Received: 25 January 2018 | Revised: 22 March 2018 | Accepted: 8 April 2018
DOI: 10.1002/mde.2932

RESEARCH ARTICLE

WILEY

Academic leadership and commercial activities at research institutes: German evidence

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JEL Classification: O31; O34; L26; L32

This paper focuses on entrepreneurship by academic leaders. With the use of patents, inventions, and spin-offs to measure commercialization, and directors, research group leaders, and business owners as academic leaders, results, using a sample of more than 2,500 German researchers, show differences across academic leaders and commercialization. Findings for spin-offs are different from those for patents and inventions. Academic leaders in sciences were more likely to commercialize. Doctoral degrees helped patents by business owners and spin-offs by group leaders, whereas female business owners and female group leaders faced challenges patenting and inventing, respectively. For business owners, age increased the likelihood of patenting but lowered spin-offs.

1 | INTRODUCTION

Academic leaders, with the discretionary powers and resources at their disposal, are instrumental in shaping the direction of research at academic institutions. Junior researchers look up to leaders for guidance and inspiration, whereas policymakers want them to set research agendas and to allocate resources effectively. In this case, however, there is no one size fits all, in terms of both input and research output (Goel and Rich (2005); Lacetera (2009)). Regarding input, there are many types of academic leaders, differing in terms of the scale and scope of their responsibilities. Further, the outputs of research may be multidimensional ranging from academic (education, publications), to commercial (patents, inventions, spin-offs), to internal (organizational improvements). Thus, evaluation of the productivity and the factors that drive the productivity of academic leaders is problematic, especially when available data are at an aggregate level.

The present paper, having access to detailed data from a survey of scientists at a large academic research organization, is able to provide some unique insights into the drivers of commercial activities by academic leaders. Specifically, we consider three different types of academic leaders (business owners, group leaders, and directors) and three different commercial outputs (patents, invention disclosures, and spin-offs) and study the factors affecting alternate commercial outputs across different leaders.[1] Are drivers of spin-offs, patents, and inventions alike across business owners, group leaders, and directors?

Higher education institutes, universities, and public research organizations have been going through several structural changes, and academics are facing new challenges (budget cuts, etc.). Entrepreneurship by academics has been encouraged by academic institutions in recent years, with a concurrent increase in research focus on the causes and effects of such efforts. Scientists are expected to not only do teaching and research but also engage with the surrounding society and industry, often under the broad name of "third mission." The notion of third mission developed from research activities. The starting point is the assimilation of fundamental research into codified knowledge. This economic assimilation is critical, as it tells that this good, once produced, is very difficult to appropriate (Laredo (2007)). Third mission activities can be quite broad, covering industrial, commercial, and entrepreneurial or other societal and policy-related activities (Lacetera (2009), Martin (2003)). Much of the literature on knowledge transfer has focused on the formal/contractual relations such as patents and licensing (Bercovitz and Feldman (2008); Siegel, Waldman, Atwater, and Link (2004)) and formation of university spin-offs (Di Gregorio and Shane (2003); O'Shea, Allen, Chevalier, and Roche (2005); Pérez and Sánchez (2003); Shane (2004)). Some of the research has focused on consulting, sponsored research, and collaboration (Cohen, Florida, Randazzese, and Walsh (1998); Mansfield and Lee (1996)), whereas others have focused on labor mobility from academia to industry (Murray (2004); Zucker and Darby (1996)).

Academic leaders are expected to not only manage research groups and produce research outputs but also convert them into commercial outcomes. It is in this world that the role of academics and academic leadership in the organization and governance of research is challenged. Thus, the faculty role is in flux (Halsey (1982)).

Academics (in particular academic leaders) are "knowledgeable agents" (Giddens (1984)) who are supposed to be aware of the rules and regulations (Morris (2016)) and of what is expected from them. They will consider paths to be taken and actively participate in the forms of leadership that evolve (Giddens (1984)).

Scientists' commercial activities, however, are not independent of their research milieu (see Buenstorf, 2009). As much research is conducted in teams, most commercial engagements (such as spin-off formation) are achieved by a group of university researchers such as professors, graduate students, and postdoctoral fellows, sometimes with industrial researchers operating as a quasi-firm (Etzkowitz (2003)). Academic leaders also institute the norms and attitudes among the younger (junior) researchers and are quite influential in establishing a culture (work environment) that accepts or encourages commercial/entrepreneurial engagements. Cunningham, O'Reilly, Dolan, O'Kane, and Mangematin (2016) define the principal investigators' role as scientists who orchestrate new research projects, combine resources and competencies, deepen existing scientific trajectories, or shape new ones that are transformative in intent, nature, and outcomes that can be exploited for commercial ends and/or for common societal good (also see Mangematin, O'Reilly, & Cunningham, 2014).

