How industry projects can stimulate academic engagement:

An experimental study among U.S. engineering professors

Abstract

Technology transfer remains one of the key functions of universities, seen with the growing importance attached to interactions between them and industry partners. Relying on self-determination theory (SDT), we develop a framework comprising the core motivational factors inherent in the design of industry projects and individual determinants which influence a professor's willingness to engage in industry interaction activities. Based on a conjoint experiment among 250 U.S. professors in engineering sciences, our findings suggest that motivational incentives shape a professor's disposition towards industry interaction. We additionally provide further insight into how intrinsic motivational structures towards industry engagement are moderated by individual characteristics, including the short-term orientation of professors towards industry activities. Our results contribute to research on university-industry interactions by developing deeper insights into the motivational structures of individual researchers. We also provide practical insights for university administrators and industry managers.

Keywords

University-industry interactions; extrinsic motivation; intrinsic motivation; academic engagement; self-determination theory.

1. Introduction

Universities have established themselves as a central component of regional and national innovation systems, and are considered an important source of novel ideas and innovations (Ankrah & Omar, 2015; Rajalo & Vadi, 2017; Scandura, 2016). With this in mind, the U.S. government implemented policy changes, including the Bayh-Dole Act of 1980 to encourage university faculty members to commercially exploit their research findings. There is broad agreement among scholars that academics can provide knowledge and technology to external partners in many ways (Abreu & Grinevich, 2013; Kesting, Gerstlberger, & Baaken, 2018; Lawson, Salter, Hughes, & Kitson, 2019; Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, & Hughes, 2013). These include commercialization of academic research outputs, or academic engagement with industry through e.g. consultation (Bodas Freitas, Geuna, & Rossi, 2013; D'Este & Patel, 2007; Iorio, Labory, & Rentocchini, 2017). Contrary to this relatively narrow focus, research on academic engagement analyzes a wider and more heterogeneous set of collaborative actions, such as consulting and advisory activities or contract research (Perkmann & Walsh, 2008). These forms of engagement with industry partners through formal and informal activities (Bodas Freitas et al., 2013; Grimpe & Hussinger, 2013; Iorio et al., 2017; Link, Siegel, & Bozeman, 2007) can collectively be referred to as *university-industry interactions*.

Although the willingness to work with businesses largely depends on a professor's individual motivation (Pablo D'este & Perkmann, 2011; Lam, 2011) arising in part from his/her granted autonomy (Renault, 2006), changing environmental conditions such as budget constraints influence the motivational structures for engaging in industry projects. In some cases, doing this is becoming more complex and diverse (Tartari & Breschi, 2012). With past literature either focused on collaborative activities (D'Este & Patel, 2007) or commercialization (Lam, 2011), recent studies (Pablo D'este & Perkmann, 2011; Franco & Haase, 2015; Lam, 2011) point to the necessity to further examine motivations towards participation in university-industry interactions. In reality, professors not only decide whether or not to enter into a university-industry interaction, but the degree of engagement they are willing to contribute as well. This makes it useful to investigate the interface between motivations and both modes of university-industry interactions (Franco & Haase, 2015).

To bridge this identified research gap, our research relies on a holistic approach by putting researchers in fictitious decision-making situations regarding their degree of engagement in specific industry project profiles. The aim of this paper will be to provide new insights into the research question: *Which motivational factors inherent in university-industry interactions determine the willingness of professors to engage in these? And how are these motivational factors influenced by the individual characteristics of a professor?*

To bridge previous shortcomings, we provide a broader selection of suitable university-industry interactions based on their sub-forms of academic engagement and commercialization (Abreu & Grinevich, 2013; Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, & Hughes, 2013). While university administrators and policymakers have often treated these complementary activities separately (R. Landry, Saïhi, Amara, & Ouimet, 2010), thus missing the opportunity to leverage the additional economic and social benefits for scientific researchers and business partners (Abreu & Grinevich, 2013; Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, & Hughes, 2013), our integration of both activity sets allows us to provide new, broader insights into the motivational driving forces of university-industry interactions.

