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Delay and secrecy: Does industry sponsorship jeopardize disclosure of academic research?

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Abstract

The viability of modern open science norms and practices depend on public disclosure of new knowledge, methods, and materials. Aggregate data from the OECD show a broad shift in the institutional financing structure that supports academic research from public to private sponsorship. This paper examines the relationship between industry sponsorship and restrictions on disclosure using individual-level data on German academic researchers. Accounting for self-selection into extramural sponsorship, our evidence strongly supports the perspective that industry sponsorship jeopardizes public disclosure of academic research.

Keywords: open science, research funding, industry sponsorship, disclosure, secrecy
JEL-Classification: O31; O32; L33

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1 Introduction

Long-run trends suggest a broad shift is taking place in the institutional financing structure that supports academic research. According to data compiled by the OECD, industry sources are financing a growing share of academic research while "core" public funding is generally shrinking.[1] This ongoing shift from public to private sponsorship is a cause for concern because these sponsorship relationships are fundamentally different. Available evidence suggests that industry financing does not simply replace dwindling public money, but imposes additional restrictions on academic researchers. In particular, industry sponsors frequently limit disclosure of research findings, methods, or materials by delaying or banning public release (Blumenthal et al. 1996; Cohen et al. 1998; Gans and Murray 2011; Thursby and Thursby 2007).

Recent economic research highlights why public disclosure of academic research is important. Disclosure permits the stock of public knowledge to be cumulative, accessible, and reliable. It limits duplication of research efforts, allows new knowledge to be replicated and verified by professional peers, and permits access and use by other researchers which enhances opportunities for complementary research (Dasgupta and David 1994). In recent work, Murray et al. (2009) found that greater access to ideas and materials in academic research not only increased incentives for direct follow-on research, but led to an increase in the diversity of research by increasing the number of experimental research lines. Mukherjee and Stern (2009), who examined the theoretical conditions supporting "open science" versus "secrecy", stressed that maintaining and growing the stock of public knowledge requires a limit on the private financial returns obtained through secrecy.

[1] OECD data show the share of industry sponsorship has grown in all countries since 1980, although this share is still relatively small. General university funds ("core" funds) as a share of civilian government budget appropriations fell from 26% in 1995 to 23% in 2007 (OECD, Main Science and Technology Indicators, 2010).

This paper examines the relationship between industry sponsorship and restrictions on publication disclosure using individual-level data on German academic researchers. Germany is an apt setting for examining this relationship. It has a strong tradition of public financial support for academic research and, among advanced economies, Germany experienced the most dramatic growth in its share of industry sponsorship, a 13.4 percentage point increase from 1995 to 2007 (OECD 2010).

German academic researchers were surveyed about the degree of publication disclosure restrictions experienced during research projects sponsored by government, foundations, industry and other sources. To examine if industry sponsorship jeopardizes disclosure of academic research, we modeled the degree of restrictiveness (i.e. delay and secrecy) as a function of the researcher's budget share financed by industry. This formulation allows us to examine two potential effects of industry sponsored research contracts. The first is an adoption effect that takes place when academic researchers commit to industry funding. The second is an intensity effect that captures how publication restrictions depend on the researcher's exposure to greater *ex post* review and evaluation by industry sponsors. Our models include covariates that control for non-industry extramural sponsorship, personal characteristics, research characteristics, institutional affiliations, and scientific fields of study.

Both the descriptive and regression results show a positive relationship between the degree of publication restrictions and industry sponsorship. The percentage of respondents who reported higher secrecy (partial or full) is significantly larger for industry sponsored researchers than it is for researchers with other extramural sponsors, 41% and 7% respectively. Controlling for selection, adopting industry sponsorship more than doubles the expected probabilities of publication delay and secrecy. The intensity effect is positive and significant with a larger effect on publication secrecy than on publication delay when academic researchers become heavily supported by industrial firms. These results are robust to the possibility that researchers self-select into extramural sponsorship and to the possibility that the share of industry sponsorship is endogenous due to unobserved variables.

Based on our analysis, the shift from public to private sponsorship seen in the OECD aggregate data reflects changes in the microeconomic environment shaping incentives for disclosure by academic researchers. On average, academic researchers are willing to restrict disclosure in exchange for financial support by industry sponsors. Our results shed light on an important challenge facing policymakers. Understanding the trade-off between public and private sponsorship of academic research involves gauging the impact of disclosure restrictions on the quantity, quality, and evolution of academic research to better understand how these restrictions may ultimately influence innovation and economic growth.

The rest of the paper is organized as follows. The next section summarizes the current literature on sponsorship of academic research. The researcher-level data, estimation issues and methods are discussed in section 3. The results and concluding remarks appear in sections 4 and 5, respectively.

2 Sponsorship of Academic Research

More than a simple transfer of funds, sponsorship of academic research involves contractual relationships that often specify the nature, ownership, and control rights for research findings, methods, or materials (Noll and Rogerson 1998; Geuna 2001; Gans and Murray 2011). While these contracts are necessarily "incomplete" due to a number of informational problems, they reflect negotiated outcomes between sponsors and researchers that can have far reaching implications for the conduct and nature of academic research. Historically, as argued by David (2004), sponsorship relationships helped to transform the norms, incentives, and organizational structures of scientific inquiry from a system dominated by secrecy to a modern "open science" system characterized by rapid public disclosure of new knowledge.[2] Relative to a secrecy system, open science is considered to be an efficient and welfare enhancing system for the production of a cumulative, accessible, and reliable stock of public scientific and technical knowledge (Dasgupta and David 1994; Mukherjee and Stern 2009).

As history suggests, the objectives and institutional reward systems practiced by different sponsors may influence the norms, incentives, and organizational structures of academic research differently. "Public" sponsors such as science-oriented state agencies or private foundations focus on advancing public knowledge. These institutions expect sponsored research to result in new knowledge that is publicly disclosed through various channels including publication. In fact, continued public support often depends on a satisfactory performance as indicated by a researcher's publication output. Advancing public knowledge through disclosure is consistent with the priority reward system and reinforces open science norms and behaviours. In contrast, "private" sponsors such as military-oriented state agencies or private industry focus on extracting rents from new knowledge by restricting public disclosure. Advocating restrictions on disclosure is likely to have a corrosive effect on open science.

In a recent paper, Gans and Murray (2011) summarize the selection and disclosure criteria used by public and private sponsors of academic research and offer a theoretical framework for understanding how conditions associated with public sponsorship may influence the mix and openness of those projects.[3] As part of this effort, they collected data from twenty major U.S. universities on the contract terms offered to industrial sponsors in

[2] Open science is broadly associated with universities and other not-for-profit research institutions that practice the "priority" reward system and support the professional ethos associated with the community of academic scientists as articulated by sociologist Robert K. Merton (see, for instance, Merton 1973; Dasgupta and David 1994; Stephan 1996). David (2004) highlights the norms of "universalism" (open entry and discourse) and "communism" (full and open disclosure) as particularly relevant to openness.

