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Does Gender really Matter? An Analysis of Jena University Scientists Collaboration with Industry and Non-Profit-Partners

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Abstract

One of the dominant changes in academics during the last 25 years has been the steadily growing political pressure on universities to strengthen their links with and knowledge transfers to external partners. This focus on university-industry collaboration has been accompanied by another fundamental change in academia, the growth in enrolments of female researchers in science (especially natural sciences) and engineering. The rising number of female scientists has led to the question of possible gender disparities as to external collaboration activities, namely a male predominance as to external collaboration activities.

This paper extends the existing empirical work in three respects. First, it covers various scientific disciplines and faculties, second different types of transfer activities and third different transfer partners, including private industry, the civil service and non-profit-organizations. Data were collected from a sample of university professors at two German universities. The resulting survey is based on 174 personal interviews lasting 40-60 minutes.

The empirical results point to a more complicated story than gender differences of productivity or simple discrimination. As to collaboration activities of female professors with the business sector the empirical evidence is not uniform and straightforward. With our data set it is easy to produce empirical outcomes seemingly confirming the gender gap, e.g. by omitting variables as to scientific fields like engineering or business economics. Even including all relevant control variables the results are influenced by the specification of the empirical model: The level-level-model strongly corroborating and the log-log-model refusing a significant negative difference related to gender. But as to the collaboration with the public sector and non-profit organisations there is no gender gap at all and this outcome does not depend on the specification of the regression equation. Thus, specific differences of collaboration partners seem to play a role.

JEL-Classification: J23 , J25 , L33

Keywords: university industry collaboration, university industry linkages, gender, male female professors, public sector, knowledge transfer

1. Introduction

One of the dominant changes in academics during the last 25 years has been the steadily growing political pressure on universities to strengthen their links with and knowledge transfers to industry. There are at least two causes for this. First, the increasing need for firms to innovate compared to earlier decades. Second, the economic literature on the competitive advantage of nations or regions and the role of industry-clusters for regional economic growth points to the crucial influence of universities as producers of know-how. This focus on university-industry collaboration has been accompanied by another fundamental change in academia, the growth in enrolments of female researchers in science (especially natural sciences) and engineering (Ginter/Kahn 2004, Gaughan 2005, Stephan 2008, de Melo-Martin 2013).

The rising number of female scientists has led to the question of possible gender disparities in science and engineering careers.[1] Differences between female and male scientists are discussed in the literature with regard to several perspectives including career paths, publications and patents. But the literature on university-industry links reveals that a broad range of different types of university-industry transfer mechanisms exist and underlines the importance of informal types of collaboration. The possibility of gender differences with respect to university-industry links including such informal transfer motivates this paper. Data collected from two German universities are used to test various hypotheses developed.

The remainder of the paper is organized as follows. Section 2 discusses the decision to collaborate with firms for the university researcher. Section 3 summarizes the existing empirical literature on the influence of gender in the external collaboration context. Section 4 derives the hypotheses and section 5 describes the data. The empirical results for collaboration with for-profit and non-profit partners are presented in Section 6 and Section 7 concludes.

2. University-industry linkages: The context

The decision to engage in university-industry transfer activities depends on constraints, benefits and costs of the alternatives for both parties. In German universities it is the decision of the individual researcher to collaborate or not. However, the pres-

[1] As to the context of student enrolments and performance see Pope/Sydnor (2010) and several other papers in the spring edition of the Journal of Economic Perspectives in 2010.

sure on universities to engage in transfer activities has increased during the last two decades, therefore increasing the incentives for scientists in this direction.[2]

University researchers actually face three different decisions: First, they have to decide whether they want to set up transfer activities at all. The alternative would be to work on pure basic research, publish in scientific journals, and contribute only to academic conferences. All these activities are possible without any direct university-industry links. This of course does not exclude the possibility that firms may indirectly benefit from the open access to scientific information.

Second, they must consider the type of collaboration they prefer. In this respect, a wide range of possible transfer channels exists: from formal collaboration, such as paid consultancy, to loose informal transfer channels, e.g. occasional discussions in workshops.

