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ARE ALL ACADEMIC ENTREPRENEURS CREATED ALIKE?

EVIDENCE FROM GERMANY

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ABSTRACT

Using data from a large survey of German researchers in public science and based on a formal structure, this paper examines determinants of academic entrepreneurship. The key contribution is to discern factors driving research-driven entrepreneurship versus overall academic entrepreneurship. The extant literature has almost exclusively focused on the latter and implicitly assumed academic entrepreneurs to commercialize their research. Results show that, despite some plausible similarities in the determinants, there are significant differences. In particular, while both entrepreneurship categories benefit from greater patent applications, more time spent on consulting by the researcher and from participation in European conferences, research leaders and engineering science disciplines are more likely to lead to research-driven entrepreneurs. However, the positive influences of university employment (compared to being employed at a public research organization) on overall academic entrepreneurship fail to show up in research-driven entrepreneurship. One implication is that universities may be unduly patting themselves on the back – they might yield more entrepreneurs, but not necessarily research-driven entrepreneurs.

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ARE ALL ACADEMIC ENTREPRENEURS CREATED ALIKE?

EVIDENCE FROM GERMANY

1. INTRODUCTION

There has been a heightened interest in recent years towards greater understanding of the productivity of scientists and researchers (Baser and Pema (2003), Coupè (2004), Crane (1965), Grimpe and Fier (2010), Jain et al. (2009), Sutter (2009)).[1] Many constituencies are interested in getting a better handle on research productivity. Research organizations and even researchers themselves are interested in quantifying productivity to garner additional resources and for performance evaluation. Further, policymakers seek productivity measures to allocate resources (Mowery et al. (2001)) and to justify resource allocation decisions.

The task of measuring research outcomes, however, is quite complicated (Office of Technology Assessment (1986)), given the unique nature of the research process (see Merton (1973); more recently Anselin et al. (1997), Audretsch et al. (2002), Bozeman (2000), Feldman et al. (2002), Goel and Rich (2005), Rothaermel et al. (2007), Stephan (1996)). For instance, the output of research is multifaceted (e.g., patents, publications, entrepreneurship, etc.), shrouded in secrecy (researchers are unwilling to prematurely disclose findings especially when a project spans multiple years and is likely to yield multiple outcomes), and often hard to quantify (Acs and Audretsch (1989), Griliches (1990), Tijssen (2006)). Pertinent question in this regard, with no easy answers, include: Are all patents/publications qualitatively the same? How can publishing and patenting productivity be compared to each other? What about (productivity of) unpublished research? What about unpatentable research? Given these obstacles, progress towards identifying the key forces driving particular research outcomes has been rather slow (Djokovic and Souitaris (2008), Rothaermel et al. (2007)). The present research is therefore intended to elucidate our understanding of these issues and to provide some answers to the questions raised.

We use findings from a large micro-level survey of German researchers in public science to study the causes of research-driven entrepreneurship. Academic entrepreneurship has been an active field of inquiry in the past few years (see, for example, Backes-Gellner and Schlinghoff (2004), Baser and Pema (2003), Fini et al. (2010), Krabel and Mueller (2009), Lacetera (2009)). However, we provide unique insights from a detailed investigation of German researchers that incorporates many social, economic and professional attributes. The key focus of this research is on teasing out the differential forces driving academic entrepreneurship in general, versus those driving entrepreneurship that is driven by scientific research.

Whereas the two types of entrepreneurship are obviously related (the latter is a subset of the former), they are not necessarily alike. For instance, two scientists A and B both become independent entrepreneurs. A's business is an offshoot of research (patented or otherwise)

[1] See Merton (1973) for an earlier significant work in this area.

that she conducted in her laboratory, whereas B becomes an entrepreneur but not based on her research (maybe due to chance, family connections, non-academic opportunity, due to someone else's research, etc.). So while both A and B would figure under general academic entrepreneurs, only A would be referred to as a research-driven entrepreneur (see Figure 1). Our unique micro-level data for German researchers enable us to tweak out the comparison between overall and specific entrepreneurship types.[2] Any distinctions in the determinants of the two entrepreneurship categories would particularly be useful in gauging the real returns to academic efforts.

Some key questions addressed in this research are the following:

- Do similar factors drive general academic entrepreneurship and research-driven entrepreneurship?
- What are important influences driving research-based entrepreneurship in Germany?
- How do various types of research behaviour (e.g., publications, patents, networking, etc.) facilitate entrepreneurship?
- Which academic disciplines are more likely to yield entrepreneurs?
- Are there significant gender differences in the emergence of entrepreneurs?

The specific contribution of the present work is that, while many studies refer to academic entrepreneurship broadly to mean any entrepreneurial activity by researchers, we are able to specially study the factors behind entrepreneurship driven by the researchers' research (and not necessarily any entrepreneurship by the researcher). Besides contributing to the literature, this focus has important implications for resource allocation – i.e., better accounting of research input-output, for figuring out returns on research investment and related research policies (Djokovic and Souitaris (2008), Jaffe (1989), Keilbach (2009)), and for economic growth more generally (Audretsch and Fritsch (2003), Feller (1990)). Further, in the context of the threefold classification scheme for university-level entrepreneurship proposed by Yusof and Jain (2010), the present research can be seen as focusing on academic entrepreneurship.

Our findings from a survey of more than 1,000 German researchers point to some interesting results. In particular, while both entrepreneurship categories benefit from a greater number of patent applications, more time spent on consulting by the researcher, and from participation in European conferences, it is particularly the research group leaders and engineering scientists who are more likely to become research-driven entrepreneurs. On the other hand, the positive influences of university employment (compared to employment at a public research organization) on overall academic entrepreneurship fail to show up in research-driven entrepreneurship. Academic publications appear to be relatively more prominent in fostering overall entrepreneurship, while the reverse is true for research

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[2] Perhaps the closest study to the present work is Fini et al. (2010) for United States. However, besides the obvious focus on a different country, we are also able to examine the entrepreneurship distinction within the context of a structured model that incorporates a number of specific factors. Also see Krabel and Mueller (2009).

leadership. Policy implications of these results are discussed. For instance, relevant research policies do not need to be gender specific to be effective. On the other hand, encouragement in attaining research leadership positions and loosening patenting bottlenecks are likely to yield more academic entrepreneurs.

