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Factors facilitating the inventing academics' transition from nascent entrepreneurs to business owners

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Joao Ricardo Faria, Rajeev K. Goel, and Devrim Göktepe-Hultén

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ABSTRACT

FACTORS FACILITATING THE INVENTING ACADEMICS' TRANSITION FROM NASCENT ENTREPRENEURS TO BUSINESS OWNERS

Joao Ricardo Faria, Rajeev K. Goel, and Devrim Göktepe-Hultén

Considering the sequential nature of nascent entrepreneurship and business ownership, this paper examines the propensities of academic entrepreneurs to be business owners. A theoretical model sets up the empirical analysis based on survey data from a large German public research institute. Traditionally, scientists and entrepreneurs have been seen to occupy opposite ends of a spectrum in terms of their role in innovation. In academic entrepreneurship the two combine on a number of activities. In order to understand the ways in which academic inventors move from pure patenting to nascent entrepreneurship to business ownership and connect seemingly divergent activities. We model their behavior by looking at various factors among German scientists. Academic inventors present a critical case since science and entrepreneurship are often seen as radically different, not the least in terms of knowledge production. By bringing the analysis from the level of social behavior and roles to the level of knowledge production, we can better address questions such as: How is knowledge in the interfaces of epistemic communities produced? How can such knowledge be organized and sustained? and How can relations between individuals on 'opposing sides' be constructively managed? The empirical results show that scientists' positive attitudes towards commercialization of results consistently contribute to tendencies towards academic entrepreneurship; however, the academic discipline and risk aversion did not have a statistically significant impact. Having a doctoral degree lowered the propensities toward nascent entrepreneurship, but had the opposite effect on business ownership. Finally, age and experience made business ownership more likely. The results of this study would contribute to a more general theory of how scientists can combine their commercial and scientific activities in spite of an alleged divergence.

Keywords: academic entrepreneurship; invention; spinoffs; business entrepreneurs; nascent entrepreneurs; commercialization costs; Germany

JEL classification: O33; O52; L26

Joao Ricardo Faria
Florida Atlantic University
777 Glades Road
Boca Raton, FL 33431, USA
Email:
jfaria@fau.edu
www.fau.edu

Rajeev K. Goel (Corresponding author)
Illinois State University,
Normal,
IL 61790-4200, USA.
Email:
rkgoel@ilstu.edu
and
Kiel Institute for the World Economy
Kiellinie 66
D-24105 Kiel, Germany
Email: rajeev.goel@ifw-kiel.de
www.ifw-kiel.de

Devrim Göktepe-Hultén
Lund University
Box 117,
221 00 Lund, Sweden
Email:
devrim.goktepe-hulten@fek.lu.se
www.lunduniversity.lu.se

1 Introduction

Innovation system approaches have been providing insights into the economic performance and competitiveness in the OECD countries. They identified that innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. These actors are primarily private enterprises, universities and public research institutes and the people within them (Freeman 1987; Lundvall 1992). The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use related technologies. Innovation policy and the related analysis has traditionally focused on inputs (such as R&D investments and research personnel) and outputs (such as scientific publications, patents, and high-tech start-ups). The interactions among these actors are as important as investments in research and development and they are key to translating the inputs into useful outputs. The flow of knowledge between enterprises, universities and research institutions is fundamental for enhancing innovative performance. Sharing of both tacit and/or codified knowledge (in publications, patents and other sources can take different forms such as joint research, personnel mobility, co-patenting, and other less formal collaborations (Goel and Grimpe 2012)). Firms are often at the center of the innovation system and the innovative firm is seen as operating within a complex network of co-operating and competing firms and other institutions, building on a range of joint ventures and close linkages with suppliers and customers (Lundvall 1992; Lundvall 2010). In some cases, specific knowledge (e.g. patents or scientific papers) transferred is not so important, but rather the general quality of researchers' knowledge and skills to solve problems. As knowledge embodied in scientists as "human capital" is central to knowledge production, the movement of people and the knowledge they carry with them (often termed "tacit knowledge") is a key flow in national innovation systems. Public policymakers are increasingly urging scientists to collaborate with industry to increase the innovativeness and competitiveness of their economies.

This discourse, especially in Europe, has paved the way for the promotion of the "third task activities", i.e. the inclusion of a commercial and economic development mandate for universities in addition to their traditional tasks of education and research (Etzkowitz 1997). In addition to teaching and research tasks, universities are expected to actively participate in the diffusion and application of knowledge to other sectors of the society. The starting point is the assimilation of basic research into codified knowledge and thus into usable information (Laredo 2007). In recent times, there is a movement towards an interpretation of third task activities as commercialization of academic research (Jacob et al. 2003). The argument for this specification of "third task" is that the propensity of commercial activities at universities is lower in Europe compared to the high levels of scientific performance and investments. This perception is partly exacerbated by the impression that universities in the USA have higher performance in commercializing their research results due to the enactment of the Bayh-Dole Act of 1980. Since its enactment, the Bayh-Dole Act has resulted in a rapid increase in university patenting activities. Despite some disagreements and skepticism, commercialization of scientific research results, in particular via patents and licensing and academic start-ups is seen largely as a potential source of revenue, and an avenue to enhance economic growth and development (Etzkowitz 2001; Mowery et al. 2004). It is, thus, not surprising that several countries, both developing and developed, have taken steps to initiate policy tools to promote academic entrepreneurship and to facilitate relations between universities, firms and public agencies.

Commercialization of scientific research results can be achieved in many different ways, but much of the literature has focused on the role of patents and licensing (Bercovitz and Feldman 2008; Siegel et al. 2004) and academic spin-offs have also received a substantial amount of attention from researchers (Di Gregorio and Shane 2003; Shane 2004). Studies on academic entrepreneurship have focused on a few themes like the characteristics of the 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 (Zucker et al. 1998).

The contribution of this paper is twofold: Firstly, it yields a theoretical model that highlights the integration among three modern sectors responsible for the production of science and technology and its commercialization, namely, universities, laboratories and private companies. The model yields a full characterization of the integration of commercial activities into a knowledge-producing environment. It provides optimal equilibrium levels for the number of scientists, patents, and as well as the determination of scientists' pay in laboratories and for-profit firms, and the optimal market value of patents. In addition, the model also determines the optimal number of entrepreneurs, distinguishing the ones with scientific background from others. The second contribution of this paper is the estimation of the optimal number of academic entrepreneurs derived from the model, using the dataset that comes from a large survey of researchers at the Max Planck Society [MPS] in Germany. The empirical estimation takes account of the sequential stages of academic entrepreneurship, with nascent entrepreneurship frequently preceding business ownership.

