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What's the Price of Academic Consulting? Effects of Public and Private Sector Consulting on Academic Research*

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ABSTRACT

Academic consulting is an important and effective means of knowledge transfer with the public and private sectors. It offers opportunities for research application but also raise concerns over potentially negative consequences for academic research and its dissemination. For a sample of social, natural and engineering science academics in Germany and controlling for the selection into consulting, we investigate the effect of consulting to public and private sector organisations on research performance. While previous research suggested that consulting activities might come at the cost of reduced research output, our analysis provides a more nuanced picture. Public sector consulting comes with lower average citations particularly for junior researchers. Moreover, engagement in consulting increases the probability to cease publishing research altogether particularly for private sector consulting. The probability of exit from academic research increases with the intensity of consulting engagement for those at the start or towards the end of their academic career and in fields for which the public-private wage gap and opportunities for engagement in duties outside academia are higher. We draw lessons for research institutions and policy about the promotion of academic consulting.

KEYWORDS

academic consulting, university-industry interaction, science advice, knowledge transfer, research performance, exit from academic research

JEL CLASSIFICATION

O31; O33; O38; I23

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1. Introduction

In recent years, universities have become more proactive in offering their professional services to non-academic organisations. In the UK, for instance, income from consulting has increased by 50% over the past 10 years and now accounts for 10% of total external university income (HEFCE, 2017). Academic consulting in this context is typically defined as an advisory service performed by academics who apply their scholarly expertise for a non-academic organisation, often – but not always – for financial compensation, and without the creation of new knowledge (Perkmann and Walsh, 2008; Amara et al., 2013; HEFCE, 2017). Academic consulting is not a new phenomenon and has played an important role in the rise of American industry and academia (Shimshoni, 1970; Lowen, 1990). Today it is increasingly conspicuous amongst academics in the US and in Europe (Perkmann et al., 2013) and highly valued in industry and government as a means to gain insights into academic research (Cohen et al., 2002; Bekkers and Bodas Freitas, 2008; Haucap and Thomas, 2014).

Despite its importance, evidence regarding the effects that consulting has on academic research is still sparse. Private and public organisations gain prominence in academia through consulting, by providing income to academics or their institutions and by shaping or inspiring research agendas, with potential consequences for academics. Prior literature on university-industry interactions has examined the potential influence that private sector involvement can have on academic research, raising concerns for openness and the pursuit of fundamental research (Boyer and Lewis, 1984; Blumenthal et al. 1996; Thursby et al., 2007) while also acknowledging positive spillovers, including ideas and revenue for research (Lee, 2000; Perkmann and Walsh, 2008; Buenstorf, 2009).

Less studied, albeit very widespread, is academics' involvement with the public sector. We could suspect that insights from the knowledge transfer literature can be applied also to the case of public sector consulting, however, the services expected by public and private organisation can differ substantially as may financial compensations. Moreover, public and private sectors clearly differ in their management and organisation with potentially different ramifications for academics working with these sectors (Boyne, 2002). Recognising that these two consulting modes may have differing effects on research is crucial for defining government and university policy.

In this paper we thus focus on two forms of academic consulting, which coexist and comprise different types of knowledge and services - consulting with the public and with the private sector -, and investigate the relationship between consulting and research outcomes. In order to do so, we firstly need to understand whether there are differences in the types of academics that provide advice to the public and private sectors. Again, while the drivers of private sector consulting have been discussed extensively within the context of university-industry interactions (e.g. Klofsten and Jones-Evans, 2000; D'Este and Patel, 2007; Link et al. 2007; Perkmann and Walsh, 2009; Jensen et al., 2010; Grimpe and Hussinger, 2013), much less is known about public sector consulting. The few insights into overall public sector engagement suggest that it is more widespread in the medical and social sciences disciplines (Hughes et al., 2016), fields that have been found to engage little with the private sector, suggesting that we could expect different selection effects.

First evidence regarding the effect of academic consulting on publication numbers, comes from the US (Rebne, 1989; Mitchell and Rebne, 1995) and Spain (Rentocchini et al., 2014). While the former find a positive but marginal effect for consulting time on publications at low to moderate levels, the latter reports a negative effect for very high amounts of income generated. These studies have some limitations: The US studies only consider private sector interactions and do not control for selection into consulting. The Spanish study, on the other hand, only considers university income generating forms of consulting. However, we know that academics often work with industry directly, bypassing their university (Bodas Freitas et al., 2013), and that consulting can happen pro bono and therefore does not always create a reliable paper stream (Amara et al., 2013; Perkmann et al., 2015).

Our analysis builds on data from a sample of more than 900 academics in Germany in various disciplines and makes use of survey information on academics' work time distributions in a usual workweek to identify the occurrence and intensity of different consulting activities. In terms of research outcomes, we study publication numbers and citations to publications for those who stay research active. In addition, we consider the outcome of zero publications as an exit from academic research as potential consequence from consulting. We observe consulting academics to have a higher probability to cease publishing altogether, but our analysis does not find lower ex-post scientific publication numbers for those who do not exit. Moreover, consulting to the public sector is associated with lower average citation numbers, which may indicate publications of less relevance for academic research. We observe disciplinary as well as academic rank differences, which we attribute to differences in career opportunities and research spillovers that can be realised.

2. Consulting and research outcomes

2.1 The effect of consulting to the public and private sector

Public debate repeatedly centred on the possible impact that consulting activities with public and private organisations may have on academic research outcomes, including scientific publications, research agenda setting, collaborative research or probability to exit from academia (Erk and Schmidt, 2014; OECD, 2015). Theoretical arguments underpinning much of the literature on university-industry interactions have generally argued that academics face time-allocation issues leading to trade-offs for research unless spillovers can be utilised (Jensen et al., 2010; Bianchini et al., 2016). Still, despite calls for more empirical evidence, little attention has been given to the investigation of consulting and its potential research spillovers.

Most empirical studies to date have considered wider knowledge transfer activities with industry, which may include consulting, contract research, academic patenting and entrepreneurship, in their investigation. This literature largely found that academic patenting and academic entrepreneurship are positively related to research performance (van Looy et al., 2006; Breschi et al., 2007; Thursby et al., 2007; Fabrizio and DiMinin, 2008; Azoulay et al., 2009; Buenstorf, 2009; Czarnitzki and Toole, 2010). The positive spillover effect has been linked to research ideas obtained through the involvement in more applied research projects or financial benefits from commercialisation that feeds positively into academic research (Lee, 2000; Breschi et al., 2007; Buenstorf, 2009). Sceptics, instead, have argued that engagement in knowledge exchange activities may result in late- or non-dissemination of research results (Blumenthal et al, 1996; Florida and Cohen, 1999; Krimsky, 2003; Czarnitzki et al., 2015) or in applied research agendas that are less suitable to journal publications (Etzkowitz and Webster, 1998; Vavakova, 1998; Hottenrott and Lawson, 2014). Empirically, several studies looking at the effect of collaborative and contract research income on research productivity[i] find that it leads to fewer publications or fewer citations per paper, thus providing some evidence for potentially negative spillovers (Manjarrés-Henríquez et al., 2009; Hottenrott and Thorwarth, 2011, Banal-Estañol et al., 2015).

Results from the few existing empirical studies that explicitly explore the influence of academic consulting on research performance suggest that, at least in the case of private sector consulting, it does not compromise academic research, at least up to a certain threshold. For example, Rebne (1989) and Mitchell and Rebne (1995), studying consulting amongst US academics, find a positive relationship at low to moderate levels of time spent on consulting with industry and research productivity, but a decline at high levels. More recently, in the case of academics in Spain, Manjarrés-Henrìquez et al. (2009) and Rentocchini et al. (2014) find a negative effect of consulting on publications, if a considerable amount of income is generated from it. These results suggest that consulting activities, particularly at high engagement intensities, may crowd out research activities, but also that consulting can complement publications up to a certain threshold.

The link between public sector consulting and research performance has instead not yet been explicitly explored. The nature of public sector consulting can be quite different from interactions with private firms with implications for the extent to which research spillovers can be realised. Public consulting often serves the purpose of supporting government decisions ex-ante or evaluating government policies ex-post. It also often involves submitting recommendations or developing guidelines (OECD, 2015). Academics may also be called on to serve on expert committees (OECD, 2015), such as the Council of Economic Advisors (CEA) where economists provide direct consulting to the US government, or the Standing Committee on Immunisation (STIKO), which is composed of medical experts and provides recommendations concerning vaccination schedules in Germany. Still, the potential for cross-fertilization in terms of ideas and funding may be low in consulting activities with the public sector which is more likely reputation-based and focused on past expertise rather than addressing problems at the research frontier. Public sector consulting may therefore to a lesser extent be linked to a specific skill or current research project of an academic compared to private sector consulting, which is more about technology- or problem-specific knowledge. Translational skills are needed for both types of consulting, but in the case of private sector consulting translation may go from basic to applied research (Hottenrott, 2012) while in public sector consulting academics translate research into policy or layman’s terms (Salter, 1988; Jasanoff, 1990). Thus even though insights into policy problems may have the potential to result in scholarly articles as well as revenue for academics (Jacobson et al., 2005), the problems may be rather context-specific or of local relevance and revenues from public sector consulting may be less substantial compared to income generated with the private sector. Overall, they may thus be less effectual at supporting academics’ overall research efforts through cross-funding.

Based on these arguments, we expect the trade-offs between consulting and research and the effects on publication numbers to be similar for private and public sector consulting. In terms of scientific quality or general scientific relevance, as indicated by citations to research articles, this may imply that public consulting comes at the price of fewer citations. Private sector consulting may also result in more applied research, but still be relevant to, and thus cited by, the applied research community.

At the far end, i.e. when a large share of time is dedicated to consulting, the negative spillovers may result in an exit from academic research. Specifically, in pursuing outside activities, academics may stop academic research to engage full time in other occupations including consulting, board services or spin-off creation. This exit can be due to insufficient relevance of consulting for research or time constraints that no longer allow for the pursuit of publishable research, such as a full-time move into consulting (Czarnitzki and Toole, 2010; Toole and Czarnitzki 2010; Hottenrott and Lawson, 2014; 2017). Hottenrott and Lawson (2017) show, for instance, that university departments that engage in contract research with industry are more likely to see departing academics move to the private sector or to non-research work within the public and university sector. Consulting may thus be conducive to a move out of academia or the take-up of more administrative or advisory posts within the university or research institute, activities that would not result in publications in academic journals.