2. KNOWLEDGE GENERATION AND EXCHANGE AS DRIVERS OF ACADEMIC ENTREPRENEURSHIP

Given the multi-faceted nature of the inputs and outputs in research markets, it is hard to come up with a single model that addresses the various aspects and their numerous inter-linkages. Yet, to provide some structure to our empirical estimation below, we borrow from the theoretical framework proposed by Goel and Rich (2005) to analyze the workings of research markets. The main premise of the Goel and Rich framework is that the well-known structure-conduct-performance paradigm from industrial organization that explains the behaviour of firms can be used to understand the workings of research markets as well. In other words, the structure of research markets affects the conduct of researchers, which in turn affects their performance. Exogenous influences from government research policy can influence both the structure and conduct.

In the present study, we are interested in examining the determinants of one performance attribute, namely academic research-driven entrepreneurship. This performance is driven by a number of factors that can be attributed to different stages including (1) basic conditions; (2) structure of research markets; and (3) conduct of researchers.[3] One could then envision specific influences under each of these categories and the key ones are listed below.

(1) Basic conditions

The basic conditions may be viewed as being exogenous for researchers. Two factors that fall into this category are gender (Corley and Gaughan (2007), Rosa and Dawson (2006), Stephan and El-Ganainy (2007), Thursby and Thursby (2005)) and age/experience of the researcher. These conditions are likely to dictate propensities towards entrepreneurship.

(2) Research market structure

The structure of research markets sets the "rules of the research game" which dictate behaviour of researchers, including entrepreneurship by scientists. Specific factors considered here include university employment of the researcher, tenure, field of specialization (not all fields are equally amenable to entrepreneurial activity); see Table 6. All these affect the incentive structures that are crucial in driving entrepreneurship.

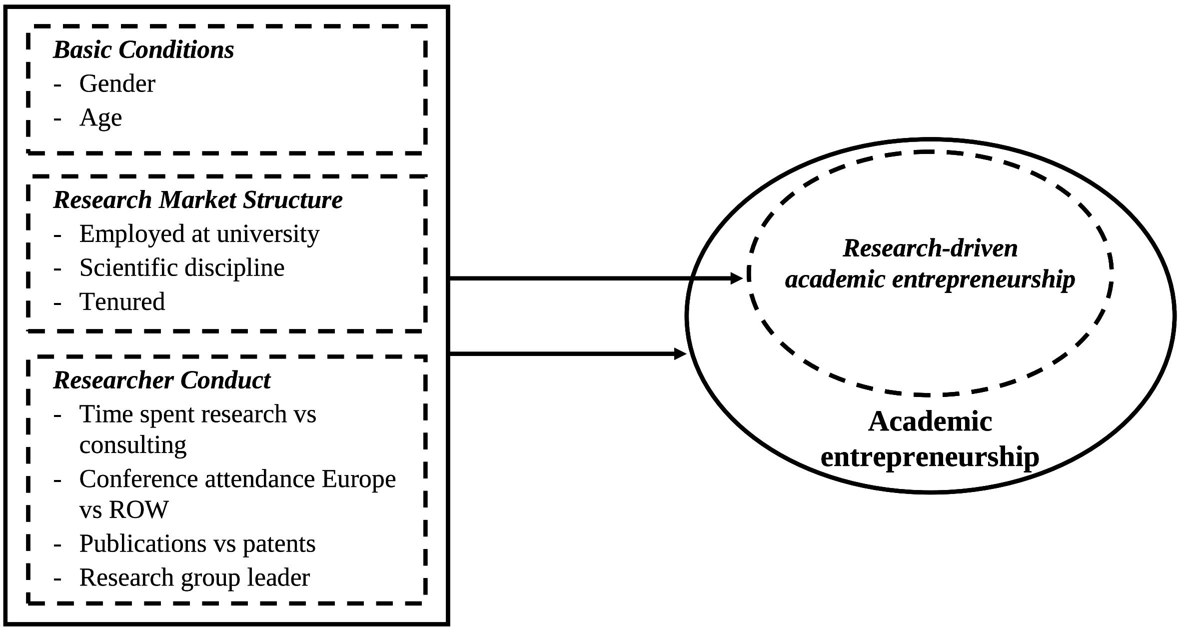
[3] While there could be some collinearity between the variables in the categories considered, such issues do not appear to be significant given the correlations in Table 5. Further, we perform various robustness checks below to test the validity of our results.

(3) Researcher conduct

The research environment and personal attributes of researchers feed into how researchers conduct themselves. Important influences affecting researcher conduct are time allocation to research versus other activities; networking through conferences or otherwise (Faria (2002), Faria and Goel (2010)); research leadership (leadership enables a broader familiarity with institutional details that might help entrepreneurship, and leadership might also aid risk taking attitude); time allocation in consulting versus research; publications; patents (Meyer (2006), Mowery et al. (2001)). These behaviours are crucial towards determining whether researchers choose to become entrepreneurs and if they do, whether such entrepreneurship is driven by their research.[4]

Figure 1 shows these different channels of influence on academic entrepreneurship. The key aspect that the figure emphasizes is that research-driven entrepreneurship is a subset of overall academic entrepreneurship. All these categories influence the probability whether a researcher will turn out to be an entrepreneur and dictate the choice of the variables used in our empirical estimation below.[5]

Figure 1: Determinants of academic entrepreneurship



[4] This study is based on a one time sample. Access to comparable data would enable one to test for reverse feedbacks from entrepreneurship to research structure.
Further, an alternate theoretical foundation to the structure-conduct-performance paradigm could be to consider a two-stage scenario where the entrepreneurship is determined in the first stage and its type (academic versus non-academic) is determined in the second stage.

[5] While the distinction between overall and research-driven entrepreneurship makes intuitive sense and is policy relevant, it is quite difficult to tease out empirically. We are fortunate to have access to survey data that enables us to address some related issues. However, the underlying survey is more general and was not conducted for the sole purpose of gathering data for this study. Consequently, some interesting related issues cannot be addressed due to a lack of corresponding micro-level information. For example, information on congruent geographic attributes of the researchers and new enterprises could enable one to consider issues of spatial diffusion of knowledge (see Anselin et al. (1997), Audretsch and Feldman (1996), Audretsch and Keilbach (2007), Audretsch and Lehmann (2005), Autant-Bernard et al. (2007), Capello (2002)).

