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INVENTIONS AND THEIR COMMERCIAL EXPLOITATION IN ACADEMIC INSTITUTIONS: ANALYSING DETERMINANTS AMONG ACADEMICS

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Abstract: Institutions of higher education are considered as an important source of innovation. Consequently, big efforts are made to facilitate technology transfer from academia into the market. However, technology transfer at German universities does not seem to live up to its full potential. We find for example that while 18,5% of our sample did in fact generate at least one invention, only 4,5% of the sample are engaged in commercialization activities. Therefore the vast majority of generated inventions remains unexploited. Based on this finding, we analyze how individual, career-related, and institutional factors affect the innovation and knowledge transfer activities of male and female academics. We show that Gender differences as well as career and human capital related factors (e.g. scope of employment, professional experience, and leadership position) affect such innovation transfer activities. While women generate fewer inventions than men, the fulltime employed researchers with a professional experience outside of academia and a leadership position lead to more inventions as well as partly higher exploitation activities.

Keywords: academics, gender, innovation, inventions, commercial exploitation, institutional context.
JEL-Classification: O31, O34, J16

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INVENTIONS AND THEIR COMMERCIAL EXPLOITATION IN ACADEMIC INSTITUTIONS: ANALYSING DETERMINANTS AMONG ACADEMICS

1 INTRODUCTION

Innovations are essential for economic growth and structural change. They are considered a job generator, especially in knowledge-driven societies. Much of the commercially utilizable and therefore highly valuable knowledge is created in institutions of higher education as research output. Therefore these institutions make great efforts to establish and incorporate services and infrastructure to facilitate the knowledge transfer to the private sector and thus the commercial exploitation of inventions. In a recent study, Bijedić et al. (2014) for example can show that 96% of institutions of higher education in Germany have some kind of facilitating infrastructure for knowledge transfer and start-up activities). These efforts predominantly target disciplines like science, mathematics, engineering, and informatics, since the research output within these fields is usually associated with patentable and marketable inventions (cf. Czarnitzki et al. 2013).

To foster a cultural shift, , Germany has modified the law regarding the ownership of inventions made with federal funding similar to the Bayh-Dole Act in the US. The goal was to facilitate the process for the researchers as well as to find an additional source of revenue for the institutions of higher education (cf. von Ledebur 2006). The statute originally provided university professors with unrestricted rights to use and commercialize inventions. With the mentioned amendment, the property rights of university research results swapped from the individuals to the institutions. From there on, the legally protected (e.g. as patents) and commercially exploited research outputs belong to the institution and the inventor receives 30 % of the gross commercialization revenues. In exchange, the institution bears all costs for patenting and acquires potential partners from the industry to facilitate the commercial exploitation of the patentable research output (Cuntz et al. 2012).

However, despite a comprehensive infrastructure and the statutory reform for facilitating commercial exploitation of research, it seems that even inventions of great commercial potential still remain unexploited in universities (Cuntz et al. 2012). For example, the amount of patents claimed by institutions of higher education dropped by 25% since the mentioned statutory amendment. Aside from the fact that the patenting potentials of available research may be exhausted and the financial incentives are decreased for the researchers (cf. Schmoch 2007), high-ranked publications become more and more important and are often prioritized over knowledge transfer activities (cf. Cuntz et al. 2012). Furthermore, only every second academic with a start-up idea and entrepreneurial propensity is willing to advance her/his idea (cf. Bijedić et al. 2014) and one out of three nascent entrepreneurs who already started with their entrepreneurial activities do not follow up a year later (cf. Werner 2011).

Based on these findings that innovations and their potential commercialization at German institutions of higher education is not being exploited despite the above mentioned reforms, the paper at hand tries to identify the gaps and barriers leading to these untapped potentials. By doing so, we base our analysis on previous research literature. Previous research shows that innovation transfer activities - which - according to our definition - includes the three stages: (a) generating inventions, (b) stating intellectual property rights of these inventions and (c) commercially exploiting them - is determined by specific internal and external context variables (cf. Polkowska 2013). Especially gender is often discussed to be an important determinant within innovation research (cf. Brink et al. 2014; vgl. Burkhardt, Greif 2001; Tonoyan, Strohmeyer 2006, Nählinder et al. 2012). Gender differences are not only prevalent regarding the innovation activity, but also regarding decisions preceding and determining the innovation activity, e.g. career choices and preferences for specific fields of study. Women, for example, are underrepresented in disciplines associated with higher innovation activity, like science, informatics, or engineering (cf. Becker et al. 2011), as well as among research staff at universities in general. Even if they are active in research, women seem to rarely take part in patenting research results as well as in participating in university start-ups (cf. Bunker-Whittington, Smith-Doerr 2008).