Third, the scientist has to choose not only the overall level of intensity of transfer activities but in the intensity with respect to the various types of collaboration. Here, complementarities on the one hand and substitution possibilities of these types of transfer activities complicate the collaboration process, or at least its theoretical analysis and empirical detection.

This paper extends the existing empirical work in three respects. First of all, it covers not only “transfer prone” scientific disciplines and faculties. The overwhelming majority of the existing literature is limited to collaboration activities of fields such as engineering, physics and the natural sciences in general. Some empirical work uses data from the life sciences, and a few papers examine business and economics departments. But there is no study of the humanities and social sciences, e.g. social work and political science. Second, unlike much literature, this study is not limited to specific types of transfer activities, e.g. consultancy, joint publications or activities resulting in patents. All types of transfer channels are included, given only that they rely at least to a certain extent on personal individual interaction of the scientist with an external partner. Third, the transfer partners are not only private enterprises but include the civil service and all types of non-profit-organizations. Thus it leads to a more comprehensive picture of university scientists external links.

[2] Perkman et al. (2013) provide a comprehensive overview.

3. Empirical findings: An overview of the literature

The question of academic women in science has attracted research since the 1970s (Hamovitch/Morgenstern 1977, Jacobs 1996, Grant et al. 2000, Long 2001, Smith-Doerr 2004, Gaughan 2005, Ginther/Kahn 2006, Wolfinger et al. 2009).[3] Earning differences, under-representation in and lower academic career success of female scientists led to more detailed investigations of possible explanations of these empirical findings. With respect to questions investigated in this paper several streams of this research are significant.

First as to publishing some work reveals that female scientists publish less in comparison to their male colleagues in the faculty (Cole/Cole 1973, Zuckerman 1987, Levin/Stephan 1998, Creamer 1999, Long 2001, Kimery et al. 2004). Explanations of this so called productivity puzzle (Cole/Zuckermann 1984) point out the disadvantages of non-tenure positions (Bozemann et al. 2001) and traditional family roles (Grant et al. 2000, Fox 1983, Fox 2005). Xie and Shaumann (1998) and Ginther and Kahn (2006) argue that much of this productivity gap is explained by organizational and family contexts. In contrast, Kolpin and Singell (1996) find that women´s publication output is higher than men´s, when controlling for the quality of the articles published. But their study is limited to publications in economics.

Second, analyses of patenting behaviour of university scientists have flourished, much of the literature building on Jaffe´s path breaking article of the effects of universities as to regional economic growth (Jaffe 1989). A descriptive report by Morgan et al. (2001) states that women who patent are more likely to be found in the life sciences instead of engineering. But this fact simply reflects the different numbers of women in these disciplines. Whittington and Smith-Doerr in a survey on a US population in the Life Sciences investigate gender disparities in patenting for scientists in both the academic and industrial sector (Whittington/Smith-Doerr 2005). They find that female researchers at universities patent less and the same is true in industry. But there are no statistically significant gender disparities in the commercial value of patents received (ibid, p. 364). Furthermore, the involvement in patenting of women in the industrial sector surmounts the corresponding involvement of male scientists at universities, indicating that the organizational context plays a crucial role (ibid, p. 359,

[3] A special report of the National Science Foundation provides an overview of the relevant literature for the US (NSF, 2003). The biannual report of the NSF contains actual data for the US (NSF 2013).

Table I). Interestingly, the internal differences of the female scientists are much greater than those of their male colleagues (ibid, pp. 364 and 368). But this paper does not include influential variables like the professional or academic position of the scientists. Azoulay et al. (2009) examine the patenting of life scientists for the years 1969 to 1999. Female researcher show a significant negative probability of patenting (ibid, p. 43). A shortcoming of all these studies is their limitation to only one type of transfer activity, patenting.

Third, some papers deal with various other university-industry know-how transfer linkages in general, but also do not consider male-female differences (Lee 2000, Schartinger et al. 2002, Bercovitz/Feldman 2003, D´Este/Perkmann 2007, Banal-estanol et al. 2009, D´Este et al. 2009).