3. RESEARCH DESIGN

3.1 Data

We use data that stem from a survey among German scientists on behalf of the German Federal Ministry of Education and Research. The survey was designed within the frame of a large-scale evaluation project of academics' activities with respect to acquiring research funds and industry-science interactions (Grimpe and Fier (2010)). Data were collected in 2008 using an online questionnaire. While contacting the respondents via e-mail involves the risk of outdated or misspelled e-mail addresses, online surveys have gained importance over the last years as a quick and efficient instrument to reach a large number of informants at reasonable cost.

The sampling procedure relied on two major data sources. The first is a database called "Hochschullehrerverzeichnis" which lists German university professors and academic personnel with a PhD with their names, degrees and contact information.[6] As a substantial share of public R&D in Germany is performed in public research organizations, the second data source had to cover scientists at the four large German PROs: Max Planck Society, Fraunhofer Society, Leibniz Association and Helmholtz Association. Scientists holding a PhD were identified via an internet search of the institutes' websites. These two data sources yielded a population of 20,519 scientists with an available and not obviously wrong e-mail address. For 4,250 scientists, delivery of the message failed. We obtained 2,797 responses, a response rate on the net sample of 17.2 percent which can be regarded as satisfactory for such a large-scale online survey. Due to missing values for some variables the actual number of observations available for analysis is, however, lower.

In order to address potential concerns whether our sample constitutes a fair representation of the population, we gathered data from the Federal Statistical Office and the German Federal Ministry for Education and Research on the distribution of scientists across scientific disciplines, aggregated into four groups of scientific fields: natural sciences (e.g., chemistry, physics, mathematics), life sciences (e.g., medicine, biology, plant sciences), engineering sciences (e.g., process, chemical, or construction engineering), and social sciences and humanities. This grouping is in line with the one used by the German Science Foundation. Table 6 in the Appendix shows the comparison between the distribution of scientists in Germany and our realized sample. A distinction is drawn between scientists working at a university and those working at a PRO. Research at these PROs is largely focused towards the natural sciences while research in social science and humanities is predominantly carried out in universities. Aggregating both groups, it turns out that scientists working in life sciences and engineering sciences are slightly over-represented in our sample while scientists in natural sciences and social sciences and humanities are under-represented. As these differences are however small, we are confident that our sample does not suffer from a response bias that would question our results. Further, while thirty percent of German public

6 This excludes the so-called "universities of applied sciences" whose major task is teaching and not research.

scientists are female, the corresponding figure in our sample is 15.5 percent. One reason for this discrepancy is the over-representation of engineering sciences in our sample.[7]

3.2 Variables and measures

3.2.1 Dependent variables

Based on the structure proposed in Section 3.1, we alternately consider two dependent variables: whether the academic entrepreneur emerged as a result of own research or if it was general entrepreneurship – due to own research or otherwise (Figure 1). Scientists were asked in the survey whether they had ever participated in founding an enterprise. If yes, they were asked whether this foundation was based on research results. As we do not ask for whether the scientist has successfully founded a start-up but just focus on being involved in the process, our definition also takes nascent entrepreneurs into account, i.e. those who are involved in start-up activities – e.g. applying for public or private funding, seeking venture capital, writing a business plan, or forming the founding team – at the time of the survey (Reynolds et al. (2004)). If the answer to both questions was yes, we classify the scientist as a research-driven academic entrepreneur. If the answer just to the first question was yes, we classify the scientist as a general entrepreneur. Therefore, the dependent variables are dichotomous, indicating whether the scientist is involved in (research-driven) start-up activities (coded as 1) or not (coded as 0).

3.2.2 Explanatory variables

Our main explanatory variables focus on knowledge generation and exchange activities of academics. In this respect, we first account for the time that scientists spend on research, on consulting for industry, and on teaching, administrative and other duties. Scientists were therefore asked to specify the share of their time they typically spend on the respective activities. We include the share of time for research and for consulting and leave the remaining share out of the regressions as a reference category. Second, knowledge exchange is measured by the average number of academic conferences and workshops that the scientists typically attend per year. We draw a distinction between more local and more distant knowledge exchange by accounting for conferences within Europe and conferences outside of Europe.

Moreover, we include the scientist's research productivity which is represented by the number of publications in refereed academic journals and the number of patent applications they were involved in.[8] The time frame the scientists were supposed to refer to was from 2002

[7] Ideally, a non-response analysis would require a control sample of non respondents for whom information on gender, age, discipline and institution is needed. While the gender, discipline and institution could be gathered manually from the available sources, there is no information on the scientist's age (Wooldridge (2007)). This makes it almost impossible to alternately fill entries for non-responses.

[8] The questionnaire did not specify a certain patent office but instead referred to the concept of a patent family representing a single invention that could have however led to patent applications at several patent offices. Although there may be differences in the technological and economic importance of patent applications, for example between the European Patent Office and national patent offices, this research is primarily interested in whether scientists consider the commercialization of their research results and not in potential differences between the institutional loci of patent application.

to 2006. We can, however, assume that research output assigned to the years 2002 through 2006 is in fact a result of research productivity in prior years due to the time lags in academic publishing and patenting.

Our analysis further includes a number of explanatory variables to control for the individual characteristics of the scientist. Dummy variables are used for the scientist's gender, whether the scientist is tenured and leader of a research group. Moreover, the scientist's age, the institutional affiliation (dummy variables for university affiliation versus being employed at a PRO) as well as the scientific field (dummy variables for life sciences; natural sciences; engineering sciences; with social sciences and humanities being the reference category) are included. The control variables we use for this research have frequently been employed in studies explaining the behaviour of academics (e.g., Bozeman and Corley (2004), Bozeman and Gaughan (2007), Gaughan and Bozeman (2002)). The underlying rationale is that more productive scientists are more likely to be senior, tenured, leading a research group and, therefore, are more likely to start a new firm. Similarly, patterns of entrepreneurial activity may vary according to the scientist's gender (e.g., Corley and Gaughan (2005)). In addition, the effects of scientific disciplines are widely acknowledged as important in a range of faculty activities (e.g., Edler et al. (2008)). These explanatory variables can be seen as fitting in the categories outlined in Figure 1 and discussed in Section 3.1 above.