2.2 Discipline and academic rank as moderating factors

In the discussion of research spillovers, it is important to consider that engagement in consulting does not occur at random. This becomes particularly apparent when comparing disciplinary fields or academic ranks (Bianchini et al., 2016). In engineering the share of academics engaged in private sector or paid consulting is particularly high when compared to other fields (D'Este and Patel, 2007; Landry et al., 2010; Rentocchini et al., 2014). A 2015 survey of more the 18,000 UK academics, for example, found that 44% of academics in engineering provided consulting services in the previous three years, compared to just 25% in natural sciences or the humanities (Hughes et al., 2016). The same survey, however, finds that public sector engagement and advisory board services are particularly relevant for groups that have been found to engage little with the private sector, such as social and medical sciences. Consulting has moreover been linked to seniority, with the most senior academics having more opportunities to engage in consulting regardless of sector, most likely for reputation reasons (Link et al., 2007, Boardman and Ponomariov, 2009; Amara et al., 2013; Rentocchini et al., 2014).

The non-random engagement in consulting has consequences for its spillovers onto research. The groups of academics that have more opportunities to provide consulting, i.e. the more experienced and those in more applied fields, may be able to generate more positive spillovers from their consulting work (Bianchini et al., 2016) as they may be better able to link consulting to their research, and thus be less likely to compromise their publishing activities. This means that for these academics consulting should be less likely to lead to a reduction in the number of publications or citations, compared to those that have fewer engagement opportunities, i.e. the younger and those in more basic science field.

Again, at the far end, i.e. when a large share of time is dedicated to consulting, these groups may be more likely to exit from academic research as discussed above. The probability to exit from academic research has generally been attributed to a low 'taste for science' (Roach and Sauermann 2010; Balsmeier and Pellens, 2014) or the attractiveness of the private sector compared to the academic one (Stephan 2012). These attributes relate heavily to external demand and time-allocation and are likely to differ by disciplinary field and academic rank. Academics in fields that provide ample opportunity for consulting may have a lower taste for science relative to other academics and see more opportunities outside of research. They may therefore ex-ante be more likely to exit from publishable research. Moreover, private sector organisations typically pay better for highly specialized scientific expertise raising the opportunity costs of a research career (Agarwal and Ohyama, 2013; Balsmeier and Pellens, 2016) especially in science and engineering (BUWIN, 2017, p. 182-183). Moreover, academics close to the end of their career may cash in on their experience and reputation through engaging in consulting or other less research-oriented activities at the expense of publishing (see Bianchini et al., 2016; Zucker et al., 2002). In terms of career progress there are usually no disadvantages to the decision of focussing on non-research related tasks for senior and tenured academic staff in countries such as Germany. Younger academics at the start or training phase of their career face a different effort allocation problem. While one could argue that their opportunity costs for leaving academic research are lower, they usually also have fewer opportunities to engage in consulting. However, those, that are not yet decided on a specific career or have an overall lower taste for science (Balsmeier and Pellens, 2014), may find that consulting raises their employability outside academia and thus are more likely to exit from research.

To summarise, a researcher's discipline and rank may moderate the effect of consulting on research outcomes and the likelihood to cease publishing altogether. At the high end of consulting we expect junior researchers who are not yet settled on an academic career and very senior academics who have more outside opportunities to be more likely to exit from academic research, while at the low-to mid-range we expect senior academic staff to generate more positive spillovers. Further, academics in engineering may be more likely to generate positive research spillovers compared to those in the social sciences or more basic science disciplines but are also expected to be more likely to exit from academic research due to better outside opportunities and demand.

3. Data and model specification

3.1 Data

We build on data from a survey of academics in Germany at both, universities and non-university public research organisations (PROs).[ii] The survey was conducted by the Centre for European Economic Research (ZEW) in 2008 and targeted academics in the humanities and social sciences, engineering, life science and natural sciences. Researchers were contacted by email. Contact information on university researchers was obtained from the "Hochschullehrerverzeichnis" which is a register of university personnel. Email addresses for researchers at PROs (Fraunhofer Society, Max Planck Society, Helmholtz Association, Leibniz Association) was collected using internet search. This yielded a sample of 16,269 researchers of which 2,797 responded to the survey (including incomplete responses). Survey questions referred to the pre-survey period from 2002 to 2008 or to the current year. We complemented the survey data with publication data from Thomson Reuters Web of Science (WoS). In particular, we performed text field searches on the academics' names in the publication database (articles, books, reviews, proceedings) and manually screened matches based on CV and website information. Further, we searched the Espace database of the European Patent Office and the database of German Patent Office for patents on which the academics appear as inventors. As in the case of publications, all matches were manually checked. Eventually, we obtain publication and patent records for all individual academics from 2002 until 2013 and citations to their publications until autumn 2015. In our cross-section of academics, publications are collected for a pre- and post-survey period. The collection window, and thus the citation time windows, are identical for all surveyed academics. The censoring of citations to newer articles should thus be of minor concern. Removing observations with incomplete records in the survey questions, the final sample comprises 951 individual-level observations. Table 1 reports descriptive statistics for all the variables used in the analysis (for pairwise correlations see Table A.1 in the Online Appendix).

Representativeness of the sample

To check for the representativeness of our sample we compare it to the German academic population as a whole in terms of institution type, gender, discipline and age (see Table A.2. in the Online Appendix) Aggregate information on the academic population was collected from the Federal Statistical Office data base (DESTATIS). The sample distribution differs somewhat from the population in terms of institution types because of an overrepresentation of PROs, an intentional aspect of the survey frame. In terms of disciplinary fields there are only small differences between the sample and the population. In terms of age classes, we find that younger researchers are underrepresented in the data, which may also contribute to the overrepresentation of males. The underrepresentation of young researchers partially stems from the fact that surveyed academics were identified using a list of university staff, the *Hochschullehrerregister*, which only lists few junior academics. The differences observed between the population and the survey respondents in terms of institution type, age and gender are therefore assumed to not represent a non-response bias. Still, to address these sample characteristics, we construct field-institution type weights to capture some of the observed differences (see also Czarnitzki et al., 2015). We apply inverse probability weighting using population weights to test the robustness of our results to these sample properties. Comparing these to the results of the unweighted models, we observe some small differences in the estimated coefficients, but these differences do not qualitatively change the results (compare Tables 3 and 4 to Tables A.4 and A.5 in the Online Appendix).

Dependent variables

The main variables of interest are the research performance of academics in the post-survey period (2009 to end 2013) and their (temporary) exit from publishing. We consider the exit from research work to be reflected in zero WoS publications in the five year post-survey period (*exit*). This variable thus reflects publication inactivity over that period and not necessarily the termination of a work contract. About 18% of academics have no publications in WoS in the post-survey period, while the average number of *publications* is 12.4 and each publication receives about 12 citations (*average citations*) in the time window considered. From the individual publication and citation counts, we further derive field-weighted counts to account for heterogeneous publication/citation patterns of different disciplines. To obtain these values we divide publication counts as well as average citations by the within-sample field averages (*field-weighted publications, field-weighted average citations*). A value below one represents a below field-average output and a value above one represents an above field-average output.

Consulting activities

Our data is distinctive from previous studies in using the time share that academics devote to consulting (*consulting*). The advantage of using survey-based time shares as opposed to consulting income or official university records[iii] is that academics have no incentives to under or over report their consultancy work. In addition, we capture consulting activities for which no financial compensation had been received. Despite the downsides in terms standardisation and recall difficulty in surveys, we avoid problems in measuring consulting activities that arise if individuals are able to charge very different fees and thus have different levels of income per hour of consulting work. It also captures activities that do not leave a paper trail. The consulting time-share refers to a typical work week and is therefore cross-sectional in nature. Based on the survey responses, we distinguish between consulting to the private (*private consulting*) and the public sector (*public consulting*).[iv] This is different from Rebne (1989) and Mitchell and Rebne (1995) who use the number of hours spend on consulting work or Rentocchini et al, (2014) who rely on consulting income.

Table 1 shows that academics spend roughly 5.3% of their time on consulting, on average. Among consulting-active academics the average time spent on consulting is 12.2%. By comparison, about 50% of time is spent on research, and 21% on each teaching and administration (see Table A.3 in the Online Appendix for more details on time distributions).[v] While the overall time-share devoted to academic consulting is not high, 44% of academics reportedly engaged in some form of consulting at the time of the survey; about 17% provide consulting only to the public sector, 13% only to the private sector, and 14% to both. A detailed comparison of consulting active and inactive academics is provided in section 3.2.

Moderators

Of the academics in the sample, 21% belong to *social sciences* (and humanities), 30% to *life sciences* (biology, medicine, agriculture and veterinary sciences), 31% to the *natural sciences* (chemistry, physics, earth science and mathematics) and 19% are active in *engineering*. More than half of the sample are employed as *professors* (54%), 11% are *assistant professors* (including academics working towards habilitation), 26% are *senior researchers* and about 10% are *junior researchers* (scientific assistance staff that do not hold and/or are studying for a PhD).

Controls

A series of other controls are included that have been shown to affect publication outcomes, such as age and gender (e.g. Toole and Czarnitzki, 2010; Mairesse and Pezzoni, 2015). Academics are, on average, 49 years old (*age*), and 15% are *female*. More than half of the academics in the sample (59%) are employed at universities (*university*), while the rest work at PROs or other research institutions. We also include variables that capture the effect of network and funding on academic output. This includes the size of the local peer group in terms of the number of people from the same institution working in closely related fields (*peergroup size*), a measure for *collaborative reach* based on the location of research partners during the 2002 to 2008 period[vi], and a measure for *international visibility* based on reported international conference participation during an average year. The survey also includes information on academics' grant-based research income from the European Union, national and regional governments, science foundations, such as the German Research foundations (DFG), industry and other external funders during the period 2002 to 2006. Funding amounts are aggregated into, *industry funding* and *public funding*. Finally, we include a binary indicator for co-authored articles with employees from the private sector in the previous 12 months *(coauthorship industry)*, and the number of patents in the pre-survey period (*patents)* as additional controls.

All regression models also include pre-survey publication and citation numbers (between 2002 and 2008) as predictors of future publication performance. In addition, we control for the average number of co-authors on publications in the pre-survey period (*average number of co-authors*). Academics published on average 12 items in the pre-survey period and received an average of 24 citations per publication. The average number of co-authors is about four with the lower values in the social sciences (1.2) and engineering (3.4) compared to the life sciences (5.4) and the natural sciences (7.8).