[3] Gans et al. (2010) use a theoretical model to examine alternative forms of disclosure under private industry sponsorship. For instance, they consider whether results are disclosed through patenting, publishing, or patent-paper pairs.

single-sponsor research agreements. They found notable heterogeneity in the provisions governing publication restrictions. For the sixteen universities that included any such provisions, pre-publication review periods and delay extensions were highly variable across contracts. The majority of contracts allowed the industrial sponsor to review and restrict disclosure of information designated as confidential, although five university contracts appeared to allow "full disclosure".

Other researchers have surveyed private firms about the characteristics of sponsored research contracts with academics.[4] Based on survey responses from 210 life science companies, Blumenthal et al. (1996b) found evidence of both publication delay and secrecy (nondisclosure) restrictions on information resulting from academic research. For instance, fifty-eight percent of the companies typically required researchers to keep information confidential for more than six months. Using survey responses from 112 firms engaged in university licensing, Thursby and Thursby (2007) reported that ninety percent of the university contracts included publication delay clauses.

Another approach, which is followed in this paper, is to ask academic researchers about any disclosure restrictions they experienced when undertaking extramurally sponsored research from any source. We found six studies that used researcher-level survey data to shed light on the relationship between industry sponsorship and disclosure. In five of these studies, Blumenthal and colleagues described the results of three separate life science faculty surveys conducted between 1985 and 2000 (Blumenthal et al.1986, 1996a, b, 1997, 2006; Campbell et al. 2000). Their findings show that researchers with at least one industry sponsored project are more likely to report industry ownership of research results, pre-

[4] Besides the limited information provided by Gans and Murray (2011), we did not find any studies that systematically analyze the contractual terms of scientific or military-oriented contracts from state sponsors or private foundations. Cohen at al. (1998) reported that 53 percent of university-industry research centers allowed firms to impose publication delays and 35 percent allowed firms to impose secrecy through the deletion of information before publishing. For a sample of 130 French public labs that have 875 industrial partners, Goddard and Isabelle (2006) reported that 55% allowed contract provisions to delay publication and 53% allowed contract provisions to suppress information from publication.

publication review, publication delays, and secrecy to protect proprietary information.[5] Taking a slightly different perspective, Hong and Walsh (2009) ask researchers how "safe" they feel about discussing their current work with non-collaborating colleagues. For their full sample, academic researchers with at least one industry sponsored project were more likely to feel "unsafe" (interpreted as being more secretive).

Overall, this literature suggests that academic researchers who adopt industry sponsorship experience greater publication restrictions through both delay and secrecy relative to unsponsored researchers or researchers who have non-industrial sponsors. In other words, the literature focuses on the "adoption effect" for those scientists who become industry sponsored by using a dummy variable specification indicating the receipt of industrial funds. The implicit assumption is that once a scientist signs the industrial sponsorship agreement, he or she has committed to the disclosure restrictions contained therein and the financial amount received from the industrial sponsor(s) is immaterial.

However, this assumption may be too simple to fully capture the influence of industrial sponsors on the disclosure of academic research. Sponsorship contracts are incomplete due to information problems stemming from the inherent uncertainty about the nature and value of research outcomes (Noll and Rogerson 1998). With incomplete contracts, publication delay and secrecy restrictions are at least partially determined *ex post* by industrial sponsors. For instance, as was described by Gans and Murray (2011), pre-publication review and the designation of confidential information frequently take place after research outcomes are known. Industrial sponsors have some flexibility to hold up publication or prevent disclosure when they evaluate research outcomes as commercially valuable. In this way, publication delay and secrecy should increase with the scientists'

[5] Using an industry funding indicator, Walsh et al. (2007) found no relationship between industry funding and compliance with requests for research inputs among biomedical researchers performing genomic and proteomic-related research.

financial share of industrial sponsorship because this share reflects their exposure to greater *ex post* review and evaluation, an "intensity effect".

Our analysis extends the literature in three primary ways. First, we expand the scope of evidence by analyzing academic researchers who work outside the United States in a broader set of scientific fields and institutional settings. All of the prior work analyzing how industry sponsorship influences disclosure looked at U.S. researchers working in a handful of scientific fields at American universities. Second, our analysis uses the budget share of industry sponsorship instead of a dummy variable formulation. With this specification, we are able to examine the intensity effect associated with greater exposure to *ex post* review and evaluation due to incomplete contracting. In line with prior work, we also examine the adoption effect for those scientists who would switch to industrial sponsored research. This effect is given by the difference in the expected probability of disclosure restrictions between academic scientists with and without industry sponsorship. Third, our empirical analysis is the first to address potential selection by academic researchers into extramural sponsorship.

3 Data and Methods

3.1 Data

To analyze the relationship between industry sponsorship and disclosure restrictions on publications we used a researcher-level database. In 2008, the Centre for European Economic Research (ZEW) undertook an online survey of German academic researchers as part of an evaluation effort for the EU's 6th European Framework programme.[6] The target sample was defined to include German researchers who held a Ph.D. degree and worked at either a university or a not-for-profit research institution. Information on university affiliated

[6] Details on the nature and purpose of the 6th European Framework programme can be found at http://ec.europa.eu/research/fp6/index_en.cfm.

researchers was collected from a register of German professors ("Hochschullehrerverzeichnis") which excludes universities of applied sciences that focus on teaching. For Germany's largest not-for-profit research institutions (Fraunhofer Society, Max Planck Society, Helmholtz Association, Leibniz Association), information on affiliated researchers was collected using internet searches.[7]

Combining the register data with those from the internet searches led to an available sample frame of 16,269 scientists whose e-mail addresses were known. In total, we obtained 2,797 responses with at least one question completed. After dropping observations with missing values for the variables of interest in this study, we end up with a final sample of 1,060 observations.[8]

To evaluate the representativeness of our sample, we obtained data from the Federal Statistical Office on the population distribution of public research scientists across institutional categories (universities and PROs), discipline, gender, and age groups. In line with the classification used by the German Science Foundation, we grouped our sample scientists into four scientific disciplines: life sciences, natural sciences, engineering, and social sciences/humanities. The official population shares and our final sample shares by discipline, gender, and age group are reported in Table 1. For the science disciplines there is

[7] Major research institutions in Germany are not only universities but other public research institutions that have many branches in a variety of different scientific disciplines. For instance, the Fraunhofer Society has 59 institutes in Germany with about 17,000 employees, the Max Planck Society has 76 institutes with about 12,000 employees. The Leibniz Association employs 16,100 people in 86 research centres.The Helmholtz Association has about 30,000 employees in 16 research centres. University professors are frequently heads of research groups at these institutions, i.e. they have a university affiliation but are typically on leave full-time when working with the research institutes.