However, there are a few exceptions. Thursby and Thursby (2005) use the disclosure of inventions and publication activities as measures of scientific productivity. The result as to the independent variable gender is highly significant: The probability that a male scientist engages in disclosure activities is 43% higher in comparison to female researchers (ibid, p. 351). Three aspects of this study deserve special attention. First, it turns out that non-linear effects are relevant as to age and publications. Second, they find a certain convergence of both groups over time. Third, as to the number of publications there is no difference between male and female scientists. Unfortunately the analysis does not include relevant variables as e.g. tenure, academic position and experience.

Corley and Gaughan (2005) focus on the gender differences in two types of academic organisations. Beside the question of gender they concentrate on the institutional differences between traditional university departments and the new established University Cooperative Research Centers. These centers aim at strengthening the cooperation between industrial firms and universities. They find gender differences common in the literature (e.g. as to tenure status and position of full professor). Two results add new insights. First, with regard to research activities on the one hand there is no difference between female and male scientists as to “grant supported research”. But on the other hand, male scientists invest more time in “paid consulting”. Second, this gender gap is attenuated by institutional setting. Women as faculty members who are affiliated with university research centers more closely resemble their male colleagues in comparison to both groups of scientists at traditional university departments.

Link et al. (2007) for the US and Grimpe/Fier (2009) for Germany analyse the propensity of university scientists to engage in informal technology transfer. They distinguish three types of informal collaboration: direct collaboration in order to transfer or commercialize know-how, co-authorship with industry researchers, and paid consultancies with an industrial firm. Male university scientists are significantly more likely to engage in consulting and commercialization. But with regard to joint publications there is no such gender difference.

Tataris paper (2009a) examines two dependent variables: On the one hand collaboration as a binary yes-no-variable and on the other hand the intensity of collaboration as a categorical and ordinal variable with three categories (infrequent to habitual collaboration). The outcomes of different econometric models reveal that several relevant factors exist, e.g. individual perceptions such as researchers' perception of freedom of research as well as institutional variables, e.g., the research orientation of the university. Gender turns out to be a very important factor. The finding is that male scientists have a stronger inclination to increase their collaboration with industry in comparison to female researchers. With regard to the decision to collaborate or not a significant effect also emerges, with males more likely than female scientists to engage with industrial partners. This result holds in a later version of her paper merging the two different models into one ordered logistic regression model (Tartari 2009b). Her study, however, lacks a clear definition of the meaning of “collaboration”.

Giuliani et al. (2010) base their study on survey data collected in the wine industry in Italy, Chile and South-Africa in 2005/2006. They include a range of collaboration activities from joint research agreements to student internship in firms. In their data set women are more likely than their male colleagues to collaborate with the industry.

To sum up, the lessons for gender as a relevant empirical factor influencing university-industry linkages reveal that the gender related differences vary with regard to the types of collaboration considered. The existing literature measuring academic-industrial collaboration is often limited to publications, patents (Whittington/Smith-

Doerr 2005), paid consultancy, disclosure of inventions (Thursby/Thursby 2005), to contracts (Azagra-Caro 2007) or to an not well defined aggregate like overall “collaboration” (Link et al. 2007, Tartari 2009a/2009b).

Furthermore, at least two independent variables have to be taken into account: different disciplines and the academic experience or the scientific reputation of researchers. Leaving these two variables out of the specification of the empirical model leads to spurious correlation results because in some disciplines there are few female scientists and on average they also lack academic experience in comparison to their male colleagues. This is especially plausible in academic fields like engineering, where there are very few female scientists and who, when they exist, tend to be young.

4. Research collaboration in the presence of potential discrimination

We develop here a simple framework, based on widely accepted labor-market premises, of scientific collaboration with the potential for discrimination against female researchers. The decision to engage in university-industry collaboration depends on constraints, benefits and costs of the alternatives for both parties.