The question addressed in this study is how/why academic leaders perform the third mission (industrial engagement) in public research organizations and how one can understand what happens. Studying the academic leadership would also contribute to the emerging studies on the microfoundations of university–industry technology transfer (see Goel & Göktepe-Hultén, 2013; Rothaermel, Agung, & Jiang, 2007). We argue that there is value in an integrated conception of the faculty role (i.e., academic leadership and academic entrepreneurship).

With regard to the literature, the present research can be seen as complementary to research that focuses on the behavior of star scientists, where star scientists are viewed as better signals to attract research resources and act as catalysts to create synergies among research scientists (Moretti and Wilson (2014), Zucker and Darby (1995)). However, whereas star scientists are supposed to lead from the front by example, academic leaders might be leaders or followers in research/commercialization.

Secondary constitutions of this work can be viewed with regard to university entrepreneurship (Perkmann, King, and Pavelin (2011), Rothaermel et al. (2007)) and the role of gender in university–industry interactions (Goel, Göktepe-Hultén, and Ram (2015), Link and Link (1999), Thursby and Thursby (2005)). The gender–entrepreneurship literature has noted the special challenges faced by female researchers in commercializing their research.

The analysis is based on survey data for researchers at the Max Planck Society (MPS), Germany's largest nonuniversity public research organization dedicated to basic research. For a variety of reasons, the MPS is well suited to study the academic leaders' commercialization activities (see Section 3). Relatively speaking, insights into the behavior of academic leaders at research institutions are less than those for universities, and this paper attempts to contribute in this regard.

The remainder of the paper is structured as follows. In Section 2, theoretical considerations concerning the commercialization activities of scientists in public research as well as the existing empirical literature are presented. Section 3 presents the research setting, that is, details about MPS. In Section 4, the data underlying the empirical analysis are described, and Section 5 presents the results of the analysis, with concluding remarks forming the final section.

2 | THEORETICAL BACKGROUND AND RELATED LITERATURE

Leadership in general has been a subject of interest for centuries, long before and much earlier than entrepreneurship. Hence, the contemporary study of leadership is rich in theories, models, and research approaches. Within the context of management and corporate entrepreneurship studies, leadership research had centered on personality traits in the 1960s and behavioral leadership and leadership styles in the 1970s (Fernald Jr, Solomon, and Tarabishy (2005); Thornberry (2006)). Research on leadership style then evolved into the concept of situational leadership theory, which advised managers to adapt their leadership styles in accordance to situation and context. This behavior and style flexibility are referred to as transactional leadership because of the emphasis on daily interpersonal interactions and transactions between leaders and their subordinates. However, if the leader is asked to bring about significant organizational change, then the type of leadership needed is referred to as transformational leadership.

In the academic setting, leadership role is important for leading research, setting teaching direction, and, increasingly, for fostering academic–industry interactions. Academic research is often done collectively within a research group, managed under the leadership of a senior (tenured) researcher. This collective working mode of a scientist is probably even becoming more frequent than before (Hicks and Katz (1996)). In this mode of working, one can identify two actors:

(a) Leaders who are more influential in the formation of the local group norms and culture, who may even lead the research group towards entrepreneurship by acting as role models.
(b) Research group members are exposed to the behaviors of the role models, and they most likely follow the behaviors of the leaders.

In earlier studies (Louis, Blumenthal, Gluck, and Stoto (1989), Roberts (1991)), it was found that the most important factor behind the involvement of scientists in commercialization was "local group norms, and culture." Likewise, Bercovitz and Feldman (2008) argued that social imprinting, that is, norms associated with training (norms from institutions where researchers are trained) and peers' attitudes towards commercialization influence the subsequent behavior and drive the adoption and diffusion of new practices. In particular, the decision of the individual faculty member to participate in commercialization is strongly influenced by "leadership effects." The actions of the chairperson of the department appear to influence the behaviors of others more than university strategies, policies, and structures do. Research leaders may also be viewed as (internal) Stackelberg leaders who take different dimensions of their followers or junior researchers' behaviors into account in allocating resources and setting research directions (Goel (1990)). In this setting, it is important to study research groups and particularly leaders in the process of commercialization of research results.

From that perspective, academic leaders play a vital role in the formation of a culture that stimulates innovation (i.e., third mission activities, knowledge transfer, industrial engagement, and entrepreneurship). An entrepreneurial leader is often seen as the deviant individual; it could prove fruitful to study the impact that these atypical leaders have in the organization (Boyett (1996)).

Entrepreneurial academic leaders may seek out and recruit like-minded individuals who share their understanding and passion for the opportunities and are interested in taking quick, decisive action. Entrepreneurial academic leaders (e.g., serial academic inventors) can either play an active role as lead entrepreneurs themselves or act as catalysts that stimulate entrepreneurial actions and energies of others (Göktepe (2008)).