[8] The discrepancy between the number of responses and observations used in this study is explained by three different reasons: a) as is common in online surveys, several potential respondents logged in (thus they are counted as 'response' by the online database), but they did actually not answer any or not more than a few questions; b) the survey was initially conducted on behalf of the German Federal Government for analyzing the participation of public science researchers in the EU's 6th Framework Programme. Therefore the first part of the survey is dedicated to FP6, and the broader questions used in this study were asked in the second part of the survey. As a result, many respondents did not complete all necessary modules under consideration here. Only about 1,400 people filled in the entire questionnaire; c) the remaining 1,400 observations had some item non-response. After eliminating such observations, we end up with our final sample of 1,060 scientists. As this response pattern raises some concern about the representativeness of the sample, we checked the robustness of our findings by using population weighted regression models. As reported in the text, our regression results do not change substantively.

a fairly good match between our sample and the population, but the gender and age group distributions are notably different. Our sample has about 5.3% more life scientists and about 3.2% fewer social science/humanities researchers than the overall population. The other science disciplines are close, especially for engineering. The Federal Statistical Office reports that 31.5% of all German scientists are females and this suggests our sample under-represents females in the population. Age groups also show some big differences. The youngest age group (less than 35 years old) is strongly under-represented while scientists in the 45 to 65 year old age groups are over-represented.

Table 1: German academic scientists: population and sample shares

	Population Share Academic Scientists	**Sample Share Academic Scientists**
Science Field		
Natural sciences	31.1%	29.2%
Engineering sciences	19.3%	19.2%
Life sciences	25.2%	30.5%
Social sciences and humanities	24.4%	21.1%
Gender		
Female	31.5%	14.8%
Male	68.5%	85.2%
Age Cohort		
Less than 35	34.2%	1.8%
35 and less than 45	26.6%	28.4%
45 and less than 55	18.2%	44.6%
55 and less than 65	15.1%	20.3%
Greater than 65	5.8%	4.9%

Source: Federal Statistical Office, 2011; authors' calculations.

The differences shown in Table 1 suggest our sample does not adequately represent all segments of the German scientist population. To assess the quantitative importance of these differences we re-estimated our regression models reported in Section 4 using population weights to correct for any over or under-sampling contained in our data. Using information from the Federal Statistical Office, we constructed three different population stratification schemes and calculated population weights based on the number of researchers. In the weighted regressions, the coefficient estimates were generally larger in magnitude and had the same sign and level of statistical significance as the results presented in Section 4. Overall our findings on publication restrictions are not sensitive to the observed differences between our sample and the population. (These regression results are available from the authors.) Of course, the weighted regressions do not rule out item response bias, which is always a potential problem with survey data. This caveat should be kept in mind when interpreting the results.

The dependent variable is drawn from a question that asked respondents to indicate the degree of disclosure restrictions on publications resulting from any extramural sponsorship. It asked: "Has the funding of your research by public or private extramural sponsors resulted in: (a) a complete ban on publishing research; (b) a partial ban on publishing research; or (c) a delay in publishing research due to contractual agreements." Respondents could check as many as three boxes for each outcome indicating "yes", "no", or "not relevant". A cross tabulation of responses shows that 186 scientists reported experiencing delay with 69 reporting only delays and 117 reporting both delay and some form of secrecy (partial or complete ban). Similarly, 178 scientists reported experiencing secrecy with 61 reporting only secrecy and 117 reporting both delay and secrecy. The cross tabulations indicate that a scientist is likely to experience combinations of delay and secrecy rather than only delay or only secrecy (i.e. 47% [=(117/247)*100] of those who report any delay or secrecy).

For the empirical analysis, we considered three alternative dependent variables based on this question. The first is a dummy variable indicating the researcher experienced any publication delay or secrecy due to extramural funding. This binary variable takes the value of one if the respondent indicated "yes" to any of the outcomes. For ease of exposition, the table headings use the phrase "publication withholding" to refer to the combined delay and secrecy outcomes. For the second and third dependent variables, we analyze delay and secrecy separately. For each, a dummy variable is set equal to one if the scientist reported experiencing that form of publication restriction.

The main explanatory variable in the analysis is the share of the researcher's extramural budget funded by private industry sponsors. As described in Section 2, the budget share will capture both the adoption and intensity effects. This variable was constructed using two survey questions. The first question asked the researcher to report his or her total extramural budget over the five year period from 2002 to 2006. Conditional on having extramural funding, a separate question asked the researcher to provide the source (as a percentage) of his or her total extramural budget over the five year period. The share of industry sponsorship is the proportion of a researcher's budget funded by private sector organizations.

We used a number of other variables collected through the survey as controls or instrumental variables in the empirical analysis. These variables are grouped into four categories: research characteristics, personal characteristics, institutional affiliations, and scientific fields of study. Research characteristics relate to the individual's position at the research institution, his or her total extramural funding, publications, patent applications, whether the scientist consults with industry, and his or her opinion about the peer review process. Personal characteristics include the individual's age and gender, and whether he or she is tenured. Institutional affiliations cover universities, the four major not-for-profit public research institutions, and a residual group for all other affiliations. As mentioned above, the researchers were grouped into four broad scientific fields specified as life sciences, natural sciences, engineering, and social sciences/humanities.

3.2 Methods

In the ideal case, we would use an experimental design to identify the causal effect of industry sponsorship on publication disclosure by academic researchers. For instance, one might randomly assign industry sponsorship to academic researchers, allow for negotiation and research, and observe *ex post* changes in disclosure. This type of experiment would eliminate any bias due to self-section by academic researchers into funding from factors such as their preferences for disclosure or their need to rely on extramural funding. Our survey data, however, were not collected using a randomized experimental design. With our data, we only observe whether or not an academic researcher has public or private extramural sponsorship and this suggests Probit estimators could be biased by self-selection. Academic researchers who received extramural funding are probably different from those who did not receive funding. For instance, researchers who are less concerned about disclosure or perform more "applied" research may be more willing to accept extramural sponsorship that imposes disclosure restrictions.[9] This would lead to an upward bias. To address this possibility, our empirical analysis includes Probit models accounting for selection into extramural funding. In these models, the academic researcher's age and gender serve as exclusion restrictions that predict the receipt of extramural funding, but do not influence the researcher's disclosure outcome. These exclusion restrictions are supported statistically. Neither gender nor age significantly influence disclosure restrictions on publications once other factors are held constant.[10]

While our survey data provide fairly rich researcher-level information, we do not observe the researcher's perception of scientific competition within his or her field. Current studies find that greater scientific competition is associated with greater secrecy (Hong and Walsh 2009; Haeussler 2011). Relevant for this analysis, however, is the relationship

[9] Define Y_{0i} as the non-disclosure (or secrecy) outcome for academic researcher i in the state of not receiving extramural funding and define D_i as the funding indicator: $D_i=1$ when funded and $D_i=0$ when not funded. Selection bias is positive when those who actually received funding value non-disclosure more in the unfunded state: $E[Y_{0i} \mid D_i = 1] - E[Y_{0i} \mid D_i = 0] > 0$.

[10] In addition to being statistically valid, other research on academic sharing behaviors and attitudes toward cooperation with private firms do not find gender to be significant (Haeussler 2011; Audretsch et al. 2010). Haeussler (2011) finds that a researcher's age decreases the percent of requested information that is shared.

between scientific competition and extramural sponsorship. Scientific competition may either increase or decrease the attractiveness of extramural sponsorship. On the one hand, researchers feeling intense competition for priority may be less willing to accept third party disclosure restrictions. On the other hand, extramural sponsorship may provide financial resources that help the researcher get work done faster. The direction of potential bias could go either way. In our analysis, we included scientific field dummy variables to capture differences in the level of scientific competition across fields. To conserve space, standard descriptive statistics for the variables used in the regression models are reported in Table A.1 of the appendix.