3.3 Estimation model

Building on the discussion in Sections 2 and 3 and Figure 1, the formal estimation model to explain determinants of each kind of entrepreneurship takes the following general form

$$\text{Academic entrepreneurship}_i = f(\text{Basic conditions}_j, \text{Structure of research markets}_k, \text{Researcher conduct}_m) \quad (1)$$

i = General, Research-driven

j = Age, Gender

k = University employment, Tenured, Discipline

m = Publications, Patents, Conferences EU, Conferences ROW, Research group leadership, Time allocation – consulting vs. research

Results from the two versions of (1), showing respectively the determinants of research driven entrepreneurship and general academic entrepreneurship are given in Tables 2 and 3. Given the dichotomous nature of the dependent variables, we estimate Probit models. Thus the estimated coefficients represent corresponding probabilities and our main focus is on the sign (and statistical significance), rather than the magnitude pre se. As a check of the robustness of our findings, Table 4 in the Appendix considers nonlinearities in some of the determinants considered in Table 2 (also see Tables 4b and 7). The results section follows.

4. RESULTS

4.1 Descriptive statistics

Table 1 shows the descriptive statistics of the dependent as well as our main explanatory and control variables. The correlation table can be found in the Appendix. There is no indication of significant collinearity in our data as evidenced by the low values of the variance inflation factors (VIF) and condition numbers (Belsley et al. (1980)).

Table 1: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
General academic entrepreneurship (*d*)	1065	0.164	0.371	0	1
Research-driven entrepreneurship (*d*)	1065	0.113	0.316	0	1
Time spent on research (share)	974	53.326	23.287	0	100
Time spent on teaching and administrative (share)	974	41.477	22.962	0	100
Time spent on consulting (share)	974	5.196	9.643	0	100
Avg. no of conferences Europe	1001	5.174	3.823	0	25
Avg. no of conferences ROW	1000	1.810	1.616	0	8
No of publications	1065	20.752	26.721	0	178
No of patent applications	1065	0.766	2.143	0	24
Research group leader (*d*)	1065	0.700	0.458	0	1
Tenured (*d*)	1065	0.821	0.384	0	1
Gender (1=female)	1065	0.155	0.362	0	1
Age (years)	1065	49.026	8.407	28	74
Employed at university (*d*)	1065	0.551	0.498	0	1
Social sciences and humanities (*d*)	1065	0.199	0.399	0	1
Life sciences (*d*)	1065	0.292	0.455	0	1
Natural sciences (*d*)	1065	0.299	0.458	0	1
Engineering sciences (*d*)	1065	0.210	0.408	0	1

(d): dummy variable

The descriptive statistics show that 16 percent of the academics in the sample had been engaged in entrepreneurial activities while 11 percent indicated their involvement in entrepreneurial activities to be research-driven. This means that around 30 percent of all academic entrepreneurship is actually not based on research results and we deal with this aspect in Section 4.4.3 (and related Table 7) below. Formally examining the factors driving the two types of academic entrepreneurship is the main focus of this work.

Academics also reported to spend most of their time on research and teaching, with consulting to industry occupying on average only 5 percent of their time. The conferences academics attend are mostly within Europe. On average, scientists had published 21 publications and filed almost one patent application during the period from 2002 to 2006. 70 percent of the scientists lead a research group, 82 percent of them are tenured, and slightly more than half (55 percent) are employed at a university. Only 16 percent of the scientists are female. The average age is 49 years. With respect to the scientific disciplines, both life sciences and natural sciences account for almost 30 percent each, followed by engineering sciences (21 percent) and social sciences and humanities (20 percent).

4.2 Determinants of research-driven entrepreneurship

Table 2 reports estimation results for determinants of research-driven entrepreneurship (see equation (1) above). Four alternative models are considered to check for sensitivity of key variables to model specification. Given the structure outlined in Section 3.1 and equation (1), it seems useful to discuss the results accordingly.

- ***Basic conditions:*** Both gender and the age of the researcher fail to significantly affect the propensity to research driven-entrepreneurship. These variables have been considered in related studies, albeit with different data and different focus, and results are mixed (Fini et al. (2010), Glaeser and Kerr (2009), Krabel and Mueller (2009)).

- ***Structure of research markets:*** Of the three categories of variables placed here (University employment, Tenured, Discipline), University employment or tenure do not significantly affect research-driven entrepreneurship. This is a key insight from our unique dataset – universities might be unduly patting themselves of the back – in the subset of research-driven entrepreneurship by researchers, employment or having tenure at a university does not necessarily give one an edge in entrepreneurship.[9] Some universities might have realized this already and are redoubling their efforts to help scientists become entrepreneurs.

  Of the academic disciplines, scientists in engineering sciences are more likely to emerge as academic entrepreneurs.[10] This discipline is likely to yield products and processes that are relatively easily commercializable.

- ***Conduct of researchers:*** As expected, more patent applications boost chances of research-driven entrepreneurship. Besides signifying innovation discovery, patents might also make it easier for budding entrepreneurs to raise financing. The resulting coefficient is positive and statistically significant in all the models in Table 2. In contrast, the number of publications, while positive, is only mildly statistically significant in Model I. This finding is consistent with the notion that publications are relatively more focused on basic research compared to patents which are more applied and the applied research more likely promotes entrepreneurship.

  Networking and information exchanges by researchers have intrigued scholars (Coupé (2004), Laband and Tollison (2000), Faria (2002) and Faria and Goel (2010)), and we capture this effect by examining the effect of conference attendance. In this context we are also able to draw on the geographic knowledge spillovers literature (see Audretsch and Keilbach (2007), Jaffe (1989) and Jaffe et al. (1993)) by making a

[9] The insignificant effect of tenure can be seen as consistent with the fact that job security that comes with tenure is unlikely to induce a researcher to engage in a relatively uncertain undertaking by becoming an entrepreneur.