University researchers actually face three different decisions: First, they have to decide whether they want to set up collaboration at all. The alternative would be to work on pure basic research, publish in scientific journals, and contribute only to academic conferences. All these activities are possible without any direct university-industry links. This of course does not exclude the possibility that firms may indirectly benefit from the open access to scientific information. In German universities it is the decision of the individual researcher to collaborate or not. However, the pressure on universities to engage in collaboration has increased during the last two decades, therefore increasing the incentives for scientists in this direction.

Second, they must consider the type of collaboration they prefer. In this respect, a wide range of possible collaboration channels exists: from formal collaboration, such as paid consultancy, to loose informal channels, e.g. occasional discussions in workshops. Third, the scientist has to choose not only the overall level of intensity of collaboration activities but in the intensity with respect to the various types of collaboration. Here, complementarities on the one hand and substitution possibilities of these types of collaboration complicate the collaboration process, or at least its theoretical analysis and empirical detection.

To investigate the nature of gender differences in such collaboration, we start from a few simple premises:

1. *Objectives*. Male and female researchers maximize research output against endowment constraints. Endowments include skill and time. These endowments can be converted into various research outputs such as publications, potentially marketable innovation, and explicit collaboration with external partners, each of which carries some exogenous reward, coming from competitive firms in for-profit and non-profit industries.
2. *Productivity*. Males and females face the same technology, i.e. are equally capable of transforming inputs into research outputs. Males and females may differ in endowments and their opportunity costs in non-research work, however.
3. *Discrimination*. Discrimination, if it exists, impacts the market in the standard Becker (1971) fashion. Firms that discriminate will be willing to pay less for research outputs of either kind. Given constant resource costs, such discrimination in a particular collaborative activity against, say, women will lead to the discriminated-against group reallocating resources away from that activity either to other ones or to non-research activity. In this framework, lower female research activity can be ascribed either to discrimination or to higher endowment opportunity costs. In the standard example, if a female professor has higher productivity in household production than a male one (e.g., she wants to have children, and the time costs are higher in this activity for women than men), then she may reallocate toward such production and away from publication and research. Females might then both publish and collaborate less than males.
4. *Information*. We suppose that firms may or may not be aware of individual productivity. If individual productivity information is difficult to obtain, previous experience leads to more confidence in industry estimates of individual productivity. Reliance on researcher reputation is a key way to economize on search costs.
5. *Time*. In addition, if publication is an input to later innovation collaboration, because publication leads to production of human capital that is useful to private

> industry, then a rational female, who expected to take time out of the labor force later to raise children, might face problems upon her return. Publication makes collaboration more productive, and one collaboration probably opens the door to others. If collaborative productivity depends in part on successful past efforts, a woman who loses collaborative opportunities in her late 20s and early 30s will have fewer opportunities to collaborate when she returns to the workforce. These effects lead to women substituting across time and publishing and collaborating more before their early 30s to make up for opportunities lost later. This assumption is sensitive to the depreciation of human capital – both knowledge and contacts with industry – in collaboration. If it depreciates fast, then a re-entering woman comes back with little human capital and will trail men forever, and there is little incentive to collaborate more early. But if it doesn't, she could return to the work force and begin publishing and perhaps collaborating again at the same rate as men. We would then expect to observe such intertemporal substitution, which would suggest both different costs and perhaps a lack of discrimination. Discrimination, in contrast, should manifest itself in less collaboration in all age groups.

To sum up, we expect no gender related differences as to collaboration. If differences exist they should be limited to certain age intervals of women, probably due to greater household productivity. We identify discrimination by lower collaboration of female professors independent of age. In addition to these hypotheses, we include a broad set of variables to control for individual and institutional differences that influence collaboration of faculty members. These control variables comprise, e.g. time constraints with respect to teaching, reputation, different scientific disciplines, and orientation of universities (applied versus research).