4 Results

4.1 Main results

Table 2 presents descriptive statistics for the full sample of German researchers and for subsamples broken out by extramural funding. Most respondents indicated some extramural sponsorship (81%) with nearly one third having industry sponsorship. Although not included in Table 2, researchers with any extramural sponsorship received support from an average of 2.1 different sponsor groups (e.g. state or federal government, foundations, European Union, industry, or other sponsors) and those with industry funding received support from an average of 2.7 different groups. This illustrates the multi-sponsor nature of extramural funding in Germany (Grimpe, 2012).[11] On average, researchers with any industry sponsorship had larger research budgets, published more in journals, applied for more patents, and had more consulting arrangements with industry. Personal characteristics of researchers were similar except for a significant drop in the proportion of females for the group of industry sponsored researchers. A greater proportion of university and Fraunhofer

[11] This is also the case in the U.S. as reported by Mansfield (1995).

affiliated researchers reported industry sponsorship while the proportion of industry sponsored researchers is quite small for affiliates of the Max Planck Society, which is strongly oriented toward basic research. Among the science fields, industry sponsorship was greatest in engineering.

Table 2: Sample averages for all covariates by extramural sponsorship

	All Respondents	**External Funding No**	**External Funding Yes**	**External Funding From Industry**
Total Observations (% of all obs)	1060	204 (19%)	856 (81%)	341 (32%)
Report a delay or ban of research	0.233	0	0.289	0.504
Research Characteristics				
Industry share	0.090	0	0.111	0.279
Total external budget (mil Euro)	1.369	0	1.695	2.163
Research group leader	0.722	0.426	0.792	0.862
Journal publications	21.42	12.451	23.557	26.595
Patent applications	0.749	0.382	0.836	1.537
Consult with industry	0.164	0.093	0.181	0.305
Personal Characteristics				
Tenure	0.842	0.75	0.864	0.918
Female	0.148	0.176	0.141	0.088
Age	49.5	50.4	49.3	50.2
Institutions				
University	0.586	0.471	0.613	0.642
Fraunhofer Society	0.051	0.049	0.051	0.117
Max Planck Society	0.085	0.132	0.074	0.035
Helmholtz Association	0.165	0.221	0.152	0.106
Leibniz Association	0.07	0.088	0.065	0.053
Other Institutions	0.087	0.098	0.084	0.073
Science Fields				
Life sciences	0.305	0.328	0.299	0.279
Natural sciences	0.292	0.294	0.292	0.214
Engineering	0.192	0.113	0.21	0.378
Social sciences/humanities	0.211	0.265	0.199	0.129

Next we examined the average values of the covariates for different levels of restriction (no delay or secrecy, delay, partial or full secrecy) grouped by extramural, industry, and non-industry sponsorship as shown in Table 3. Out of the 341 respondents that reported some industry sponsorship, 50% reported no delay or secrecy on publications, 9% reported a delay, and 41% reported a partial or full secrecy on publications. The percentage of respondents who reported the higher secrecy (partial or full) is significantly larger (at the 1% level) for industry sponsored researchers than it is for researchers with non-industry sponsorship, 41% and 7% respectively. The positive association between industry share and level of secrecy is already evident in Table 3. As one looks across the columns from no restrictions (no delay/ban) to higher secrecy (partial/full), researchers reported larger industry sponsorship shares. Higher secrecy was reported more frequently by researchers affiliated with applied public research organizations such as the Fraunhofer Society and Helmholtz Association. Among the science fields, the proportion who reported partial or total secrecy on publishing is greatest in engineering.

Table 3: Sample averages by level of publication restriction and type of extramural sponsorship

	Any External Funding (N=856)			Industry Funding (N=341)			Non-Industry Funding (N=515)		
	No Delay or Ban	**Delay**	**Partial or Full Ban**	**No Delay or Ban**	**Delay**	**Partial or Full Ban**	**No Delay or Ban**	**Delay**	**Partial or Full Ban**
Total Observations (%)	609 (71%)	69 (8%)	178 (21%)	169 (50%)	32 (9%)	140 (41%)	440 (85%)	37 (7%)	38 (7%)
Research Characteristics									
Industry share	0.067	0.116	0.26	0.241	0.25	0.331	0	0	0
Total external budget (mil Euro)	1.517	1.633	2.327	1.993	1.938	2.42	1.334	1.370	1.982
Research group leader	0.788	0.841	0.787	0.882	0.938	0.821	0.752	0.757	0.658
Journal publications	25.504	27.507	15.365	34.64	34.906	14.979	21.993	21.108	16.789
Patent applications	0.473	1.551	1.803	0.941	2.031	2.143	0.293	1.135	0.553
Consult with industry	0.144	0.290	0.264	0.296	0.375	0.300	0.086	0.216	0.132
Personal Characteristics									
Tenure	0.856	0.884	0.888	0.911	0.969	0.914	0.834	0.811	0.789
Female	0.151	0.159	0.101	0.089	0.1875	0.064	0.175	0.135	0.237
Age	49.2	50	49.2	50.4	51.2	49.7	48.9	48.9	47.3
Institutions									
University	0.65	0.609	0.489	0.769	0.688	0.479	0.605	0.541	0.526
Fraunhofer Society	0.016	0.058	0.169	0.041	0.094	0.214	0.007	0.027	0
Max Planck Society	0.094	0.029	0.022	0.053	0.031	0.014	0.109	0.027	0.053
Helmholtz Association	0.146	0.13	0.180	0.065	0.063	0.164	0.177	0.189	0.237
Leibniz Association	0.062	0.072	0.073	0.036	0.094	0.064	0.073	0.054	0.105
Other Institutions	0.076	0.116	0.101	0.059	0.063	0.093	0.082	0.162	0.132
Science Fields									
Life sciences	0.332	0.333	0.174	0.385	0.344	0.136	0.311	0.324	0.316
Natural sciences	0.322	0.304	0.185	0.213	0.25	0.207	0.364	0.351	0.105
Engineering	0.13	0.116	0.522	0.266	0.219	0.55	0.077	0.027	0.421
Social sciences/humanities	0.217	0.246	0.118	0.136	0.397	0.107	0.248	0.297	0.158

Our regression analysis begins by analyzing a binary "publication withholding" outcome that indicates whether a researcher who was supported by any extramural sponsor experienced any type of publication delay or secrecy. Model A in Table 4 shows the results of a basic Probit regression that ignores selection into extramural funding. Model B controls for selection into extramural funding (see e.g. Wooldridge, 2002: 570, for technical details).[12] Holding the size of the researcher's extramural budget constant (as well as other factors), the share of industry sponsorship significantly increases the probability of publication delay or secrecy in both models. The correlation across equations in Model B, reported at the bottom of the table as ρ, is negative and significant which indicates selection into extramural funding is important. After controlling for selection, the coefficient estimate on industry share is 16.6% smaller but still highly significant.

