informally exchange information with colleagues working for other, and sometimes competing, firms, as e.g., in the specialized steel industry (e.g., von Hippel, 1987; Schrader, 1991) and in semiconductors (Rogers, 1982). It is argued that information exchange across organizational boundaries stimulates learning processes and thus increases the innovative power of participating firms (Allen 1997).

In this paper, we are interested in explaining the determinants of information-sharing in academic and industrial science. We believe that economic and social factors influence sharing behavior in both realms, but to different extents.

2.2.1. Hypotheses

Economic factors

Human action is the efficient outcome of rational individuals pursuing their self-interest (Hirshleifer 1985). According to this view, information is shared only if this is in the economic interest of scientists. In this context, Schrader (1991) provides evidence that while company-based researchers exchange information with colleagues employed by other firms, they take into account the intensity of competition between the involved parties and share information only if it does not harm the interest of their employer. In the case of academia, Walsh et al. (2007) report that in the life sciences, scientists working in highly competitive research fields are less likely to reveal knowledge to their peers. Hence, university-based scientists might also be guided by similar considerations in their sharing behavior, which implies that they may not share information that could threaten their competitive status within the scientific community.

While prior research suggests that considerations of economic interest are present in academic as well as in industrial science, we propose that the reward systems in these institutional frameworks have distinct features, as a result of which company-based scientists are less likely to disclose sensitive information than university-based scientists. In the industry, the protection of commercially valuable information is critical for ensuring profit. In academia, on the other hand, the negative effect of endangering a future publication may compete with another, positive effect: releasing information might translate into being cited more often. For example, in a recent study, Furman and Stern (2008) show that in the field of biology, scientists who give access to their material are cited more frequently in related publications.

In view of the above, we postulate:

> HYPOTHESIS 1. *The likelihood that company-based and university-based scientists share information decreases with the economic value of the requested information. This tendency is stronger in the case of company-based scientists.*

Social factors

Traditional economic theories focus on the utilitarian side of human behavior but are frequently criticized for falling short of explaining the side of human behavior that is not confined to motives of self-interest (Rumelt et al., 1991; Sethi and Somanathan, 2003; Glaeser 2006). Economic sociologists stress that the social context in which individuals are embedded may give rise to generalized behavioral patterns that may contradict the purely utility-driven behavior of "homo economicus" (Granovetter 1985). In addition to sociology and social psychology, behavioral economics also possesses an increasing body of literature documenting that social factors are of critical importance in explaining individual and organizational behavior (e.g., Fehr and Schmidt, 2000).

One social factor that gains more and more attention with regard to the accumulation and exchange of information is reciprocity. Reciprocity implies that the recipient of a favor from another party is

obliged to reciprocate the gesture in order to maintain the balance of benefits and contributions. The "return" is mostly unspecified with regard to timing and form. In the context of information exchange, this mechanism is supported by two elements: (i) the interest in sustaining a good relationship with the provider of the information, which increases the chances of future exchanges and (ii) an inherent sense of "quid pro quo," which induces feelings of guilt and fear of bad reputation to those unwilling to return a favor (Takahashi, 2000).

Considerations of reciprocity can be present when individuals are the recipients of a particular benefit and feel obliged to give something back, but also when individuals provide a benefit in the faith that it will be reciprocated. In the latter case, information-sharing is dependent on whether offering a favor to another party increases the chances that the recipient reciprocates the gesture in the future. This "quid pro quo" mechanism works well when parties know each other so that trust can be developed quickly (Ostrom, 1999) or when parties are social "neighbors," which increases the probability that the gesture will be repeated in the future (e.g., Boyd and Richerson, 2002).

Von Hippel (1987) and Schrader (1991) were among the first to observe that engineers who informally shared information expected the inquirers to reciprocate the move. Similarly, Bouty (2000) concludes from her interviews with company-based scientists working for research and development (R&D) units that a willingness for reciprocity is an important element of mechanisms of information exchange. Statements by interviewees like "[t]he relation must be reciprocal, otherwise it makes no sense" point to reciprocity as an even necessary condition for the disclosure of information (Bouty 2000, p. 60).

While these studies have provided some support for the idea that considerations of reciprocity influence company-based researchers, the question of whether the same applies to academic researchers, and if so to what extent, is left open. In this paper, we propose that reciprocity is a factor that impacts knowledge-sharing in both institutional systems. We argue that the decision of company-based scientists to exchange information is more strongly determined by the willingness and ability of a peer who requests information to reciprocate such an offer in the future, than that of university-based scientists. While the latter are in general not restricted in their sharing behavior, company employees are urged to act in line with their employers' interest. Therefore, we presume that company-based scientists feel a stronger obligation to "get something" in return when they give something away.

> HYPOTHESIS 2. *The likelihood that company-based and university-based scientists share information increases with expected reciprocity. The tendency is stronger in the case of company-based scientists.*

The second social factor we investigate is the extent to which individual scientists perceive the community of which they are part to conform to the "Mertonian" norm of communalism. Merton (1973)

introduced four norms: communalism, universality, disinterestedness, organizational skepticism, which are thought to "provide effective and legitimate rules for interaction in "routine" scientific situations (Storer, 1973, p. xix). Among those, the norm of communalism is considered to be the most important with relation to science and is specifically related to information-sharing. The norm of communalism encourages scientists to contribute to a common fund of knowledge by openly communicating the results of their research to other scientists.