Using data from a conjoint experimental design conducted among 250 U.S.-based engineering professors, we analyze how the motivational factors inherent in the characteristics of an industry project incentivize a professor's degree of academic engagement. We find support for our predictions of a positive association between university-industry interactions and motivational factors, including research funding, access to in-kind resources, reputation, academic freedom, and congruence of industry projects with an own research focus. Regarding individual factors, we find empirical support for our prediction that the short-term orientation of professors towards industry projects negatively moderates the influence of the intrinsic motivational factors on the willingness to engage in university-industry interactions. We also find support for the prediction that research performance in terms of patents positively moderates the influence of intrinsic motivational, and negatively moderates the influence of extrinsic motivational factors on the willingness to engage in university-industry interactions.

Our study makes two main contributions to research on university-industry interactions. First, from a theoretical perspective, we contribute to the ongoing discourse on the motivation of professors to engage in university-industry interactions (e.g., Pablo D'este & Perkmann, 2011; Franco & Haase, 2015; Lam, 2011). Here we identify the motivational factors inherent in the characteristics of university-industry projects that incentivize towards greater engagement by professors, while further indicating that individual-level factors such as research performance and the engagement orientation of a professor interact with the motivational factors to engage in university-industry interactions. Although these interactions were ultimately not fully in line with our theoretical predictions, we nevertheless contribute to a more comprehensive picture on how certain motivational factors are influenced by individual researchers' characteristics. Second, using the conjoint experimental design is a relative novelty in light of how it is rarely applied in the discourse on university-industry interactions. By using a fictitious decision-making scenario, we provide a more realistic outcome in the relationship between university-industry interaction and various motivational incentive factors.

2. Theoretical background and hypotheses development

2.1. Modes of university-industry interactions

A growing body of literature has striven to understand the relations between universities and industry, with extant literature particularly benefitting from empirical research including large-scale studies, and patent or bibliometric analyses (Fontana, Geuna, & Matt, 2006; Perkmann, Salandra, Tartari, McKelvey, & Hughes, 2021). However, many issues regarding research on university-industry relationships remain unclarified, with today's literature on this topic being fairly fragmented and lacking coherent frameworks (Ankrah & Omar, 2015; Miller, McAdam, & McAdam, 2018). Relatively systemic and university-wide perspectives, or a perspective focusing on the individual researcher are often adopted in this realm (Kesting et al., 2018).

Following Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, and Hughes (2013), academic engagement and, for that matter, university-industry interaction, embraces all types of knowledge-related collaborative activities between academics and non-academic organizations (Perkmann et al., 2021). In line with this, we understand university-industry interaction as an umbrella term for all forms of interactions between these actor groups. Regarding interaction channels, academic engagement encompasses a multitude of activities. These can include informal engagements activities which refer to knowledge transfer mechanisms through informal communication processes such as collaborative research and consulting (Link et al., 2007). There tend to be no established contractual relationships or agreements between university researchers and industry partners in informal engagement activities, which are primarily based on trust (Bodas Freitas et al., 2013; Colyvas et al., 2002). They may comprise meetings, talks, public lectures, contacts made at conferences, etc. Informal engagement activities tend to occur more frequently than formal engagement activities, and thus provide higher transfer-of-knowledge economic value (Hewitt-Dundas, 2012). Formal engagement on the other hand consists of mechanisms designed to transfer research outcomes such as patents governed by contracts, and agreements between academics and industry partners (Grimpe & Hussinger, 2013). These formal mechanisms may be facilitated by universities through administrative initiatives such as technology transfer offices or university departments (Bodas Freitas et al., 2013). It is not uncommon for informal and formal engagements to exist simultaneously or complement each other (Link et al., 2007; Siegel, Waldman, & Link, 2003), with informal mechanisms helping to improve the quality of formal arrangements (Grimpe & Hussinger, 2013).

While university-industry interactions at first glance bear the characteristics of inter-organizational collaboration (Cohen, Nelson, & Walsh, 2002), the relations between universities and businesses turn out to be more complex because universities provide an exceptional work environment for professors. In practice, it is often typically up to the professor himself/herself, not the university or faculty, to decide on the extent of a university-industry interaction's concrete conditions, agreements, and contracts. This means that linkages between both parties are determined by several drivers, including an academic's individual characteristics (Haeussler & Colyvas, 2011), as well as the organizational and institutional setting, such as a university department (Lam, 2011) or a university's overarching commercial orientation (D'Este & Patel, 2007).