The estimation results from Model B indicate that both the adoption and intensity of industry sponsorship are associated with greater publication withholding. The adoption effect is given by the difference in the expected probability of experiencing publication withholding between industry and non-industry sponsored scientists conditional on selection into extramural funding. If an academic scientist were to switch to the group with industrial sponsorship, his or her expected probability of publication withholding would more than double from 0.185 to 0.437 and this difference is statistically significant at the 1% level.

[12] We consider the selection decision into any extramural funding as most appropriate because non-industry sources of support also involve non-trivial choices about publication delay and secrecy as show in the appendix. Moreover, it is consistent with the multi-sponsor nature of extramural funding described earlier in the section. Table A.3 of the appendix shows the regression results that control for selection into industry funding.

Table 4: Probit of Publication Withholding

Variable	Model A: Probit (No Selection)	Model B: Probit with Selection – Second stage Outcome Equation	Model B: Probit with Selection – First stage selection (External Funding/No External Funding)
Industry share	1.362***	1.136***	
	(0.238)	(0.211)	
ln(total extramural funding)	0.150***	0.112***	
	(0.040)	(0.033)	
Female			0.021
			(0.116)
Age			0.121**
			(0.053)
Age-squared			-0.001***
			(0.0005)
Research group leader	0.061	-0.359***	0.720***
	(0.138)	(0.130)	(0.107)
Tenure	-0.034	-0.085	0.222
	(0.154)	(0.127)	(0.148)
Journal publications	-0.006***	-0.007***	0.007***
	(0.002)	(0.002)	(0.003)
Patent applications	0.095***	0.087***	0.052
	(0.023)	(0.022)	(0.031)
Consult with industry	0.237*	0.134	0.161
	(0.131)	(0.120)	(0.150)
Fraunhofer Society	0.609**	0.552**	-0.288
	(0.248)	(0.225)	(0.234)
Max Planck Society	-0.364	-0.092	-0.337**
	(0.246)	(0.204)	(0.168)
Helmholtz Association	0.249	0.253*	-0.233*
	(0.153)	(0.132)	(0.140)
Leibniz Association	0.444**	0.383**	-0.197
	(0.201)	(0.174)	(0.185)
Other institutions	0.301*	0.230	-0.009
	(0.178)	(0.157)	(0.174)
Life sciences	-0.203	-0.149	-0.050
	(0.156)	(0.133)	(0.139)
Natural sciences	-0.160	-0.206	0.144
	(0.162)	(0.138)	(0.144)
Engineering	0.366**	0.165	0.425***
	(0.161)	(0.146)	(0.165)
Intercept	-0.807***	0.028	-2.407*
	(0.207)	(0.197)	(1.290)
Log-Likelihood	-414.167	-852.575	
Equation corr (ρ)	-	-0.910***	
# Observations	856	1060	

Note: Standard errors in parentheses. *** (**,*) indicate a significance level of 1% (5%, 10%).
Reference: male, non-group leader, untenured, university, social/humanities scientist.

To examine the intensity effect, we analyze the difference in the expected probability of publication withholding within the group of industry sponsored scientists. We calculate and compare the expected probabilities at two points in the industry share distribution. In the sample, industry sponsored scientists in the lowest decile get 5% or less of their research budgets from industry while those scientists in the highest decile get 70% or more. With industry share fixed at 5%, the expected probability of experiencing publication withholding among industry sponsored scientists is 0.338. At a 70% share, this probability increases to 0.622 and the difference is significant at the 1% level. These results support concerns that adopting industry sponsorship and having greater exposure to *ex post* review and evaluation both undermine the norms and practices of open science and may jeopardize the cumulative nature and reliability of public scientific and technical knowledge.

It is also informative to examine how other covariates influence publication delay or secrecy while holding other factors constant, including industry share. A larger extramural budget is associated more publication withholding. This result indicates that delay and secrecy restrictions are also imposed by other sponsors. For instance, publicly supported research may be restricted if it is judged by the government agency to contain sensitive findings or confidential information. From Model B, research characteristics and institutional affiliations matter even after controlling for selection into sponsored research. A researcher who is a group leader or had more journal publications is less likely to experience delay or secrecy restrictions. Group leaders and productive researchers are likely to value disclosure more and possess more bargaining power with extramural sponsors. This is consistent with Audretsch et al. (2010) who found group leadership to be associated with more cooperation experience and planned cooperation with private companies. In Model A, academic scientists who have formal consulting relationships with industry are more likely to experience publication withholding, although this effect disappears when selection into funding is taken into account. Researchers who submit more patent applications are more likely to restrict publications through either delay or secrecy.

With regard to institutions and science fields, those affiliated with the Fraunhofer Society, Helmholtz and Leibniz Associations are more likely to experience publication delay or secrecy relative to university researchers. Given our data, we cannot distinguish between an institutional "management" effect, reflecting the strength of the technology transfer capabilities at these institutions, versus an institutional "focus" effect, reflecting the relatively applied orientation of research at these institutions. As emphasized by Dasgupta and David (1994), alternative institutional settings can influence a researcher's choice about disclosure and our results highlight the need for further research into these relationships. As described in Section 2, most of the literature has focused on researchers in the life sciences and its subfields. Looking at Model A, our results indicate that the life scientists are not significantly more likely to experience delays or secrecy on publications relative to the base group of academics in social sciences/humanities. Only engineering researchers are more likely to experience these publication restrictions. Interestingly, after controlling for selection into extramural sponsorship in Model B, engineering researchers are no longer significantly different from social scientists.

Beyond the combined outcome of publication withholding, it is also possible that industry sponsorship has different adoption and intensity effects on delay versus secrecy. To examine this possibility, we re-estimated the models discussed above using delay and secrecy as separate dependent variables. For both outcomes, as reported in Tables 5 and 6, industry share is positive and significant at the 1% level and controlling for selection reduces the size of the industry share coefficients as expected. The adoption effect for each of the outcomes is quite similar. Industrial sponsorship increases the expected probability of delay from 0.14 to 0.33, a difference that is statistically significant at the 1% level. For secrecy, the adoption effect also leads to a statistically significant difference by increasing the expected probability from 0.112 to 0.35. For each outcome, the intensity effect is positive and significant at the 1% level; however, greater exposure to *ex post* review and evaluation by industrial sponsors produces a larger effect on publication secrecy than it does on delay. Increasing the share of industry sponsorship from 5% to 70% increases the expected probability of publication secrecy by 0.30 while it increases delay by 0.21.

With the exception of a few control variables, the results for the separate delay and secrecy outcomes are quite similar to those found using the combined publication withholding outcome. One covariate that shows a differential effect is consulting with industry. As seen in Table 4, consulting is significantly related to publication delay even after controlling for selection into extramural sponsorship, but not significantly related to publication secrecy. This suggests that academics who consult primarily face publication delay restrictions. Among the scientific fields, natural scientists experience significantly less delay than social scientists while engineers experience significantly greater secrecy.