Whether the norm of communalism is a social norm depends on the degree to which it is accepted in the community. In general, social norms are structural characteristics of a group that influences strongly individual behavior (e.g., Hackman, 1976; Rimal and Real, 2003). Individuals conform to norms because they want to be liked and accepted by others. A social norm may evolve through an inherent obligation to behave in a certain way, as well as through "lived and legitimated behavior" of the group members (Feldman, 1984; Westphal et al., 1997; Rai, 1999). Norms are sustained by individuals' feelings (e.g., of shame, guilt, happiness, anger) and the anticipated consequences of conforming to or violating norms (Elster, 1989; Azar, 2004). Their existence and power become particularly apparent when deviations from a norm are punished (Bendor and Swistak, 2001; Henrich and Boyd, 2001; Gintis, 2003). For example, in their study of stand-up comedy, Oliar and Sprigman (2008) suggest that comedians take action when they detect theft of their ideas, whereby the forms of retaliation range from verbal insults, to refusing to work with the thief, even to physical violence. Studying interbank currency trading, Knorr Cetina and Bruegger (2002) report that market makers are expected to offer deals to other traders even if the deal runs against their current financial interest, because solidarity supports a common goal, that of sustaining the market. Azar (2001) points out that individuals may be motivated to conform to norms not only by the desire to avoid disapproval and feelings of guilt and shame, but also by the possibility of making a good impression and improving their self-image, e.g. being perceived as generous and kind when giving a larger tip than what is considered "normal." Hence, norms are sustainable because individuals derive benefits that may outbalance the costs of following them. In addition, individuals or firms may comply with external pressures to respect norms, because conformity enhances their legitimacy and sustains the logic of confidence, which is important for conducting activities in good faith (Meyer and Rowan, 1983; Oliver, 1991).

In this paper, we propose that the extent to which individual scientists perceive their community to conform to the norm of communalism impacts their decision to exchange information or not. We argue that when scientists are aware that their colleagues adhere to the norm of communalism they are more likely to behave in accordance with this norm. That norm provides effective and legitimate rules for the behavior of scientists in communities where it is highly respected. We believe that this holds for scientists employed in both academia and the industry. With regard to the degree of this tendency, we presume that university-based scientists put more weight on this factor than industrial-based scientists. Merton (1973)

and Ziman (2002), among others, have emphasized that the norm of communalism is essential for the functioning of the so-called "republic of science." a scientist is obliged to make available publicly scientific data or material in order to, e.g., justify public funding, contribute to scientific progress and the accumulation of knowledge, and to avoid duplication of research. Scientists who believe in this norm should also credit colleagues who follow it and punish others who fail to contribute to the public good or over-extract from the commons (Fehr and Gaechter, 2000; Sethi and Somanathan, 2003). The incentives for scientists to exchange information depend fundamentally on the belief that the recipients will build on this information and acknowledge the providers with appropriate citations (Mukherjee and Stern, 2007).

> HYPOTHESIS 3. *The likelihood of information-sharing increases with the extent to which the community is perceived to conform to the norm of communalism. The tendency is stronger in the case of university-based scientists.*

Furthermore, we argue that considerations of economic interest and social factors are intertwined. Only a handful of studies have investigated whether and how social factors impact economic considerations (Azar 2004). For example, Fehr, Fischbacher, and Gaechter (2002) conducted laboratory experiments which show that when individuals credit fair and punish unfair behavior, the incentives to "cheat," i.e., not to reciprocate a gesture of cooperation, change. They argue that cheating comes not only with short-term benefits but also with long-term costs. Studying physicians, Encinosa, Gaynor, and Rebitzer (2007) find that group sociology, i.e., the non-contractual and informal interactions that occur between members of work groups, influences pay practices and behaviors. They conclude that the design of optimal contracts is influenced by group norms, which are related to the consequences that interpersonal comparisons of income and effort have on group members. However, they emphasize that the relationship is too complex to be fully captured by any of their models. We argue that two social factors, the prospect of reciprocity and norm-based behavior in the community, moderate the effect of the economic value of the requested information on the likelihood of that information being shared. More specifically, we argue that these factors greatly increase the likelihood that highly valuable information will be exchanged.

For example, in a situation where a scientist is able and willing to reciprocate an offer of information, both recipient and provider might benefit more from sharing highly valuable information than low-value information. This is because the recipient of highly valuable information is much more indebted to the provider than a recipient of low-value information. It might even be the case that a request for information is especially attractive for a scientist when the inquirer is prominent in the field, as this could imply that he or she has potentially interesting material to offer in return for the favor. On the contrary, a request for precious information is more likely to be refused than a request for low-value information when the recipient is unlikely to be able or willing to "give something back" in the future. In view of the above, i.e. that, on the whole, company-based scientists feel a stronger obligation to get something back when giving something away, we suggest that the moderating effect of reciprocity is

stronger in the case of industry-based scientists than university-based scientists, and reach our fourth hypothesis:

> HYPOTHESIS 4. *The expectation of reciprocity moderates the negative impact of high economic value on the likelihood of that information being shared. Specifically, the likelihood of sharing high-value information increases with expected reciprocity. The tendency is stronger in the case of industry-based scientists than university-based scientists.*

Furthermore, we argue that when a scientist perceives that his or her community conforms to the norm of communalism this encourages the disclosure of highly valuable information. For example, when a scientist's community is strongly committed to the norm of communalism, the members of that community are more likely to share highly valuable information than low-value information. When the community is perceived to respect the norm of communalism, the incentives for scientists to share precious information are much stronger, as in those circumstances, sharing increases their reputation without posing a risk to profits from their scientific advancement. Sharing quite valuable information might even lead to greater scientific recognition through an increased number of citations. In view of the above, we suggest that the moderating effect of respecting norms in the community is stronger in the case of university-based scientists than industry-based scientists.