While public sector engagement through e.g. consulting is a distinct form of industry interaction or knowledge transfer (Rentocchini, D'Este, Manjarrés-Henríquez, & Grimaldi, 2014), Fudickar, Hottenrott, and Lawson (2018) stress that in comparison to private sector consulting, academic collaboration with the public sector is basically not linked to specific skills or ongoing fields of research by academics. Private collaboration and public sector collaboration also differ in several respects including compensation, how the engagement is organized, and its effect on academics (Boyne, 2002). Of important note here is that our conceptualization of university-industry interactions is limited to interactions with private industrial companies.

The following sections discuss from a theoretical perspective which individual factors drive a professor's willingness to engage in interactions with industry.

2.2. Self-determination theory and motivational factors inherent in the characteristics of university-industry interactions

According to Ryan and Deci (2000), self-determination theory (SDT) focuses on "(…) the investigation of people's inherent growth tendencies and innate psychological needs that are the basis for their self-motivation and personality integration, as well as for the conditions that foster those positive processes" (p. 68). SDT allows motivational factors to be characterized into intrinsic and extrinsic motivation (Ryan, 1995; Ryan & Deci, 2000). *Intrinsic motivation* involves activities which are done either for the sake of the activity itself or its inherent values (such as satisfaction) rather than some separable and instrumental outcome. Not surprisingly, especially in the educational context, intrinsically motivated behavior has evolved into its own central and important context because it encourages learning and creative engagement (Ryan, 1995; Ryan & Deci, 2000).

Contrary to intrinsic motivation, *extrinsic motivation* is related to activities which are performed with the purpose of achieving a separable value. While intrinsic motivation is considered an exclusively autonomous activity, extrinsically motivated behavior is more diverse and ranges between controlled and autonomous behavior (Ryan, 1995; Ryan & Deci, 2000).

We note that dynamically changing environmental conditions influence an individual's objectives and the motivational factors regarding his/her willingness to engage in any activities. Characterized by high autonomy and an exceptional reward system, universities provide a unique work environment which allows researchers to freely make decisions towards industry projects (Iorio et al., 2017; Lam, 2011). This means that their actual motivation is influenced to a large extent by the scientific reward system (P. F. Stephan,

Stephan, Levin, & Levin, 1992), and includes outcomes such as recognition, monetary gain, and knowledge gain (Iorio et al., 2017; Stephan et al., 1992). This reward system forms the basis of an individual's motivation to engage with industry, and as a result may evoke a combination of both extrinsic and intrinsic motivational factors (D'Este & Patel, 2007).

By reviewing the extensive literature on extrinsic and intrinsic motivational factors incentivizing professors' academic engagement, we were able to identify five key factors, three of which are extrinsic, and two of which are intrinsic in nature. In line with our research question, we particularly focus on the features that are directly related to the particular university-industry interaction. This means that other motivational factors related to e.g. environmental or institutional characteristics of a researcher are not considered. The extrinsic factors include research funding, access to in-kind resources, and reputational gain. The intrinsic factors are academic freedom and congruence with own research.

Research funding is an important extrinsic motivational factor in university-industry interactions. Because research is a scientist's core task, each professor has to make sure to dispose of his or her required resources to pursue research activities, e.g. by ensuring funding for junior researchers (Ylijoki, 2003). The need for acquiring additional research funding has increased the entrepreneurial ethos among university scientists (Bok, 2003). Given that research activities often require increasingly expensive laboratories, laboratory equipment, and personnel (D'Este & Perkmann, 2011; Hottenrott & Lawson, 2017), universities are becoming more and more dependent on further sources of external research funding to maintain their research activities. This development is additionally exacerbated by increased competition in academia (Ylijoki, 2003). According to Landry, Amara, and Ouimet (2007), researchers receiving external funding from businesses are more prone to university-industry interaction than researchers whose activities are financed exclusively by public funding. This is consistent with the research by Lee (1998), who finds an increasing pressure to engage in university-industry interaction in the case of high external funding dependency on businesses. This makes access opportunities to research funding a highly relevant motive for researchers to engage in university-industry interactions (Fransman, 2008; Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, & Hughes, 2013). In line with extrinsic motivation where individuals are driven by external pecuniary incentives, it is likely that research funding provided by industry will positively incentivize researchers to engage in industry projects. We therefore assume:

Hypothesis 1: Access to research funding positively influences a professor's willingness to participate in university-industry interactions.