[10] Fini et al. (2010) on the other hand find that scientists in bio-science departments in the United States are more likely to be academic entrepreneurs. Besides using data for a different country, this study does not make the fine distinction between research-driven and general academic entrepreneurship considered by us. Note, however, that the effect of engineering sciences turns statistically insignificant when European conference participation is considered.

distinction between European conferences attended by the German researchers and conferences in the rest of the world (ROW).[11] We find that European conference participation positively affects academic entrepreneurship; however, the effects of conferences in the rest of the world, while positive, are statistically insignificant. Thus networking returns are greater in geographically closer locations – "the apple falls under the tree".

Turning to resource allocation decisions by scientists, it turns out that greater time spent on consulting (Models II and IV in Table 2), rather than on research, helps in the emergence of research-driven entrepreneurs. Consulting activities are likely to better familiarize researchers with different institutional aspects of industry and also help in networking, both of which prove useful when they decide to turn entrepreneurs. On the other hand, the time spent on research might be spent on doing more basic research (see Goel and Rich (2005)).

Finally, leadership of a research group better prepares a researcher for research-driven entrepreneurial activity. Again, this could be due to better networking opportunities for leaders and better familiarization with a broad range of institutional details that are conducive to entrepreneurship.

[11] Given appropriate data one could examine additional spatial influences in terms of their impact on entrepreneurship (see Autant-Bernard et al. (2007), Anselin et al. (1997)).

Table 2: Determinants of research-driven entrepreneurship

	Research-driven entrepreneurship			
	I	**II**	**III**	**IV**
No of publications	0.004*	0.003	0.003	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
No of patent applications	0.096***	0.095***	0.095***	0.093***
	(0.021)	(0.023)	(0.026)	(0.027)
Research group leader (*d*)	0.374**	0.419**	0.282*	0.373**
	(0.147)	(0.165)	(0.156)	(0.170)
Tenured (*d*)	0.032	-0.018	-0.011	-0.043
	(0.167)	(0.178)	(0.171)	(0.179)
Gender (1=female)	-0.192	-0.177	-0.159	-0.149
	(0.177)	(0.184)	(0.180)	(0.186)
Age (years)	0.005	0.007	0.007	0.008
	(0.007)	(0.007)	(0.007)	(0.008)
Employed at university (*d*)	0.099	0.206	0.001	0.078
	(0.120)	(0.140)	(0.124)	(0.143)
Life sciences (*d*)	0.151	0.205	0.084	0.120
	(0.172)	(0.180)	(0.177)	(0.184)
Natural sciences (*d*)	-0.108	-0.021	-0.103	-0.04
	(0.184)	(0.190)	(0.194)	(0.199)
Engineering sciences (*d*)	0.419**	0.436**	0.275	0.298
	(0.179)	(0.188)	(0.190)	(0.196)
Time spent on research (share)		0.001		0.000
		(0.003)		(0.003)
Time spent on consulting (share)		0.016***		0.012*
		(0.005)		(0.006)
Avg. no of conferences Europe			0.057***	0.049***
			(0.014)	(0.015)
Avg. no of conferences ROW			0.019	0.027
			(0.038)	(0.039)
Constant	-2.126***	-2.440***	-2.361***	-2.576***
	(0.384)	(0.440)	(0.402)	(0.463)
R^2	0.098	0.110	0.108	0.115
Number of observations	1065	974	995	927
LR Chi^2	74.289	75.254	72.695	73.781
P-value	0.000	0.000	0.000	0.000

(d): dummy variable; standard errors in parentheses.
//*** indicate statistical significance at the 10%, 5% and 1% level*
Social sciences and humanities are the reference groups.

4.3 Determinants of general academic entrepreneurship

Turning to general academic entrepreneurship in Table 3, the set of explanatory variables is the same as that in Table 2, the difference is in the dependent variable – now the dependent variable is broader to capture all entrepreneurial activity by German researchers in our sample. This general type of entrepreneurship is the one mostly studied in the literature.

Overall the findings generally support the results in Table 2, with some subtle and important differences. Specifically, we find that greater patenting (versus publications, research leadership, greater consulting time, and EU conferences boost overall academic entrepreneurship as they did its subset, the research-driven entrepreneurship. The magnitude of the effect of European conference participation is similar on overall and academic entrepreneurship. However, the advantages of being in engineering sciences are no longer present in overall entrepreneurship. Conversely, university employment does have benefits in overall academic entrepreneurship (Models Ia, IIa and IVa in Table 3). Comparing Tables 2 and 3, one can also see that the positive effect of academic publications is relatively more pronounced in the case of overall entrepreneurship than it is on research-driven entrepreneurship, while the reverse is true for research leadership. Further, the marginal effect of patent applications is greater than that of academic publications and this difference is somewhat more pronounced for general entrepreneurship than research-driven entrepreneurship. In terms of magnitude, a one standard deviation increase in the number of patent applications (2.143 in Table 1) would increase the probability of general entrepreneurship by about 0.23 (Model Ia in Table 3) and research-driven entrepreneurship by 0.21 (Model I in Table 2).

To summarize, while some determinants are equally effective at promoting general as well as research-driven entrepreneurship (e.g., patenting, research leadership, consulting time), there are some other determinants that would promote one, but not the other.

4.4 Robustness checks

In order to check the robustness of our findings, we perform several checks. These include (i) consideration of nonlinearities in explanatory variables; (ii) allowing for possible simultaneity between entrepreneurship and time spent on consulting; and (iii) considering determinants of non-research driven entrepreneurship.

4.4.1 Nonlinear effects

In Table 4a in the Appendix we consider nonlinearities in some of the explanatory variables from Table 2. Specifically, we include quadratic terms of age and patent applications and an interaction term between age and gender (Model Vb). The logic is that the rates of changes in these variables might be non-constant in their effects on the propensities to turn entrepreneurs. None of the quadratic terms or the interaction term attains statistical significance, implying that the linear effects considered in Table 2 are reasonable.

The results for the other variables are largely similar to what was reported in Table 2 – i.e., greater patenting, consulting time, EU conferences and being in engineering sciences all boost research-driven entrepreneurship.