> HYPOTHESIS 5. *The extent to which a scientist perceives his or her community to conform to the norm of communalism moderates the negative impact that the high economic value of information has on the likelihood of that information being shared. Specifically, the likelihood of sharing highly valuable information increases when the community is perceived to conform strongly to the norm of communalism. The tendency is stronger in the case of university-based scientists than industry-based scientists.*

3. Field of study and data

3.1. Field of study

The bio-sciences provide an attractive testing ground for our propositions. Compared with many other scientific and technological fields, in the bio-sciences, research has developed dramatically in the last few decades. It is a highly competitive field characterized by great emphasis on IP protection and patent races (McKelvey, 2000; Cohen et al., 2002). However, in that field the building of collective knowledge is a key strategic task for the success of company-employed and university-employed scientists (Powell et al., 2005). While past research has documented that withholding research results is present in the bio-sciences (e.g., Campbell et al., 2002), Hope (2004) has pointed to some recent signs of an open-source attitude in biotechnology.

3.2. Survey

Our empirical approach requires measuring both the extent to which information is shared between individuals and specific characteristics of those individuals that are relevant to information-sharing. This kind of data is unavailable in public databases. We therefore developed and administered a survey in 2007. The survey population is composed of bio-scientists in Germany and the UK, the two leading countries in the bio-sciences in Europe. Our approach to identifying bio-scientists was twofold: first, we sampled bio-scientists that are listed as authors in PubMed, the most prominent database of bio-scientific and medical abstract citations. We identified 9,074 German scientists and 8,189 British scientists who have published an article between 2002 and 2005, using search categories related to the bio-scientific field. Second, we sampled all inventors who filed patents with bio-scientific IPC codes with the European Patent Office between 2002 and 2005. We ended up with 8,265 German and 4,196 British inventors. All identified scientists were invited to participate in an online questionnaire. About 22% of the German and British invitations did not reach the scientists, mostly because of incorrect data in the public databases, and because the addresses of scientists who had the country or retired had not been updated. Where scientists had changed employers, we asked the former employer for the current address, which was provided in about 88% of the cases.

The search categories we used for identifying scientists in the two databases were very broad.. We concluded from discussions with experts and a small telephone survey with non-respondents that about 30% of the scientific authors and about 25% of the inventors caught in our sample were not in fact involved in bio-scientific research. In PubMed, as well as in the European Patent Database (Epoline), there are no search categories or IPC classes that explicitly identify bio-scientific research. When designing the study, we therefore decided to use rather broad categories. In the invitation letter to scientists we pointed out that our target group were scientists involved in the bio-scientific field. A total of 2,169 scientists identified through PubMed and 2,452 identified through the European Patent Database filled out our questionnaire.[3] This translates into a response rate of 16% of publishing scientists and 25% of inventors. Once we had corrected for the percentage of people who had received an invitation but were not involved in the bio-sciences (30% for publishing scientists and 25% for inventors), we ended up with a response rate of 23% in the case of publishing scientists and 33% in that of inventors.

For the purposes of this study, we only considered scientists who had received a request for information in the 12 months preceding the survey from a researcher outside their own organization, with whom they were not currently collaborating. An additional prerequisite was that the requested information was not publicly available. We excluded questionnaires from scientists who were no longer

[3] 3,534 of the scientists are employed in Germany, 1,087 in the UK.

actively engaged in research and were older than 65 years. We ended up with 1,694 observations that met our criteria and for which we had all necessary variables to conduct the analysis (393 from the sample of British scientists and 1,301 from that of German scientists). We tested for non-response bias by comparing early and late responses (Armstrong and Overton, 1977). A series of t-tests for independent samples failed to identify significant differences between early and late respondents in the dependent and independent variables, indicating that a non-response bias was unlikely to be a problem in this study.

3.3. Data and descriptives

In the questionnaire, we asked scientists to think back to the last instance in the past 12 months when someone from outside their own organization, with whom they were not currently collaborating, had made a request for information or material that was not publicly available. Instead of asking our respondents to provide information on a conjectural typical decision, we asked them to report on a concrete, specific decision they had to make on information exchange. This approach reduces the problems that may arise from post-rationalization and allows us to ask very detailed questions about a respondent's most recent decision on information transfer. Moreover, focusing on a specific request for information allowed us to gain in-depth insights into the specific social and economic context in which a particular decision to share or withhold information is embedded.

Factor analysis

We constructed items for economic and social factors, as no appropriate scales were available in the existing literature. To enhance the validity of the items, we conducted in-depth interviews with ten scientists working in academia and seven scientists working in the industry. On the basis of those interviews, we came up with nine items. Several items measured by the questionnaire correlate strongly, opening up the possibility of reducing the number of variables. We used factor analysis to reduce the number of variables and detect underlying dimensions. This method allowed us to build three factors that were conceptualized as formative indices (Cohen et al., 1990): one factor depicting the economic value of the requested information with two items, one factor describing expected reciprocity and consisting of five items, and one factor that comprised two items and depicted the perceived conformity with the norm of communalism in a scientist's community. These items are reported in Table 1. All items were measured on a Likert scale ranging from 1 to 5. The items concerning the economic value of the requested information and expected reciprocity refer to the specific information request.[4] The two items regarding the norm factor ask to what extent the norm of communalism is respected in the respondents'

[4] After running the factor analysis we conducted some interviews with biotechnology experts to discuss our constructs. From our interviews, we learned that the notion of reciprocity is fed by both rational utility concerns and factors related to embeddedness, which increased our confidence in the validity of our reciprocity factor.

community, in their experience. The factor analysis uses principal component analysis and Varimax rotation. The number of factors extracted was determined by the Kaiser criterion (Eigenvalue>1). The factors account for 63% of the total variance and yield good quality measures (KMO: 0.75, $p<0.001$).