5. The database

We use information from a survey questionnaire which took place during the time period autumn 2004 to spring 2005. Data were collected from a sample of university professors at two German universities, the Friedrich-Schiller-University of Jena (FSU) and the University of Applied Sciences Jena (EAH). Each school represents one of the two main types of universities in Germany. The FSU is a traditional Research University, which contains the full range of faculties from faculty of philosophy to nat-

ural science and business schools. The EAH Jena is a young applied-research-oriented university concentrating on engineering, business economics and social work. The survey is based on personal interviews lasting 40-60 minutes. The population of all professors of both universities comprises 464 academics, with 348 coming from FSU and 116 from EAH Jena. A random sampling method was used and 90% of the selected interview partner could be interviewed. Therefore the survey comprises 37.5% of the population. 127 of the 174 interviews were completed at the FSU and 47 at the EAH Jena. The sample includes only tenured professors, so the academic position per se is the same for male and female scientists.
The questions focus mainly on diverse aspects of collaboration behaviour in university-industry links. 17 different collaboration options were identified and requested, from formal (personal contract based work, consultancy, internship jobs etc.) to informal (workshops, fairs, personal non-contract based work, etc.). By distinguishing among these channels we should be able to cancel out differences in the variety of possible collaboration activities. In order to identify the importance of these different types more precisely, the questions measure the intensity of use of these channels. “Importance” is defined in relation to the time allocated by the individual scientists for their collaboration activities. In addition we have information on researcher discipline and collaboration partners (for-profit versus public-sector/non-profit sector).

The dependent variables we use aggregate the 17 identified channels by summing up their respective intensities measured on a 6 point Likert scale from 0 (not used) to 5 (intensive use). This results in an overall indicator of the collaboration activities of a professor. In a second step two different types of collaboration partners are considered – on the one hand for-profit business enterprises and on the other public service and non-profit-organizations. For the for-profit sector we define a dependent variable BUSINtransfer indicating the intensity of collaboration activities, while PUBNPOtransfer measures the intensity of collaboration with public service and non-profit organisations (e.g. schools, social work). For calculating these dependent variables the overall indicator of collaboration is multiplied with the share of both collaboration partners in all collaboration activities of a professor (see Table 1).

The variable Gender shows that in the sample 21 female professors exist (coded 1), that is about 12 % of all professors. The age of the researchers ranges from 35 to 70 years, due to the fact, that only tenured full professors are in the basic population. A battery of control variables catches the influence of different scientific disciplines, academic orientations and individual characteristics. Several dummy variables control for types of scientific fields. The variable Univtype distinguishes the two types of universities at hand (1 in case of the EAH Jena). Engineer includes engineering departments and applied natural sciences (e.g. laser physics and glass chemistry). Medicine indicates the medical sciences, Businessecon business departments and orientations and Socialwork the applied social work.

Table 1: Descriptive summary of variables

Variable	Obs	Mean	Std. Dev	Min	Max
BUSINtransfer	174	748.11	1000.47	0	5300
PUBNPOtransfer	174	773.42	1103.60	0	5100
Gender	174	.12	.33	0	1
Age	174	52.60	7.47	35	70
Teachload	174	35.61	16.48	1	90
Adminload	174	27.27	20.46	0	95
Reserload	174	32.03	14.47	0	73
Funds	174	222.98	327.05	0	1600
Univtype	174	.27	.45	0	1
Engineer	174	.17	.37	0	1
Medicine	174	.14	.35	0	1
Businessecon	174	.06	.23	0	1
Socialwork	174	.05	.22	0	1
Basicresearch	174	.13	.34	0	1

In addition, the dummy Basicresearch is coded 1 in case of e.g. pure mathematics and theoretical physics. With regard to academic time allocation Teachload captures the amount of working time (percentages) devoted to teaching. The same applies to Adminload (time devoted to administrative activities) and Reserload (Research time). The reference category comprises other activities, e.g. own business and political activities. The variables Funds and Age are used to count for reputational and individual characteristics. Funds is an indicator variable for the reputation of a professor. It is the number of research assistants of a professor multiplied with the share of external funding of a professors budget. We expect the following coefficients: Basicresearch (-), Adminload, Reserload and Teachload (-/+), Funds (+), Age (+). In addition, given the results in the literature Funds and Age may exhibit nonlinear relationships with collaboration.