Table 1 about here

3.2 Descriptive analysis of consulting-activity

Table 2 compares the mean values of the dependent variables (publications, citations and exit), and the moderators academic rank and discipline by consulting activity. We observe higher average number of publications, but fewer citations for consulting active researchers and no significant different share of “exits”. In addition to the mean comparisons, Figure 1 shows the number of publications and average citations per publication (in the post-survey period) over different percentiles of the consulting time-share distribution. For both variables and both types of consulting, research output, in particular the median, tends to be lower at higher time-shares spent on consulting. These descriptive statistics suggest that not consulting engagement as such matters, but the intensity of the engagement.

Table 2 about here

Figure 1 about here

Table 2 further shows that in the social sciences, public sector consulting is more prevalent than private sector consulting or no consulting, while in life and natural sciences the differences are less pronounced. In natural sciences, we observe the overall lowest involvement in consulting. In engineering, consulting with the private sector is reported by about 34% of academics (see Table A.3 in the Online Appendix for consulting time-shares and the share of consulting-active academics by discipline). Looking at academic rank, we see that the share of full professor is largest in all consulting groups and also significantly larger than in the non-consulting active sub-sample. Also a large share of senior researchers is engaged in consulting, with little differences between types, while assistant professors are least represented in all consulting types. For junior researchers public consulting is slightly less common than private sector consulting or no consulting.

It is moreover interesting to point out, that certain attributes differ considerably between consulting-active and non-consulting active academics. While the former spend significantly less time on block-funded research (17% versus 23%) and less time on grant-based research (30% versus 34%), teaching loads differ only slightly (20% versus 23%) and administrative duties are similar (both 21%). These numbers suggest that consulting may substitute research, but is not associated with a higher administrative burden or less time devoted to teaching (see Table A.3 in the Online Appendix).

3.3 Estimation Strategy

We estimate the probability of exit and the publication performance while accounting for selection into consulting. Engagement in consulting does not occur at random and modelling the selection into consulting enables us to correct for the selection bias in consulting activity. Moreover, we prefer selection type models over other treatment effects models as they allow to follow a suggestion by Wooldridge (2002, p. 594) to include the logarithm of an academic's pre-sample research performance[vii] in the outcome equations to capture i) path dependency and cumulative advantage effects in publication and citation numbers and ii) the otherwise unobserved ability to publish of an individual academic. These initial performance variables proxy for permanent individual unobservable effects, or "fixed" effects, which are not directly observable, but associated with underlying variables, including individual capability, motivation and talent (Mairesse and Pezzoni, 2015). Finally, our modelling approach also has the advantage that we can explicitly model the propensity to engage in consulting. The results from the selection stage are informative as such and also enable a closer comparison to the existing academic consulting literature.

In the model's selection equation we include personal and institutional attributes which have been shown to be of relevance in explaining academic consulting in several previous studies. In addition, the selection equation includes a set of exclusion restrictions which help to identify the second stage. These are the share of employment in knowledge-intensive industries in a region (*regio skills*), and commercial activities that have been linked to consulting such as firm foundation experience (*firm*) and technology transfer activities with industry (*techtransfer industry*) during the previous 12 months (the latter two are based on survey responses). The variables enter the consulting equation significantly, but are insignificant in the outcome equations. The share of employment in knowledge-intensive industries is calculated at the 4-digit municipality level based on data from the INKAR database provided by the German Statistical Offices in cooperation with The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). The skill-wise labour market composition in a region may determine the demand for academic consulting services both for the public and private sector, but not affect an individual researcher's publication performance. Founder experience (unlike current entrepreneurial activity) may reflect networks that facilitate consulting, but does not directly correlate with the output measures. Likewise, technology transfer through means other than consulting create networks to the private sector and generate consulting opportunities, but not necessarily affect publications in a particular direction. We test the statistical appropriateness of these exclusion restrictions in auxiliary regressions which show that the excluded variables are individually and jointly insignificant in the outcome equations, but indeed relevant in the selection equation.

The selection into consulting is thus estimated for each academic i as:

$$\Pr(Consulting)_i = \beta_0 + \sum_{n=1}^{3} \beta_n \, er_i + \sum_{n=4}^{k} \beta_n \, controls_i + u_i \qquad (1)$$

With the vector *er* referring to the set of exclusion restrictions, *k* is the total number of regressors and parameter u is the error term.

We then proceed in two steps, differentiating between the effects of consulting on exit and on research performance. In the research performance models, we exclude individuals with zero publications in the five-year post-survey period since we consider these as no longer research active. Their zero publication output is captured in the exit models and including them in the research performance equations would confound reduced output of research-active academics with those that are research in-active. It should be noted here, that inactivity in terms of publications is defined over the relatively long period of 5 years and thus does not apply to someone with a publication break of just a single year (or two, or three). If consulting indeed leads to a higher probability of exit, we would potentially overestimate the (negative) effect of consulting on research output of those who remain research active due to the zero publication counts.

We thus resume in two steps as follows. We firstly estimate the probability of exit from academic research while accounting for the selection into consulting (as specified in equ. 1) using a Heckman-type procedure for binary outcome variables estimated by maximum likelihood method (van de Ven and van Pragg, 1981; De Luca, 2008). Exit probability is then modelled as follows:

$$\Pr(exit)_i = \gamma_0 + \gamma_1\, Consulting\ share_i + \gamma_2\, Consulting\ share_i^2 + \sum_{n=3}^{k} \gamma_n\ controls_i$$

$$\alpha^{\rho} + \tilde{u}_i \qquad (2)$$

with $corr\,(u, \tilde{u}) = \rho_{u,\tilde{u}}$. A statistically significant $\alpha^{\rho} = 0.5\ln(1+\rho)\,/(1-\rho)$ indicates that some selection bias would be ignored in the absence of the selection equation. In addition, we estimate models with interaction effects between the consulting share and the moderators academic rank and disciplinary field.

This model is first estimated for overall consulting, before we specify a model in which we explicitly distinguish time devoted to public sector versus private sector consulting. The second order term is included to account for possible non-linear effects. The vector *controls* includes the academics' age*,* a gender dummy*,* a university dummy, field-weighted publications and field-weighted average citations in the pre-sample period, patents, grant-based research funding, scientific field and rank dummies.

Next, we estimate research performance in terms of publications and citations for those academics that remain research active using linear endogenous switching models (LES). LES models are a variant of the selection model (see Lokshin and Sajaia, 2004) that account for the non-randomness of consulting activity in the effect of consulting on post-survey research performance. Unlike Heckman-type correction models, LES models estimate the outcome equation for both groups of the selection. This means they also provide an outcome equation for consulting *in*active academics, allowing for a comparison of control variables between the two groups.

As above, we estimate separate models for consulting in general and the two types of consulting, and for the different publication-based outcome variables:

$$\ln(outcome)_i = \gamma_0 + \gamma_1\, Consulting\ share_i + \gamma_2\, Consulting\ share_i^2 + \sum_{n=3}^{k} \gamma_n\, controls_i + \alpha^{\rho} + \tilde{u}_i \qquad (3)$$

The consulting equation is specified according to equation (1) and is estimated jointly with the outcome equation (3) via full information maximum likelihood method (FIML) and α^{ρ} is calculated as described above. We employ the natural logarithm of the publication count and average citation numbers. Log transforming variables with skewed distributions has several advantages and is quite common in the context of publication measures (see for instance, Fabrizio and Di Minin, 2008; Buenstorf, 2009; Banal-Estañol et al. 2015). First, it reduces the skewness of the distribution as well as heteroscedasticity because it suppresses variation in the data and makes the error distribution more normal. Second, it makes interpretation straight forward. A one percentage point change in our consulting share can be interpreted in terms of percentage change in the outcome variable.[viii] In addition to these baseline models, we again estimate models with interaction effects between the consulting share and the moderators academic rank and disciplinary field.

The exclusion restriction are neither individually nor jointly significant in the publication outcome stage for logged publications and for logged average number of citations as outcome variables.

In addition to the selection models that rely on the set of exclusion restrictions, we test the robustness of the results to using an instrumental variable (IV) approach suggested by Lewbel (2012). This method does not rely on external IVs, but achieves identification through the generation of IVs based on heteroscedasticity (see section A.3 and Table A.7 in the Online Appendix for details).

4. Results

4.1. Selection into consulting

Table 3 shows the results (marginal effects) from the set of probit models that represent the selection equation, i.e. the probability of engaging in any consulting (model 1), and results from simultaneous probit models on public consulting and/or private sector consulting (model 2).[ix] As expected, we find that academics in the social sciences are more active in public consulting than in science and engineering. There are however fewer differences with regard to involvement with the private sector. We further find that professors and junior researchers are more likely to be active in consulting, especially in public consulting, than mid-career researchers. Professors are also most active in consulting to the private sector. Similar findings were reported in Amara et al. (2013) who show that research staff and full professors are more likely to engage in paid consulting than mid-career academics. We further find consulting positive effect of age, which supports prior findings on the higher likelihood of older academic staff to engage in industry consulting (Louis et al., 1989; Boardman and Ponomariov, 2009). Interestingly, the effect of age is higher for consulting with the public sector compared to the private sector. We also find that women are less likely than men to engage in private sector consulting, while there is no difference for public sector consulting. This confirms Abreu and Grinevich (2013), who find that women engage less with the private sector but more with the public sector compared to men, and is also in line with prior research on industry consulting that consistently showed lower activity for women (e.g. Link et al., 2007; Grimpe and Fier, 2010).

In terms of pre-survey scientific activity, we see that field-weighted average citations are negatively correlated with consulting, whereas publication counts show a positive correlation. Industry funding correlates strongly and positively with private sector consulting and negatively with public sector consulting. The contrary is the case for public funding which contradicts previous research by Jensen et al. (2010) and Muscio et al. (2013) who stressed that public funding can be a facilitator for research contracts and consulting with the private sector (see also D'Este et al., 2013; Amara et al., 2013). The findings further show that collaborative reach correlates positively with public sector consulting. The local peer group size is negatively associated with public consulting, suggesting that academics working in isolated areas are more likely to look for external consulting options. Patenting academics are also less likely to engage in public consulting. Finally, co-authorship with industry correlates positively with private sector consulting, confirming prior findings in the field (Louis et al., 1989; Landry et al., 2010). The correlation between the public and private sector consulting equation is positive and significant, pointing to the importance of estimating these equations jointly.[x] It also indicates that academics make use of both engagement modes simultaneously.