Table 1 about here

Descriptives and definition of variables

Dependent variable.

Table 2 reports summary statistics for the dependent variable *% of request filled*. Our sample consists of 341 company-employed and 1,353 university-employed scientists. Thus, about 20% of bio-scientists work in firms. We used the percentage of the required information that has been shared as our dependent variable. The variable *% of request filled* ranges from 0 to 100%. Within our sample, the university-employed scientists have, on average, provided 85% of the requested information, compared to a lower 58% provided by company-employed scientists. The t-test indicates a significant difference between the two samples (t-value: 13.7, $p<0.001$). Hence, university-employed scientists share more information than industry-employed scientists. Whereas other studies on information-sharing measured only whether an individual shared information or not (e.g., Schrader, 1991; Walsh et al., 2007), we used metric measurements of *how much* of the requested information is shared. We learned from interviews with experts that scientists sometimes provide only part of the information requested and withhold crucial parts. Hence, there is much more variety in sharing behavior, which cannot be captured solely by finding out whether a respondent has shared information or not. We find that most observations, however, are at the extremes, e.g., 30% of company-based scientists and 8% of university-based scientists did not share any information, while 39% of company-based scientists and 72% of university-based scientists fulfilled 100% of the request.

Table 2 about here

Independent variables.

Table 3 presents summary statistics of the independent variables. Columns 2 and 3 list the sample mean and standard deviation of the sample of company-based scientists, Columns 4 and 5 those of the sample of university-based scientists. Column 6 depicts the p-value in the test for differences of means among the two groups.

Table 3 about here

The variable *economic value of requested information* has been extracted from the factor analysis. This factor takes on a high value if the requested information has a high impact on the scientific research program of the recipient of the request and if the inquirer and the recipient work in very similar research areas. All factors were constructed to have a mean of 0 and a variance of 1 for the total sample. The mean of this variable is –0.037 for the sample of company-based scientists, a little bit lower compared to the mean of the sample of university-based scientists, which is 0.016.

The second factor, *expected reciprocity*, is characterized by five items: the likelihood of entering into co-authorship or co-inventorship in the future, the extent to which giving the information might increase the inquirer's willingness to provide information in the future, how the recipient of the request appraises previous exchanges with the inquirer, and whether the inquirer is considered to be a close colleague from another organization. The mean of the factor is –0.052 for the sample of company-based scientists and significantly lower than the 0.013 for the sample of university-based scientists.

The third factor, *conformity to norm*, takes on a high value when the following statements are perceived to apply in the community (ranging from "does not apply" to "fully applies"): (i) open exchange is usually practiced among researchers and (ii) the first to come up with new research results is highly esteemed among peers. These two items follow from the definition of the norm of communalism, according to which, scientists in academia are supposed to unconditionally share information and give up intellectual property rights in exchange for recognition and esteem (Merton, 1973). The mean of the industry sample is –0.126 and statistically lower compared to the mean of 0.037 for the academic sample. Hence, on average, university-based scientists perceive that their community conforms more to the norm of communalism than industry-based scientists do with respect to their own community.

We included some variables that are known or expected to influence a scientist's decision on whether to share information, even though we excluded them from the discussion of our hypotheses. These variables are:

- *Type of inquirer*: we asked the respondents whether the inquirer was a university-employed or company-employed scientist. Interestingly, 70% of the requests received by company-employed scientists have come from university-employed scientists, and 94% of the requests received by university-employed scientists came from scientists employed in academia. We presume that both groups of scientists are more likely to share information with colleagues who are not employed in the industry and therefore probably do not pursue commercial interests. Moreover, we presume that this tendency is stronger in the case of university-employed scientists.

- *Protection of requested information*. The respondents were asked to rate, on a five-point Likert scale, how confidential the requested information was, i.e., whether it was protected by a non-disclosure agreement. In line with Bouty (2000), we expected that when the requested information is confidential, scientists are less likely to share that information. Table 3 shows that the requested information is much more likely to be confidential in industrial than in academic science (mean of sample of company-based scientists: 2.8; mean of sample of university-based scientists: 1.4). Moreover, we presumed that company-based scientists are less likely to share confidential information than university-based scientists.
- *Exogenous entrepreneurialism*. We employ the variable *exogenous entrepreneurialism* to investigate whether scientists whose families include a company founder (parent or sibling) are more inclined to withhold information. Our assumption is that these scientists are more aware of information leading to entrepreneurial opportunities and are therefore more careful in their sharing behavior so as not to undermine possible opportunities of future commercialization. In our sample, 26% of company-based scientists and 23% of university-based scientists have an entrepreneur in their family.
- *Age.* The variable *age* is included in order to control whether age impacts sharing behavior . In this sample, company-based scientists are on average 46 years old and university-based scientists are 44 years old.
- *Country*. We employ the variable *British scientist* to control for differences in the sharing behavior between British and German scientists. Previous research has shown that British and German scientists are parts of very different "ecosystems", which might result in different sharing behaviors. For example, in a recent study Haeussler (2008) reports that British biotechnology firms rely on market-related criteria to a greater extent when making commercialization decisions than German firms.
- *Type of requested information or material.* We employ a range of variables to distinguish between various types of information. These classes have been the outcome of extensive discussions with bio-scientists. Whether the inquirer asked for a *database or software* serves as the reference group in the analysis.
- *Academic qualification.* The variables *Professor* and *Assistant Professor* were included in order to control for differences associated with the formal academic qualifications of the respondents. The reference group for these two variables in the multivariate analysis consists of scientists holding an academic qualification lower than *Assistant Professor*. In the industry-employed scientists in our sample, 5% are professors and 7% are assistant professors. In the sample of university-employed scientists, 26% are professors and 24% are assistant professors.
- *Gender*. The variable *female* is included to control for differences in the sharing behavior associated with gender. In our sample, 25% of university-based scientists are female compared to only

13% of company-employed scientists. Past research has shown that female scientists are less likely to file for patents than their male counterparts (e.g., Ding et al., 2006).