Table 5: Probit of Publication Delay

Variable	Model A: Probit (No Selection)	Model B: Probit with Selection Second stage Outcome Equation	First stage selection (External Funding/No External Funding)
Industry share	1.015***	0.837***	
	(0.236)	(0.211)	
ln(total extramural funding)	0.098**	0.077**	
	(0.041)	(0.034)	
Female			0.035
			(0.119)
Age			0.110**
			(0.055)
Age-squared			-0.001**
			(0.0005)
Research group leader	0.041	-0.369**	0.722***
	(0.142)	(0.156)	(0.107)
Tenure	0.027	-0.048	0.227
	(0.163)	(0.135)	(0.150)
Journal publications	-0.002	-0.004**	0.007***
	(0.002)	(0.002)	(0.003)
Patent applications	0.095***	0.085***	0.053*
	(0.022)	(0.022)	(0.032)
Consult with industry	0.358***	0.239*	0.158
	(0.131)	(0.125)	(0.151)
Fraunhofer Society	0.637***	0.569***	-0.279
	(0.232)	(0.213)	(0.234)
Max Planck Society	-0.199	-0.003	-0.351**
	(0.245)	(0.208)	(0.169)
Helmholtz Association	0.203	0.216	-0.241*
	(0.158)	(0.137)	(0.141)
Leibniz Association	0.383*	0.342*	-0.192
	(0.208)	(0.182)	(0.186)
Other institutions	0.115	0.088	0.001
	(0.188)	(0.164)	(0.177)
Life sciences	-0.260	-0.195	-0.054
	(0.162)	(0.141)	(0.141)
Natural sciences	-0.234	-0.263*	0.155
	(0.168)	(0.144)	(0.145)
Engineering	0.051	-0.112	0.426**
	(0.168)	(0.153)	(0.167)
Intercept	-1.039***	-0.172	-2.152
	(0.216)	(0.261)	(1.337)
Log-Likelihood	-384.122	-824.304	
Equation corr (ρ)	-	-0.866*	
# Observations	856	1060	

Note: Standard errors in parentheses. *** (**,*) indicate a significance level of 1% (5%, 10%).
Reference: male, non-group leader, untenured, university, social/humanities scientist.

Table 6: Probit of Publication Secrecy (partial or full ban on publication)

	Model A: Probit	Model B: Probit with Selection	
Variable	(No Selection)	Second stage Outcome Equation	First stage selection (External Funding/No External Funding)
Industry share	1.578***	1.261***	
	(0.244)	(0.216)	
ln(total extramural funding)	0.163***	0.118***	
	(0.044)	(0.035)	
Female			0.030
			(0.113)
Age			0.109**
			(0.052)
Age-squared			-0.001**
			(0.0005)
Research group leader	0.056	-0.408***	0.705***
	(0.150)	(0.147)	(0.108)
Tenure	-0.071	-0.120	0.232
	(0.172)	(0.134)	(0.146)
Journal publications	-0.009***	-0.010***	0.008***
	(0.003)	(0.002)	(0.003)
Patent applications	0.061**	0.053**	0.048
	(0.024)	(0.022)	(0.032)
Consult with industry	0.053	-0.038	0.168
	(0.145)	(0.128)	(0.149)
Fraunhofer Society	0.517**	0.452**	-0.304
	(0.241)	(0.216)	(0.232)
Max Planck Society	-0.227	0.075	-0.340**
	(0.287)	(0.221)	(0.169)
Helmholtz Association	0.306*	0.290**	-0.264*
	(0.166)	(0.139)	(0.139)
Leibniz Association	0.557**	0.443**	-0.193
	(0.218)	(0.184)	(0.185)
Other institutions	0.198	0.095	-0.100
	(0.198)	(0.171)	(0.171)
Life sciences	-0.083	-0.050	-0.051
	(0.180)	(0.142)	(0.139)
Natural sciences	-0.066	-0.149	0.152
	(0.187)	(0.149)	(0.144)
Engineering	0.757***	0.432***	0.433***
	(0.176)	(0.159)	(0.165)
Intercept	-1.186***	-0.164	-2.079
	(0.232)	(0.236)	(1.262)
Log-Likelihood	-324.946	-763.861	
Equation corr (ρ)	-	-0.930**	
# Observations	856	1060	

Note: Standard errors in parentheses. *** (**,*) indicate a significance level of 1% (5%, 10%).
Reference: male, non-group leader, untenured, university, social/humanities scientist.

4.2 Discussion

Publication disclosure restrictions may adversely impact the conduct and nature academic science. Delay limits the flow of new knowledge (ideas, methods, and materials) by restricting the rate of disclosure. This reduces the amount of knowledge available at every point in time relative to an unrestricted disclosure regime. Secrecy, of course, means that scientific results never become part of the stock of public knowledge. Because the size and growth rate of the stock of public knowledge are reduced, the overall character and potential usefulness of scientific research also changes. Both delay and secrecy may lead to duplication of research efforts, limit possibilities for complementary follow-on research, or foreclose new research lines as pointed out by Murray et al. (2009) and others. From a sociological perspective, if disclosure restrictions become accepted as commonplace, the professional ethos supporting open science will be significantly weakened. At the present time, however, the quantitative importance of these harmful effects on the conduct and nature academic research cannot be assessed due to a paucity of empirical research.

Acting to balance the potential costs of disclosure restrictions are the benefits to academic scientists from interacting with industry sponsors, gaining access to greater resources, and obtaining commercialization opportunities such as licensing. While our results suggest that adopting industry sponsorship will significantly increase the chances of publication delay and secrecy, it may still be the case that industry sponsorship allows scientists to increase their overall volume of publication output. Even with delay, it is a “net increment” to the stock of knowledge if a new article gets published that would not have been completed otherwise. For partial secrecy, even with a larger knowledge stock, the value of the net increment is smaller because withholding information may decrease the quality of the publications so that replication is not possible. This diminishes the reliability of the public stock of knowledge. For complete secrecy, there is no contribution to the public knowledge stock and academic scientists are completely diverted to proprietary research.