The majority of studies which analyzed effects on innovation activity used singular determinants (e.g. gender, field of study), or applied a small and/or limited sample (e.g. within a certain field of study). In order to close this research gap, our study incorporates individual, career-related as well as institutional determinants of innovation activity in a holistic manner and among a wide range of academic fields.

2 LITERATURE REVIEW AND RESEARCH QUESTIONS

In the following, we theoretically and empirically derive a hierarchy of steps towards innovation activity. The first and crucial step illustrates "whether to innovate at all" which is considered a step of opportunity recognition (OR) in order generate an invention. This first step differentiates innovators from non-innovators. The subsequent two steps demonstrate the process of opportunity exploitation (OE), i.e. the commercially-oriented interest to protect and further exploit the generated invention.

In our research model, opportunity recognition (OR) and opportunity exploitation (OE) are considered as two separate processes which are affected by different factors. OR is considered as a cognitive process and thereby strongly determined by human capital or career-related factors (e.g. knowledge, occupational history) and job-related preferences. OE in contrast can be seen as a market-oriented behavior (cf. Davidsson 2006). It is therefore predominantly affected by institutional factors (e.g. environmental conditions) and individual factors like gender or risk taking propensity (cf. Bijedić 2014).

2.1 Individual Factors

In general, a lower amount of *women* remains in the academic sector and pursues an academic career (cf. Svinth 2006). This becomes obvious in the distribution of leading positions at universities: an increase in the hierarchy level goes hand in hand with a decrease in the amount of women (cf. Berryman 1983). Furthermore, the majority of studies reveal that women are still under-represented when it comes to generating an invention (cf. Bunker-Whittington/Smith-Doerr 2008). Gender differences are also existent regarding the exploitation of inventions. The so-called pipeline leak shows that fewer women register patents than men (cf. Bunker-Whittington/Smith-Doerr 2008). This is due to several reasons (cf. Burè 2007).

First, to generate inventions the *human capital* of the academic is crucial. Usually, female academics have more interruptions in their work-life history than their male counterparts, which leads to a reduced human capital stock. The number of inventions produced and registered by universities reflects this (cf. Thursby/Thursby 2005). Another individual factor that also influences human capital endowments and thus effects innovation activities is the *age* of the potential inventor. With increasing age, the individuals gain more work experience and thus a broader and more defined human and social capital basis (cf. Murray 2004).

Another possible driver of innovation activity is the *nationality* of the potential innovator. From entrepreneurship research we know that foreign researchers show higher founding intentions compared to German researchers (cf. Bijedić et al. 2014). A similar tendency can be expected for innovation activity. Bijedić et al. (2014) for example can show that founding intentions of researchers are only stated if own inventions were generated before. From innovation research in existing firms, we learn that companies with an above-average number of migrants generate a higher innovation output (cf. Welter et al. 2015). This leads to our assumption that the nationality of academics affects their innovation activity.

Finally, innovation activity is considered a *risky* behavior which can lead to failure. The patenting usually occurs at an early stage of the product development where the innovator cannot foresee the successful exploitation and final market entry of her/his invention (cf. Jensen/Thursby 2001; Jones/Bouncken 2008). Therefore the level of risk taking propensity is expected to have an effect on the opportunity recognition and exploitation processes.

For our research model, we include the above mentioned individual factors (gender, age, nationality, and risk taking propensity) and test their effects on the different steps of innovation activity. Therefore, we derive the following explorative research question:

> *Question 1: How do the individual factors affect the different steps of innovation activity, from opportunity recognition to opportunity exploitation?. We expect stronger effects for opportunity exploitation than for opportunity recognition.*

Please see figure 1, where we present our research model.

"Insert Figure 1 Here"

2.2 Career-related Factors

We refer to the field of study, research activity as part of the working contract, and scope of employment (i.e. contractual and factual working hours) as career-related factors which are expected to have an effect on innovation activity. In addition, we test for several career-related effects: job title (e.g. professor), leadership position, research focus (i.e. basic, applied, or multidisciplinary research), occupational history, and a potential sideline business.