4. Analysis

Table 4 reports the results of our analysis of the determinants of information-sharing. We performed an interval-based regression. A tobit model did not fit the data as the distribution of our dependent variable is weighted towards the boundaries. An interval-based regression is an ordered probit with known constants, where the constants are the boundaries of the intervals of our *% of request filled* variable (see Table 2). Using an interval-based regression, as opposed to a standard ordered probit, allows us to estimate the standard error of the distribution, which can be retrieved from the estimation, given that the constant terms are observed.[5] In order to detect differences in the degree to which our respondents take into account the economic and social factors (see our hypotheses) when they make a decision on whether to share information or not, we ran a pooled regression and interacted all variables for which we presumed that there are differences between the two groups, with dummy variables indicating a company-based scientist or a university-based scientist. In Models 3 and 4 we added the two interaction variables between the economic factor and the two social factors. In Models 2 and 4 we show the reduced model without the type of field variables which mostly appear to be non-significant.

Table 4 about here

A main objective of this paper is to investigate how economic and social factors impact the likelihood of information being shared. In all models, the economic factor shows a significantly negative coefficient. The willingness to share information decreases with the economic value of the requested information. Thus, scientists working for companies, as well as those working for the university, are less likely to share information that is important for preserving their personal competitiveness in the field, as well as that of their employer. We performed a Wald test to check whether the coefficients estimated with relation to the group of company-based scientists are equal to the coefficients estimated with relation to the group of university-based scientists. The Wald test indicates that company-based scientists are not significantly more influenced by the economic value of the required information than university-based scientists (e.g., model 2: Chi2: 0.51, p=0.47).

[5] The results using an ordered probit model are reported in the Appendix 3. The dependent variable ranges between 1 and 4 (see Table 2). The ordered probit model produces very similar results to the interval regression.

With regard to expected reciprocity, our analyses show that it is significantly positively related to the likelihood of information being shared, but only in the case of company-based scientists (at a 1% significance level). The Wald test for differences between the coefficients suggests that the effect of expected reciprocity is significantly stronger in the sample of company-employed scientists (e.g., model 2: Chi2: 6.04, p=0.01). Hence, company-based scientists pay greater attention to whether the inquirer is able and willing to return a favor in the future than university-based scientists.

The coefficients of the variable *conformity to norm*, measuring the extent to which scientists perceive that their community conforms to the norm of communalism, show a positive coefficient for both the samples of company-based (at 5%) and university-based scientists (also at 5%). Hence, scientists who perceive that their colleagues conform to the norms of science are more likely to share information. However, we did not find differences in the weight that company-based and university-based scientists put on this factor (e.g., model 2: Chi2: 1.22, p=0.27).

We now turn to the interaction variables in models 3 and 4: the interaction effect between expected reciprocity and economic value of the requested information shows a positive and significant coefficient in the sample of university-based scientists (1%), but not in that of company-based scientists. Thus, the former group is more likely to share information that is of high economic value when there are good chances of the offer being reciprocated in the future. The Wald test indicates that the interaction effect is significantly stronger among university-based than among company-based scientists (e.g., model 4: Chi2: 7.48, p<0.01). Analyzing the sample of university-based scientists, we were particularly surprised to find that reciprocity has no direct effect on sharing (Models 1 and 2) but that the interaction effect has a strong impact (Models 3 and 4).

Finally, we shed light on how the interaction between conformity to norm and the economic value of a particular piece of information affects sharing behavior. While this has no significant effect in the sample of university-based scientists, we found that it has a positive and significant effect among company-based scientists (at 10%). Hence, company-based scientists are more likely to share highly valuable information when their community is strongly committed to the norm of communalism. The Wald test for differences in the coefficients suggests that company-based scientists put more weight on the interaction effect than university-based scientists (e.g., model 4: Chi2: 5.95, p=0.01).

In the models, we included variables to control for potential sources of unobserved heterogeneity. The coefficient of the variable *type of inquirer*, which measures whether the inquirer is a university-based scientist as opposed to a company-based scientist, is significantly positively related to the likelihood of sharing in all models. Thus, company-based and university-based scientists are more likely to share information if the inquirer is employed in academia, rather than the industry. The Wald test indicates that when the inquirer is employed in the academic system, university-based scientists are more likely to share information with him or her than company-based scientists are (e.g., model 4: Chi2: 7.26, p<0.01).

When the requested information is to a large extent confidential, i.e., protected by a non-disclosure agreement, both groups of scientists are less likely to share it. Hence, scientists are unlikely to exchange resources that they consider confidential (Bouty, 2000). Interestingly, we find that scientists with an entrepreneur in their family are less likely to share information. Age appears to be negatively related to the likelihood of sharing. Scientists employed by a British university appear to be more likely to share information than their German counterparts. The controls for academic qualification, i.e., professor and assistant professor, and for gender do not show significant coefficients. With regard to the type of requested information we employed a large number of controlling variables. Here, we find only a significantly positive effect for *cloned gene or plasmid* and *pre-publication information* in the sample of company-based scientists.

5. Discussion and conclusion

5.1. Theoretical implications

Sharing information can be neither supervised nor enforced. In this paper, we aimed to understand the underlying mechanisms that influence the decision of scientists working in academia or the industry whether to share information or not. While past research has tended to analyze either economic or social factors (e.g., Bouty, 2000) as incentives that encourage or discourage information-sharing, we extended this work by taking into account both factors as well as the interplay between them. Thus, our paper contributes to the literature on the sharing and accumulation of knowledge.