Regarding scientists' scholarly vs. entrepreneurial activities, Jain et al. (2009) suggested that academic entrepreneurs have an entrenched and usually well-developed academic identity that is more valued than the newly adopted "entrepreneurial persona". They proposed two separation mechanisms, buffering and delegation, that help protect and defend the academic self from entrepreneurial 'contamination'. Karhunen et al. (2017) challenged this view by affirming that, in the Finish context, academic entrepreneurs viewed their two roles as compatible and complementary and that science-based entrepreneurship is described as an integral part of the research process. Some scholars have tried to identify why (and how) scientists choose a particular mode for technology transfer and have aimed to distinguish *academic entrepreneurs* as "active versus passive commercializer". While the former type tries to implement their research results in the form of university spin-offs by starting their own business, the latter refers to scientists who adapt their basic research agendas to the new funding sources (industry) but without a financial growth motive, forming a start-up or any perspective of leaving academia. (Meyer 2005; Göktepe-Hultén 2008). They have referred to financial incentives and support provided by institutions and organizations to explain the entrepreneurial activities of researchers. Göktepe-Hultén and Mahagaonkar (2010) and Lam (2010) investigated the motivations of scientists to patent and commercialize their scientific research results.

High level of mobility of qualified personnel contributes to the overall skill level of the labor force as well as to the innovative performance of the economy (Stenberger et al.1996). Although the evolution of pure scientists to become academic entrepreneurs has been the subject of several studies (Etzkowitz 2001; Meyer 2005), science and technology policy analysts have paid relatively little attention to independent or lone inventors, in particular the transition from inventorship to entrepreneurship. Factors that may influence inventors and or aspiring (nascent) academic entrepreneurs to become business owners are less well understood compared to the praise or criticism that academic entrepreneurship has received. That is the gap that this paper is trying to address.

The paper is structured as follows. The next section provides the background and develops a theoretical framework on the relationship between the different types of factors on the academic entrepreneurship, followed by the empirical model and estimation results. The paper ends by discussing some policy implications.

2 Literature Review

Universities and Public Research Organizations (PROs hereafter) have been traditionally tasked with the key roles of education and producing basic research. This understanding had changed when several policy initiatives began pushing in the direction of adding a “third mission” of technology transfer (Etzkowitz 2001). This is supported by reference to a number of important developments of successful cases such as Stanford and MIT as source of university income maximization (Etzkowitz 2001) and to compensate the need for new sources of funding for academic research (Geuna 2001), and the need to close the gap between discovery and utilization of university research by industry (Mowery et al. 2004) and a tool for making a social and economic impact (Grimaldi 2011). The process of innovation, through which knowledge is created, is increasingly a collective endeavor, shaped by institutional and knowledge-sharing systems. The movement of scientists carrying the “tacit knowledge” from one epistemic sphere to another epistemic sphere where knowledge is being applied and commodified is key in national innovation systems. Personal interactions, whether on a formal or informal basis, are an important channel of knowledge transfer within industry and between the public and private sectors. Despite some policy measures, the mobility rate of university researchers is low and research institute personnel’s movement to the industry is low. A majority of scientists entering the business sector quit research and switch to other activities within industry (Stenberger et al. 1996).

Studies of academic entrepreneurship have focused on a few themes like the scientists’ values and attitudes towards commercialization, traits of the scientists (demographics, age, experience, position, citizenship and other related human capital aspects); the environment surrounding the scientists (peers and leadership towards commercialization), as well as pecuniary and non-pecuniary rewards of commercialization and the support provided by institutions and organizations to explain the entrepreneurial activities of researchers in the new ventures created and the process of new venture creation (Zucker et al. 1998). In the light of these studies, we aim to investigate the factors behind the transition of individual scientists’ engagement in commercial acts in entrepreneurial and commercial acts. Which factors significantly impact entrepreneurship propensities of academics, and especially their transition from nascent entrepreneurs to business owners?

a. Impacts of values and attitudes

While considerable attention has been devoted to institutional and contextual factors when investigating the concept of academic entrepreneurship, individual-level studies remained relatively few (Rothaermel et al. 2007). Most policy suggestions often inaccurately assume that scientists have not developed their own values, implying that once laws, institutions and organizations are established, scientists will be satisfied and thus follow the rules and regulations automatically. Although most academics aren’t religiously adhering to Merton’s norms in practice, they nevertheless have a major normative significance for the community and influence scientists’ identity (Lam 2010). Merton (1957) defined cultural expectations related to academic work through four different norms of behavior: universalism (or the dissociation between the scientific statements and the personal characteristics of the scientist), communality (or the duty to share one's research results with all other researchers, thus allowing for its wide dissemination and replication), disinterestedness (which implies that research is conducted only for the sake of pursuing the truth and intellectual progress and not for financial or personal motives), and organized skepticism (or the need for critical review of scientific statements to ensure the correctness of deduction and conclusions).

Latour (1987) argued scientists acquire a range of investments – skills, beliefs, past achievements, objectives – throughout their career trajectory, which they intrinsically try to preserve and enhance. Such investments could be offered explanations of scientists' decisions and judgments in their endeavors. Scientists may not be influenced directly by policy tools as their own values may prevail over the alleged impacts of institutions and organizations (Shapin 1988). Scientists may want others to follow their values and objectives and impose their behaviors on others.

The commercialization of scientific research results is risky and uncertain (Audretsch and Stephan 1999). Attitudes towards risk are shaped partly by a person's psychological bent and partly by past experiences (Goel and Göktepe-Hultén 2013). Scientists' attitudes towards risk and uncertainty have an impact on their transition from inventing (invention disclosure to start-up formation and business ownership). The scientific reputation and skills of scientists provide credibility and capability to any anticipated commercial project (Audretsch et al. 2006). Due to low risks of losing their image and credibility, scientists with strong scientific reputations have higher incentives to patent. The propensity of a scientist to engage in patenting is positively related to the amount of the expected rewards. Negative tendencies would be more pronounced, ceteris paribus, for more risk-averse inventors. Due to the uncertainties regarding commercialization of science, one would expect greater uncertainty to lower tendencies toward invention disclosure and patenting (Goel and Göktepe-Hultén 2013).

b. Impacts of internal experience

Institutional experience can lower transaction costs of entrepreneurship via familiarity with rules and norms, yet it can also lead to lethargy. Stephan and Levin (2005) investigated whether scientists' personal characteristics, age (life-cycle), citizenship status, gender and receipt of federal funding were related to patenting activities. They found little evidence of age effects, yet they found that tenured scientists are more likely to patent than non-tenured ones (Levin and Stephan 1991). Goel and Göktepe-Hultén (2018) consider the behavior of academic leaders.

Bercovitz and Feldman (2008) found that certain high-opportunity departments, such as genetics and pharmacology, showed high levels of disclosure events per researcher. Faculty who are involved in multidisciplinary fields or who collaborate with industrial partners are more likely to patent. In emerging fields, scientists are more open and motivated to patent in order to establish their emerging fields or ideas. In emerging fields, scientists are more open and motivated to patent and even start a spin-off company when there is no industrial interest in order to launch an emerging field or embryonic idea.