Similar to the studies on leadership, research on academic entrepreneurship has focused on a few themes such as the characteristics of scientists (human capital aspects), the environment surrounding the scientists, the role of scientists (social or human capital) in the new ventures created, and the process of new venture creation (Murray (2004); Zucker, Darby, & Brewer (1998)). A similar argument concerns the academic quality of scientists and their ability to allocate time for commercial activities. The scientific reputation and skills of scientists provide credibility and capability to any anticipated commercial project, which are often risky and highly uncertain (Audretsch and Stephan (1996)). Senior scientists (e.g., with tenure in the United States) are also found to be involved in patenting activities more often than juniors (Thursby and Thursby (2004)). Researchers with more publications and citations as compared with their peers (so-called star scientists) are the ones who are most interested in commercializing research results (Zucker et al. (1998)). In contrast to those who claim that commercialization may lower the academic quality, novelty, and scientific relevance of the research (Azuloay et al., 2006), prolific researchers are able to strike a balance between scientific research and commercial engagements. However, not all scientists (e.g., juniors with less experience and resources) may achieve double roles. Academic leaders may delegate some of their tasks to others within the research group (Göktepe (2008)).

Academic leaders often understand the organizational complexity of public research organizations and universities and the wisdom in shared decision making. Effective leaders avoid the exercise of unilateral power; they have a clear understanding of who has the authority and/or responsibility for decision making, and they respect the roles of various groups and constituents (faculty, staff, students, alumni, legislators, etc.) in the process (Morris (2016)). As such, academic leaders (research group leaders, directors, business owners) who, in comparison with other researchers, may have stronger social networks may have easier access to complementary skills, financial support, and resources that may be necessary for commercial engagements. They may leverage their social capital in a way that helps them commercialize research results more than do scientists who do not enjoy the similar social networks.

From the above literature, it is clear that academic leaders play vital and multidimensional roles. Thus, we derive two overarching lines of theoretical thinking.

(a) Active (bottom-up reasoning): Academic leaders' human capital and social capital enable them with necessary skills and networks to commercialize their research results, more than researchers who do not have leadership positions.

(b) Reactive (top-down reasoning): Academic leaders follow the rules and regulations of their institutes that enforce to commercialize their research results more than nonleader researchers do. They cannot bypass the technology transfer office (TTO; e.g., academic leaders may use in-house TTO [or other similar agents] in order to intermediate their relations with outside actors such as industry or investors).

The above discussion enables us to formulate one testable hypothesis.

> **Hypothesis 1.** *Academic leaders in higher positions with greater resources and discretionary powers are likely to engage in a wide range of commercial activities.*

With regard to 1, among the three academic leaders considered, we would expect higher positioned leaders (e.g., directors) to more likely engage in commercial activities (denoted by spin-offs, patents, and inventions in this study).[2]

Next, we move to formal analysis with the three leadership types and three alternate commercialization modes to see relative propensities of academic leaders towards commercialization.

3 | RESEARCH SETTING: MAX PLANCK SOCIETY

Survey data from MPS in Germany makes this study possible. MPS was founded in the late 1940s in Germany. It is funded to a large extent by both the federal and state governments. The MPS consists of 83 institutes and research facilities worldwide, of which 78 are situated in Germany and employ about 9,000 researchers in natural sciences, life sciences, and humanities. Within the public science sector in Germany, the MPS is complementing universities by performing research in fields that universities are not able to embed in their research agendas, especially in cases of new and innovative research that is uncertain, is of a basic nature, and requires long-term commitment (i.e., structures and funding; Slavtchev and Göktepe-Hultén (2016)). Research excellence of the MPS is documented by 33 Nobel Prizes since 1911.

In 1970, MPS established a specific office (Garching Innovation) to apply for patents related to the inventions of its employees. Systematic support of spin-offs was taken up in the early 1990s. In Germany, it is acknowledged as the most professional and successful TTO. Rules concerning the ownership of intellectual property at MPS have been always different from the former university patent legislation (Law on Employees' Inventions). According to MPS employment contracts and also the Employees' Inventions Act, all occupational findings or ideas that may have inventive character must be reported to the institute's management. Employees, in particular those in a leadership position, are all informed and aware of the MPS's institutional setups regarding transferring academic research results into innovative outputs. Thus, access to the unique survey insights from MPS provides an ideal setting for this study.

4 | DATA AND ESTIMATION

4.1 | Data

This paper is part of a larger project on the identification of commercial activities among scientists employed at MPS. The collection of the data was accomplished through a screening survey of all scientists associated with different institutes of MPS and follow-up surveys. Specifically, more than 2,500 scientists' engagement in different forms academic entrepreneurship was identified and in-depth data about their work environments and perceptions of the commercialization of science was collected. The survey was conducted in the last part of 2007 and during 2008 at around 80 institutes that specialized in different scientific disciplines and are located in Germany (see Goel & Göktepe-Hultén, 2013, etc., for further information about the research context).