First, we found that economic considerations impact sharing behavior. The likelihood of company-based or university-based scientists' sharing information decreases with the economic value of the requested information. Second, our results showed that social factors influence sharing behavior. We investigated two social factors: the perceived conformity to the communalist norm in the scientist's community and expected reciprocity. We found that, the stronger the conviction that the scientific community follows the norm of communalism, the higher the likelihood that scientists in either the industry or academia will share information. What's more, this conviction counterbalances the inhibiting effect of the potential drawbacks of information-sharing. Scientists comply with external pressures because conformity benefits their status. Our findings are in line with the argument of Meyer and Rowan (1983), as well as Oliver (1991, p. 153), that the level of conformity to norms in a community plays an important role in sustaining "… the logic of confidence necessary to conduct organizational activities in good faith."

With regard to reciprocity, we investigated whether individuals are more inclined to do a favor for a colleague when there is the prospect of "quid pro quo" (Hippel, 1987; Schrader, 1991; Bouty, 2000). In our dataset, we found that company-based scientists are more willing to share information when they expect that their gesture will be reciprocated by the inquirer. However, we did not find that reciprocity

had a similarly direct effect among university-based scientists. Furthermore, our paper revealed interesting insights when we analyzed the interaction of our economic and social factors. Our study showed that social factors influence the impact of the economic factor on a scientist's decision to share or withhold information. We found that while reciprocity has no direct effect on the likelihood of university-based scientists' sharing information, it affects the impact that considerations of economic interest have on that likelihood. Our results suggest that when university-based scientists expect the inquirer to be able and willing to return a favor, they are much more likely to share highly valuable information than low-value information. In other words, the prospect of "quid pro quo" appears to make the sharing of highly valuable information attractive as the recipient of a request expects to benefit from an offer of highly valuable information, in return for his or her gesture, in the future. This suggests that reciprocity supports significantly the "Mertonian" ethos of information exchange in the community of academic science and, as a result, even highly competitive information is shared. Our findings challenge the argument of Kim and Mauborgne (1998, p. 329) that "high-quality knowledge sharing will likely be stifled as long as quid pro quo attitudes toward cooperation prevail."

With regard to the interaction between the extent to which a scientist perceives that his or her community conforms to the norm of communalism and considerations of economic interest, our results help to understand whether and how conformity to norms in the community encourages the sharing of highly valuable information. With respect to our sample of company-based scientists, we found that the likelihood of scientists' sharing information increases with the economic value of the information, when the community is perceived to follow the norm of communalism. In the context of high conformity to norms, company-based scientists might improve their scientific status when they share highly valuable information, without risking the ability to appropriate returns from their scientific advances. In this respect, our results add a new and important aspect to the findings of Westphal et al. (1997), who have shown that the more certain practices become adopted by companies, the greater the pressure on competitors to adopt the same normative practices, as this affects their status in the community.

In our research, we found that the perceived level of conformity to the communalist norm in the community of a scientist is especially important wherever highly valuable information is concerned. More specifically, community behavior affects confidence in the disclosure of information when this is done in good faith and is perceived to be a matter of public interest. This interaction effect was only present in the sample of company-based scientists. Hence, while the decision of university-based scientists to share or withhold information is influenced by their community's conformity to the communalist norm, that factor does not moderate the negative impact that the high economic value of certain information has on the likelihood of that information being shared.

The investigation of social factors allows us to contribute to a second strand of literature, the literature on IP protection mechanisms. While there is a large body of literature examining the impact of

how formal IP mechanisms support information disclosure (Scotchmer, 1991; Gill, 2008), recent attempts have been made to investigate alternative, informal mechanisms. O'Mahony (2003) argued that software developers reveal information to the commons and protect their work by using legal and normative tactics. Oliar and Sprigman (2008) suggest that a norms-based system that regulates IP protection and punishes theft helps safeguard ideas in stand-up comedy. Fauchart and von Hippel (2008) promote the concept of a norms-based IP system. They have demonstrated that a recipe is more likely to be shared among French chefs when it is expected that the inquirer will follow specific rules of handling the requested information. Ostrom emphasizes that the tragedy of the commons, i.e., the over-exploitation of pools of publicly available intellectual property by some at the expense of others, only becomes a tragedy when those who take advantage of such resources are "norm-free maximizers of immediate gains, who will not cooperate to overcome the common dilemmas they face" (Ostrom, 1991, p. 493).

In our paper, we find that norms-based mechanisms support the sharing of information. Among industry-based scientists, we found that when the community is perceived to conform to the communalist norm, a scientist's reluctance to share information in order to protect personal financial interest is reduced. This is not surprising, because company-employed scientists are urged to act in line with their employers' interests and are therefore only willing to share information when there appears to be no risk that the shared information will be appropriated. Conformity to norms in the community might reduce the potential negative effects of sharing and can be viewed as an alternative, informal mechanism of IP protection. Thus, the community acts as a source of authority that credits those who conform, and calls for sanctions on violators (who may suffer e.g. loss of status). In that respect, a norms-based system enables scientists to establish and enforce rights to protect their intellectual property, at least in part, and might work as a complement to the formal IP protection system. Hence, because norms provide incentives for scientists to share information, promoting norms supports the accumulation of knowledge.