While scientific discipline plays an important role in the commercialization of research results, local group norms and culture social norms and the university's tradition encouragement of entrepreneurship were important determinants of successful and widespread entrepreneurship at MIT (Louis et al. 1989; Roberts 1991). In addition, professional training does more than simply transfer technical knowledge; it actively socializes people to value certain things above others (Bercovitz and Feldman 2008).

From the early 1980s, government agencies have encouraged collaboration through requiring it as a condition for funding, especially between universities and industries (Geuna 2001) and technology transfer policies have facilitated collaboration among researchers and industrial R&D organizations.

University–industry collaboration may play a unique role in each country, based on the specific conditions of firms, universities and the socioeconomic context (Azagra-Caro 2007; Bergman 2010). For instance, Freitas et al. (2013) discuss the role of university–industry collaboration for the development of innovation in mature and emergent industries in newly industrialized countries. They show that university–industry collaboration in Brazilian industries is more likely to be initiated by current and former students, and to be funded from several sources, including postgraduate grants. Industrial interactions with universities may be facilitated either by sending employees to a university for training or by firms investing in networking with a university. Faria et al. (2018), however, show that innovation in Brazilian universities is negligible, and that universities' market evaluation is negatively related to innovation, suggesting that the focus on patenting and on the transfer of knowledge/technology to industrial processes is still precarious in Brazil. A study by Cowan and Zinovyeva (2013) investigates whether the development of a university system affected local industry innovation in Italy between 1985 and 2000. They find that opening of new schools increased regional innovation activity within 5 years, thus suggesting that local industry innovation is mostly caused by the high-quality scientific research brought to the region with new schools. A similar study by Kafouros et al. (2015) examines how collaborations with universities influence the ability of Chinese emerging-market enterprises to develop innovations. These authors show that sub-national institutional disparities have a deep impact on the relationship between academic collaborations and firms' innovation performance.

Scientists who have stronger social networks may have easier access to complementary skills and resources that may be necessary for patenting. They may, therefore, patent more than scientists who do not enjoy the same social networks. Researchers who change jobs between academia, industry and government, sometimes changing sectors, or are working in multiple settings simultaneously, should have developed more diverse skills and networks that may motivate them to patent (Dietz and Bozeman 2005). Such meaningful relations and linkages that scientists have with others are important. Goel and Göktepe-Hultén (2013) find that both industrial cooperation and consulting boost patenting by academic researchers, with the influence of cooperation being more statistically robust.

c. Other factors: Citizenship, leadership, gender

We consider other factors, based on the personal attributes of researchers. These include their citizenship, gender, internal leadership.

Citizenship

Alongside scientific skills, demographic factors also influence the transition of scientists from one type of commercialization to another. Innovation productivity of foreign researchers and the human capital that empowers them is an important issue for policymakers due to implications for technology transfer and knowledge dissemination. Previous studies report that foreign-born and foreign-educated scientists made are likely to be more productive for several reasons (Levin and Stephan 1999, Teichler 2015, see Goel and Göktepe-Hultén 2020 for more information about discussions on brain-drain, brain-grain, brain-circulation). However, despite new geographical location certain important cultural, social, institutional and organizational barriers remain for foreign (non-citizen) scientists. Success for foreign scientists in innovation activities depends heavily on becoming integrated in the host country's knowledge and commercial flows and networks. In order to address such challenges, an increasing number of countries are implementing measures to empower foreign researchers' role for the overall national innovation system of the country, especially in nations with a significant presence of expatriate researchers. Understanding "hybridization of foreign scientists" (i.e. the transition from one role to another) is therefore important for science and innovation policy.

Gender

As the persisting gender gap to women's disadvantage in scientific productivity is well documented, it is further hypothesized that commercialization of scientific outcomes (research results, publications, knowledge) in terms of industrial and commercial uses will be also disadvantageous to women (Goel, Göktepe-Hultén and Ram 2015). Despite the political and institutional pressures on women scientists to be competitive in the commercial and innovation front it is still hard for women scientists to combine different tasks. Well-known human and social factors that are often utilized to explain the likelihood of becoming an entrepreneur indicate advantages for male faculty. Studies showed that more established faculty (e.g. having a tenured position) with higher scientific productivity (publications) or with industrial work or collaboration/consultancy experience consultancy) who are having more or resources are found to be mostly men and they are generally found to be more successful in commercializing research results (Link et al. 2017; Bozeman and Gaughan 2011; Bozeman et al 2013). Understanding "hybridization of women scientists" (i.e. transition from one role to another) is therefore important for science and innovation policy.

Leadership

Academic leaders often understand the organizational complexity of PROs 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). Academic leaders not only shape the norms and culture will follow the institutional rules and regulations and expectations. They know whom to consult -formally and informally- and when to bring about change.

In comparison to researchers, academic leaders (PIs, research group leaders, directors) may have stronger social networks and 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 to commercialize their research results more than scientists who do not enjoy the similar social networks (Goel and Göktepe-Hultén 2018). Likewise, understanding the relevance of leadership on the "hybridization of scientists" (i.e. transition from one role to another) is important for science and innovation policy.

To sum-up, we have reviewed the literature on university technology transfer and there are a number of studies that examine ex-post entrepreneurial behavior, based on data from actual entrepreneurs (Goel and Grimpe 2012; Goel and Göktepe-Hultén 2013; Krabel and Mueller 2009). Accordingly, we aim to control for impacts of internal (institute) experience, perceived commercialization costs, spillovers from institute spinoffs, effects of risk aversion. If factors facilitating or inhibiting the tendencies towards the transition from one type of commercial endeavor to entrepreneurship can be identified, then institutional support and technology policies can be appropriately (tailored) adopted. This should result in a greater number of academics who do eventually become entrepreneurs.

3 Max Planck Society: Background & Research Context

This study is based on a European Public Research Organization, the Max Planck Society (MPS hereafter). MPS was founded in the late 1940s in Germany and it is funded to a large extent by both the federal and state governments. Although the aim is to conduct basic research in the interest of the general public in natural sciences, life sciences, social sciences and the humanities; the institutes associated with MPS-scientists pursue new and innovative ideas that the teaching-intensive German universities are not in a position to conduct adequately. In order to accelerate the transfer of research results to potential applications, MPS has recently launched several initiatives to facilitate collaboration between MPS-scientists and industrial firms. Research contracts and co-operations, with commercial enterprises and consultancy agreements in connection with research contracts are encouraged yet the institutes are encouraged to keep a degree of scientific freedom in these co-operative endeavors. Moreover, cooperative projects and joint activities with other public research organizations (e.g. Fraunhofer Society) in certain fields have been initiated.