Previous research shows, that the innovation activity strongly depends on the particular field of study which partially determines if the research results are patentable and thus can be commercially protected and exploited. Within the STEM-fields (science, technology, engineering and mathematics), patents are looked upon as a valid measure for innovation activity, while the research output in other fields like the humanities often does not meet the requirements of patenting (cf. Pohlmann 2010). According to the requirement of "absolute novelty" for patents in Germany the publication of research in academic journals (which is another possible exploitation of research output) eliminates the opportunity of additional patenting of these results (cf. BMBF 2002).

Thus, technology-oriented fields like STEM provide a more suitable environment for the commercial protection and exploitation of research output than other fields of study. This leads to our assumption that the different fields of study have an effect on the innovation activity. Regarding the distribution of gender within the different fields of study, it stands out that women outweigh men in humanities, arts and cultural sciences, as well as in life sciences. However, men still dominate the STEM-fields (cf. GWK 2010, 2014).

In the recent past, academics face an area of conflict as they have to juggle teaching activities, research activities, and the exploitation of their research results (cf. Glauber et al. 2015). The scope of employment which comes along with a certain amount of time spend at work not only influences the opportunity recognition of the academics but also their opportunities of exploiting research results. Thus, with limited working time the necessity to teach and publish research can hinder or at least postpone the innovation activities (Chang/Yang 2008; Heller/Eisenberg 1998).

In a similar vein, we expect that it makes a difference whether research activities are part of the working contract of the academics or not. For creative output not only a certain amount of working time is needed but also the "permission" to use this working time for research and innovation. Summing up, we expect career-related factors to have an effect on innovation activity and therefore derive the second question.

> *Question 2: How do career-related decisions which directly influence the human capital of the academic affect the different steps of innovation activity, from opportunity recognition to opportunity exploitation? We expect stronger effects for opportunity recognition than for opportunity exploitation.*

2.3 Institutional Factors

Besides teaching and research, technology transfer is another core area of academic institutions. Meanwhile the technology transfer is included in the state law as part of the activities of universities and colleges (cf. Bijedić et al. 2014). However, this still resembles a challenge for academic institutions as they have to create an infrastructure which not only facilitates excellent research and teaching but also the exploitation of research results (cf. Chang/Yang 2008; Heller/Eisenberg 1998). When comparing the different academic institutions, we find that at universities research activities are part of the job profile while at institutions of applied sciences this is not the case. To actively invest in the infrastructure of technology transfer, many academic institutions installed so-called centers for technology transfer and patent exploitation agencies to assist in the innovation exploitation process (cf. Schmoch 2007). These agencies and support centers help the academics in the process of protecting and commercially exploiting their inventions (cf. Siegel et al. 2004; Siegel et al. 2007). Especially when it comes to patenting, these agencies not only test whether the inventions fulfill the requirements for patenting but also whether or not they have the potential of economic exploitation (cf. Schmoch 2007).

The above-mentioned support structures positively affect the knowledge and technology transfer in academic institutions and stimulate academics to commercially exploit their research results (cf. Chang et al. 2009). With the university's growing experience in the patenting process an increase in the registration of patents can be found. This is due to the growing ability to recognize promising inventions and research ideas (cf. Foltz et al. 2003; Glauber 2015; Huelsbeck/Menno 2007; von Ledebur et al. 2009). Therefore, we derive the third question.

> *Question 3: How does the institutional infrastructure that facilitates knowledge and technology transfer affect the different steps of innovation activity, from opportunity recogni-*

tion to opportunity exploitation? We expect stronger effects for opportunity exploitation than for opportunity recognition.

3 METHODS

3.1 Sample and Data

As a data base, we use a survey that was conducted among 36,918 academics in November and December 2013in 73 randomly selected German institutions of higher education from a variety of disciplines. We included all hierarchical levels of academic staff. Our final sample base for consists of 7,317 completed questionnaires.

3.2 Variables and data analysis

Our dependent variable is innovation activity, which we operationalized as a three-stage dichotomous variable including: having generated an invention (first stage), having claimed patenting or other protection of intellectual property (second stage) and finally having commercially exploited the invention(s) (third stage). In the following, we refer to all three activity stages as innovation activity.