Our paper also extends the institutional perspective. Several studies investigate the institutional differences between academic and industrial science (e.g., Dasgupta and David, 1994), although there is little data on whether similarities and differences in sharing behavior exist between the two realms. Applying the same survey instrument to company-employed and university-employed scientists, our study reveals that in both groups, scientists decide strategically whether to share information or not. Our results suggest that overall, strategic action is more common among company-employed scientists than university-employed scientists. The decision to share information is influenced by the economic value of the information requested but more so in the case of company-based scientists. Surprisingly, the prospect of reciprocity seems to have a direct impact only on the decision of company-based scientists, while it moderates the impact of the economic value of that information on the likelihood of university-based scientists' sharing such information. Hence, when university-based scientists receive a request for highly valuable information, they are more inclined to share it when the inquirer is perceived as likely to return

the benefit in the future. This implies that, among university-based scientists, "equitable exchange" (Bouty, 2000) is particularly important when the requested information carries a high value for the scientist.

5.2. Practical implications

Our findings have implications for both practice and public policy. Our results highlight a positive tendency in the industrial sector, as it appears that company-based scientists take the economic interest of their employer into account when they decide whether to share information or not. In addition, they base their decision to exchange information on social factors and choose to share data with colleagues when the danger of it being appropriated is low and the prospect of reciprocity is high. While companies are known to have great concerns about information leakage (Henkel, 2008), we promote a company policy that is more open to inter-organizational exchange since on the level of individuals, scientists appear to be making highly strategic decisions on when and with whom they share information.

With regard to the university system, our results imply that there too scientists decide strategically whether to share information or not. We found that university-employed scientists are influenced by economic and social factors. In that respect, the "Mertonian ethos" of unconditional contribution to the "scientific commons" conflicts with the personal interests of scientists. The decision to disclose information appears to be much more strategic than is commonly assumed. In that respect, our results might call for a critical reconsideration of research management policies that may discourage information-sharing within academia, e.g., promoting practices such as rankings to increase competition between scientists.

Our findings have a range of implications for public policy. Previous research has shown that with regard to public policy, it is desirable that information is shared and publicly disclosed (e.g., Sorenson and Fleming, 2004), but has rarely provided action plans or recommendations. From our findings, we conclude that if information-sharing is desired it is important to strengthen the norm of communalism. Norms-based mechanisms can act as alternative forms of IP protection that induce scientists to disclose information. Community-wide conformity to the communitarian norm encourages the exchange of even highly valuable information among industry-based scientists. The promotion of norms-based behavior should therefore have a direct impact on the propagation and accumulation of knowledge. The sharing behavior of scientists depends on whether they are aware – and if so, to what degree – of the attitude of the community to which they belong towards the norm of communalism. More specifically, as patenting becomes more widespread in academia, the promotion of the old normative rules of communalism may be necessary to prevent the erosion of the norm of open exchange among scientists by emphasizing that it is essential for maintaining a robust scientific system.

5.3. Limitations and future research

As all studies, this one has certain limitations. First, our findings are based on survey data. As with all studies based on survey data, we cannot exclude the possibility that our results suffer from "common method bias" (Podsakoff et al., 2003). However, we completed a large number of pre-tests and validation tests before the questionnaire was submitted to scientists, and are therefore confident in our data and results. Second, we address the question of generalizability. Caution must always be exercised when transferring results from a single industry to others. The bio-scientific field is a prominent example of a highly competitive and collaborative industry. Firms are often spin-outs of public laboratories and most scientists who work in the industry have spent a long time in academia before joining the industrial sector. While this allows us to make a conservative test of differences in sharing behavior between company-based and university-based scientists, our findings might overestimate the effects of social factors in both groups. In addition, we sampled only scientists who have either had their research published or applied for a patent. Hence, our sample may consist of a group of output-oriented scientists. We hope that future research will verify our findings in a larger number of settings, including other types than those on which we have focused.

Furthermore, while we have shown that norms-based mechanisms support information-sharing, we have no data on whether norms-based behavior pays off. Merton (1957, p. 297) stresses that "[l]ike other institutions, the institution of science has developed an elaborate system for allocating rewards to those who variously live up to its norms." However, so far we have no evidence on whether scientists who openly share information adequately benefit from their scientific advances. In our view, it would be very useful if this would be further investigated.

This paper takes one step towards shedding light on the role of economic and social factors, as well as their interplay, in information-sharing. In that respect, the results advance our understanding of how scientists cope with the tensions that are at the heart of the academic and industrial systems: the tension between supporting innovation by sharing information, and thus, promoting the accumulation of collective knowledge on the one hand, and the economic considerations of individual scientists and their employers on the other.

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Tables

Table 1. Factor loadings

Variable	Economic value of requested information	Expected reciprocity	Conformity to norm in community
Value of information for scientific research program	0.79	0.07	0.05
Similarity of research program between inquirer and recipient of request	0.73	0.16	–0.013
Likelihood of entering into co-authorship/co-inventorship in the future	0.10	0.74	0.12
Expected change in inquirer's willingness to provide information	0.05	0.68	0.18
Value of previous exchange between inquirer and recipient of request for inquirer	0.03	0.63	–0.11
Value of previous exchange between inquirer and recipient of request for recipient of request	0.13	0.61	–0.12
Inquirer is considered to be a close colleague from another organization	0.13	0.71	0.09
Open exchange is perceived to be usually practiced among researchers	–0.05	0.05	0.73
The first to produce new research results/ideas is highly esteemed	0.09	0.01	0.75

Note: n=1,694

Table 2. Summary statistics of dependent variable

% of request filled	Mean	Std. Dev.	0% =1	1-50% =2	51-99% =3	100% =4
Company-based scientists	57.927	43.074	0.30	0.13	0.17	0.39
University-based scientists	85.190	29.795	0.08	0.07	0.13	0.72