In our sample of more than 2,500 survey responses, more than half the respondents were associated with a spin-off, with 11–12% being associated with patenting/invention disclosure (Table 1).[3] In terms of academic leadership, about 2% were directors, 5% business owners, and 13% group leaders.

With regard to personal attributes, half held doctoral degrees, about 61% were German citizens, and a third were females. The average respondent age was a little over 35 years, with average MPS work experience of 6 years. Finally, the sample was dominated by the science disciplines, with humanities forming only 10% of the overall sample.

In terms of pairwise correlations (Table 2), research group leaders had the highest correlations with patents and invention (although the magnitudes were still modest), whereas business owners had a larger correlation with spin-offs.[4]

4.2 | Estimation

On the basis of the discussion in earlier sections and with the use of the data discussed in Section 4.1, the estimated model to address commercialization propensities of academic leaders takes the following form (here i denotes a survey respondent [MPS scientists]):

$$\begin{aligned}\text{Commercial research activity}_{ij} = f(&\text{Education}_i(\text{PHD}), \text{Experience}_i,\\ &\text{AGE}_i, \text{Gender}_i(\text{Female}),\\ &\text{Citizenship}_i(\text{German}), \text{Academic field}_{ik}),\end{aligned} \tag{1}$$

where j is Spin-off, Patent, Invention, and k is Discipline1 (biology, medicine), Discipline2 (chemistry, physics, technics).[5]

The dependent variable is a commercialization activity, alternately Spin-off, Patent, or Invention. As Table 1 shows, spin-offs were

TABLE 1 Variable definitions, summary statistics, and data sources

Variable	Definition (mean; standard deviation)
Spin-off	Dummy variable = 1 if respondent's institute had a spin-off (0.555; 0.50)
Invention	Dummy variable = 1 if respondent disclosed invention to MPS (0.111; 0.31)
Patent	Dummy variable = 1 if respondent filed or applied for a patent at MPS (0.116; 0.32)
Director	Dummy variable = 1 if respondent is a director of a unit (0.024; 0.15)
BusOwner	Dummy variable = 1 if respondent is a business owner or started a business in the past (0.055; 0.23)
GroupLead	Dummy variable = 1 if respondent is a group leader (0.131; 0.34)
Discipline1	Dummy variable = 1 if the academic discipline of the respondent is biology or medicine (0.442; 0.50)
Discipline2	Dummy variable = 1 if the academic discipline of the respondent is chemistry, physics, or technics (0.474; 0.50)
PHD	Dummy variable = 1 if respondent holds a PhD (0.509; 0.50)
AGE	Age of the respondent in years (35.458; 9.57)
Experience	Years of MPS work experience of the respondent (5.918; 7.07)
German	Dummy variable = 1 if respondent is a German citizen (0.609; 0.49)
Female	Dummy variable = 1 if respondent is a female (0.321; 0.47)
IndustryEXP	Dummy variable = 1 if respondent had experience working in industry (0.693; 2.18)

Note. The source of this cross-sectional survey data is MPS survey (see Max Planck Society, 2009, for details). The default academic field is humanities.

TABLE 2 Correlation matrix of key variables

	Spin-off	Patent	Invention	Director	GroupLead	BusOwner
Spin-off	1.00					
Patent	.077	1.00				
Invention	.081	.596	1.00			
Director	−.002	.189	.219	1.00		
GroupLead	.004	.234	.236	−.061	1.00	
BusOwner	.014	.164	.187	.174	.053	1.00

Note. N = 2,582. See Table 1 for variable details.

(on average) nearly five times as many as inventions/patents in our sample, and, as expected, Patent and Invention, were positively correlated (correlation = .6; Table 2). We report results across these commercialization modes for the full sample, as well as for the subsamples of directors, research group leaders, and business owners. Thus, this consideration uniquely enables us to examine the qualitative differences across commercialization modes and how incentives, abilities, and resources of various academic leaders bear upon research commercialization.[6] It could be the case that administrative job requirements and research resources of directors and group leaders were sufficiently different that they favored certain types of research commercialization over others. Furthermore, internal disclosure requirements and technology transfer procedures might impose greater transactions costs on certain commercialization modes over others (Goel & Göktepe-Hultén, 2018).

As to explanatory variables driving research commercialization, we consider both personal attributes of researchers (including age, gender, and citizenship) and their professional characteristics (compromising of education, professional experience, and academic discipline). Age, on the one hand, confers wisdom but might alter opportunity costs sufficiently to make certain types of commercialization less desirable. A similar type of reasoning can be thought of for professional experience, although experience is more organization specific. With regard to gender, women generally favor nonscience areas and have disadvantages in raising finance for commercialization (see Goel et al. (2015)). German citizenship might confer advantages such as greater familiarity with norms and regulations that might be useful in certain commercialization routes, for example, patents.