Apart from direct monetary rewards, another important extrinsic motivational factor that is closely connected to the requirements for raising the resources to pursue academic research is *access to in-kind resources*. Collaboration with businesses may additionally provide relevant, non-financial resources such as knowledge from them, and in-kind resources such as equipment, data, and the opportunity to work in the laboratories of these businesses (D'Este & Patel, 2007; D'este & Perkmann, 2011). Along with budget constraints, researchers are also confronted with general resource scarcity challenges. This conversely means that having access to external resources can be relevant for their research projects, constituting an additional extrinsic motivational factor which may contribute to industry projects among academics (D'este & Perkmann, 2011). We propose the second hypothesis as a result:

Hypothesis 2: Access to in-kind resources positively influences a professor's willingness to conduct university-industry interactions.

Another extrinsic motivational factor regarding engagement with industry partners is the incentive of expected *reputational gain* derived from this kind of collaboration (Kruss & Visser, 2017; Lam, 2011). Merton (1957) argues that recognition from peer researchers is both an incentive and a reward, and thus a core driver of a researcher's daily work.

Researchers strive for recognition within their respective scientific community (Martinelli, Meyer, & von Tunzelmann, 2008). This is a critical factor for scientific careers, with junior researchers in particular needing publications to achieve tenure (Lam, 2011). In addition, a researcher's reputation in the scientific community typically affects his or her prospects for financial rewards (Stephan, 1996) (e.g. the potential success of research proposals). Considering the changing environmental conditions in academia, further activities provide researchers with the opportunity to enhance their reputation (e.g. peer recognition) (Audretsch, Bönte, & Krabel, 2010). Hence, the necessity to procure additional external research funding through university-industry interaction promotes the willingness of researchers to engage in these kinds of activities. Haeussler and Colyvas (2011) argue that a researcher's perceptions of reputational values and peer esteem shape whether and which interactions with industry might be considered to be additional sources of reputational gains. For instance, they found that researchers who perceive their peer group as attaching value to patenting are more involved in commercial activities. Especially when commercial activities result in success, these can increase the researcher's and, particularly, a university chair's visibility (Audretsch et al., 2010). Consequently, a professor will tend more strongly towards academic engagement and commercialization if he/she assumes higher reputational benefits from an engagement.

Hypothesis 3: High reputation-based incentives positively influence a professor's willingness to engage in university-industry interactions.

The SDT framework categorizes motivations based on the relative autonomy from external influences that individuals exercise in any given activity (Ryan & Deci, 2000). In view of this, intrinsically motivated individuals may feel that the effort they invest in engagement activities are voluntary (Acar, 2019). With respect to potential engagement in industry projects, *academic freedom*, which can be described as the freedom to pursue long-term fundamental research which is not influenced by third parties (Lee, 1996), should be considered as a critical attribute of academia (Lam, 2011). Bladh (2007) states that academic freedom comprises the self-determination of a researcher within the context of his/her work. As such, academic freedom and autonomy are considered the main drivers of job satisfaction among academic researchers. Previous studies have emphasized that a loss of academic freedom or the mere idea of possible restrictions regarding autonomy are predominantly perceived as decisive collaboration barriers, consequently decreasing researchers' willingness to engage with industry partners (Azagra-Caro, Archontakis, Gutiérrez-Gracia, & Fernández-de-Lucio, 2006). This relation not only applies to collaboration, but commercialization tendencies as well. After all, similar to traditional researchers, (academic) entrepreneurs are also characterized by a high personal desire for autonomy and independence (Shane, 2004). This is why we consider academic freedom to be a key intrinsic motivational factor, which should be preserved to increase the likelihood that professors engage in university-industry interactions. Following these considerations, we propose our fourth hypothesis:

> *Hypothesis 4: Academic freedom positively influences a professor's willingness to conduct university-industry interactions.*