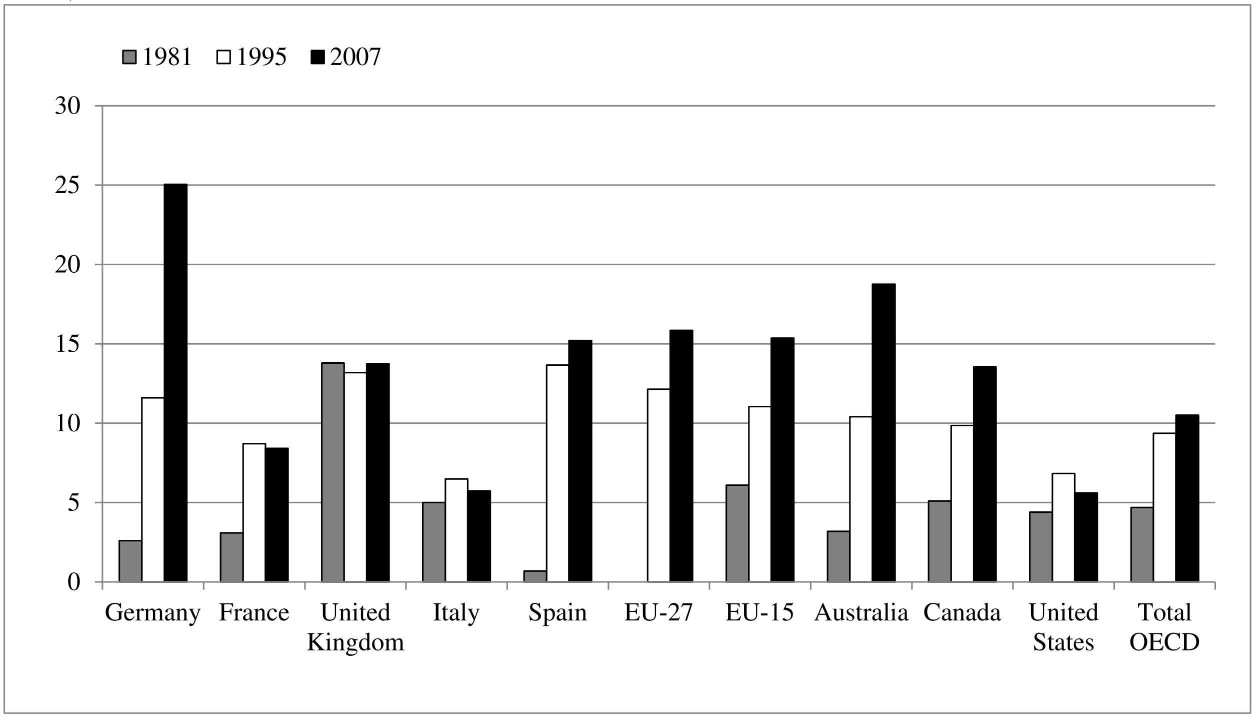
Thursby et al. (2007) make a similar point about the volume of publication in their analysis of how licensing income might influence faculty research output and the stock of knowledge. Inferring from their simulation results, industry sponsorship should lead to a higher ratio of applied to basic research, but more importantly, its effect on the stock of knowledge depends on whether the industry supported "applied" research is published or not. Cross-sectional evidence generally supports the idea that adoption of industry sponsorship increases academic publication volume, although none of these studies examine the relative quality of these industry sponsored publications (Blumenthal et al. 1986; Godin and Gingras 2000; and Gulbrandsen and Smeby 2005; Manjarres-Henriquez et al. 2009).

While disclosure restrictions from adopting a small share of industry sponsorship might not be large enough to offset an increase in publication volume, our analysis suggests the intensity effect due to an increasing share of industry sponsorship is a more serious threat to research output and the stock of knowledge. When industry finances a large share of a scientist's research budget, the likelihood of publication secrecy increases more than the likelihood of delay. The implication is that any beneficial effects of industry sponsorship on publication volume are likely to disappear. Current evidence in the literature is consistent with greater secrecy. Blumenthal et al. (1996) found that publication output was lower for American scientists who obtained more than two-thirds of their budgets from industrial sponsors. Based on panel data for a sample of UK faculty in engineering, Banal-Estanol et al. (2011) found that some industry collaboration increases publication output, but publication output falls as the fraction of research grants with industrial partners increases. For a sample of German academic scientists, Hottenrott and Thorwarth (2011) find that both publication output and the number of citations to those publications fall as the share of industry sponsorship increases (also see Manjarres-Henriquez et al. 2009; Schmoch and Schubert 2009).

From the contractual perspective offered here, the decrease in publication output reflects greater *ex post* review and evaluation by industry sponsors because the research is judged to be more commercially valuable. It is unlikely to represent a diversion to "applied" research since this research is easily published in professional journals. As suggested by Toole and Czarnitzki (2009), the decrease in publications could also reflect less effort devoted to scientifically-driven opportunities as a result of more involvement with industry (also see Toole and Czarnitzki 2010). Their interpretation cannot be ruled out based on the data and analysis presented here.

Our microeconomic evidence provides a lens for interpreting the on-going aggregate shift in institutional financing that supports academic research. As revealed in Figure 2, country-level OECD data show the share of industry sponsorship is generally rising, although not universally or monotonically. Our researcher-level evidence from Germany suggests the aggregate shift does not simply represent the substitution of private money for public, but involves a real change in when (or if) academic research findings, methods, and materials are publicly disclosed. This interpretation is consistent with prior research that examined researchers working in a handful of science fields at American universities. It appears the adverse effect of industry sponsorship on disclosure of academic research is not country specific or university specific.

Figure 1: Percentage of higher education and government R&D financed by industry 1981, 1995, 2007



Source: OECD, Main Science and Technology Indicators 2010

As the German case illustrates, policymakers and the leaders of academic institutions strongly influence the extent of industry sponsorship and extramural sponsorship more generally. Among OECD countries, Germany experienced the largest growth in its share of industry sponsorship, up to about 25% by 2007. Part of this growth is related to the tightening of public budgets and a change in the perspective of public administrators. Geuna (2001) argues that many European governments changed positions from an older "post-World War II" paradigm in which universities relied heavily on "core" funding to a new "contractual-oriented" approach intended to stimulate economic development and increase the efficiency of academic research institutions. This new perspective emphasizes competitive mechanisms to allocate public funds. German public administrators have also given preferential treatment to industry-university collaborative research projects in the funding selection process (see, for instance, Schiller 2011; Schmoch 1999; Laudel 2006a; Czarnitzki et al. 2011). In turn, leaders of academic institutions have changed their internal allocation rules to reward greater extramural funding (Schmoch and Schubert 2009; Laudel 2006b). While these changes may be legitimate responses to budgetary pressure, more research is needed to understand how country-level and institution-level characteristics influence the conduct and output of academic researchers.

5 Conclusion

This analysis finds that industry sponsorship is associated with changes in the disclosure behavior of academic researchers. In line with the literature, we argue that academic scientists who adopt industry sponsorship are subject to more stringent contract terms that restrict publication disclosure through delay and secrecy. Controlling for scientist selection, the results show that the expected probability of experiencing these restrictions more than doubles when moving to industry sponsorship. Adding to the literature, we argue that incomplete contracting due to the nature of research output allows for greater *ex post* review and evaluation by industrial sponsors. Publication delay and secrecy should increase with a scientist's financial share of industrial sponsorship as this share reflects his or her exposure to *ex post* review. Controlling for scientist selection, this intensity effect is positive and significant with a larger effect on publication secrecy than on publication delay.

Our data on German academic researchers supports the perspective that industry sponsorship jeopardizes public disclosure of academic research. Firms expect proprietary benefits from their sponsorship relationships and realizing these benefits often requires disclosure restrictions that academic researchers would not otherwise impose. While we cannot unequivocally state that our methods identified causal relationships, our empirical analysis offered significant advances in this direction.

The challenge facing policymakers is to gauge the impact of disclosure restrictions on the quantity, quality, and evolution of academic research to better understand how these restrictions may ultimately influence innovation and economic growth. This is a significant challenge and our study only lays the groundwork for more research. Before policy recommendations can be made numerous follow-on questions must be answered. For instance: What is the quantity and nature of information delayed or withheld? How do these disclosure restrictions affect the access costs, fidelity, and use of ideas that compose the stock of public scientific and technical knowledge? How important is the information delayed or withheld for private returns? What are the net social costs or benefits of disclosure restrictions? At this stage of the research, policymakers should at least be aware that academic researchers are accepting disclosure restrictions in exchange for financial support by industrial sponsors. If, as David (2004) argued, sponsorship relationships played an important role in the emergence of open science, it is only logical that sponsorship relationships are influential enough to undermine open science norms and practices.