4.4.2 Allowing for simultaneity between entrepreneurship and time spent on consulting

It is possible that the causality between entrepreneurship and time spent on consulting might be two-way. In other words, the time spent on consulting might be an endogenous regressor, given that the academic might need to establish a firm in order to perform consulting tasks. Hence, we estimated two instrumental variable regressions, instrumenting the consulting time share with two variables that are available from the questionnaire. Both refer to the aspects that potentially drive the scientist’s choice for research topics, i.e. (i) the likelihood to commercialize the findings; and (ii) the likelihood to obtain funding from industry. Both variables are measured on a five-point Likert scale, indicating the importance of the two aspects for the scientist. The instruments need to be correlated with the time share spent on consulting – conditional on the other covariates – and affect the scientist's choice for becoming an entrepreneur only through their effect on the consulting time share. In fact, it turns out that the two instruments do not have a direct effect on academic entrepreneurship, but they are strongly related to the time share spent on consulting which confirms their suitability as instruments (see Table 4b). The results from the instrumental variable regression for both the research-driven and the general academic entrepreneurship indicate robustness of our results obtained from the Probit models in Tables 2 and 3. We can therefore conclude that endogeneity is not significantly affecting our findings.

4.4.3 Determinants of non research-driven entrepreneurship

Besides investigating the effects of our explanatory variables on general academic entrepreneurship, we also estimate two models for the probability of an academic to engage in non research-driven entrepreneurship (Table 7). Interestingly, our findings indicate that scientific productivity in terms of publications and patents does not matter at all, nor is it important whether the scientist is leading a research group. Scientists working at a university are however more likely to found a non research-driven firm, and life scientists are less likely to do so. These results indicate clear differences between research-driven and non research-driven academic entrepreneurship which complements our analysis. The concluding section follows.

Table 3: Determinants of general entrepreneurship

	General academic entrepreneurship			
	Ia	**IIa**	**IIIa**	**IVa**
No of publications	0.004**	0.003*	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
No of patent applications	0.108***	0.111***	0.115***	0.115***
	(0.022)	(0.024)	(0.026)	(0.026)
Research group leader (*d*)	0.277**	0.265*	0.172	0.204
	(0.126)	(0.140)	(0.133)	(0.144)
Tenured (*d*)	0.038	-0.056	-0.001	-0.082
	(0.152)	(0.163)	(0.156)	(0.165)
Gender (1=female)	-0.247	-0.240	-0.226	-0.230
	(0.155)	(0.164)	(0.157)	(0.167)
Age (years)	0.005	0.009	0.008	0.010
	(0.006)	(0.007)	(0.007)	(0.007)
Employed at university (*d*)	0.243**	0.393***	0.183	0.316**
	(0.110)	(0.130)	(0.114)	(0.135)
Life sciences (*d*)	-0.090	-0.050	-0.164	-0.123
	(0.151)	(0.158)	(0.154)	(0.161)
Natural sciences (*d*)	-0.192	-0.088	-0.189	-0.095
	(0.154)	(0.159)	(0.163)	(0.167)
Engineering sciences (*d*)	0.253	0.251	0.113	0.137
	(0.155)	(0.165)	(0.163)	(0.171)
Time spent on research (share)		0.001		0.001
		(0.003)		(0.003)
Time spent on consulting (share)		0.023***		0.022***
		(0.006)		(0.006)
Avg no of conferences Europe			0.055***	0.042***
			(0.013)	(0.014)
Avg no of conferences ROW			0.018	0.023
			(0.034)	(0.035)
Constant	-1.745***	-2.170***	-1.990***	-2.322***
	(0.329)	(0.407)	(0.347)	(0.428)
R^2	0.087	0.113	0.098	0.116
Number of observations	1065	974	995	927
LR Chi^2	77.995	85.477	79.377	84.901
P-value	0.000	0.000	0.000	0.000

(d): dummy variable; standard errors in parentheses.
,,*** indicate statistical significance at the 10%, 5% and 1% level*
Social sciences and humanities are the reference groups.

5. CONCLUSIONS

There has been increasing interest in academic entrepreneurship in recent years (see Audretsch et al. (2002, 2009), Bozeman (2000), Djokovic and Souitaris (2008), Feldman et al. (2002), Link et al. (2007) and Stephan (1996)). Various scholars have examined the causes and effects of academic entrepreneurship using data at different levels of detail and for various jurisdictions. The findings are somewhat sensitive to the period, jurisdiction and detail of the underlying data. Almost invariably, however, the broader academic entrepreneurship has been considered, whereas in many instances it is its subset – the research-driven entrepreneurship – that must be examined. Not all academic entrepreneurs are necessarily becoming entrepreneurs as a result of their academic accomplishments. In our sample, around 70 percent of all academic entrepreneurship is based on research results. Besides contributing to the literature, an examination of research-driven entrepreneurship would aid research organizations aiming to have a better accounting of their outputs and impacts.

We add to the literature by examining the determinants of research-driven entrepreneurship and comparing those to the overall entrepreneurship by academics. Our research uses a theoretical structure to explain the incidence of academic entrepreneurship (Figure 1; also Goel and Rich (2005)), and is based on a survey of more than 1,000 German scientists from universities and PROs.

Addressing the question posed in the title of the paper, all academic entrepreneurs are not created alike. The findings confirm most of our hypotheses, qualify others, and bring to the fore a set of results that need deeper and more comparative research. Our results show that while there are some common determinants of research-driven and general academic entrepreneurship, there are some significant differences (see Tables 2 and 3). Patenting activity by researchers, research leadership, greater relative time spent on consulting, conference participation in relative proximity to home (Europe), and engineering sciences showed greater propensity to yield research-driven entrepreneurial activity. On the other hand, academic publications, researcher's gender, age, academic tenure, and university employment (compared to employment at a public research organization) did not seem to have appreciable impact on entrepreneurial activity. Interestingly, the positive influences of university employment on overall academic entrepreneurship fail to show up in research-driven entrepreneurship. Academic publications seem relatively more effective at fostering overall entrepreneurship, while research leadership seems relatively less prominent in this instance.

Robustness checks of the models considered in Tables 2 and 3 are conducted by including (i) nonlinear effects (Table 4a); (ii) simultaneity between entrepreneurship and consulting time (Table 4b); and (iii) determinants of non research-driven entrepreneurship (Table 7). Overall, the findings in Tables 2 and 3 are upheld. One implication is that universities may be unduly patting themselves on the back – they might yield more entrepreneurs, but those entrepreneurs are not necessarily emerging due to research accomplishments.