Patenting and start-up companies have become important channels for transferring technology and intellectual knowledge originating from the MPS to industry. MPS established one of the first technology transfer offices in Germany; formerly named Garching Instrumente, this company is now known as Max Planck Innovation GmbH. MP-Innovation (hereafter) provides legal advice and support to those interested in patenting or establishing a start-up company. Over the last 50 years, MP-Innovation has supervised more than 4,500 inventions and concluded 2,500 license agreements. Almost 80 percent of the roughly 160 spin-offs supervised by Max Planck Innovation are still in business today; seven of them have even made it to the stock exchange. Measured by its income of approximately EUR 500 million, Max Planck Innovation is one of Germany's leading technology transfer organizations, the other being Fraunhofer (another public research organization in Germany). Additional details can be found at https://www.max-planck-innovation.com/files/Downloads/MPR_2020_Sp_EN.pdf.

4 Data: MPS Scientists' Survey

This study is part of a larger project on the identification of commercial activities among scientists employed at Max Planck Society. The collection of the data was accomplished through a screening survey of all scientists associated with different institutes of Max Planck Society and follow-up surveys with them. Specifically, the survey first identified almost more than 2500 scientists' engagement in different forms of academic entrepreneurship, and collected in-depth data about their work environments; perceptions on the commercialization of science. The survey was conducted in the last part of 2007 and during 2008 at around 80 institutes specialized in different scientific disciplines and located different cities in Germany. This rich data set has been comprehensively used in previous studies -e.g. Krabel and Muller (2009), Göktepe-Hultén and Mahagaonkar (2010), Krabel, Siegel, Slavtchev (2012), Goel and Göktepe-Hultén (2013).

Before performing the survey, the executive directors of each institute were asked for permission to interview the scientists. 67 out of 80 institutes agreed to participate in the study and provided us with the necessary contact information to scientists. The population for the survey consisted of 7,808 scientists of 67 Max Planck Institutes, and 2,604 responded to the survey denoting a response rate of 33.35 percent (see Krabel and Muller (2009) for details).

The survey questions were particularly designed to analyze the entrepreneurial activities of scientists. Accordingly, besides the questions explicitly focusing on entrepreneurship, also a broad range of individual characteristics (work experience, skills and competences; risk aversion and psychological traits; social, family and demographic factors; etc.) and professional characteristics (position; type and innovativeness of research; scientific excellence; industry contacts; institutional characteristics; etc.) were collected which might be related to both the propensity to start a business and to the development and success of the ventures (see Max Planck Innovation GmbH. (2020) and Max Planck Research (2020)).

5 The Theoretical Model

The model shows the integration among three modern sectors responsible for the production of science and technology and its commercialization, namely, universities, laboratories and private companies. Universities by offering a number of scientific graduate programs are responsible for the formation of PhDs. Laboratories hire PhDs who are responsible for patenting efforts, and these efforts face the trade-off between public and private science. Sequentially, firms play after universities and laboratories. They use scientists and patents to create spin-offs that depend on entrepreneurial vision and organization. This formulation, however, ignores the possibility where firms and laboratories may be integrated (Goel 1992). The model allows us to distinguish between academic entrepreneurs [the ones holding a PhD degree] from others.

The model provides a full characterization of the integration of commercial activities into a knowledge-producing environment. It determines the equilibrium levels for the number of scientists, patents scientists pay in laboratories and for-profit firms, and market value of patents. In addition, the model also determines the optimal number of entrepreneurs, allowing for the distinction between academic entrepreneurs and others. Next, we model the representative university's problem.

5a. The University's Problem:

The representative university aims at maximizing formation of human capital, i.e., the number of newly minted PhDs, *N*. The faculty of graduate programs at time t is composed by people with PhDs in time *t-j*, where *j* = 1,2,...We assume quadratic costs to form (produce) a PhD, so as that the university maximizes:

$$U = (aN_{t-j})N_t - 0.5\vartheta N_t^2 \quad \text{... (1)}$$

Where parameter *a* captures the marginal productivity of PhDs, and the parameter ϑ its marginal cost. Without loss of generality, let us assume *j* = 1, so as we can rewrite (1) as:

$$U = (aN_{t-1})N_t - 0.5\vartheta N_t^2 \quad \text{... (1')}$$

The first-order condition for a maximum yields the optimum number of PhDs supplied by the university:

$$N_{t} = \frac{aN_{t-1}}{\vartheta} \quad \text{...(2)}$$

Let us assume that the variation of newly minted PhDs is constant, equal to g:

$$g = N_{t} - N_{t-1} \qquad \text{...(3)}^{1}$$

Advancing Eq. (2) in one period and using Eq.(3) yields the optimal number of PhDs:

$$N_{t} = \frac{\vartheta g}{a-\vartheta} \qquad \text{...(4)}$$

Notice that the right-hand side of Eq.(4) is constant, therefore it yields the optimal number of PhDs, N^*:

$$N^{*} = \frac{\vartheta g}{a-\vartheta} \qquad \text{...(4')}$$

Note that $(\partial N^*/\partial a) < 0$, implying that with a higher marginal product, fewer PhDs are needed,[2] and $(\partial N^*/\partial \vartheta) > 0$, which follows from the assumption of a constant growth in PhDs in (3). In the empirical analysis below, we have informed on whether a scientist holds a PhD (variable PHD in Table 1).

5b. The Laboratory's Problem:

The representative laboratory may have two different objectives: (1) to produce basic science that is a public good; and/or (2) to produce applied science that may yield patents that is a private good. The laboratory uses qualified personnel, mostly PhD holders,[3] to achieve either or both objectives:

$$L = \tau D N_{t} S_t - 0.5\beta S_t^2 - wN_t \qquad \text{...(5)}$$

Where S is science, D is the scientific area [medicine, engineering, etc], w is the salary paid to PhD personnel, τ is patenting effort, β is academic effort to produce pure science. In our empirical section, we have information on the academic discipline, with 44 percent of the respondents being in biology or medicine, 47 percent in physics, chemistry or technics, and the rest in humanities (Table 1). The laboratory faces convex costs, given by the term $0.5\beta S_t^2$ associated with the production of basic or pure science.

The optimal choice of S yields:

$$S_{t} = \frac{\tau D N_{t}}{\beta} \qquad \text{...(6)}$$

Inserting Eq. (4) into (6) yields the optimal amount of science produced by the laboratory:

$$S^{*} = \frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right) \qquad \text{...(7)}$$

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[1] *This constant growth of PhD's is assumed for analytical tractability.*

[2] *Also, $(\partial^2 N^*/\partial a^2) > 0$, signifying a convex relation.*

[3] *More than half the respondents in our sample held a PhD degree (Table 1).*

Note that $(\partial S^*/\partial g) > 0$, implying that the production of science increases as the growth of PhD's increases.

Maximizing (5) with respect to *N* and using Eqs. (4), (6) and (7), one can determine the optimal wage of scientists working for Laboratories as:

$$w^* = \tau D S_t = \tau^2 \frac{D^2 N_t}{\beta} = \tau^2 \frac{D^2}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right) \qquad \ldots(8)^4$$

The representative firm's (i.e., business owner's) problem in modeled next.