Overall, we found that 18.5% of the sample did in fact generate at least one invention. 12.5% secured property rights of their invention and 4.5% commercially exploit them. I.e. 14% of our sample generated an invention but did not protect or exploited it commercially. In order to analyze the various influences on innovation activity, we included three categories of determinants which - based on previous empirical findings stated above - are expected to have an impact on innovation activity of academics. Within the category of ***individual factors***, we include the variables gender, age, nationality, and risk taking propensity. The variables job title (e.g. professor), leadership positon, research activity as part of the working contract and research focus (basic, applied or, multidisciplinary), as well as occupational history, current sideline business and scope of employment (i.e. working hours) constitute the category ***career-related factors*** which have a critical impact on human capital. This category also contains the variable field of study, which we subsumed into seven sub-categories: STEM (Science, Technology, Engineering and Mathematics), life sciences (e.g. medicine, psychology, and health management), economics (e.g. business studies and similar disciplines), architecture and creative studies (e.g. music, arts, design and, communication), and humanities (including social sciences and law). Finally, the category ***institutional factors*** consists of the type of academic institution (university vs. school of applied science), and the infrastructure supporting the knowledge transfer within each institution (technology transfer bureau and patenting agency). Table 1 summarizes our dependent and independent variables.

"Insert Table 1 Here"

We analyze the data using probit regression analyses. Since we regress three stages of innovation activity (invention, commercial protection, and commercial exploitation) on the introduced innovation drivers, we separately estimate three specifications of the empirical model. An overview of all included variables with their pairwise correlations can be found in Table 2.

"Insert Table 2 Here"

We find that the correlation between the explanatory variables is only of moderate size. Thus, multicollinearity should not be an issue in this study. To report the results, we use the difference of probabilities of the academics' likelihood of realizing one of the three stages of innovation activity and the academics who did not realize the particular stage of innovation activity (average marginal effects).

4 RESULTS

Our analyses show that gender strongly influences the first step of innovation activity, i.e. women are significantly less likely to generate inventions than men (dF/dx=-.062). However, we find no significant gender effects regarding commercial property rights (dF/dx=-.014) and commercial exploitation of the invention (dF/dx=-.002). In sum, these results partly support our assumption 1. The results of the probit regressions are reported in Table 3.

"Insert Table 3 Here"

In addition, age has a significant positive effect on the generation of inventions (dF/dx=.003) and their protection (dF/dx=-.007). On average, the probability to generate an invention raises for .3 percentage points and for .07 percentage points to commercially protect the invention, for every year of life. This is an expected outcome considering the growing professional experience and skills conducive to innovation activity.

We also find that non-German academics generate significantly more inventions than German scientists (dF/dx=.072), but do not protect or exploit their inventions significantly more than German researchers. This result is partially in line with previous research, which provided evidence that foreign scientists also have higher propensity of founding a new venture, and by doing so, exploiting knowledge from the university environment (see e.g. Bijedić et al. 2014) due to the fact, that academic start-ups are predominantly based on a previously generated invention. However, our findings do not provide evidence for higher exploiting activities of inventions.

Within our sample, a high risk taking propensity leads to a significantly higher likelihood to generate inventions (dF/dx=.036): On average, the probability to generate an invention raises for 3.6 percentage points when the academic has a high risk taking propensity. However, it has no significant impact on the commercial protection and exploitation activities, which we found surprising, given the previous findings that opportunity exploitation depends highly on environmental factors and is therefore more affected by the perception, assessment, and tolerance of potentially risky circumstances.

We also find significant positive effects of several career related factors on the innovation activity. Academics engaged in STEM-fields are most likely to generate inventions (dF/dx=.117), followed by life sciences (dF/dx=-.023): On average, the probability for scientists in STEM-fields to generate an invention is 11.7 percentage points higher than for academics in other fields of studies.. However, STEM-academics are not more likely to commercially protect or exploit these inventions. Furthermore, contractually stipulated research activities have a significant fostering effect on invention activities (dF/dx=.046), as well as the research focus: An applied (dF/dx=.069) or multidisciplinary research focus (dF/dx=.019) leads to significantly more inventions and their commercial exploitation than basic research (cf. Table 3).