Higher education (PHD) might send signals that facilitate raising finance, while also increasing human capital. These are likely to increase research productivity and commercialization. Finally, a researcher's academic discipline might have a crucial bearing on commercialization. Research outputs in science-based disciplines are better suited for traditional commercialization modes, with many outputs of humanities not readily patentable.[7]

Given the dichotomous nature of the dependent variable, we use probit as our estimation technique and report robust standard errors. Thus, the estimated coefficients denote the predicted probabilities of the respective dependent variables. The overall fit of different models was quite decent as shown by the pseudo-R^2s and significance of the Wald χ^2.[8]

5 | RESULTS

5.1 | Full sample results

Whereas the main focus of this paper is to study the commercialization incentives of academic leaders, it seems useful to first get an overview of the full sample and the influences of various drivers along the three commercialization dimensions—patents, inventions, and spin-offs. The full sample also enables us to test the hypothesis posed earlier.

Greater MPS experience made the three commercialization dimensions more likely. This finding is consistent with institutional experience contributing to reputation, networking, and familiarity with institution-specific norms and procedures.

With regard to the other influences, the results for patents and inventions were more aligned with each other than with spin-offs. For instance, both doctoral degrees (PHD) and age made patenting and invention more likely but had opposite effects on spin-offs. Interestingly, whereas the absolute values of the estimated coefficients were identical across Models 3.1–3.3, the absolute value of the coefficient on PHD was remarkably smaller in Model 3.1 (with Spin-off). Thus, the insights from higher education and age did not seem to transfer to spin-offs. Furthermore, females were less likely to patent and invent (with the estimated coefficients being of a similar magnitude—denoting lower propensities or probabilities), but gender did not have a significant influence on spin-offs (for gender issues in academic research, see Goel et al., 2015).

Both science disciplines made commercialization more likely, which makes sense given that the research outputs of humanities are generally not amenable to commercialization via traditional routes. Furthermore, the magnitudes of the estimated coefficients with Discipline1 were larger than with Discipline2, signifying greater commercialization opportunities in life sciences over physical sciences. Also, the magnitudes for both science disciplines were higher in the case of spin-offs (Model 3.1), as sciences experienced greater advantages in turning out spin-offs, relative to patents and inventions.

Finally, German citizenship did not generally seem to confer any undue advantages in terms of commercialization activities (despite the marginal significance in Model 3.1). This can be seen as a positive aspect of the German institutional structure that likely values intrinsic research merit over national affinity.

As an alternate consideration and to address 1 above, Models 3.4–3.6 in Table 3 add BusOwner, GroupLead, and Director as regressors to Models 3.1–3.3. The results show that Directors were more likely to be associated with all three (spin-offs, patents and invention disclosures), whereas business owners and research group leaders were more likely to patent and disclose inventions. Further, consistent with 1, the propensities of directors to be associated with spin-offs, patents, or invention disclosures were greater than those for business owners and group leaders (i.e., the coefficients on Director in all three cases are greater than the respective coefficients on BusOwner and GroupLead). In other words, greater resources and discretion at the disposal of directors likely facilitated their attitudes towards spin-offs, patents, and invention disclosures (relative to business owners and research group leaders). The results for other regressors are similar to those in Models 3.1–3.3.

5.2 | Business owner subsample

In Table 4, we report results showing the incentives of business owners to engage in commercial research activities. Business owners are academic entrepreneurs who own their business following either their successful innovations or patents. This group stands out due to their entrepreneurial risk-taking (see Goel & Göktepe-Hultén, 2017, for focus on related risk aspects). In our sample, patents and spin-offs were associated with about a third of business owners, with more than half this subsample being associated with spin-offs at their institutes (see Note to Table 4).

TABLE 3 Academic leaders and commercial research activities: Full sample

Dependent variable	Spin-off (3.1)	Patent (3.2)	Invention (3.3)	Spin-off (3.4)	Patent (3.5)	Invention (3.6)
Discipline1	6.48** (0.05)	1.17** (0.23)	0.87** (0.20)	6.49** (0.01)	1.16** (0.25)	0.87** (0.22)
Discipline2	5.55** (0.05)	0.97** (0.23)	0.66** (0.20)	5.56[a]	0.99** (0.25)	0.68** (0.22)
Experience	0.03** (0.01)	0.01* (0.01)	0.02** (0.01)	0.03** (0.01)	0.02** (0.01)	0.03** (0.01)
PHD	−0.11* (0.07)	0.46** (0.09)	0.34** (0.09)	−0.13* (0.07)	0.35** (0.09)	0.21** (0.09)
AGE	−0.02** (0.005)	0.02** (0.01)	0.02** (0.01)	−0.02** (0.01)	0.01* (0.007)	0.0005 (0.01)
Female	0.03 (0.06)	−0.32** (0.09)	−0.28** (0.09)	0.04 (0.06)	−0.24** (0.09)	−0.19** (0.09)
German	−0.10* (0.06)	0.09 (0.08)	0.01 (0.08)	−0.11* (0.06)	0.04 (0.08)	−0.05 (0.08)
BusOwner				0.08 (0.12)	0.58** (0.12)	0.70** (0.12)
GroupLead				0.12 (0.09)	0.48** (0.10)	0.60** (0.10)
Director				0.46** (0.20)	0.79** (0.19)	1.08** (0.19)
N	2,583	2,576	2,571	2,580	2,573	2,568
Wald χ^2	29,631.84**	233.95**	199.77**	—[a]	283.82**	288.10**
Pseudo-R^2	.20	.15	.13	.20	.18	.18

Note. See Table 1 for variable details. The numbers in parentheses are robust standard errors from these probit regressions.