6. Empirical findings

6.1 Collaboration with business

First, the transfer activities with private enterprises are taken into consideration (dependent variable: BUSINtransfer). Table 2 shows the results for different specifications of the regression model. Visual inspection of the residuals and a Breusch-Pagan Test reveal heteroscedasticity so, White´s robust variance-covariance estimator applies for all models. As to the possibility of non-linear relationships the model is limited to two specifications widely used in applied regression analyses: A level-level model includes the variables and in addition the quadratics of all continuous explanatory variables (e.g Teachload and Teach2) and a log-log model is based on the logs of the dependent and all the independent continuous variables (e.g. LNBUSINTransfer, LNTeachload).[4]

Table 2 reveals that the control variables as to types of scientific fields have the expected signs and often significant influences, e.g. professors in the disciplines of engineering and business economics have more collaboration activities with private industries. This result does not depend on the specification of the model.

[4] The statistical software package STATA, 11.0, was used for the estimations.

Table 2: Business collaboration

Dependent variable	BUSINTransfer				LNBUSINTransfer	
Independent variables	model1 OLS	model2 OLS	model3 OLS	model4 Tobit	model5 OLS	model6 Tobit
Gender	-383.40***	-318.13***	-334.73*	-566.43**	-0.7	-1.05
Intergenage45	-	-274.19	-258.07	-315.43	-0.23	-0.21
Intergenage55	-	-	32.47	-	-	-
Age/LN	68.60	52.32	51.93	73.42	-0.52	-0.77
Age2	-0.62	-0.48	-0.47	-0.71	-	-
Teachload/LN	-28.37	-27.71	-27.89	-44.34	-0.32	-0.39
Teach2	0.16	0.16	0.16	0.28	-	-
Adminload/LN	-15.05	-15.39	-15.38	-12.35	-0.10	-0.05
Admin2	0.03	0.03	0.03	-0.06	-	-
Reserload/LN	15.62	15.58	15.58	27.70	0.47	0.82
Reser2	-0.28	-0.28	-0.28	-0.42	-	-
Funds/LN	1.74***	1.74***	1.74***	2.81***	0.33***	0.57***
Funds2	-0.001**	-0.001*	-0.001*	-0.001*	-	-
Univtype	96.47	99.76	95.64	777.77**	2.67***	5.0***
Engineer	1144.53***	1132.65***	1137.10***	1226.11***	1.71**	1.6
Medicine	202.85	214.94	213.00	424.09	1.23	1.9
Businessecon	1627.59***	1654.28***	1659.07***	2018.86***	3.36***	4.13***
Socialwork	-101.96	-130.49	-131.72	-1141.50**	-3.21***	-6.60**
Basicresearch	-171.39	-172.95	-172.56	-650.09*	-1.61***	-3.31**
cons	-638.25*	-193.09	-181.80	-1157.41	5.87	4.18
N	174	174	174	174	174	174
R2/PseudoR2	0.36	0.37	0.37	0.05	0.37	0.10
F	12.37***	12.05***	12.29***	8.51***	19.90***	9.09***

legend: *p<0.1; **p<0.05; ***p<0.01

Controls for the time allocation are plausible as to their signs, e.g. a high teaching burden (Teachload) diminishes the transfer activities. However, these variables are not significant with one exception: Teachload and its quadratic (Teach2) are jointly significant in model4 (F-test, 10%-level). The variable Funds shows the expected positive link with collaboration and is highly significant, but the causal direction is debatable. Furthermore, the variable Age is not significant. This outcome does not depend on the specification of age (e.g. different age intervals instead of a continous variable).