Moreover, we find that a higher scope of work (dF/dx=.001), a postdoctoral (dF/dx=.045) as well as a leadership position (dF/dx=.084) have a positive effect on generating, but not on commercially protecting or exploiting inventions: On average, full time employed academics are 0.1 percentage points more likely to generate inventions than their part time employed colleagues. Furthermore, academics in leadership positions are also about 8.4 percentage points more likely to invent than academics with no leadership responsibilities. Finally, a wider scope of occupational experience, i.e. a previous job experience (dF/dx=.016) as well as a current sideline business outside the university (dF/dx=.030), has a significant positive impact on the innovation activity in general. In sum, these results partly support our assumption 2.

Finally, we found significant influences of all analyzed institutional factors on the likelihood to generate an invention. Academics working at universities are more likely to generate inventions than those working at institutions of applied sciences (dF/dx=.024). Additionally, academics who use the services of patenting agencies (dF/dx=.053) and technology transfer bureaus (dF/dx=.361) are more likely to engage in invention activities as well as opportunity exploitation activities. In sum, these results partly support our assumption 3.

5 DISCUSSION

In the presented study we analyzed potential drivers and barriers of innovation activity of academics. With our unique and representative sample containing data from over 7,300 academics in 73 German institutions of higher education, this study simultaneously tests the effects of individual, career-related, and institutional conditions on the innovation activity of female and male academics.

Based on our results, we draw the following profile of an innovator: A typical innovator is predominantly male, active within STEM-disciplines, in a post-doctorate position, foreigner, in a leadership position and full-time employed, with a high risk taking propensity. Furthermore, he possesses work experience outside of the university (e.g. a current sideline business or previous job experience) and focuses on multidisciplinary and applied research rather than basic research.

Our study reveals that women generate significantly less inventions than men, in general as well as within each field of study. The results indicate that these differences between female and male academics cannot only be explained by gender-specific preferences for certain disciplines, for example an underrepresentation of women in highly innovative STEM-fields but are caused by additional innovation drivers.

When inventions already exist, no gender differences regarding commercial protection or commercial exploitation of the inventions can be found. This contrasts previous research, where women are claimed to have less propensity to engage in commercialization activities (like e.g. start-ups) than men (cf. Bijedić et al. 2014). A similarly surprising finding relates to the effect of risk taking propensity on innovation activities. Previous research indicated that the commercial protection and exploitation of inventions as a market-related process depends more on environmental factors and personal characteristics compared to the generation of inventions. However, our results indicate that a high risk taking propensity fosters the first step of invention activity and has no significant impact on opportunity exploitation.

Based on the literature review, we find positive effects of several career-related factors on the innovation activity. An applied or multidisciplinary research focus as well as a leadership position has a significant fostering effect on creating invention(s). Moreover, a wide range of career experiences, in form of previous employments or a current sideline business outside the university, have an impact on innovation activities in general – regarding opportunity recognition as well as opportunity exploitation. These results emphasize the importance of outeruniversity professional experience on inner-university innovation activity – especially concerning the commercial exploitation activities. This leads to more market-related experience as well as a wider social network crucial to exploitation activities (Jensen/Thursby 2001).

When comparing the different academic positions, researchers in post-doc positions are most likely to generate inventions. However, this advantage disappears for the commercial protection and exploitation of inventions. Since requirements for tenured positions at universities focus mainly on highly ranked publications, which are considered the main criteria for research excellence, post-doctorate researchers, mostly short-term appointed, feel the pressure to engage in publishing rather than in knowledge transfer into the market. Once the research results are published, they are not patentable anymore, i.e. in our current system academic publishing prevents patenting and commercialization.

Using the services of technology transfer bureaus or patenting agencies goes along with a high innovation activity, which makes sense, given that in order to use these services, the researchers need to have generated patentable or market-relevant invention(s). Last but not least, our results indicate, that academics at institutions of applied sciences, where they have a higher teaching load as integral part of their employment contracts, are less likely to engage in innovation activity.

Based on our survey, we recommend encouraging female academics early on in their career to engage in research activities across the disciplines as well as making research activities a contractually stipulated part of their job profile regardless of the kind of institution. Furthermore, we recommend partially revising and broadening the requirements of tenure positions within the universities, e.g. by acknowledging achievements in knowledge transfer and market-relevant experience in addition to the number of publications.