5c. The Representative Firm's Problem:

The representative firm also has two options at hand: (1) it may continue operating as usual, using entrepreneurial effort *E* and scientists to produce good *Q*; and/or (2) it may form a spin-off by producing innovations with the science created by the laboratory. The firm aims at maximizing profits:

$$\pi = E_t^b N_t^{1-b} + \varepsilon E_t N_t S_t - c E_t - r(S_t) - w' N_t \qquad \ldots(9)$$

Where $E_t^b N_t^{1-b}$ is the production function of good *Q* [whose price is normalized equal to 1] and *b* and (1- *b*) are the output elasticities of entrepreneurial effort and scientists, respectively. The term $\varepsilon E_t S_t$ is the introduction of innovation, where εE_t is the entrepreneurial effort to make the innovation happen, c is the unit cost of entrepreneurial effort, *r*(.) is the patent pay and *w*' is the salary of a scientist employed by the firm.

The firms choose the optimal level of entrepreneurial effort that maximizes profit:

$$E_t = \left(\frac{b N_t^{1-b}}{c - \varepsilon S_t N_t}\right)^{1/(1-b)} \qquad \ldots(10)$$

Plugging Eqs. (4) and (7) into Eq. (10) yields the optimal level of entrepreneurial effort:

$$E^* = \left(\frac{b\left(\frac{\vartheta g}{a-\vartheta}\right)^{1-b}}{c - \varepsilon \frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^2}\right)^{1/(1-b)} \qquad \ldots(11)$$

One can determine the market value of the patent by maximizing (9) with respect to *S*:

$$r'(S_t) = \varepsilon E_t N_t \qquad \ldots(12)$$

Where $r'(S_t)$ is the market value of the patent (see Kamien and Tauman 1986).

[4] *Unfortunately, our data sample does not have information on scientists' salaries.*

Introducing (4) and (7) into (12) yields:

$$r'\left[\frac{\square}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)\right] = \varepsilon E_t\left(\frac{\vartheta g}{a-\vartheta}\right) \qquad ...(13)$$

In the same vein, one can find the optimal pay of scientists in the market, *w*′, by maximizing (9) with respect to *N*:

$$w' = (1-b)E_t^b N_t^{-b} + \varepsilon E_t\, S_t \qquad ...(14)$$

Substituting the optimal levels of *S*, *N* and *E* into (14) yields:

$$w' = (1-b)\left(\frac{b\left(\frac{\square}{a-\vartheta}\right)^{1-b}}{c-\varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^2}\right)^{b/(1-b)}\left(\frac{\vartheta g}{a-\vartheta}\right)^{-b} + \varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)\left(\frac{b\left(\frac{\vartheta g}{a-\vartheta}\right)^{1-b}}{c-\varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^2}\right)^{1/(1-b)} \qquad ...(15)$$

If scientists working for laboratories are perfect substitutes for scientists working for private firms, then *w** = *w*′, and we have from Eqs. (8) and (15)[5]

$$\frac{\square}{\beta}\left[\tau - \varepsilon\left(\frac{b\left(\frac{\square}{a-\vartheta}\right)^{1-b}}{c-\varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^2}\right)^{1/(1-b)}\right] = (1-b)\left(\frac{b\left(\frac{\vartheta g}{a-\vartheta}\right)^{1-b}}{c-\varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^2}\right)^{b/(1-b)}\left(\frac{\vartheta g}{a-\vartheta}\right)^{-b-1} \qquad ...(16)$$

This model provides a full characterization of the integration of commercial activities into a knowledge-producing environment. It provides optimal equilibrium levels for the number of scientists, *N**, patents *s** [assuming a fixed proportion *y* between science production and the number of patents *e*, e.g., *s**= *yS**], and as well as the determination of scientists pay in laboratories and for-profit firms, and the optimal market value of patents. In addition, the model also determines the optimal number of entrepreneurs *e**, which is the object of the next section.

5d. Entrepreneurs:

The model allows us to distinguish between academic entrepreneurs [the ones holding a PhD degree] from others. First, we assume a proportion x between entrepreneurial effort and the number of entrepreneurs *e*:

$$e^* = xE^* \qquad ...(17)$$

The term *x* can be decomposed in two terms, the first relates to the number of academic entrepreneurs, scientists that become entrepreneurs, and the second term depends on other types of entrepreneurs [denoted by *M*], without a PhD degree and deep scientific knowledge:

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[5] *This aspect is somewhat accounted for in our empirical analysis by including the variable INDwork that identifies scientists with industry work experience.*

$$x = \alpha N^{*} + (1-\alpha)M \qquad \text{...(18)}$$

Where the parameter α captures risk and/or commercialization attitudes of the academic entrepreneur.

Plugging Eq.(18) into (17) and using (4) and (11) yields the optimal number of entrepreneurs:

$$e^{*} = xE^{*} = [\alpha N^{*} + (1-\alpha)M]E^{*} = \left[\alpha \frac{\vartheta g}{a-\vartheta} + (1-\alpha)M\right]\left(\frac{b\left(\frac{\vartheta g}{a-\vartheta}\right)^{1-b}}{c-\varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^{2}}\right)^{1/(1-b)} \qquad \text{...(19)}$$

From (18) and (19) one can have the determination of the optimal number of academic entrepreneurs:

$$\alpha N^{*}E^{*} = \left[\alpha \frac{\vartheta g}{a-\vartheta}\right]\left(\frac{b\left(\frac{\vartheta g}{a-\vartheta}\right)^{1-b}}{c-\varepsilon\frac{\tau D}{\beta}\left(\frac{\vartheta g}{a-\vartheta}\right)^{2}}\right)^{1/(1-b)} \qquad \text{...(20)}$$

Equation (20) is the focus of the empirical section of this paper. Therefore a detailed analysis of it is necessary. According to Eq. (20) the optimal number of academic entrepreneurs depend positively on the following parameters: the marginal cost of forming newly minted PhDs, ϑ; the growth rate of newly minted PhDs, g; the scientific area in which the academic entrepreneur holds a PhD, D; patenting effort, τ ; entrepreneurial effort to make the innovation happen, ε; the risk and/or commercialization attitudes of the academic entrepreneur, α.

The optimal number of academic entrepreneurs is negatively impacted by the unit cost of entrepreneurial effort, c; the universities' marginal productivity of forming PhDs, a; academic effort to produce pure science, β ; and by the output elasticity of scientitsts,1- b. The formal empirical model follows.

6 The empirical model

Our empirical model accounts for the sequential stages in entrepreneurship, with nascent entrepreneurship preceding business ownership. While the empirical section will address the issues raised above, the correspondence with the theoretical model is imperfect due to the detail in the survey data (the survey was not conducted with this study in mind). About six percent of the survey respondents in our sample were business owners (BUSown), which was double the percentage for nascent entrepreneurs (NASCENTent), see Table 1. This makes sense since not all business owners are necessarily nascent entrepreneurs earlier. Based on the data described in Section 4 and Table 1, the estimated model takes the following form.