The variable Gender in the OLS-models 1-3 has a negative sign and turns out to be significant at the one percent level. Thus, model 1 confirms much of the empirical results of the literature: Female professors have fewer collaboration activities with private business in comparison to their male colleagues (the reference group coded 0). This outcome holds for different specifications of the variable Age not reported in table 2 (e.g. different age intervals). Models 2 and 3 test the hypothesis that the influence of age may be different for men and women. The variable Intergenage45 is the interaction effect of gender and the age interval up to 45 years. Thus, the effect of age on the amount of business related collaboration activities can be distinct not only for men and women but also as to the age interval at hand. The decision to rely on this age interval is not arbitrary but motivated first by the fact that in Germany academic women tend to have children between 33 and 38 so child-caring should be relevant at least up to the age of 45. Second, the age of 45 is established in the literature as a crucial age of gender related differences (Ichino/Moretti 2009: 183). Model 3 adds a second interaction of gender and the age interval of above 45 up to 55 (Intergenage55. In models 2 and 3 both interaction variables are insignificant, suggesting a lack off intertemporal substitution for these two age intervals. But the F-statistic testing for joint significance of these two variables in model 3 reveals that together they have a significant influence on the 1% level. So, the influence of gender turns out to be more complicated. The negative sign of Interegenage45 means that women up to the age of 45 exhibit less business collaboration activities in comparison to women above 55 years. In addition, women between 45 and 55 years (Intergenage55) have more collaboration activities with regard to this reference group. These outcomes in principle do not vary with the specification of the age intervals (not reported).

Because BUSINtransf has 73 cases with zeros a Tobit-estimation is reported in model 4 of table 2. The sign and significance of most of the control variables do not vary, although Socialwork and Basicresearch are now significant with an expected negative sign. Gender and age results do not change.

Finally, models 5 and 6 present a log-log specification. The controls for scientific fields, academic orientations and reputation corroborate the previous findings. Model 5 confirms the signs of all control variables and in general their significance levels. But a major difference exists as to the influence of gender. The coefficient of gender alone ceases to be of statistical significance. In addition, the significance of the joint influence of gender and its interaction vanishes even at the 10 % level. This outcome holds for a Tobit-estimation (model 6) and different age intervals (not reported).

6.2 Collaboration with the public and non-profit sector

To check these findings we analyse the collaboration activities with civil service (e.g. public administration, law courts, police, public education) and non-profit-organisations and enterprises (dependent variable: PUBNPOtransfer). Results for the same estimations as in section 6.1 are shown in table 3.

Due to heteroscedasticity robust standard errors are appropriate. The models 1 to 6 match the models of the business related transfer activities of table 2. The results are in many respects similar.

The control variables of the various disciplines and scientific fields are in general significant and their estimated coefficients exhibit the expected signs: Basic research is negatively related to public and non profit collaboration and the same is true as to medical sciences. Also engineering and business economics show negative parameter estimates (regardless of specification and estimation method), but the significance level varies. The controls for workload have no individual or jointly significant influences (with the exception of Adminload in case of the log-log models).

Unlike the private sector case, here gender (and, as before, its interactions with age) is not significant, and the interaction terms are not jointly siginificant in models 2 to 5. Looking at the different specifications of model 1 to 6 the robust outcome is that no gender related differences, and hence presumably no discrimination, is detected with respect to collaborative activities with the public sector and non-profit organisations.

Neglecting the statistical significance, the signs of the interaction variables of gender with age intervals exhibit the same pattern to be found as to business collaboration. Women up to 45 have less transfer in comparison to the reference group and the opposite is true with regard to the age interval of 45 to 55.