Junior as well as foreign researchers need to increase their awareness of the opportunities for patenting and knowledge transfer. Patenting agencies as well as technology transfer bureaus provide support for the commercial protection and exploitation of technology-based innovations. In order to recognize and exploit more opportunities for knowledge transfer, these agencies might offer services for a wider range of innovations. Therefore, the knowledge transfer practice in German institutions of higher education might profit from a broader and more current definition of innovation, as already perpetuated in the contemporary academic discussion.

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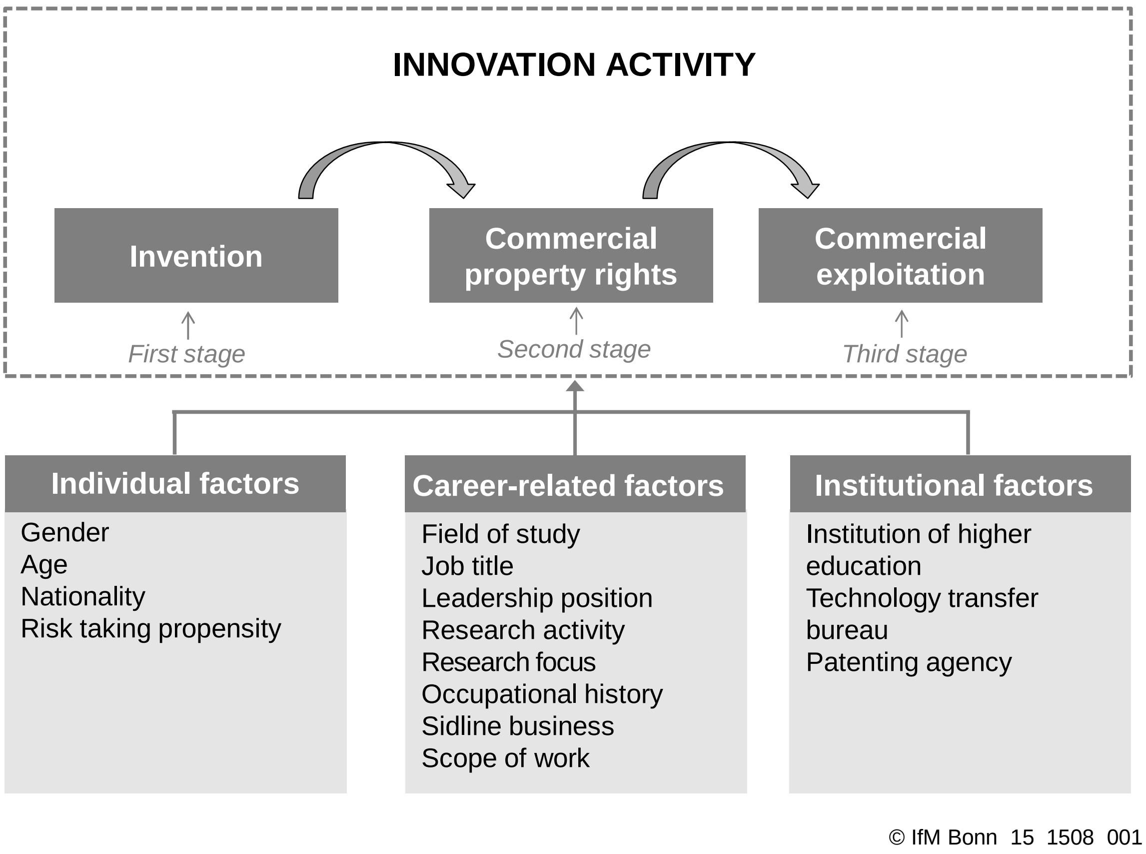
APPENDIX

Figure 1: Model of analysis: Stages of innovation activity and categories of their determinants



Source: Based on Bijedić et al. (2016).