Probability of business ownership: $p_1(\text{BUSown} = 1 | X_1) = f_1(X_1'\psi_1)$ ...(21)

and

Probability of nascent entrepreneurship: $p_2(\text{NASCENTent} = 1 | X_2) = f_2(X_2'\psi_2)$ ...(22)

Where

X_1 = NASCENTent. INDwork, ATTRACTent, GROUPlead, PHD, FEMALE, GERMAN, AGE, Discipline1, Discipline2, Z*m*;

And

X_2 = INVENTION, ATTRACTent, GROUPlead, PHD, FEMALE, GERMAN, AGE, Discipline1, Discipline2, Z*m*

m = YEARSMPS, COMMcost, SPINOFFS, RISKaverse

Complete details about these variables, including definitions and summary statistics are in Table 1.

Given the sequential and interdependent nature of business ownership and nascent entrepreneurship, with nascent entrepreneurship frequently preceding business ownership, we use bivariate probit regressions. INVENTION is the offset variable in the NASCENTent in Eq. (22), while industry work experience (INDwork) is the offset variable in the business ownership (Eq. (21)). Tying to the theoretical model above, our dependent variables can be seen as following from Eq. (2) above.

Nascent entrepreneurs generally do not have production facilities set up and are generally testing the waters to see if their venture is viable, before becoming full-fledged business owners. Thus, prior industry experience is less likely to be relevant in someone's propensity to become a nascent entrepreneur (see Dietz and Bozeman, 2005; Goel and Göktepe-Hultén, 2013).

The main explanatory variable of interest is respondents' attitudes towards entrepreneurship (ATTRACTent). Other things being the same, one would expect greater attractiveness of entrepreneurship to lead to greater propensities to be business owners and nascent entrepreneurs. This variable varied between 1 and 5, with higher values signifying greater attractiveness. In our sample, the average value of ATTRACTent was 2.7.

The other control variables, related to scientists' personal attributes and training, include scientists' internal leadership position (i.e., whether the scientists is a group leader (GROUPlead), education (PHD),[6] gender (FEMALE), citizenship (GERMAN), and experience (AGE or YEARSMPS). These have bearings on entrepreneurship costs and networking (Bozeman et al., 2013).

The consideration of age is tied to the life cycle productivity of scientists (Levin and Stephan, 1991), whereas education and leadership are tied to human capital (Zucker et al., 1998). Furthermore, German citizens likely have lower transaction costs due to greater familiarity with the language and institutions (Goel and Göktepe-Hultén, 2019b). Many of these aspects have been reviewed in reviews of the literature – see, for example, Bozeman et al. (2013) and Rothermael et al. (2007).

Discipline1 and Discipline2 account for academic disciplines, with humanities being the default group. Academic disciplines are denoted by the parameter "*D*" in the theoretical model (Eq. (5)). Research output from certain disciplines (e.g., the applied sciences) is more readily commercialized than others.

Later variations of the estimated models also account for perceived commercialization costs (COMMcost), risk aversion (RISKaverse), and spillovers from spinoffs (SPINOFFS). Higher commercial-ization costs can be seen as a barrier to entrepreneurship, while greater risk aversion will make

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[6] *The variable PHD corresponds to N in Eqs. (4) and (4') of the theoretical model.*

entrepreneurship less likely (Goel and Göktepe-Hultén, 2019a).[7] The consideration of spinoffs is tied to spillovers (see Audretsch and Stephan, 1999).

The correlation between BUSown and NASCENTent in our sample was about 0.2 (Table 1A). In our sample, about 13 percent of the respondents were group leaders, 61 percent were German citizens, and a third were females (Table 1). The estimation results are discussed next.

7 7. Results

7.1 Baseline models

Table 2 presents the results for the baseline models. The cross-equation correlation (rho) is significant and different from zero.

We see that attractiveness of entrepreneurship, doctoral degrees and age make business ownership more likely, while being a female has the opposite effects. The challenges facing female academics in becoming entrepreneurs have been well considered in the literature (Bozeman and Gaughan, 2011; Goel et al. 2015; Link, 2017; Stephan and Levin, 2005). Doctoral degrees add to human capital, while also sending positive signals for raising finance. Another aspect of human capital may be tied to age via experience. The effects of academic discipline, German citizenship and being a group leader are statistically insignificant.

However, doctoral education makes nascent entrepreneurship less likely, as does German citizenship, with the impact of entrepreneurship attractiveness remaining positive. These findings may be reflective of different opportunity costs for scientists with doctoral degrees and for German citizens.

In terms of the marginal effects, only ATTRACTent and AGE have positive and significant marginal effects (with BUSown=1; NASCENTent=1).

7.2 Impacts of internal (institute) experience

Table 3 considers the effect of years of internal experience. Greater internal experience, besides adding human capital, would make researchers familiar with the incentives for entrepreneurship. The average work experience among the sample respondents was about 6 years (Table 1).

Results show that greater internal experience (YEARSMPS) makes business ownership more likely, but does not have a significant effect on nascent entrepreneurship. The effects of internal experience are similar to those of age in Table 2. Both age and experience can impact the costs of entrepreneurship, as denoted by c in the theoretical model. The findings with respect to the other control variables were similar to what was presented in Table 2.

7.3 Impacts of perceived commercialization costs

As another dimension, we consider the effects of perceived commercialization costs on the incentives of academics to become business owners and nascent entrepreneurs. In Table 4, While the coefficient

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[7] *Incidentally, the parameter α in the theoretical section captures the risk and/or commercialization attitudes of academic entrepreneurs.*

on COMMcost is, as expected, negative in both cases, it is statistically significant (at the 10% level) in the NASCENTent equation. These findings corroborate the theoretical predictions. Specifically, from equation (20), one can see that the optimal number of academic entrepreneurs (αN^*E^*) would go down as the costs of commercialization (c) increase, i.e., ($\partial \alpha N^*E^*/\partial c$) < 0.

Higher perceived commercialization costs dissuade nascent entrepreneurship, but not necessarily business ownership. This may be due to the fact that entrepreneurs expect to make profits under business ownership, but not necessarily under nascent entrepreneurship.

7.4 Spillovers from institute spinoffs

The total spinoffs at an institute might general positive or negative spillovers for academic entrepreneurs. Such spillovers would be positive when spinoffs add to the researcher's reputation and make securing external credit easier, while at the same time having strengthened internal support such as TTO offices. On the other hand, greater spinoffs might crowd out funding for new ventures or the administration might not feel the need to support new budding ventures when spinoffs are taking place on their own. The corresponding findings in Table 5 are qualitatively similar to those in Table 4 – the coefficient on SPINOFFS is negative in both cases, but (marginally) statistically significant in the case of nascent entrepreneurship. This finding is consistent with the crowding out story.