Table 3 about here

4.2. Consulting and the probability to exit from academic work

Table 4 presents estimated coefficients from the models on exit from academic research. In models 3 and 4 we account for the possibility of retirement and check the sensitivity of the results to the exclusion of individuals who were 64 years or older at the time of the survey. In line with our expectation, we find that consulting increases the propensity to exit from publishing. This is in keeping with studies that report exit following other forms of non-research activities such as academic entrepreneurship (Toole and Czarnitzki, 2010). The average marginal effect (AME) for consulting (which cannot be directly seen from the coefficient) is 0.002 in model 1 and 0.003 in model 3 indicating that, on average, an increase in consulting by 10 percentage points increases exit probability by about 3% in the subsample of academics below the age of 65 (model 3). The effect of consulting, however, is unlikely to be the same for all consulting time-shares. Figure 2 therefore depicts graphically the predictive margins of consulting on exit probability at different consulting shares. We find that the probability to exit increases as consulting increases, but with diminishing marginal effects. The slope of the curve is determined by the marginal effects at representative values (MERs), i.e. the marginal impact of consulting on exit probability at different values of the consulting distribution, and is steepest at consulting time shares between 10 and about 20%.

Looking at private and public sector separately we find that in model 4, the AME for private sector consulting is 0.002 (significant at 1% level), while the AME of 0.001 for public sector consulting is insignificant. The graphs in Figure 2 show that for public sector consulting the impact on exit is initially small, explaining the smaller and insignificant AME. At larger intensities, particularly between 20 and 50 percent of time spent, exit probability increases substantially. This high exit propensity for public sector consulting may be due to academics taking on the role of brokers or full time advisors, no longer concerned with their scientific research (Haucap and Moedl, 2013). For private sector consulting exit probability increases with consulting time-shares, but with decreasing marginal impact at very high intensities around the 95^{th} percentile and beyond. For relatively common levels of private sector consulting, say 5% of time, an increase of consulting by 10 percentage points to 15% will increase exit probability from 8.9 to 11.1%. For an increase from 20 to 30% the marginal effect is still positive, but slightly smaller with an increase from 12.1 to 13.5% exit probability.

The average effects are thus rather small, but Figure 3 shows that results differ substantially by moderators (detailed regression results available upon request). Exit propensity as such is highest for junior (pre-PhD) research staff and lowest for assistant professors. Initially, exit propensity increases with consulting time-shares for all ranks, except for junior researchers (top left of Figure 3). At higher consulting shares, however, exit probability increases particularly for junior researchers and full professors, i.e. the groups that are also more likely to engage in consulting. For example, at a consulting time-share of 40% (90th percentile), junior researchers have an exit propensity of 80%. These results show that consulting may distract junior academics from research and thus steer them away from a research career, in line with concerns voiced by the knowledge exchange literature (Blumenthal et al, 1996; Florida and Cohen, 1999). The effect for junior researchers is driven by public sector consulting (see bottom left of Figure 3), though overall there is little increase in exit probability at lower time-shares, explaining the insignificant AME for public consulting. In the case of private sector consulting (see bottom right of Figure 3), curves also show minor differences for low values, with the steepest slope for senior researchers. For full professors the curve is flat up to a 20% consulting share, but positive at higher consulting shares. For instance, for an increase in the time-share from 40 to 50% the effect on exit probability increases by about 10 percentage points.

Effects also differ by disciplinary field. In the social sciences, an increase in the consulting share is associated with a higher exit probability with an AME of 0.035 (top right of Figure 3). In engineering the slope is flatter, but also positive for the entire range of consulting time-shares (AME = 0.022). In the publication intensive fields of life and natural science an increase in consulting increases exit probability at similar rates as in engineering (with AMEs of 0.021 and 0.024), but with constant or declining impact and a lower exit probability in absolute terms. The higher exit propensity for social sciences is contrary to what we would expect based on prior evidence (e.g. Rentocchini et al. 2014) and is most likely due to the consideration of public sector consulting and its high prevalence in the social sciences in this study.

In terms of control variables, we find that exit probability increases with age. We do not find women to have a higher propensity to cease publishing, even though prior literature has attributed exit to gender and family situation (Ginther and Kahn, 2004; Mairesse and Pezzoni, 2015). We further find that the better the ex-ante publication performance and international visibility, as measured by conference attendance, the less likely an academic is to stop publishing. The propensity of exit from academic research also decreases with other measures of research activity, such as peer group size within the institution and patenting (Table 4).

Table 4 about here

Figure 3 about here

4.3. Consulting and publication and citation outcomes

The results from the endogenous switching models on research outcomes in the post-survey period are presented in Table 5 which shows the outcome equation for consulting-active and non-consulting-active academics separately. Exiting academics, i.e. those that do not publish in the post-survey period, are excluded from these models as we are only interested in the productivity effects of those who remained research active. When we run these models inclusive of those that exit, estimated coefficients are naturally larger because they capture the "exit" effects from consulting as reflected in more zeros in the outcome variable.

Our results suggest that consulting does not have a significant effect on publication numbers (model 1), which is contrary to prior studies by Mitchell and Rebne (1995) and Rentocchini et al. (2014) who found a positive or negative effect respectively. Consulting is however associated with fewer citations (model 3), an effect that stems from public sector consulting (model 4). The coefficient of public sector consulting is -0.014 and the squared term is positive, though very small, indicating a diminishing negative impact at higher consulting shares rather than a positive one. The AME of public consulting is still negative at -0.013 (s.e. = 0.004) which indicates that an increase in the public consulting share by 10 points leads to an average loss of 13% of field-weighted citations per publication. The coefficient of private sector consulting is also negative, but much smaller in magnitude and insignificant. The AME is 0.010, but only significant at the 10% level. These results suggest that public sector consulting could allow for fewer research spillovers as it primarily requires the preparation of reviews and commissioned reports that may result in publications of only little academic relevance (Salter, 1988; Jasanoff, 1990). While we find no negative effect for private sector consulting, we also do not confirm the positive effect for low levels reported in prior research (Mitchell and Rebne, 1995; Rentocchini et al. 2014).

Again, the effect is likely not linear and the marginal effect may depend on the intensity of consulting. Figure 4 therefore depicts predicted values of field-weighted average citations as outcome variable over the consulting time-share range. The slope of the curve therefore illustrates the marginal effect of consulting at different levels of consulting (MERs). Here we see that an increase in public consulting from zero to 5% implies a decline in the predicted logged number of field-weighted citations from 0.88 to 0.81. In non-weighted and non-logged terms, the same increase in consulting results in a decline from 11.5 to 9.9 average citations per paper, i.e. to the loss of 1.6 citations per paper which corresponds to about 19% of the sample median. At higher consulting shares the marginal effect of public consulting becomes smaller and eventually insignificant. For private sector consulting the effects are insignificant for the full range of consulting shares.

Table 5 about here

Figure 4 about here

Looking at the MERs of moderators in Figure 5, we see that fewer field-weighted average citations are observed for most of the observed range of consulting time-shares for all academic ranks (detailed regression results available upon request). For assistant and full professors the effect reverses (i.e. turns positive) in the top percentiles of the consulting time-share distribution. Instead, the AME is -0.028 (s.e. = 0.017) for junior researchers and -0.038 (s.e. = 0.011) for assistant professors and thus substantially more negative than the overall effect and particularly compared to the -0.016 (s.e. = 0.008) for full professors. This confirms our expectation that those with fewer consulting opportunities will be less able to generate positive spillovers for their research.

The lower part of Figure 5 differentiates the effects by type of consulting. Again we see that for all academic ranks the impact of public consulting is negative for most of the observed consulting time-share distribution. The impact is strongest for junior researchers [AME = -0.044 (s.e. = 0.014)] and assistant professors [AME = -0.032 (s.e. = 0.011)] and more modest for full professors [AME -0.015 (s.e. = 0.006)] and senior researchers [-0.005 (s.e. = 0.010)]. In terms of non-field weighted citations this implies that for junior researchers an increase from zero to 10% consulting time-share leaves them with about 2.3 fewer citations per paper which corresponds to 31% of the median value for junior researchers.

Some assistant professors who engage heavily in consulting efforts with the public sector, however, benefit and receive relatively more citations than those at lower consulting time-shares, but still not more than those not active in consulting at all. Private sector consulting has no negative and even a positive effect on outcomes of assistant professors, but a negative effect for full professors [AME = -0.018 (s.e. = 0.010)] and, at lower consulting shares, also for junior researchers [AME = -0.049 (s.e. = 0.023)]. These mixed effects may explain the overall only very weakly significant effect from private sector consulting.

Differentiating by disciplinary field (top right of Figure 5), we see a continuous negative effect only for the life sciences, which is significantly negative up to a time-share of 50%. The marginal effects for natural sciences are negative up to 20% consulting time-share. In engineering, on the other hand, the marginal effects are initially negative and the curve has the steepest slope of all subject areas, but marginal effects become positive and significant for values above 30%, i.e. above the 90th percentile in this field. The AME [-0.031, (s.e. = 0.008)] is still negative and sizable for engineering. Our results only partially confirm Rentocchini et al. (2014) who find a negative effect of paid consulting science and engineering but not in medical sciences and social sciences. They also only find the strongest effect at high engagement levels, which is contrary to our findings which show the steepest slopes in the middle-ranges.

We further see from the models presented in Table 5 that publication and citation performance is highly path-dependent. The pre-sample mean is positive, highly significant and the coefficients are similar in size for both consulting-active and non-consulting-active academics. We also find that publication output is larger for older academics and for professors. We do not observe differences between men and women regarding their publishing when we use field-weighted publication counts. Scientific attributes such as collaborative reach and international visibility are also all positively associated with publication output. We also find that publication numbers are lower for university academics, who have teaching obligations unlike most academics at PROs, whereas average citations do not differ. Patents are positively associated with field-weighted publication numbers for consulting-active academics only. Note that the correlation coefficient α^{ρ} is negative and significant only for the correlation between the consulting equation and the outcome equation for consulting active individuals. This suggests that individuals who engage in consulting publish fewer articles and receive fewer citations than a random individual from the sample would have published. Instead, those not engaged in consulting do no better or worse than the sample average. The likelihood-ratio test for joint independence of the three equations, however, is not significant in the publication count models where we exclude "exited" individuals suggesting that consulting and publication equations are not jointly determined. It should be noted, however, that the test is significant in models that include those that "exit". In other words, much of the endogeneity in terms of two-way causation is taken out of the model by considering only those who remain research active.