Table 1: Operationalization of variables and descriptive statistics

	Dependent variables	Mean	(SD)*
Invention	Scientists have realized at least one invention during their tenure at the university: Yes = 1, No = 0	.19	(.39)
Commercial property rights of invention	Scientists who have realized at least one invention during their tenure at the university have also commercially protected at least one of these inventions: Yes = 1, No = 0	.13	(.33)
Commercial exploitation of invention	Scientists who have commercially protected at least one invention have also commercially exploited at least one of these inventions: Yes = 1, No = 0	.04	(.21)
	Independent variables	Mean	(SD)*
Gender	Gender: Female = 1, Male = 0	.32	(.47)
Age	Age of scientist (in years)	37.32	(.13)
Nationality	Nationality: Foreign = 1, German = 0	.10	(.30)
Risk taking propensity	Risk Attitude: (very) high = 1, not (very) high = 0	.19	(.39)
Field of study	Field of Study: Science, Technology, Engineering, Mathematics (STEM Fields) = 1, Other = 0	.71	(.45)
Position	Vocational Position: Professor = 1, Other = 0	.18	(.38)
Leadership position	In charge of supervising staff: Yes = 1, No = 0	.26	(.01)
Research activity	Research is a contractually stipulated part of the working contract: Yes = 1, No= 0	.76	(.43)
Basic research	Focus on basic research: Yes= 1, No = 0	.41	(.49)
Applied research	Focus on applied research: Yes= 1, No = 0	.56	(.01)
Multidisciplinary research	Focus on multidisciplinary research: Yes = 1, No = 0	.43	(.01)
Occupational history	Prior job experience in and outside of academia: Yes = 1, No = 0	.57	(.01)
Sideline business	Scientist has a second job assignment in addition to the current job at the institution of higher education: Yes = 1, No = 0	.29	(.01)
Scope of work	Weekly working hours	32.68	(.13)
Institution of higher education	Type of the institution of higher education: University = 1, Schools/Colleges of Applied Sciences = 0	.80	(.40)
Patenting agency	Used services of a patenting agency: Yes = 1, No = 0	.05	(.22)
Technology transfer bureau	Used services of a Technology transfer bureau: 1 = yes, No = 0	.06	(.24)

* SD = Standard deviation

Table 2: Pairwise correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 Gender	1.00																			
2 Age	-.1266***	1.00																		
3 Nationality		-.0937***	1.00																	
4 Risk taking propensity	-.0723***	.0688***	.0636***	1.00																
5 Field of studies	.1875***	.1274***	-.0434***	.0483***	1.00															
6 Position (Professor)	-.1429***	.5397***	-.0939***	.0737***	.0425***	1.00														
7 Leadership position	-.1459***	.3494***	-.0307***	.1029***	-.0095	.3962***	1.00													
8 Research activity	-.0203*	-.3203***	.0871***	.0054	-.1370***	-.1000***	-.0080	1.00												
9 Basic research	.0159	-.1553***	.0795***	-.0048	-.1092***	-.0923***	-.0132	.3497***	1.00											
10 Applied research	-.0843***	-.0901***	.0177	.0440***	-.0306***	.0522***	.0733***	.3013***	-.2214***	1.00										
11 Multidisciplinary research	-.0199***	-.0785***	.0561***	.0784***	.0346***	.0054	.0934***	.2871***	.0461***	.3509***	1.00									
12 Previous employment	-.014	.3699***	.0023	.0975***	.1821***	.2776***	.1508***	-.2078***	-.1921***	.0192	-.0053	1.00								
13 Sideline business	-.0508***	.2820***	-.0024	.1124***	.1981***	.2001***	.1342***	-.1912***	-.1949***	.0568***	.0002	.3083***	1.00							
14 Scope of employment	-.1344***	.0252**	.0356***	-.0213***	-.1319***	.1159***	.1654***	.1656***	.0325***	.1471***	.1115***	-.0650***	-.1834***	1.00						
15 Institution of higher education	.0395***	-.3974***	.1091***	-.0255**	-.1208***	-.4073***	-.0773***	.4146***	.3231***	.0263**	.1452***	-.3422***	-.2862***	.1199***	1.00					
16 Technology transfer bureau	-.1088***	.1828***	-.0411***	.0514***	-.0543***	.1971***	.2041***	.0150	-.0568***	.0881***	.0616***	.0632***	.1109***	.0807***	-.0749***	1.00				
17 Patenting office	-.1037***	.1111***	-.0185	.0283**	-.0729***	.1198***	.1905***	.0570***	.1635	.0922***	.0767***	.0264***	.0607***	.0751***	.0266***	.4897***	1.00			
18 Invention	-.1549***	.1109***	.0664***	.0720***	-.1227***	.0868***	.2057***	.1063***	.0222**	.1473***	.1054***	.0379***	.0532***	.1138***	.0410***	.2223***	.3244***	1.00		
19 Commercial property rights	-.0734***	.2232***	-.0190	0.004	-.0856***	.1618***	.2193***	.0042	-.0585***	.0621**	.0085	.0098	.1005***	.0424	-.0134	.1904***	.2068***	X	1.00	
20 Commercial exploitation	-.0577***	.0719***	-0.0112	.0828***	-.0095	.0915**	.1329***	.0340	-.0773***	.1331***	.1077***	.1570***	.1581***	-.0501	-.0802**	.1329***	.1587***	X	X	1.00

Significance level: *(.1); **(.05); ***(.01).