Turning to the five questions posed in the introduction, we are now able to provide some answers based on our analysis.

- *What are important influences driving research-based entrepreneurship in Germany?*

Patenting activity by researchers, research leadership, greater relative time spent on consulting, conference participation in Europe, and engineering sciences showed greater propensity to yield research-driven entrepreneurial activity. However, academic researcher's gender, age, academic tenure, and university employment did not seem to have appreciable impact on such entrepreneurial activity (see Table 2).

- *Do similar factors drive general academic entrepreneurship and research-driven entrepreneurship?*

Our results are mixed. They show that, despite some plausible similarities, there are significant differences. In particular, while both entrepreneurship categories benefit from greater patent applications, more time spent on consulting by the researcher and from participation in European conferences, research leaders and engineering science disciplines are more likely to lead to research driven entrepreneurs. On the other hand, the positive influences of university employment (and mostly academic publications) on overall academic entrepreneurship fail to show up in research-driven entrepreneurship.

- *How do various types of research behaviour (e.g., publications, patents, networking, etc.) facilitate entrepreneurship?*

Patenting activity by researchers, research leadership, greater relative time spent on consulting, and networking (conference participation) in relative proximity to home (Germany) showed greater propensity to yield research-driven entrepreneurial activity (see Jaffe et al. (1993)). Academic publications and university employment, on the other hand, turned out to be relatively more effective at fostering overall entrepreneurship.

- *Which academic disciplines are more likely to yield entrepreneurs?*

Of the different academic disciplines considered, it seems that scientists in engineering sciences are more likely to emerge as research-driven entrepreneurs (Table 2; also see Table 6).[12] The relative advantage of this discipline disappears when overall academic entrepreneurship is considered (Table 3).[13]

- *Are there significant gender differences in the emergence of entrepreneurs?*

We were unable to find significant gender differences in terms of becoming entrepreneurs in Germany. This is true for both overall entrepreneurship and research-driven entrepreneurship. Evidence regarding the gender effects in entrepreneurship is mixed in the literature (see Corley and Gaughan (2007), Fini et al. (2010), Krabel and Mueller (2009)), Rosa and Dawson (2006), Stephan and El-Ganainy (2007), Thursby and Thursby (2005)).

In closing we mention some caveats to put this work in perspective. There has been some focus in the literature on the role of technology transfer offices in fostering technology commercialization and entrepreneurship (see, for example, O'Gorman et al. (2008)). We are unable to incorporate such information in our analysis due to a lack of corresponding survey data. Another important issue, albeit one that is not easy to capture empirically, is the role of innovation/technology commercialization uncertainty in affecting incentives to engage in entrepreneurship. Finally, it remains to be seen how these findings hold for other countries.[14]

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[12] The effect of engineering sciences, however, is sensitive to the consideration of European conference participation.

[13] This finding should, however, be tempered by the fact that not all research is equally commercializable.

[14] For instance, Fini et al. (2010), Jain et al. (2009), Link et al. (2007) and Reynolds et al. (2004) are among the studies that focus on entrepreneurship in the United States.

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Appendix

Table 4a: Robustness check – non-linear effects

	Research-driven entrepreneurship				
	Ib	**IIb**	**IIIb**	**IVb**	**Vb**
No of publications	0.004*	0.003	0.002	0.001	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
No of patent applications	0.136***	0.142***	0.170***	0.166***	0.096***
	(0.042)	(0.044)	(0.054)	(0.055)	(0.021)
Research group leader (*d*)	0.373**	0.412**	0.280*	0.364**	0.374**
	(0.148)	(0.165)	(0.156)	(0.171)	(0.148)
Tenured (*d*)	0.068	-0.037	0.031	-0.054	0.036
	(0.176)	(0.186)	(0.181)	(0.188)	(0.168)
Gender (1=female)	-0.182	-0.171	-0.144	-0.139	0.048
	(0.177)	(0.184)	(0.180)	(0.187)	(0.949)
Age (years)	-0.036	0.02	-0.044	0.009	0.005
	(0.079)	(0.086)	(0.083)	(0.091)	(0.007)
Employed at university (*d*)	0.11	0.225	0.020	0.098	0.098
	(0.121)	(0.143)	(0.126)	(0.146)	(0.120)
Life sciences (*d*)	0.144	0.185	0.062	0.089	0.149
	(0.171)	(0.181)	(0.178)	(0.186)	(0.171)
Natural sciences (*d*)	-0.118	-0.038	-0.115	-0.058	-0.110
	(0.183)	(0.191)	(0.194)	(0.200)	(0.183)
Engineering sciences (*d*)	0.394**	0.414**	0.236	0.268	0.417**
	(0.181)	(0.191)	(0.192)	(0.200)	(0.178)
Time spent on research (share)		0.001		0.000	
		(0.003)		(0.003)	
Time spent on consulting (share)		0.016***		0.012*	
		(0.005)		(0.006)	
Avg no of conferences EU			0.060***	0.052***	
			(0.014)	(0.015)	
Avg no of conferences ROW			0.016	0.025	
			(0.038)	(0.039)	
Age (years, squared)	0.000	0.000	0.001	0.000	
	(0.001)	(0.001)	(0.001)	(0.001)	
No of patent applications (squared)	-0.003	-0.004	-0.008	-0.007	
	(0.003)	(0.003)	(0.005)	(0.005)	
Interaction age*gender					-0.005
					(0.020)
Constant	-1.144	-2.756	-1.149	-2.600	-2.147***
	(1.986)	(2.201)	(2.049)	(2.319)	(0.406)
R^2	0.099	0.113	0.113	0.119	0.098
Number of observations	1065	974	995	927	1065
LR Chi^2	79.109	77.194	79.608	78.562	74.81
P-value	0.000	0.000	0.000	0.000	0

(d): dummy variable; standard errors in parentheses.
//*** indicate statistical significance at the 10%, 5% and 1% level*
Social sciences and humanities are the reference groups.