7.5 Effects of risk aversion

Finally, in Table 6 we examine if greater risk aversion made entrepreneurship less likely by entrepreneurs. We incorporate risk in the theoretical model above via the parameter α. The results show the impact of risk aversion to be insignificant, with the other findings remaining similar to the baseline model in Table 2. Goel and Göktepe-Hultén (2019a) use different measures of risk aversion and find that risk aversion has a negative effect on invention disclosures, but not on patenting.

In sum, we see that attractiveness of entrepreneurship consistently increases the propensity to become a nascent entrepreneur and business owner in all cases, with age/internal experience having a positive effect on business ownership but not on nascent entrepreneurship. On the other hand, greater perceived commercializing costs made nascent entrepreneurship less likely, but not necessarily business ownership. Interestingly, doctoral degrees had opposite effects on the two forms on entrepreneurship, and being a German citizen actually turned out to be handicap with regard to nascent entrepreneurship. The concluding section follows.

8 Conclusions

The concept of the innovation system argues the importance of the flow of technology and information among people, enterprises, and institutions as key to an innovative process. Innovation does not occur in a perfectly linear sequence, but through feedback loops and interaction within this system. It contains the interactions between the actors needed in order to turn an idea into a process, product, or service on the market (Lundvall 1992). Firms, universities, laboratories (public research organizations) and other public organizations are the key stakeholders within the innovation systems. As innovation and entrepreneurship are widely seen as remedies for increasing unemployment and economic problems, public policymakers are increasingly urging scientists to actively participate in the diffusion and application of knowledge to other sectors of society and commercialize their research results in addition to teaching and research tasks. As a result, scientists (universities) are expected to offer a number of scientific graduate programs are responsible for the formation of PhDs, as well as new knowledge, laboratories are responsible for patenting efforts, and these efforts face the trade-off between public and private science. Investors and or firms often use scientists, researchers and patents to create new products or spin-offs that depend on entrepreneurial vision and organization. The mechanisms for knowledge flows include joint industry research, public/private sector partnerships, technology diffusion and movement of personnel. Yet, each actor aims to pursue their own raison d'etre which may eventually lead to conflicts of interest and may hinder the alleged flow and interaction between the actors of innovation systems. While the creation, retention of scientific staff (e.g. PhDs and scientific inventors) are fundamental roles of universities and public research organizations, transition of skilled scientists as business owners, is an aspect of the mobility of human resources, it is a subset of the overall mobility experience in the innovation system. Loss of valuable human resources (scientists) is a challenge for universities and public research organizations.

Considering the sequential nature of nascent entrepreneurship and business ownership, this paper examines the propensities of academic entrepreneurs to be business owners. A theoretical model sets up the empirical analysis based on survey data from a large German public research institute. Traditionally, scientists and entrepreneurs have been seen to occupy opposite ends of a spectrum in terms of their role in the innovation.

By bringing the analysis from the level of social behavior and roles to the level of knowledge production, we can better address questions such as: how is knowledge in the interfaces of epistemic communities produced? how can such knowledge be organized and sustained? how do individuals reconcile ostensibly incommensurable epistemic norms? and how can relations between individuals on 'opposing sides' be constructively managed?

The theoretical model provides a full characterization of the integration of commercial activities into a knowledge-producing environment. It determines the equilibrium levels for the number of scientists, patents scientists pay in laboratories and for-profit firms, and market value of patents. In addition, the model also determines the optimal number of entrepreneurs, allowing for the distinction between academic entrepreneurs from others.

Using survey data on scientists from the Max Planck Society,[8] in the empirical model we take account of the stages of academic entrepreneurship, with nascent entrepreneurship preceding business ownership. The empirical results show that scientists' positive attitudes towards commercialization of results consistently contribute to tendencies towards academic entrepreneurship; however, the academic discipline and risk aversion did not have a statistically significant impact. Having a doctoral degree lowered the propensities toward nascent entrepreneurship, but had the opposite effect on business ownership. This result might signify different opportunity costs of the two entrepreneurship types. The result regarding the negative impacts of commercialization costs suggests the need for government subsidies to boost academic entrepreneurship. Finally, age and experience made business ownership more likely. These findings are consistent with experience lowering the transaction costs of business ownership. While the survey was not conducted with this study in mind, some of the

[8] Additional details about MPS can be found at https://www.max-planck-innovation.com/files/Downloads/MPR_2020_Sp_EN.pdf.

predictions of the theoretical model hold up to empirical verification (e.g., the negative effects of commercialization costs on entrepreneurship).

According to the innovation systems approach, innovation and technology development are the result of a complex set of relationships among the key stakeholders, enterprises, universities and government research institutes (Lundvall 2010). Knowledge flows primarily through joint research activities and technical collaborations, co-patenting, co-publications as well as through more informal linkages and personnel mobility. The lack of interaction between the actors in the system, mismatches between basic research in the public sector and more applied research in industry, malfunctioning of technology transfer organizations, and information and absorptive deficiencies on the part of enterprises may all contribute to poor innovative performance in a country. However, with such broad definition it is nebulous for policy-makers to develop an understanding of how knowledge is actually produced and shared among different epistemic spheres. These findings underscore the specific avenues that policymakers can target in promoting transition from basic science to the market. This would increase the social returns from investment in R&D and basic science.

Table 1: Variable definitions, summary statistics and data sources

Variable	Definition (mean; std. dev.)
BUSown	Respondent was a business owner or started a business in the past, (=1; 0 otherwise), (0.055; 0.227)
NASCENTent	Respondent is a nascent entrepreneur, (=1; 0 otherwise), (0.032; 0.177)
INVENTION	Respondent "disclosed invention to MPS", (=1; 0 otherwise), (0.111; 0.314)
ATTRACTent	Respondent's perceptions about "Attractiveness of starting a business", (1–5 scale, with 1 = Not attractive at all; 5 = Highly attractive), (2.725,1.193)
GROUPlead	Respondent is group leader at MPS, (=1; 0 otherwise), (0.131; 0.337)
COMMcost	Respondent's perceptions about commercialization costs, "Cost of commercialization high", (1–5 scale, with 1 = strongly disagree; 5 = strongly agree), (3.809, 0.778)
RISKaverse	"Researcher does not invest any money", 1=yes; 0=no, (0.249,0.432)
SPINOFFS	Number of spinoffs at the respondent's Institute, (1.855; 3.122)
YEARSMPS	Experience working at Max Planck Society, years, (5.918; 7.070)
INDwork	Respondent has industry work experience =1; 0 otherwise, (0.250; 0.586)
PHD	Respondent has a PhD degree (=1; 0 otherwise), (0.509; 0.500)
FEMALE	Respondent is a female = 1; 0 otherwise, (0.321; 0.467)
AGE	Respondent's age, years, (35.458; 9.573)
GERMAN	Respondent is a German citizen =1; 0 otherwise, (0.609; 0.488)
Discipline1	Respondent's discipline is biology or medicine, (=1; 0 otherwise), (0.442; 0.497)
Discipline2	Respondent's discipline is chemistry, physics or technics, (=1; 0 otherwise), (0.474; 0.499)

Notes: The data come from a large survey of researchers at the Max Planck Society (MPS) in Germany. Humanities is the default academic discipline.