Figure 5 about here

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5. Conclusions and implications

Our study contributes to the literature on academic consulting and its impact on research and research dissemination. Investigating the effect of public and private sector consulting activities on exit from publishing and publication performance in a sample of academics at universities and public research organisations in Germany we find that, especially in the case of private sector consulting, a higher share of time devoted to consulting increases the probability of exit from academic work. At higher consulting time-shares this effect is strong for lower rank (pre-PhD) researchers, but also for faculty in permanent positions (full professors). Public sector consulting also affects exit probability, but only at relatively high consulting shares. The positive relationship between consulting and exit from publishing is more pronounced in the social sciences and engineering than in the natural sciences and life sciences. This is consistent with the observations that public-private wage gap is particularly high for engineers while opportunities for taking up new responsibilities outside academia, or external demand, may be particularly high for those from the social sciences and engineering.

Results for academics who remain research-active show that consulting does not further reduce their ex-post research performance in terms of publication numbers. This result thus does not confirm concerns related to a potential detrimental effect of consulting on research disclosure as we do not find a decline in overall publication numbers. However, in the case of public consulting, we see lower average citations per paper in the ex-post period. Public sector consulting, likely requires participation in expert committees and boards of advisors which comes with the preparation of reviews and commissioned reports and thus entails work aspects that may create few financial and other positive spillovers for academic research. Quantitatively we show that an increase in public consulting by ten percentage points implies a loss of up to 31% of citations per paper. While this price of consulting is not paid by researchers from all ranks, it should be noted that the decline is most pronounced for junior researchers. Considering, that typically junior researchers are still seeking to obtain permanent positions this puts them at a potential disadvantage on the academic labour market compared to their peers. It may also have a longer term impact on their research paths.

The finding that private sector consulting, instead, does not impact research output, once we exclude non-publishing academics, suggests that it may be closer to the knowledge frontier and may therefore create more research spillovers which offset some of the negative trade-offs. Still, negative effects are observed for junior researchers, suggesting that they may lack the experience to realise such spillovers.

Disciplinary field differences exist in the prevalence of consulting to different sectors, but less so in terms of the impact of consulting. While in the natural sciences consulting has little impact on citations, in the social and life sciences and in engineering higher engagement in consulting is associated with fewer citations per publication. In engineering the marginal effect turns, however, positive for consulting time-shares above the 90^{th} percentile. This indicates that at the higher end consulting can create positive spillovers in more applied fields of science that apply academic knowledge to real-world problems. Thus, for highly engaged academics in engineering there seems to be a prize for consulting.

Our findings have important implications for research institutions and policy. First, for academics in earlier stages of their academic career and also for senior academic staff, consulting activities may pave the way for alternative career paths or activities outside academic research, as indicated by an exit from academic publishing. Training and institutional consulting support for junior academic staff could thus have the potential to open up career options outside academic research. Professors and research group leaders may engage junior researchers in consulting work to broaden their profile and to point to career opportunities outside academe. The provision of alternative options is important as not all those trained in academia are able to remain there (e.g. Stephan, 2012; Hottenrott and Lawson, 2017). However, encouraging external consulting could also lead to a brain drain at both junior and senior levels if academics cease to focus on scientific research relevant for the scientific community. This may also have detrimental career effects for those young researchers seeking an academic career path.

Second, our selection equations show that academics that engage in consulting are on average involved in more grant acquisition and are highly connected. They may therefore serve as important knowledge brokers with external organisations, leveraging additional income for their institution while providing advice. While this may come at the cost of lower quality research output or the exit from academic publishing, it may contribute to a division of labour within the academic institution that allows for different work patterns amongst academics. Universities may therefore selectively encourage specific academics to act as such knowledge brokers.

Third, policies (e.g. promotion requirements) to engage *all* academics to interact with external organisations may have negative consequences for academic research. In particular, explicit or implicit obligations to take on consulting roles should not exist. We find that academics that do not engage in consulting are often less focussed on external interactions in general and pursue research that attracts more citations. Such individuals may as a result of engagement policies have their time diverted from their research efforts to the detriment of their research. Eventually, the results suggest that a one-size-fits-all rule for managing consulting activities of researchers at universities or PROs will not work best, but that universities may be advised to arrange disciplinary and rank specific rules. Specifically, the consulting activities of junior researchers need to be carefully managed.

Overall, the benefits from academic consulting likely outweigh the costs in terms of research output. For example, Cohen et al. (2002) report that 32% of surveyed US firms consider consulting an important mechanism to gain insights into academic research. This figure is higher than for other forms of knowledge transfer such as contract research, patents or personnel exchanges. In the case of public consulting, Haucap and Thomas (2014) find in a survey of more than 300 civil servants and politicians in Germany that more than 70% of users of academic knowledge consider expert reports and personal communication with academics as helpful or very helpful for their work, making consulting more important than academic publications. Thus, while we do find some negative effects on research quality as measured through citations, we cannot conclude that the price of consulting is high compared to the likely benefits for private sector firms and public sector agents.

Despite all efforts, the study is not without some limitations. First, we do not observe consulting activity over time. Individuals may undergo different phases in their career in which they are more or less consulting active. The balance between these periods could be pivotal to understand the full effects of consulting engagement. Second, some individual level unobserved heterogeneity might remain despite our attempts to capture these econometrically. Thus, longitudinal treatment effects analysis might be used in future research to test for the observed cross-sectional patterns. Finally, some limitations arise in terms of generalizability of our results to the overall population of researchers in Germany and to the population of academics in general. Individual wage levels, specific salary schemes or contracts may determine the attractiveness of consulting. Further the division of public research into universities, universities of applied sciences and public research organisation without teaching mission in Germany and the mobility of researchers between these institutions may have implications for the results. We therefore encourage further research on academic consulting especially regarding its role for inter-sector mobility of academics and for the evolution of career paths. Moreover, while we considered time shares rather than monetary rewards for consulting, it would be desirable to better understand the link between remuneration and the effects of consulting on other academic activities. While well paid consulting that is informed by research may increase the academics' institutional research budget through follow-up research contracts and therefore facilitate growth and productivity of the research group, consulting activities that result in private income may be more prone to lead to a brain drain from academic work. It seems therefore crucial to further study the contractual mechanisms in future work.

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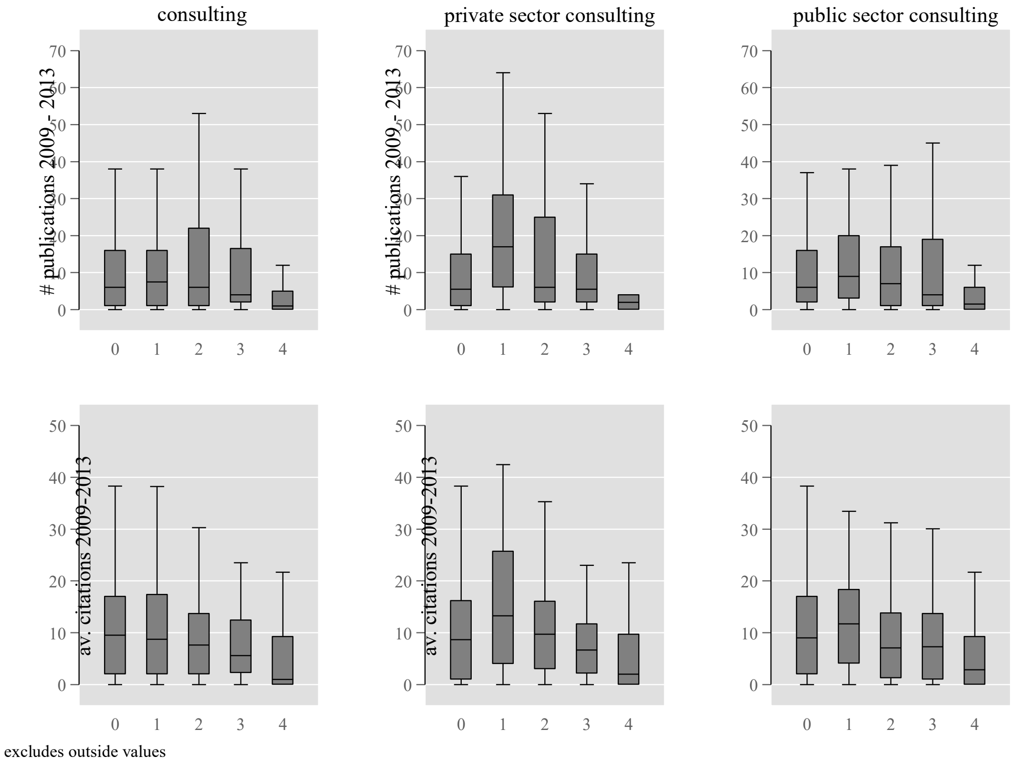
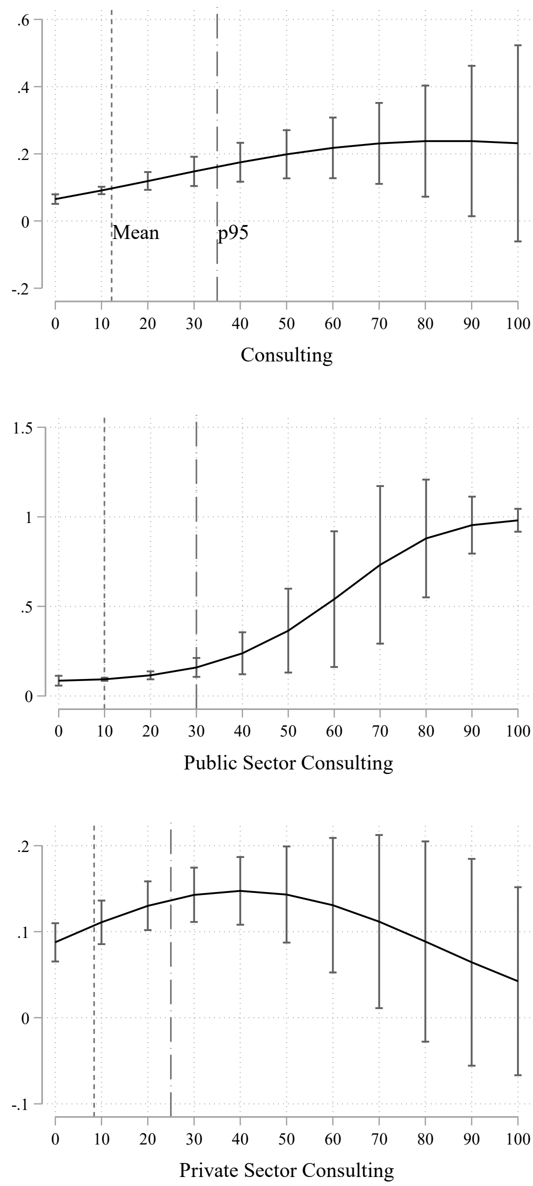
Figures