Table 3: Public and NPO related collaboration

Dependent variable	PUBNPOtransfer				LNPUBNPOtransfer	
Independent variables	model1 OLS	model2 OLS	model3 OLS	model4 Tobit	model5 OLS	model6 Tobit
Gender	373.52	548.96	288.81	809.27*	1.24	1.85
Intergenage45	-	-737.03	-484.37	-1418.99*	-2.13	-4.25
Intergenage55	-	-	508.95	-	-	-
Age/LN	44.55	0.78	-5.20	-103.97	-0.26	-0.95
Age2	-0.26	0.13	0.20	1.07	-	-
Teachload/LN	12.8	14.55	11.65	37.43	0.41	1.07
Teach2	-0.33	-0.35	-0.31	-0.70*	-	-
Adminload/LN	-1.13	-2.04	-1.91	17.95	0.99***	2.55***
Admin2	-0.03	-0.03	-0.03	-0.19	-	-
Reserload/LN	-27.27	-27.39	-27.28	-49.48	-0.25	-0.39
Reser2	0.09	0.09	0.1	0.15	-	-
Funds/LN	-0.69	-0.71	-0.71	-0.85	-0.10	-0.17
Funds2	0.0002	0.0002	0.0002	-0.0006	-	-
Univtype	-237.22	-228.38	-292.85	-1074.71**	-1.47	-3.74*
Engineer	-660.14***	-692.07***	-622.32**	-881.07*	-1.64*	-2.15
Medicine	-632.98**	-600.48*	-631.00**	-1214.40**	-1.81*	-3.31**
Businessecon	-738.05**	-666.32**	-591.26*	-907.73	-1.32	-1.59
Socialwork	1205.56***	1128.88***	1109.55***	2404.50***	4.00***	7.59***
Basicresearch	-962.94***	-967.14***	-961.11***	-1323.54***	-2.06***	-2.80**
cons	482.47	1679.12	1855.97	4375.77	3.62	1.96
N	174	174	174	174	174	174
R2/PseudoR2	0.26	0.27	0.28	0.04	0.25	0.07
F	5.90***	5.58***	5.20***	4.09***	15.89***	6.25***

legend: *p<0.1; **p<0.05; ***p<0.01

7. Conclusion

To a certain extent the gender gap in scientific output produced by male and female university scientists has been seen as a matter of fact. The literature therefore concentrates on explanations of this gap, e.g. personal and structural characteristics (Xie/Shaumann 2003). These include access to resources during training (Fox 1995) and mentoring and scientific collaboration (Long/McGinnis 1985) or differences and problems due to family responsibilities (Stephan/Levin 2005).

Our results point to a more complicated story. With respect to collaboration by female professors with the business sector the empirical evidence is not uniform and straightforward. With our data set it is easy to produce empirical outcomes seemingly confirming the gender gap, e.g. by omitting variables such as fields like engineering or business economics. But even including all relevant control variables the results are influenced by the specification of the empirical model: The level-level-model strongly corroborates and the log-log-model fails to find a significant gender difference. With regard to collaboration with the public service and non-profit organisations there is no gender gap at all and this outcome does not depend on the specification.

Several hypotheses may explain the simultaneous existence of a possible gender gap in the for-profit sector and the lack of such a difference in case of public and non-profit collaboration. The model allows for demand and supply side reasons. Demand side means a discrimination originating on part of the collaboration partners. It could be stemming from "brute" taste based discriminatory prejudice or lack of information. Taste based discrimination is not plausible because there is good reason to assume that prejudice is not sector dependent. Otherwise, the explanation "taste based discrimination" had to put forward reasons for sector specific taste differences. A concurrent hypothesis relies on the dynamic aspects of the model and refers to the ongoing influences of the high depreciation of human capital. But this hypothesis too, fails to explain the sector specific differences. Information based discrimination is an explanation having in mind that in Germany in the public sector and in non-profit organisations women are much more represented at the medium and upper management level. Thus, if there is a gender gap in business collaboration it can be attributed to a lack of information as to the productivity of academic women. Looking at the literature, the very different outcomes of e.g. Tatari (2009a) and Giuliani et al. (2010) can be explained by such industry-specific differences of collaboration partners.

As to the supply side if higher child-rearing costs of women exist their effects are only detected in the for-profit sector, and are not robust to model specification. Furthermore, if it exists there is some evidence that this gender difference is depending on age. Women from 35 up to 45 are less transfer prone in comparison to women above 45: the coefficient of this interaction (Intergenage45) is uniformly negative for all specifications and transfer partners (business and public), although only in some cases significant. An explanation based on the model points to the possibility of a higher household productivity at the age interval from 35 to 45 years leading to less time devoted to transfer activities.

The most relevant limitation of the empirical analysis is the lack of data as to younger women at the beginning of their academic career, e.g. at the post-doc level from 25 to 35 years. In addition, this should be panel data of individuals to assess in more detail the substitution over time proposed by the model

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