For details, see Max Planck Society: Annual Report 2008. http://www.mpg.de/7313642/Annual_Report_2008.pdf. Accessed June 2019.

Table 1A: Correlation matrix of key variables

	NASCENTent	BUSown	INVENTION	SPINOFFS
NASCENTent	1.000			
BUSown	0.167	1.000		
INVENTION	0.180	0.187	1.000	
SPINOFFS	-0.015	-0.002	0..072	1.000

Notes: See Table 1 for variable definitions. Observations: 2579

Table 2: Inventing academics' transition from nascent entrepreneurs to business owners: Baseline models

Dependent variable→	BUSown	NASCENTent	Marginal effects
ATTRACTent	0.34**	0.40**	0.002**
	(0.04)	(0.06)	(0.001)
GROUPlead	0.02	0.10	0.0003
	(0.13)	(0.18)	(0.001)
PHD	0.23**	-0.26*	-0-0001
	(0.11)	(0.14)	(0.0004)
FEMALE	-0.30**	0.14	-0.0003
	(0.13)	(0.13)	(0.0004)
GERMAN	0.03	-0.41**	-0.001#
	(0.10)	(0.12)	
AGE	0.03**	0.001	0.0001*
	(0.005)	(0.01)	(0.00003)
Discipline1	-0.06	-0.29	-0.0008
	(0.18)	(0.21)	(0.001)
Discipline2	-0.11	-0.18	-0.0007
	(0.18)	(0.22)	(0.001)
N	2549		
Wald chi2	202.41**		
rho	0.26**		
	(0.086)		
Wald test of rho = 0 (chi. sq.)	8.11**		

Notes: See Table 1 for variable details. Constant included but not reported in these bivariate probit regressions.

INVENTION is the offset variable in the NASCENTent equation; INDwork is the offset variable in the BUSown equation.

Discipline3 (Humanities) is the default group.

not reported by STATA

The numbers in parentheses are robust standard errors. * and **, respectively, denote statistical significance at the 10% and 5% (or better) levels.

Table 3: Inventing academics' transition from nascent entrepreneurs to business owners: Impacts of internal experience

Dependent variable→	BUSown	NASCENTent	Marginal effects
ATTRACTent	0.33** (0.04)	0.39** (0.06)	0.002** (0.001)
GROUPlead	0.05 (0.13)	0.14 (0.18)	0.001 (0.001)
PHD	0.39** (0.10)	-0.24* (0.13)	0.0003 (0.0004)
FEMALE	-0.33** (0.12)	0.13 (0.13)	-0.0004 (0.0004)
GERMAN	0.09 (0.10)	-0.38** (0.12)	-0.001 (0.001)
YEARSMPS	0.02** (0.01)	-0.01 (0.01)	0.00002 (0.00004)
Discipline1	-0.12 (0.18)	-0.27 (0.22)	-0.001 (0.001)
Discipline2	-0.17 (0.18)	-0.17 (0.22)	-0.001 (0.001)
N	2558		
Wald chi2	189.49**		
rho	0.26** (0.09)		
Wald test of rho = 0 (chi. sq.)	8.49**		

Notes: See Table 2.

Table 4: Inventing academics' transition from nascent entrepreneurs to business owners: Impact of perceived commercialization costs

Dependent variable→	BUSown	NASCENTent	Marginal effects
ATTRACTent	0.34** (0.05)	0.43** (0.06)	0.002** (0.001)
GROUPlead	0.02 (0.14)	0.11 (0.18)	0.001 (0.001)
PHD	0.24** (0.11)	-0.22 (0.15)	-0.00001 (0.0004)
FEMALE	-0.32** (0.13)	0.18 (0.13)	-0.0002 (0.0004)
GERMAN	0.05 (0.11)	-0.36** (0.12)	-0.001 (0.0005)
AGE	0.03** (0.005)	0.002 (0.01)	0.0001* (0.00003)
COMMcost	-0.08 (0.06)	-0.13* (0.07)	-0.0004* (0.0003)
Discipline1	-0.07 (0.18)	-0.29 (0.23)	-0.001 (0.001)
Discipline2	-0.15 (0.18)	-0.22 (0.23)	-0.001 (0.001)
N	2366		
Wald chi2	209.24**		
Rho	0.22** (0.09)		
Wald test of rho = 0 (chi. sq.)	5.56**		

Notes: See Table 2.

Table 5: Inventing academics' transition from nascent entrepreneurs to business owners: Spillovers from institute spinoffs

Dependent variable→	BUSown	NASCENTent	Marginal effects
ATTRACTent	0.35** (0.04)	0.40** (0.06)	0.002** (0.001)
GROUPlead	0.01 (0.13)	0.10 (0.18)	0.0003 (0.001)
PHD	0.22** (0.11)	-0.27* (0.14)	-0.0002 (0.0004)
FEMALE	-0.30** (0.13)	0.14 (0.13)	-0.0003 (0.0004)
GERMAN	0.04 (0.10)	-0.40** (0.12)	-0.001 (0.001)
AGE	0.03** (0.005)	0.002 (0.01)	0.0001** (0.00003)
SPINOFFS	-0.02 (0.02)	-0.04* (0.02)	-0.0001* (0.0001)
Discipline1	0.002 (0.19)	-0.18 (0.22)	-0.0004 (0.001)
Discipline2	-0.09 (0.18)	-0.14 (0.22)	-0.0005 (0.001)
N	2549		
Wald chi2	207.62**		
rho	0.26** (0.08)		
Wald test of rho = 0 (chi. sq.)	8.52**		

Notes: See Table 2.

Table 6: Inventing academics' transition from nascent entrepreneurs to business owners: Impact of risk aversion

Dependent variable→	BUSown	NASCENTent	Marginal effects
ATTRACTent	0.34** (0.05)	0.40** (0.06)	0.002** (0.001)
GROUPlead	0.02 (0.13)	0.10 (0.18)	0.0003 (0.001)
PHD	0.23** (0.11)	-0.26* (0.14)	-0.0001 (0.0004)
FEMALE	-0.30** (0.13)	0.14 (0.13)	-0.0002 (0.0004)
GERMAN	0.03 (0.10)	-0.41** (0.12)	-0.001#
AGE	0.03** (0.005)	0.001 (0.01)	0.0001* (0.00003)
RISKaverse	0.06 (0.11)	0.05 (0.13)	0.0002 (0.0004)
Discipline1	-0.06 (0.18)	-0.28 (0.22)	-0.001 (0.001)
Discipline2	-0.10 (0.18)	-0.18 (0.22)	-0.001 (0.001)
N	2549		
Wald chi2	203.01**		
rho	0.26** (0.09)		
Wald test of rho = 0 (chi. sq.)	8.05**		

Notes: See Table 2. # Not reported by STATA.

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