Figure 1: Box plots of outcome variables over consulting time-shares (951 observations)



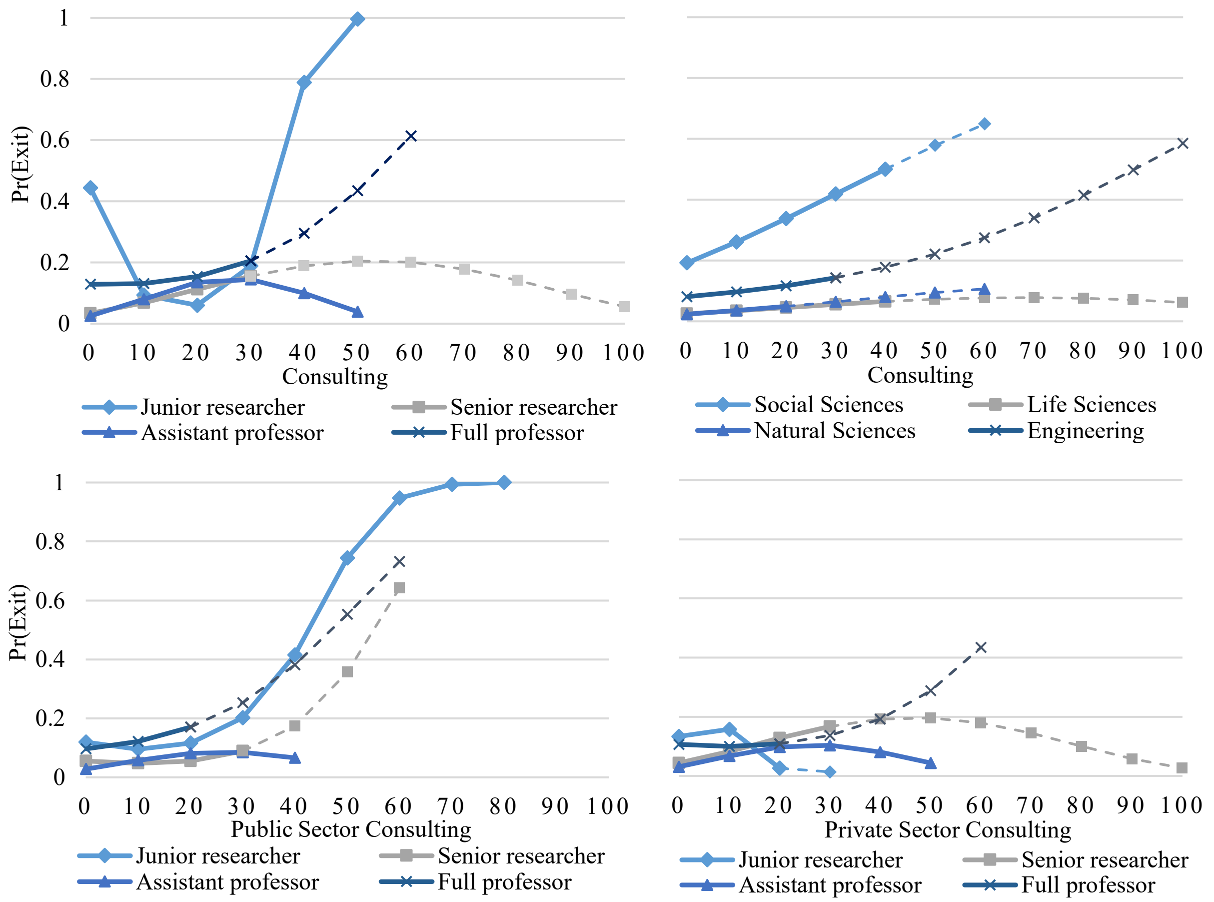
Note: Percentiles defined as ranges based on the consulting time-share percentiles for consulting-active researchers 1 to 10 = 1, 11 to 50 = 2, 51 to 90 = 3 and > 90 = 4. Graph colour scheme from Bischof (2016).

Figure 2: Predictive margins (95% confidence intervals) for “exit” (909 obs.: age<65)



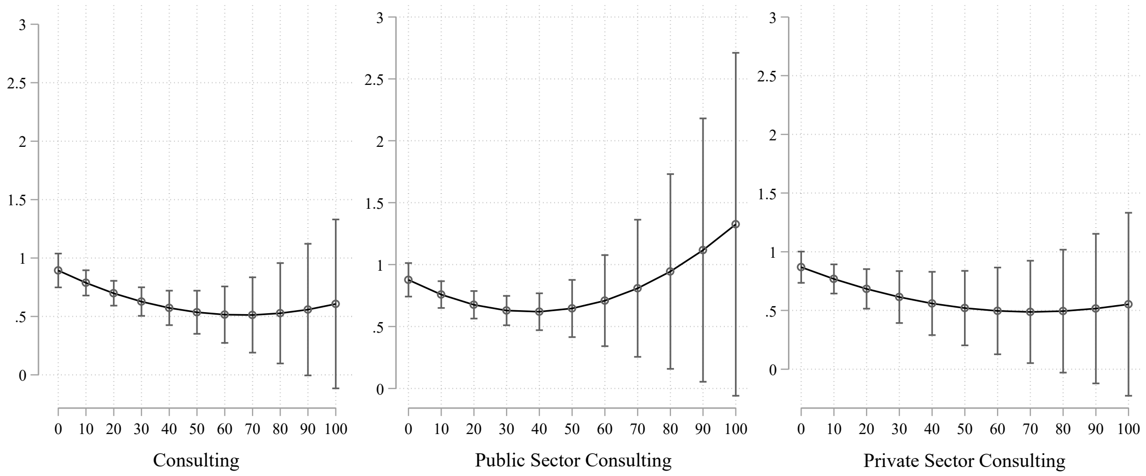
Note: Predicted exit probability depicted in the y-axis and consulting share on the x-axis. Predictive margins are calculated at the deciles of the consulting time-share distribution. The slope of the predictive margins curve represents the marginal change in the predicted probability for a change in the consulting time-share, i.e. the marginal effect. The mean values and the 95th percentiles refer to the subsample of consulting-active researchers.

Figure 3: Predictive margins for “exit” by rank and field



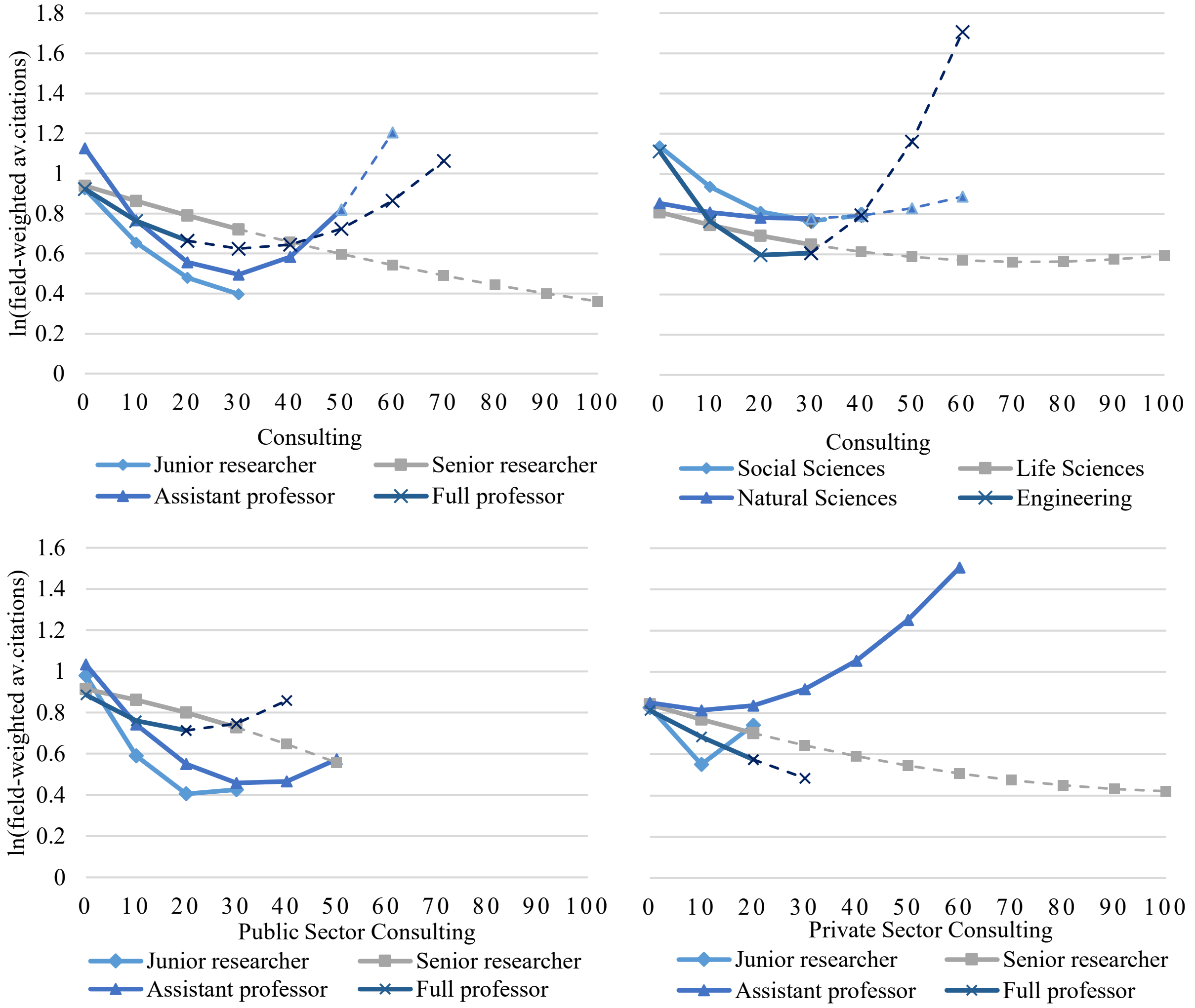
Note: Predictive margins are only shown for the range of consulting values where the margins are significant at least 10% confidence level. Predicted exit probability depicted in the y-axis and consulting share on the x-axis. Predictive margins are calculated at the deciles of the consulting time-share distribution. The slope of the predictive margins curve represents the marginal change in the predicted probability for a change in the consulting time-share, i.e. the marginal effect. Dashed lines indicate values beyond the 95th percentile of the consulting share distribution.