[a]Not reported by STATA.

*Statistical significance at the 10% level.

**Statistical significance at the 5% (or better) level.

TABLE 4 Academic leaders and commercial research activities: Business owner subsample

Dependent variable	Spin-off (4.1)	Patent (4.2)	Invention (4.3)
Discipline1	5.87** (0.29)	5.78** (0.33)	5.38** (0.28)
Discipline2	4.96** (0.29)	5.47** (0.35)	5.07** (0.29)
Experience	0.09** (0.03)	−0.01 (0.02)	0.03 (0.02)
PHD	−0.40 (0.32)	0.63** (0.33)	0.45 (0.30)
AGE	−0.03* (0.02)	0.04** (0.02)	0.01 (0.02)
Female	0.18 (0.40)	−1.07** (0.54)	−0.28 (0.41)
German	−0.11 (0.26)	0.06 (0.28)	0.26 (0.27)
N	145	145	144
Wald χ^2	1,214.78**	826.03**	1,088.99**
Pseudo-R^2	.25	.27	.19

Note. See Table 3. The respective averages of Spin-off, Patent, and Invention for the BusOwner subsample were 0.59, 0.33, and 0.35, respectively.

*Statistical significance at the 10% level.

**Statistical significance at the 5% (or better) level.

With regard to patenting by business owners, doctoral degree holders and gender (female) had opposite effects—having a PhD made patenting more likely—whereas being a female made patenting less likely. The challenges faced by females in innovation have been recognized elsewhere in the literature (Goel et al., 2015; Link, 2017).

Greater MPS experience, signifying familiarity with internal institutional structure and effects of networking/reputation, made spin-offs more likely by business owners but did not significantly impact patenting or inventions. Furthermore, both science disciplines made commercial research activities more likely for business owners, whereas German citizenship conferred no special privileges. Interestingly, unlike the full sample in Table 3, the propensities to commercialize were similar across disciplines in the three commercialization modes for business owners.

5.3 | Group leader subsample

With research group leaders (GroupLead) as the subsample in Table 5, we see that greater MPS experience of group leaders made spin-offs and invention disclosures more likely but did not have a statistically significant impact on patenting. In contrast, spin-offs became somewhat less likely with age of the group leader. One plausible explanation for this finding is that spin-offs require longer term commitment, whereas patents or inventions can be licensed.

The positive impact of doctoral degrees was seen in the case of spin-offs only, whereas female group leaders were less likely to disclose innovations, and German citizenship did not confer any commercialization advantages. With spin-offs, doctoral degrees might be seen

TABLE 5 Academic leaders and commercial research activities: Group leader subsample

Dependent variable	Spin-off (5.1)	Patent (5.2)	Invention (5.3)
Discipline1	6.22** (0.14)	1.39** (0.49)	0.94** (0.40)
Discipline2	5.06** (0.14)	1.05** (0.49)	0.39 (0.41)
Experience	0.03** (0.01)	0.01 (0.01)	0.03** (0.01)
PHD	1.01** (0.49)	0.51 (0.44)	−0.09 (0.42)
AGE	−0.02* (0.01)	0.004 (0.01)	−0.01 (0.01)
Female	−0.05 (0.24)	−0.12 (0.23)	−0.66** (0.27)
German	−0.18 (0.19)	0.13 (0.18)	0.19 (0.19)
N	338	338	336
Wald χ^2	3,548.82**	18.15**	27.24**
Pseudo-R^2	.23	.05	.09

Note. See Table 3. The respective averages of Spin-off, Patent, and Invention for the GroupLead subsample were 0.56, 0.31, and 0.30, respectively.

*Statistical significance at the 10% level.

**Statistical significance at the 5% (or better) level.

as signaling credentials that might enable easier raising of finance (or lower transactions costs in general). Furthermore, the magnitude of the (negative and significant) coefficient for Female in the case of Invention (Model 5.3) was much larger than that of the other two cases, suggesting reluctance among females to disclose inventions. Reverse (greater) commercialization propensities were present for group leaders with PHD (Model 5.1), over the other cases.

Finally, group leaders in both science fields were more likely to engage in commercial research activities, ceteris paribus. This is consistent with greater commercialization possibilities in science fields over humanities, and in line with the greater propensities of commercialization in sciences for spin-offs. These results are similar to corresponding findings for the full sample (Table 3).