Appendix A

This appendix contains the descriptive statistics and supplementary regression results accounting for selection into industry funding. Table A.1 reports the descriptive statistics for the sample of German academic scientists used in the regression analysis. The top panel provides the mean, standard deviation, minimum, and maximum for each variable used in the selection equation. The bottom panel reports the same statistics for those academic scientists who received extramural sponsorship from any category of sponsor (e.g. state or federal government, foundations, European Union, industry, or other sponsors).

Table A.1: Regression Descriptive Statistics

Data used in selection equation (N = 1,060)				
Dependent variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Any extramural sponsorship	0.808	0.394	0	1
Research Characteristics				
Research group leader	0.722	0.448	0	1
Journal publications	21.420	26.920	0	178
Patent applications	0.749	2.101	0	24
Consult with industry	0.164	0.371	0	1
Personal Characteristics				
Tenure	0.842	0.364	0	1
Female	0.148	0.355	0	1
Age	49.531	8.225	28	74
Institutions				
University	0.586	0.493	0	1
Fraunhofer Society	0.051	0.220	0	1
Max Planck Society	0.085	0.279	0	1
Helmholtz Association	0.165	0.371	0	1
Leibniz Association	0.070	0.255	0	1
Other Institution	0.087	0.282	0	1
Science Fields				
Life sciences	0.305	0.461	0	1
Natural sciences	0.292	0.455	0	1
Engineering	0.192	0.394	0	1
Social sciences	0.211	0.408	0	1
Data used in withholding regressions (N = 856)				
Dependent variables	Mean	Std. Dev.	Min	Max
Publication Withholding	0.289	0.453	0	1
Delay	0.217	0.413	0	1
Secrecy (partial or full)	0.208	0.406	0	1
Research Characteristics				
Industry share	0.111	0.212	0	1
Total external budget (mil Euro)	1.695	3.738	0.001	75
Research group leader	0.792	0.406	0	1
Journal publications	23.557	28.125	0	176
Patent applications	0.836	2.215	0	24
Consult with industry	0.181	0.385	0	1
Personal Characteristics				
Tenure	0.864	0.342	0	1
Institutions				
University	0.613	0.487	0	1
Fraunhofer Society	0.051	0.221	0	1
Max Planck Society	0.074	0.261	0	1
Helmholtz Association	0.152	0.359	0	1
Leibniz Association	0.065	0.247	0	1
Other Institution	0.084	0.278	0	1
Science Fields				
Life sciences	0.299	0.458	0	1
Natural sciences	0.292	0.455	0	1
Engineering	0.210	0.408	0	1
Social sciences	0.199	0.399	0	1

The main analysis views selection into any extramural sponsorship (e.g. government, industry, foundation, etc.) as the most relevant decision node when considering publication delay and secrecy choices by individual researchers. One reason for this view is that non-industry sources of support also involve non-trivial choices about publication delay and secrecy. This fact is evident in the survey responses. For alternative combinations of extramural sponsorship, Table A.2 shows that both delay and secrecy were reported for non-industry sponsorship. For instance, among those academic researchers with only government support, 9.2% reported experiencing publication delays and 23.1% reported partial or full publication secrecy. The comparable responses from those researchers who received only industry support were 9.4% and 41%, respectively.

Table A.2: Delay and Secrecy Responses by Sponsorship Combination

	Combinations of Sponsorship (% responses)			
Response Category	No government[1] No industry Yes Other[2]	Yes Government No industry No Other	Yes Government Yes industry Yes other	No Government Yes industry No Other
No delay or secrecy	74.7%	67.7%	53.9%	49.6%
Delay	8.0%	9.2%	10.8%	9.4%
Partial or full secrecy	17.3%	23.1%	35.3%	41.0%
	100%	100%	100%	100%

1 Government includes state, federal and EU sources
2 Other includes foundations, foreign sources, or other.

A second reason to view selection into any extramural sponsorship as the relevant decision node is the multi-sponsor nature of extramural funding. Once a researcher decides to seek extramural support, he or she can choose to pursue a variety of alternative sponsors. Our survey data show that academic researchers with any extramural sponsorship have an average of 2.1 different sponsor types and those with industry funding have an average of 2.7 different sponsor types.

Focusing only on selection into industry funding would not account for the multi-sponsor nature of the researcher's extramural funding decision.

These arguments notwithstanding, we re-estimated the regression models for publication withholding using the subsample of academic researchers who received at least some industry funding. In Table A.3, Model A shows the results of a Probit regression that ignores selection into industry funding. Model B controls for selection into industry funding. Holding other factors constant, the level of industry sponsorship significantly increases the probability of publication delay or secrecy in both models. The correlation across equations in Model B, reported at the bottom of the table as ρ, is negative and significant which indicates selection into industry sponsorship is important. After controlling for selection, the coefficient estimate on industry share is 32% smaller, but still highly significant.

Table A.3: Probit of Publication Withholding with Selection into Industry Sponsorship

Variable	Model A: Probit (No Selection) Only researchers with industry sponsorship	Model B: Probit with Selection Second stage Outcome Equation	First stage selection (Industry sponsorship / No industry sponsorship)
ln(industry funding)	0.184***	0.125***	
	(0.064)	(0.046)	
Female			-0.101
			(0.116)
Age			0.085
			(0.055)
Age-squared			-0.001
			(0.0005)
Research group leader	0.011	-0.350**	0.478***
	(0.231)	(0.171)	(0.117)
Tenure	-0.009	-0.176	0.180
	(0.287)	(0.196)	(0.153)
Journal publications	-0.010***	-0.011***	0.005***
	(0.003)	(0.002)	(0.002)
Patent applications	0.068**	0.028	0.117
	(0.028)	(0.025)	(0.025)
Consult with industry	0.089	-0.292*	0.519***
	(0.171)	(0.153)	(0.117)
Fraunhofer Society	0.622**	0.167	0.643
	(0.281)	(0.256)	(0.219)
Max Planck Society	-0.285	0.194	-0.486**
	(0.447)	(0.307)	(0.192)
Helmholtz Association	0.640	0.561***	-0.384***
	(0.257)	(0.202)	(0.140)
Leibniz Association	0.840**	0.484*	-0.134
	(0.341)	(0.279)	(0.188)
Other institutions	0.364	0.257	-0.148
	(0.287)	(0.216)	(0.160)
Life sciences	-0.371	-0.332*	0.073
	(0.257)	(0.186)	(0.135)
Natural sciences	-0.079	-0.129	0.031
	(0.267)	(0.187)	(0.141)
Engineering	0.049	-0.529***	0.917***
	(0.242)	(0.189)	(0.145)
Intercept	0.376	1.998***	-3.475***
	(0.391)	(0.302)	(1.348)
Log-Likelihood	-195.364	-721.092	
Equation corr (ρ)	-	-0.913***	
# Observations	341	1060	

Note: Standard errors in parentheses. *** (**,*) indicate a significance level of 1% (5%, 10%).
Reference: male, non group leader, untenured, university, social scientist.

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