Figure 4: Predictive margins with 95% confidence intervals for field-weighted av. citations per publication (without “exits”, 784 obs.)



Note: Predicted outcome variable depicted in the y-axis and consulting share on the x-axis. Predictive margins are calculated at the deciles of the consulting time-share distribution. The slope of the predictive margins curve represents the marginal change in the predicted value of the outcome variable for a change in the consulting time-share, i.e. the marginal effect.

Figure 5: Predictive margins for field weighted av. citations per publication by rank and field (without "exits", 784 obs.)



Note: Predictive margins are only shown for the range of consulting values where the margins are significant at least 10% confidence level and only within the relevant observed conulting intensity range for the respective group. Predicted outcome variable depicted in the y-axis and consulting share on the x-axis. Predictive margins are calculated at the deciles of the consulting time-share distribution. The slope of the predictive margins curve represents the marginal change in the predicted value of the outcome variable for a change in the consulting time-share, i.e. the marginal effect. Dashed lines indicate values beyond the 95th percentile of the consulting share distribution.

Tables

Table 1: Descriptive statistics

Variable	unit	source	median	mean	s.d.	min.	max.
Outcome Variables							
$exit_{2009\text{-}2013}$	count	ISI WoS	0	0.18	0.38	0	1
$publications_{2009\text{-}2013}$	count	ISI WoS	6	12.44	20.13	0	278
av. $citations_{2009\text{-}2013}$	fraction	ISI WoS	8.44	11.85	15.82	0	157.67
field-weighted $publications_{2009\text{-}2013}$	fraction	ISI WoS	0.53	1	1.57	0	16.93
field-weighted av. $citations_{2009\text{-}2013}$	fraction	ISI WoS	0.68	1	1.57	0	23.14
Consulting activities							
consulting [yes / no]	binary	Survey	0	0.44	0.50	0	1
public consulting [yes / no]	binary	Survey	0	0.31	0.46	0	1
private consulting [yes / no]	binary	Survey	0	0.27	0.44	0	1
consulting	percentage	Survey	0	5.31	10.27	0	100
public consulting	percentage	Survey	0	3.06	7.96	0	100
private consulting	percentage	Survey	0	2.25	6.23	0	100
Moderators							
junior researcher	binary	Survey	0	0.09	0.29	0	1
senior researcher	binary	Survey	0	0.26	0.44	0	1
assistant professor	binary	Survey	0	0.11	0.32	0	1
full professor	binary	Survey	1	0.54	0.50	0	1
social sciences	binary	Survey	0	0.21	0.41	0	1
life sciences	binary	Survey	0	0.30	0.46	0	1
natural sciences	binary	Survey	0	0.31	0.46	0	1
engineering	binary	Survey	0	0.19	0.39	0	1
Controls							
age	count	Survey	49	49.40	8.28	28	74
female	binary	Survey	0	0.15	0.36	0	1
$publications_{2002\text{-}2008}$	count	ISI WoS	4	11.70	21.03	0	305
average $citations_{2002\text{-}2008}$	fraction	ISI WoS	16.13	24.18	31.67	0	344.2
field-weighted $publications_{2002\text{-}2008}$	fraction	ISI WoS	0.47	1	1.81	0	24.52
field-weighted average $citations_{2002\text{-}2008}$	fraction	ISI WoS	0.69	1	1.39	0	17.18
average number of $co\text{-}authors_{2002\text{-}2008}$	fraction	ISI WoS	4.46	5.99	17.30	0	332.83
collaborative $reach_{2002\text{-}2008}$	ordinal	Survey	3	3.06	1.36	0	5
international visibility	fraction	Survey	0.71	0.69	0.17	0	1
industry $funding_{2002\text{-}2006}$	amount	Survey	0	0.16	0.46	0	11
public $funding_{2002\text{-}2006}$	amount	Survey	0.40	1.10	3.03	0	75
peergroup size	count	Survey	10	39.46	148.47	0	3,000
university	binary	Survey	1	0.59	0.49	0	1
$patents_{pre2009}$	count	EPO/DPMA	0	1.06	3.72	0	41
coauthorship industry	binary	Survey	0	0.22	0.41	0	1
Exclusion restrictions							
regio skills	percentage	INKAR	9	10.01	6.03	0.70	43.80
firm	binary	Survey	0	0.17	0.38	0	1
techtransfer industry	binary	Survey	0	0.43	0.50	0	1

Note: Number of observations = 951. Funding variables in 100.000€. There are two individuals with consulting shares of 100%, one for each type of consulting. Both are project leaders so that the answer seem indeed realistic and no measurement error. The reference period for the citation variables (for instance 2009-2013 or 2002-2008) refers to publication in that period and the citations received by these publications until autumn 2015.

Table 2: Descriptive statistics by type of consulting (selected variables)

	No consulting I	Consulting active II.	Private sector consulting III.	Public sector consulting IV.	I. vs II.	I. vs. III.	I. vs IV.
Observations	537	414	255	292			
	mean (s.d.)	mean (s.d.)	mean (s.d.)	mean (s.d.)		t-test	
Outcome variables							
$exit_{2009\text{-}2013}$	0.17 (0.37)	0.19 (0.39)	0.13 (0.34)	0.19 (0.39)	0.46	0.91	0.38
$publications_{2009\text{-}2013}$	11.33 (17.63)	13.88 (22.90)	15.55 (24.24)	13.58 (22.25)	0.05	0.01	0.11
av. $citations_{2009\text{-}2013}$	12.72 (16.99)	10.71 (14.11)	11.41 (14.85)	9.93 (11.84)	0.05	0.29	0.01
field-weighted $publications_{2009\text{-}2013}$	0.88 (1.44)	1.15 (1.73)	1.26 (1.73)	1.14 (1.74)	0.01	0.00	0.03
field-weighted av. $citations_{2009\text{-}2013}$	1.01 (1.51)	0.99 (1.65)	1.02 (1.68)	0.92 (1.36)	0.90	0.92	0.42
Moderators							
junior researcher	0.10 (0.31)	0.08 (0.27)	0.06 (0.24)	0.09 (0.29)	0.24	0.06	0.48
senior researcher	0.26 (0.44)	0.25 (0.43)	0.27 (0.44)	0.21 (0.02)	0.67	0.86	0.12
assistant professor	0.15 (0.36)	0.06 (0.24)	0.05 (0.01)	0.06 (0.01)	0.00	0.00	0.00
full professor	0.48 (0.50)	0.61 (0.49)	0.62 (0.49)	0.64 (0.48)	0.00	0.00	0.00
social sciences	0.19 (0.40)	0.23 (0.42)	0.14 (0.35)	0.26 (0.44)	0.18	0.07	0.02
life sciences	0.28 (0.45)	0.32 (0.47)	0.31 (0.46)	0.33 (0.47)	0.29	0.54	0.16
natural sciences	0.38 (0.49)	0.21 (0.41)	0.21 (0.41)	0.22 (0.41)	0.00	0.00	0.00
engineering	0.14 (0.35)	0.24 (0.43)	0.34 (0.48)	0.18 (0.39)	0.00	0.00	0.09

Note: 133 researchers (14%) engage in both public and private sector consulting. Two-sided t-tests presented [Pr(|T| > |t|)].

Table 3: Results of probit and simultaneous probit models on private and public sector consulting

Model	1		2			
Dependent variable	**consulting** [yes / no]		**public consulting** [yes / no]		**private consulting** [yes / no]	
	df/dx	s.e.	df/dx	s.e.	df/dx	s.e.
Moderators						
junior researcher			*Reference Category*			
senior researcher	-0.022 ***	0.006	-0.064 ***	0.009	0.018 ***	0.003
assistant professor	-0.129 ***	0.022	-0.143 ***	0.020	-0.063 ***	0.020
full professor	0.062 *	0.036	-0.017	0.047	0.066 ***	0.021
social sciences			*Reference Category*			
life sciences	-0.097 *	0.057	-0.100 *	0.057	0.023 *	0.013
natural sciences	-0.246 ***	0.025	-0.217 ***	0.051	-0.056	0.036
engineering	-0.122 ***	0.039	-0.138 ***	0.034	0.047	0.046
Controls						
age	0.003 ***	0.001	0.005 ***	0.001	0.002 **	0.001
female	-0.005	0.022	0.035	0.029	-0.052 **	0.021
field-weighted publications$_{2002\text{-}2008}$	0.006 **	0.003	0.006	0.004	0.009 ***	0.003
field-weighted av. citations$_{2002\text{-}2008}$	-0.026 ***	0.006	-0.026 ***	0.005	-0.009	0.009
collaborative reach$_{2002\text{-}2008}$	0.016 *	0.009	0.034 ***	0.012	-0.002	0.008
international visibility	0.035	0.046	-0.003	0.040	0.081	0.054
ln(industry funding)$_{2002\text{-}2006}$	0.225 **	0.112	-0.085	0.053	0.225 ***	0.088
ln(public funding)$_{2002\text{-}2006}$	0.083 *	0.043	0.200 ***	0.015	-0.059 ***	0.019
ln(peergroup size)	-0.021 ***	0.008	-0.019 ***	0.007	-0.008	0.010
university	-0.116 **	0.053	-0.078 **	0.037	-0.042 *	0.023
ln(patents$_{pre2009}$)	-0.012	0.026	-0.061 ***	0.011	0.012	0.012
coauthorship industry	0.077 *	0.042	0.057	0.048	0.061 *	0.034
Exclusion restrictions						
regio skills	-0.006 **	0.003	-0.008 **	0.003	-0.005 *	0.002
firm	0.042 **	0.018	0.050	0.031	0.052	0.034
techtransfer industry	0.212 ***	0.020	0.073 ***	0.016	0.255 ***	0.011
Log pseudolikelihood	-560.226		-921.189			
ρ[equ. 1/2]	-		0.522 (0.046)***			

Note: Number of observations = 951. Average marginal effects presented. *** (**,*) indicate a significance level of 1% (5%, 10%). All models contain a constant. If we include unweighted publication and citation variables the signs and significance levels are similar.