5.4 | Director subsample

Directors can be seen as higher in the administrative/management hierarchy than are group leaders, with directors being typically responsible for managing numerous group leaders, often across different subdisciplines.[9] Unlike business owners or group leaders, more than half the directors were associated with a patent or an invention (see Note to Table 6).

With Director as the subsample determinant in Table 6, directors in most science fields were more likely to engage in commercial research activities, ceteris paribus. The greater propensities for sciences to commercialize into spin-offs for directors were similar to those for group leaders and for the full sample, (and unlike business owners).

Although the other explanatory variables generally followed similar patterns to earlier results, statistical support was low. Two possible explanations emerge for this relatively low support. First, as expected, the number of directors in the sample was relatively small.[10] This is one reason for the lower statistical support for the explanatory variables in Table 6. Second, the multifaceted administrative tasks, coupled with generally decent remuneration packages that directors receive, likely diminished their incentives and time towards (additional) commercial research activities. Nevertheless, this finding is instructive for technology policymakers.

TABLE 6 Academic leaders and commercial research activities: Director subsample

Dependent variable	Spin-off (6.1)	Patent (6.2)	Invention (6.3)
Discipline1	6.18** (0.38)	1.70** (0.69)	1.55** (0.62)
Discipline2	5.43** (0.32)	0.73 (0.61)	1.09** (0.56)
Experience	0.02 (0.03)	0.01 (0.03)	0.01 (0.03)
PHD	0.65 (0.74)	0.19 (0.70)	0.24 (0.76)
AGE	0.0001 (0.03)	−0.03 (0.03)	−0.01 (0.03)
Female	—	−0.87 (0.84)	—
German	0.03 (0.45)	0.30 (0.40)	0.40 (0.42)
N	60	62	59
Wald χ^2	586.34**	10.24	9.08
Pseudo-R^2	.24	.16	.12

Note. See Table 3. Female dropped out of Models 6.1 and 6.3 due to missing observations. The respective averages of Spin-off, Patent, and Invention for the Director subsample were 0.56, 0.51, and 0.55, respectively.

*Statistical significance at the 10% level.

**Statistical significance at the 5% (or better) level.

5.5 | Robustness check: Using an additional factor

Studies, such as this one, based on information from unique, one-time surveys are susceptible to omitted variable bias. Although the overall regression-fit statistics (i.e., Wald χ^2 and pseudo-R^2s reported towards the bottom of the results tables) somewhat alleviate concerns about omitted variable bias, we further check the robustness by including an additional regressor. Specifically, Table A1 adds a dummy variable identifying researchers with industry work experience (IndustryEXP) as a determinant to Models 3.1–3.3 from Table 3. Greater industry experience fosters networking and makes researchers better realize their opportunity costs, all of which might facilitate certain types of research outputs (e.g., patents and invention disclosures; see Cunningham, Menter, & O'Kane, 2018; Goel & Göktepe-Hultén, 2013). In our sample, nearly 70% of the respondents had experience working in the industry (Table 1).

The results in Models 3.1a–3.3a from Table A1 are remarkably similar to those in Models 3.1–3.3 from Table 3. Further, with regard to the new variable, IndustryEXP, the resulting coefficient was positive in all cases and statistically significant in Models 3.2a and 3.3a. This implies that researchers with industry work experience were more likely to patent and to disclose inventions.[11] Relatively speaking, researchers with industry experience were more likely to disclose inventions than to patent. This finding is consistent with greater transactions costs with patenting (compared with invention disclosures). Overall, the robustness check supports our baseline results in Table 3. The concluding section follows.

6 | DISCUSSION AND CONCLUDING REMARKS

Adding a somewhat new dimension of empirical investigation of propensities of academic scientists to commercialize their research, this paper focuses on the behavior of academic leaders. The extant literature has mainly focused on the role of star scientists, whereas formal research into the behavior of academic leaders seems to be missing. Yet focus on academic leaders is warranted for evaluation of productivity, resource allocation, and for signaling to lower level academics.

With the use of patents, invention disclosures, and spin-offs as measures of research commercialization and focusing on directors, research group leaders, and (academic) business owners as academic leaders, the results, based on a large sample of more than 2,500 German researchers, show differences across academic leaders and across commercialization. In particular, the findings for spin-offs are different than those for patents and invention.

In general, academic leaders in science fields were more likely to commercialize. Doctoral degrees helped patents by business owners and spin-offs by group leaders, whereas female business owners and female group leaders faced challenges patenting and inventing, respectively (see Goel et al., 2015; Link, 2017). Professional experience never aided patenting by any academic leader. The results for the full sample support the hypothesis that academic leaders with greater resources and discretion are more likely to engage in commercial activities.