Table 4b: Robustness check – instrumental variable regressions

	Ic		IIc	
	Research-driven entr.	**Time spent on consulting**	**General entr.**	**Time spent on consulting**
No of publications	0.003	0.015	0.003	0.015
	(0.002)	(0.010)	(0.002)	(0.010)
No of patent applications	0.070***	-0.199	0.069***	-0.199
	(0.022)	(0.146)	(0.022)	(0.146)
Research group leader (*d*)	0.399**	-0.626	0.199	-0.622
	(0.189)	(0.988)	(0.154)	(0.988)
Tenured (*d*)	-0.021	0.761	-0.05	0.748
	(0.181)	(0.850)	(0.152)	(0.850)
Gender (1=female)	-0.168	0.711	-0.25	0.718
	(0.194)	(1.098)	(0.178)	(1.099)
Age (years)	0.007	0.002	0.009	0.002
	(0.007)	(0.041)	(0.007)	(0.041)
Employed at university (*d*)	0.520**	-6.730***	0.867***	-6.734***
	(0.211)	(1.013)	(0.137)	(1.013)
Life sciences (*d*)	0.283	-1.764*	0.158	-1.774*
	(0.190)	(0.955)	(0.155)	(0.953)
Natural sciences (*d*)	0.151	-3.925***	0.255	-3.932***
	(0.235)	(0.886)	(0.178)	(0.885)
Engineering sciences (*d*)	0.390*	-0.644	0.177	-0.676
	(0.206)	(1.163)	(0.170)	(1.158)
Time spent on research (share)	0.011**	-0.168***	0.016***	-0.168***
	(0.005)	(0.026)	(0.003)	(0.026)
Time spent on consulting (share, instr.)	0.070***		0.102***	
	(0.025)		(0.015)	
Res. driven by likelihood to comm.		0.988***		0.952***
		(0.306)		(0.295)
Res. driven by avail. of industry funds		0.645**		0.688**
		(0.298)		(0.270)
Constant	15.882***		-3.404***	
	(2.946)		(0.394)	
Number of observations	742		742	
LR Chi^2	103.559		268.811	
P-value	0.000		0	

(d): dummy variable; standard errors in parentheses.
,,*** indicate statistical significance at the 10%, 5% and 1% level*
Social sciences and humanities are the reference groups.
Instruments employed for time spent on consulting were: (i) the likelihood to commercialize the findings; and (ii) the likelihood to obtain funding from industry.

Table 5: Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Time spent on research (share)	1.000													
2. Time spent on consulting (share)	-0.234	1.000												
3. Avg. no of conferences EU	-0.082	0.188	1.000											
4. Avg. no of conferences ROW	-0.116	0.006	0.366	1.000										
5. No of publications	-0.048	-0.052	0.219	0.365	1.000									
6. No of patent applications	-0.019	0.062	0.095	0.141	0.142	1.000								
7. Research group leader (*d*)	-0.295	0.018	0.228	0.235	0.262	0.112	1.000							
8. Tenured (*d*)	-0.224	0.103	0.096	0.064	0.115	0.076	0.244	1.000						
9. Gender (1=female)	-0.012	0.042	-0.045	-0.115	-0.112	-0.087	-0.098	-0.155	1.000					
10. Age (years)	-0.104	0.010	0.029	-0.015	0.092	0.040	0.150	0.431	-0.114	1.000				
11. Employed at university (*d*)	-0.492	-0.155	0.088	0.139	0.139	-0.092	0.324	0.106	-0.032	0.125	1.000			
12. Life sciences (*d*)	0.070	-0.009	0.068	0.082	0.170	-0.016	0.072	-0.083	0.096	0.025	-0.035	1.000		
13. Natural sciences (*d*)	0.084	-0.145	-0.098	0.027	0.161	-0.014	-0.060	-0.019	-0.083	-0.027	-0.096	-0.429	1.000	
14. Engineering sciences (*d*)	-0.024	0.136	0.039	0.059	-0.167	0.217	0.022	0.127	-0.120	-0.016	-0.077	-0.325	-0.336	1.000
Variance inflation factor (VIF)	1.61	1.24	1.26	1.36	1.38	1.12	1.32	1.37	1.08	1.26	1.68	2.04	2.12	1.89
Condition number	27.85													

Table 6: Distribution of academic scientists across disciplines and gender in Germany, 2005

	Share university scientists	Share PRO scientists	Share total scientists	Realized sample
Natural sciences	23.95%	57.78%	32.06%	20.70%
Engineering sciences	15.94%	28.61%	18.97%	29.50%
Life sciences	30.36%	7.17%	24.80%	29.60%
Social sciences and humanities	29.75%	6.44%	24.17%	20.20%
Total	100.00%	100.00%	100.00%	100.00%
Gender = female	30.55%	27.78%	29.51%	15.50%

Source: Federal Statistical Office (Destatis), 2009; BMBF, 2008; authors' calculations.

Table 7: Determinants of non research-driven entrepreneurship

	Non research-driven entrepreneurship	
	Id	**IId**
No of publications	0.001	0.002
	(0.003)	(0.003)
No of patent applications	0.039	0.039
	(0.026)	(0.027)
Research group leader (*d*)	0.039	-0.031
	(0.166)	(0.181)
Tenured (*d*)	0.06	-0.03
	(0.214)	(0.228)
Gender (1=female)	-0.236	-0.238
	(0.213)	(0.223)
Age (years)	0.003	0.007
	(0.008)	(0.009)
Employed at university (*d*)	0.381**	0.513***
	(0.155)	(0.190)
Life sciences (*d*)	-0.396*	-0.391*
	(0.213)	(0.220)
Natural sciences (*d*)	-0.151	-0.07
	(0.189)	(0.194)
Engineering sciences (*d*)	-0.076	-0.107
	(0.207)	(0.223)
Time spent on research (share)		0.002
		(0.004)
Time spent on consulting (share)		0.022***
		(0.007)
Constant	-1.948***	-2.365***
	(0.424)	(0.595)
R^2	0.043	0.072
Number of observations	1065	974
LR Chi^2	20.049	26.837
P-value	0.029	0.008

(d): dummy variable; standard errors in parentheses.
******* indicate statistical significance at the 10%, 5% and 1% level*
Social sciences and humanities are the reference groups.