Table 4: Estimation results from probit models with selection on "exit"

	Model 1 (full sample)		Model 2 (full sample)		Model 3 (age < 65)		Model 4 (age < 65)	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Consulting activities								
consulting	0.025 **	0.010			0.030 ***	0.011		
consulting²	<-0.001	<0.001			<-0.001	<0.001		
public consulting			-0.003	0.014			0.007	0.018
public consulting²			0.001 *	<0.001			<0.001	<0.001
private consulting			0.024 ***	0.006			0.026 ***	0.004
private consulting²			<-0.001**	<0.001			<-0.001 **	<0.001
Controls								
age	0.023 ***	0.005	0.026 ***	0.008	0.028 ***	0.010	0.031 **	0.012
female	-0.017	0.190	-0.031	0.210	0.007	0.187	-0.008	0.205
junior researcher				*Reference Category*				
senior researcher	-0.304 ***	0.049	-0.224 ***	0.038	-0.372 ***	0.062	-0.287 ***	0.047
assistant professor	-0.514 ***	0.128	-0.452 ***	0.108	-0.586 ***	0.138	-0.508 ***	0.132
full professor	-0.230 **	0.103	-0.252 *	0.148	-0.256 *	0.142	-0.259	0.186
field-weighted publications$_{2002-2008}$	-0.648 ***	0.038	-0.670 ***	0.060	-0.631 ***	0.036	-0.655 ***	0.059
field-weighted av. citations$_{2002-2008}$	-0.101	0.119	-0.117	0.125	-0.108	0.122	-0.121	0.133
ln(industry funding)$_{2002-2006}$	1.143	0.737	1.233 *	0.748	1.458 **	0.663	1.620 **	0.650
ln(public funding)$_{2002-2006}$	0.013	0.151	-0.035	0.164	0.074	0.115	0.012	0.118
collaborative reach$_{2002-2008}$	<-0.001	0.059	0.024	0.054	0.009	0.063	0.031	0.055
international visibility	-1.509 ***	0.270	-1.710 ***	0.263	-1.281 ***	0.189	-1.452 ***	0.273
ln(peergroup size)	-0.070 **	0.031	-0.090 ***	0.013	-0.089 *	0.046	-0.108 ***	0.030
university	0.130	0.142	0.173	0.182	0.037	0.209	0.067	0.243
social sciences				*Reference Category*				
life sciences	-0.974 ***	0.083	-1.021 ***	0.083	-1.078 ***	0.111	-1.121 ***	0.102
natural sciences	-1.106 ***	0.135	-1.171 ***	0.084	-1.090 ***	0.095	-1.145 ***	0.063
engineering	-0.570 **	0.291	-0.601 **	0.241	-0.599 **	0.288	-0.618 **	0.273
ln(patents$_{pre2009}$)	-.108 **	0.047	-0.127 ***	0.036	-0.181	0.160	-0.202	0.152
coauthorship industry	-0.205	0.224	-0.281	0.264	-0.199	0.225	-0.260	0.242
# observations	951		951		909		909	
# consulting-active obs. (2nd stage)	414		414		392		392	
Log pseudolikelihood	-686.24		-683.62		-653.92		-651.66	
Wald test of indep. equations $chi^2(1)$	3.09*		2.97*		4.62**		3.03*	
α^{ρ}	0.966 (0.549)*		0.731 (0.424)*		1.128 (0.524)**		0.896 (0.515)*	

Note: Number of observations is= 951. Marginal effects at means. *** (**,*) indicate a significance level of 1% (5%, 10%). All models contain a constant. Clustered standard errors in parenthesis. If we include unweighted publication and citation variables the signs and significance levels are similar.

Table 5: Estimation results from endogenous switching models on research outcomes (without "exits")

	ln(field-weighted publications$_{2009-2013}$)		ln(field-weighted publications$_{2009-2013}$)		ln(field-weighted av. citations$_{2009-2013}$)		ln(field-weighted av. citations$_{2009-2013}$)	
	no consulting	consulting	no	consulting	no consulting	consulting	no consulting	consulting
consulting		<-0.001				-0.011 ***		
		(0.004)				(0.004)		
consulting²		<-0.001				<0.001		
		(<0.001)				(<0.001)		
public consulting				-0.006				-0.014 ***
				(0.005)				(0.005)
public consulting²				<0.001				<0.001 *
				(<0.001)				(<0.001)
private consulting				-0.002				-0.011 *
				(0.005)				(0.006)
private consulting²				<-0.001				<0.001
				(<0.001)				(<0.001)
age	0.043 **	0.076 ***	0.043 **	0.077 ***	-0.006	0.030	-0.006	0.031
	(0.019)	(0.027)	(0.019)	(0.027)	(0.028)	(0.022)	(0.028)	(0.022)
age²	-0.001 ***	-0.001 ***	-0.001 ***	-0.001 ***	<0.001	<-0.001	<0.001	<-0.001
	(<0.001)	(<0.001)	(<0.000)	(<0.000)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
ln(average number of co-authors)	0.055	0.029	0.055	0.026	0.078 **	-0.071	0.078 **	-0.071
	(0.047)	(0.050)	(0.047)	(0.050)	(0.031)	(0.057)	(0.031)	(0.057)
ln(field-weighted pubs)$_{2002-2008}$ /	0.568 ***	0.680 ***	0.568 ***	0.683 ***	0.506 ***	0.490 ***	0.506 ***	0.485 ***
ln(field-weighted	(0.042)	(0.043)	(0.042)	(0.043)	(0.071)	(0.062)	(0.071)	(0.062)
no_publication_d / no_avcit_d	0.190 **	0.216 **	0.190 **	0.219 **	0.277 ***	0.029	0.277 ***	0.029
	(0.093)	(0.095)	(0.093)	(0.095)	(0.083)	(0.124)	(0.083)	(0.124)
ln(industry funding)$_{2002-2006}$	-0.120	-0.018	-0.120	-0.002	-0.134	0.309 *	-0.134	0.311 **
	(0.166)	(0.111)	(0.166)	(0.120)	(0.175)	(0.159)	(0.176)	(0.156)
ln(public funding)$_{2002-2006}$	0.069	<0.001	0.069	0.001	0.092	-0.061	0.092	-0.060
	(0.057)	(0.074)	(0.057)	(0.076)	(0.067)	(0.077)	(0.067)	(0.075)
collaborative reach$_{2002-2008}$	0.028 **	0.019	0.028 **	0.022	0.016	0.003	0.016	0.004
	(0.012)	(0.016)	(0.012)	(0.016)	(0.016)	(0.017)	(0.016)	(0.017)
ln(patents$_{pre2009}$)	0.007	0.070 **	0.007	0.067 **	-0.027	-0.033	-0.027	-0.034
	(0.027)	(0.029)	(0.027)	(0.029)	(0.024)	(0.029)	(0.024)	(0.029)
Log pseudolikelihood	-643.51		-642.52		-776.96		-776.52	
Wald test of indep. equations chi²(2)	4.16		3.94		7.95**		7.74**	
α^{ρ} (consulting = 0)	-0.074 (0.175)		-0.071 (0.173)		0.111 (0.234)		0.110 (0.236)	
α^{ρ} (consulting = 1)	-0.398 (0.186)**		-0.387 (0.187)**		-0.358 (0.126)***		-0.356 (0.127)***	

Note: N = 784. *** (**,*) indicate a significance level of 1% (5%, 10%). All models contain a gender dummy, a dummy variable for coauthorship with industry, ln(peergroup size), international visibility and rank dummies as well as a variable indicating university affiliation and a constant. Coefficients presented; robust standard errors in parenthesis below. For unweighted publication and citation variables the signs and significance levels are similar. Outcome variables and logged controls are calculated as the natural logarithm of the variable plus one. First stage estimation results and results for the full sample available upon request.

Notes:

[i] Especially sponsorship from the private sector may include income from consulting projects with firms and therefore indirectly reflect an academic's engagement in consulting activities with the private sector. In addition, consulting and contract research for industry are highly correlated (Gulbrandsen and Smeby, 2005).

[ii] PROs play an important role in the German academic research landscape. PROs include the Fraunhofer and Max-Planck Society, as well as the Helmholtz- and Leibniz Associations, and accounted for around 20% of academic staff in 2012 and for 34.4% of the European Research Council grants awarded to German institutions during the period 2007-2013 (DFG, 2015).

[iii] While German law in principle requires research staff at universities and PROs to report additional consulting income to their employer, there are certain exemption levels that vary between different institutions below which no reporting is required (Hochschul-Nebentätigkeitsverordnung, HNtV). Thus, income information provided by institutions would not provide a full picture.

[iv] The questionnaire asked: "Please give the percentage of working time you currently spend on the following activities." Respondents distributed timeshares over: research, research funded by research grants, teaching, administration, private sector consulting and public sector consulting. Unlike research funded by research grants the general research category refers to research financed by institutional core funding which is in Germany typically distributed to the universities or PROs through the state and is not subject to a specific project proposal, application or selection process. See Table A.4 in the Online Appendix for an overview of the division of time.

[v] By comparison, a 2015 survey of academic staff in the UK found that academics spend about 40% on research, 30% on teaching and 21% on administrative tasks (Hughes et al., 2016). The higher teaching share will be primarily due to the additional surveying of PROs in our case rather than country differences.

[vi] The variable takes values from zero to five, where zero stands for 'no collaborative work', one for 'collaboration only within the home institution', two for 'collaboration only inside Germany', three for 'European-wide collaboration, but not beyond'. Categories four and five capture collaboration with North America and the rest of the world, respectively.

[vii] The pre-sample variables are adjusted to the respective dependent variable, i.e. based on field-weighted publication counts if the dependent variable is ln(field-weighted publications+1) and field-weighted average citations in the model for ln(field-weighted av. citations+1).

[viii] We checked the sensitivity of the results of the publication outcome models to different estimation methods (OLS, Tobit, Poisson and negative binomial estimation) and to different specifications of the dependent variable (levels versus log transformation). These tests showed that estimated coefficients are quantitatively and qualitatively similar (see Table A.6 in the Online Appendix).

[ix] See Table A.5 in the Online Appendix for corresponding estimations using population weights. More precisely, we employ field-institution type inverse probability weights that should capture some of the observed differences also in terms of gender and age, and apply inverse probability weighting to test the robustness of our results to these sample properties, especially bias caused by field or institute sampling through population weights. The differences in estimated coefficients are minor and not qualitatively in nature.

[x] We also estimate simultaneous equation models on the timeshares devoted to public and private sector consulting. The effects of the explanatory variables are very similar to the ones in the probit and the correlation coefficient between the timeshare equations is insignificant (see Table A4.b in the Online Appendix).