Note: n=1,694

Table 3: Summary statistics of independent variables

Variable	Company-based scientists		University-based scientists		Diff. mean
	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Economic value of requested information	–0.037	0.847	0.0157	0.759	0.131
Expected reciprocity	–0.052	0.688	0.0129	0.678	0.116
Conformity to norm	–0.126	0.753	0.037	0.767	p<0.001
Inquirer = university-based scientist	0.695		0.940		p<0.001
Protection of requested information (NDA)	2.818	1.663	1.428	1.019	p<0.001
Exogenous entrepreneurialism	0.258		0.234		0.343
Age (years)	45.721	7.706	44.055	7.792	p<0.001
British scientist	0.161		0.250		p<0.001
Type - Database or substance REFERENCE GROUP	0.106		0.097		0.628
Type - research/lab protocol	0.543		0.562		0.508
Type - cloned gene or plasmid	0.123		0.271		p<0.001
Type - cell line or tissue	0.073		0.203		p<0.001
Type - recombinant organism	0.047		0.081		0.031
Type - antibody or protein	0.106		0.137		0.119
Type - other chemical substance	0.340		0.120		p<0.001
Type - research result (preliminary)	0.032		0.007		p<0.001
Type - pre-publication information	0.053		0.018		p<0.001
Type - other	0.032		0.013		p<0.001
Professor	0.053		0.267		p<0.001
Assistant Professor	0.073		0.243		p<0.001
Female	0.126		0.247		p<0.001

Note: Company-based scientists: n=341; university-based scientists: n=1,353; for the dummy variables the last column shows the two-sample test of proportion; for the ordinal variables see the Mann–Whitney test.

Table 4. Interval-based regression on % of requested information filled

	Dependent variable: % request filled			
	Model 1	Model 2	Model 3	Model 4
Economic value of requested info. (company)	–26.23***	–25.39***	–23.89***	–22.60**
	(8.711)	(8.680)	(8.858)	(8.830)
Economic value of requested info. (university)	–18.28***	–18.09***	–14.42**	–14.20**
	(5.565)	(5.576)	(5.674)	(5.683)
Expected reciprocity (company)	23.99**	24.42**	23.83**	23.92**
	(10.38)	(10.45)	(10.41)	(10.47)
Expected reciprocity (university)	4.957	4.300	–6.212	–6.892
	(6.044)	(6.012)	(6.370)	(6.340)
Conformity to norm (company)	21.91**	23.47**	23.38**	25.02***
	(9.328)	(9.346)	(9.248)	(9.266)
Conformity to norm (university)	12.63**	11.72**	14.23***	13.38***
	(5.141)	(5.154)	(5.178)	(5.183)
Expected reciprocity x economic value (company)			1.536	2.882
			(11.78)	(11.84)
Expected reciprocity x economic value (university)			42.47***	43.08***
			(8.613)	(8.672)
Conformity to norm x economic value (company)			19.13*	20.92*
			(11.15)	(11.22)
Conformity to norm x economic value (university)			–10.56	–11.14
			(6.776)	(6.810)
University-based scientist	34.13	31.39	24.34	21.52
	(25.20)	(25.14)	(24.96)	(24.89)
Inquirer=university-based scientist (company)	40.73***	43.75***	39.59***	42.67***
	(15.18)	(15.09)	(15.09)	(15.00)
Inquirer=university-based scientist (university)	91.72***	95.61***	95.38***	99.45***
	(15.21)	(15.26)	(15.12)	(15.16)
Protection of requested information (company)	–7.395*	–9.352**	–7.658*	–9.572**

	(4.357)	(4.321)	(4.311)	(4.271)
Protection of requested information (university)	–18.59***	–18.34***	–17.95***	–17.66***
	(3.782)	(3.786)	(3.758)	(3.759)
Exogenous entrepreneurialism	–21.08***	–19.70**	–19.78**	–18.45**
	(7.827)	(7.855)	(7.755)	(7.779)
Age (years)	–1.158**	–1.198**	–1.249***	–1.284***
	(0.468)	(0.470)	(0.466)	(0.467)
British scientist	22.29***	20.06**	19.97**	17.94**
	(8.648)	(8.664)	(8.601)	(8.622)
Professor	10.52	10.90	10.80	11.19
	(9.662)	(9.692)	(9.588)	(9.616)
Assistant Professor	0.0543	0.907	0.404	1.280
	(9.146)	(9.199)	(9.070)	(9.120)
Female	1.235	2.573	2.165	3.413
	(8.406)	(8.408)	(8.358)	(8.357)
Type - database or software				
Type - research or lab protocol	5.905		5.025	
	(7.144)		(7.076)	
Type - cloned gene or plasmid	25.01***		23.68***	
	(8.762)		(8.682)	
Type - cell line or tissue	9.853		9.877	
	(9.289)		(9.205)	
Type - recombinant organism	10.01		10.16	
	(13.40)		(13.21)	
Type - antibody or protein	8.690		8.524	
	(10.28)		(10.19)	
Type - other chemical substance	–6.019		–5.217	
	(9.376)		(9.265)	
Type - research results (preliminary)	18.15		15.90	
	(30.28)		(29.84)	
Type - pre-publication	65.86***		62.66***	

	(24.16)		(23.82)	
Type - other	–34.58		–35.81	
	(24.24)		(24.05)	
Constant	107.0***	121.4***	111.6***	124.6***
	(29.44)	(28.75)	(29.16)	(28.48)
ln(σ)	4.692***	4.702***	4.678***	4.687***
	(0.0453)	(0.0453)	(0.0452)	(0.0452)
Observations	1,694	1,694	1,694	1,694
Cox–Snell R2	0.18	0.17	0.20	0.19
Chi2	344.6631	322.0408	375.8706	354.5371
LL	–1,564	–1,575	–1,549	–1,560

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1