Table 3: Probit regression analyses

	Basic Model					
	Invention (Yes)		Commercial property rights (Yes)		Commercial exploitation (Yes)	
	dF/dx	z-Value	dF/dx	z-Value	dF/dx	z-Value
Individual factors						
Gender (female)	-.062***	-6.57	-.014	-.42	-.020	-.45
Age (max. 50)	.003***	5.93	.007***	4.69	-.001	-.83
Nationality (Foreigner)	.072***	5.03	.058	1.72	.027	.59
Risk taking propensity: ((very) high)	.036***	3.41	-.016	-.55	.053	1.47
Career-related factors						
Field of studies (STEM)	.117***	11.70	.118***	3.10	.047	.88
Position (Professor)	-.031**	-2.39	.021	.56	-.015	-.34
Leadership position (Yes)	.084***	7.81	.115***	4.06	. 069*	1.89
Research activity ((fully) applies)	.046***	3.72	.031	.78	.067	1.32
Basic research ((fully) applies)	.011	1.17	-.046*	-1.67	-.039	-1.10
Applied research ((fully) applies)	.069***	6.97	.038	1.28	.070*	1.82
Multidisciplinary research ((fully) applies)	.019**	2.10	-.008	-.31	.077**	2.31
Occupational history (Yes)	.016*	1.71	-.064**	-2.37	.112***	3.05
Sideline business (Yes)	.030***	2.92	.052*	1.86	.086**	2.43
Scope of work (full time)	.001***	2.76	-.001	-.52	-.004**	-2.06
Institutional factors						
Institution of higher education (University)	.024*	1.78	.053	1.34	-.057	-1.16
Technology transfer bureau (used services)	.053***	2.69	.078*	1.86	.044	.94
Patenting agency (used services)	.361***	13.47	.149***	4.05	.135***	3.09
Number of observations	7.317		1.355		912	
Log pseudolikelihood	-2.888.4		-768.7		-567.6	
Pseudo-R^2	.176		.102		.073	

Note: Average marginal effects and z-Values; Significance level: *(.1); **(.05); ***(.01).

Continuation of Table 3: Probit regression analyses

	Fields of studies (Reference category: STEM)								
	Invention (Yes)			Commercial property rights (Yes)			Commercial exploitation (Yes)		
	dF/dx		z-Value	dF/dx		z-Value	dF/dx		z-Value
Economics	-.136	***	-1.45	-.068		-1.22	-.040		-.50
Architecture	-.097	***	-3.94	-.307	***	-3.28	-.151		-1.02
Life sciences	-.023		-.75	.057		.68	.065		.59
Arts and media	-.117	***	-3.99	.037		-.32	.131		.87
Humanities	.119	***	-4.52	-.231	*	-1.93	-.293		-1.62
Other	-.105	***	-3.53	-.210	*	-1.94	-.226		-1.38
Number of observations	7317			1355			912		
Log pseudolikelihood	-2878.0			-762.6			-564.6		
Pseudo-R^2	.179			.120			.078		
	Position (Reference category: Professor)								
	Invention (Yes)			Commercial property rights (Yes)			Commercial exploitation (Yes)		
	dF/dx		z-Value	dF/dx		z-Value	dF/dx		z-Value
Post-doctoral position	.045	***	2.84	.059		1.41	.013		.25
Pre doctoral researcher. assistant researcher	.024	*	1.65	-.040		-.92	.019		.35
Other	.027		1.56	-.095	*	-1.76	.014		.21
Number of observations	7.317			1.355			912		
Log pseudolikelihood	-2.886.9			-762.8			-567.6		
Pseudo-R^2	.177			.109			.073		

Note: Average marginal effects and z-Values; Significance level: *(.1); **(.05); ***(.01).