There were some differences across commercialization even within a subsample. For instance, for business owners, age increased the likelihood of patenting while lowering the chances of spin-offs. German citizenship did not confer appreciable advantages in the three subsamples as well as the full sample. The main findings were robust to the inclusion of industry work experience as an additional regressor (Section 5.5).

The implications for technology policy suggest that multifaceted roles and duties of academic leaders warrant alternate evaluations of their productivities and that some of their innovations such as organizational innovations might not fit the traditional molds of patenting and spin-offs. The other policy take is that the special commercialization challenges faced by female researchers are also to a large extent felt by female academic leaders.

Entrepreneurial academic leaders could be activating (initiating) as well as reacting to the opportunities that are generated within a research group. However, if academic leaders are merely reactive (passive) and following existing rules and regulations, initiatives of the individuals (researcher group members, juniors) may have little chances of being exploited. Incentives to engage in bottom-up entrepreneurial activity are harmed as a result (cf. Rotemberg & Saloner, 1993). Traditional academic leaders with managerial experience will still be attractive candidates in some contexts. However, instead of searching for right leadership traits, universities and public research organizations (should) question what the leadership challenges are, how those challenges can be solved, and who has the right mix of abilities to do it. We leave these issues for future research.

ACKNOWLEDGEMENTS

We thank James Cunningham and a referee for useful comments and suggestions. Göktepe-Hultén acknowledges the financial support of Riksbankens Jubileumsfond and KNOWSCIENCE Project, and Project Leader Tomas Hellström.

ENDNOTES

[1] Most empirical research on academic leadership focuses on academics who are having a leadership position in the formalized structure of a university such as vice chancellors or deans. These studies are focusing on traits, roles, and administrative activities. Given the importance of knowledge transfer from academia to industry and academic leaders' role, it is important to investigate (zoom into) this specific subset of scientists, that is, academic leaders and their commercial engagements.

[2] Cunningham, O'Reilly, O'Kane, and Mangematin (2014), however, note the limitations that some academic leaders like principal investigators might face.

[3] It is worth pointing out that the Spin-off variable is somewhat more general (than Patent or Invention) in that the underlying question asked the respondent whether there was a spin-off at their institute (coded 1; see Table 1). Thus, the spin-off could be by the respondent or by other researchers (in which case, Spin-off would partly capture spillovers).

[4] It could conceivably be the case that being a group leader enhanced one's chances of eventually being a director. We are unable to track this in our one-time survey. The correlation between Director and GroupLead in Table 2 was −.061.

[5] The default discipline is humanities.

[6] As the reader would note, the aspects considered do not exhaust all research output, which would include presentations, publications, and other dimensions in humanities (see, for example, Lacetera, 2009). We are, however, constrained by the information available in the underlying survey, which was conducted without this particular study in mind.

[7] Similar disadvantages are also faced by certain inventions that are nonpatentable, for example, organizational innovations (Goel & Rich, 2005). This aspect might be particularly relevant for academic leaders.

[8] An exception is the models in Table 6 with Director as the subsample cutoff. This is likely due to the low sample size in these cases.

[9] Using a different MPS sample, Buenstorf (2009) examines the effects of commercial activities of directors on their research output (denoted by publications and citations) and found that invention does not adversely affect research output.

[10] The differences in the sizes of the subsamples also prevent us from comparing them more directly to check 1 (see Section 1 for more on this hypothesis).

[11] The insignificance of IndustryEXP in Model 3.1 with Spin-off as the dependent variable is partly due to the general nature of the Spin-off variable (see Table 1).

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How to cite this article: Goel RK, Göktepe-Hultén D. Academic leadership and commercial activities at research institutes: German evidence. *Manage Decis Econ*. 2018;39:601–609. https://doi.org/10.1002/mde.2932

APPENDIX A

TABLE A1 Academic leaders and commercial research activities: Robustness check using an additional factor

Dependent variable	Spin-off (3.1a)	Patent (3.2a)	Invention (3.3a)
Discipline1	6.48** (0.06)	1.15** (0.23)	0.86** (0.20)
Discipline2	5.55** (0.06)	0.95** (0.23)	0.66** (0.20)
Experience	0.03** (0.01)	0.02** (0.01)	0.02** (0.01)
PHD	−0.12* (0.07)	0.50** (0.09)	0.39** (0.09)
AGE	−0.02** (0.005)	0.02** (0.01)	0.01** (0.01)
Female	0.03 (0.06)	−0.29** (0.09)	−0.26** (0.09)
German	−0.10 (0.06)	0.12 (0.08)	0.06 (0.08)
IndustryEXP	0.06 (0.07)	0.29** (0.09)	0.37** (0.09)
N	2,573	2,566	2,561
Wald χ^2	13,367.70**	235.78**	212.38**
Pseudo-R^2	.20	.15	.14

Note. See Table 3.

*Statistical significance at the 10% level.

**Statistical significance at ttphe 5% (or better) level.