A professor's research focus is strongly nurtured by his/her personal interest, making it a strong intrinsic motivational driver. An additional motivation can best be described as an integrated motivation where the activity in question has been appraised and deemed as in congruence with the values and needs of the individual. Regarding industry projects, this refers to their congruence with a scientist's own research focus (Perkmann & Schildt, 2015). Congruence in this case means that interaction with industry additionally fosters and enables the publication of research outcomes that allow researchers to benefit from synergy effects derivable from these activities with industry (Lee, 1996). The possibility to apply research results in practice is highly dependent on the degree of knowledge proximity. In terms of engineering disciplines, this proximity is largely given, which in turn favors industry projects. Indeed, previous studies have suggested that many researchers appreciate the chance to apply their research results in practice, such as in field tests or testing their technical inventions for further exploitation (Ismail et al., 2015). The matching process between academic and industrial partners can however be challenging for both parties because a professor's research focus has to be promising enough in commercial terms for industry, while industry partners have to deliver sufficiently interesting research questions and challenges (Arvanitis, Kubli, & Woerter, 2008). Professors should therefore perceive these kinds of interactions with industry partners as appealing, signalizing a high congruence with their own research focus. We formulate the following hypothesis as a result:

Hypothesis 5: Congruence with the own research focus positively influences a professor's willingness to conduct university-industry interactions.

2.3. The moderating influence of researchers' individual characteristics

Having looked at how different motivational factors influence the willingness to engage in university-industry interactions, we now turn to the notion of how these motivational factors may be affected by individual-level differences. Previous research has demonstrated that the preference structures of academic researchers are not uniform, but instead vary substantially in accordance with certain individual characteristics. Roach and Sauermann (2010) for instance show that the preference structures of science and engineering PhD students are fundamentally different depending on their career aspirations. PhD students who prefer industrial employment show a generally weaker "taste for science," and a greater concern for extrinsic motivational factors such as salary and access to resources compared to PhD students who prefer an academic career.

Researchers may approach university-industry interaction with varying objectives and outcomes in mind based on their individual characteristics. Therefore, the effects of the key extrinsic motivational factors (research funding, academic reputation, and in-kind resources) and intrinsic motivational factors (academic freedom and area of research congruence) on the willingness of an individual academic to engage in industry projects may vary substantially depending on the individual characteristics of a researcher. We identify two main attributes here that may moderate the hypotheses above: researchers' short-term orientation, and researchers' status as indicated by their performance level.

The orientation of professors towards short-term or long-term engagement can significantly influence the effect of key motivational factors on university-industry interactions (Garcia, Araújo, Mascarini, Santos, & Costa, 2020). It is generally thought that universities are oriented toward long-term concerns in pure science research, which tend to create a mismatch with short-term-driven industry partners (Bruneel, d'Este, & Salter, 2010). These differences in expectations can foster or hinder industry interactions. Nevertheless, individual motivations can in fact change depending on the available incentive factors, or accepted orientation of engagement, which in turn may influence university-industry interaction differently. We note that joint activities between industry and academia are prone to potential conflicts because academics often consider businesses as too short-term oriented (Gulbrandsen & Smeby, 2005). On the other hand, industry partners sometimes consider the long-term focus of academic researchers to be a major obstacle to collaboration and cooperation (Bruneel et al., 2010).

There are two conflicting views about how the short-term orientation of a professor may influence the effects of motivational factors. On the one hand, it can be argued that a short-term orientation may increase the role of intrinsic motives, as professors who are oriented towards short-term collaboration may try to leverage their existing knowledge and expertise to align with industry, instead of building new competences and knowledge for the collaboration. We also know from research that researchers who correspond to the traditional

Mertonian role of scientists do not necessarily aspire to be commercially successful in the short-run (Merton, 1957). This Mertonian reasoning is akin to intrinsic motivation where professors are influenced by non-pecuniary outcomes such as areas of research congruence and academic freedom, suggesting that short-term oriented researchers may seek intrinsic motivational factors rather than extrinsic motivational ones. On the other hand, there are very plausible arguments for an opposite effect. As short-term interactions with industry partners naturally provide very limited opportunities to utilize the university-industry interaction for academic achievement, the benefits of short-term interactions will be higher for more manifest outcomes such as monetary rewards. Following this argumentation, intrinsic motivational factors may be particularly useful and thus positively moderated by professors' long-term orientation as compared to extrinsic motivational factors.

Hypothesis 6: The effects of intrinsic motivational factors (extrinsic motivational factors) on the willingness to engage in university-industry interactions are negatively (positively) moderated by the short-term orientation of the professor.

In addition to the role of short- vs. long-term orientation, we assume that the academic status (i.e. the researchers' performance) will affect the importance of certain motivational factors of the willingness to engage in university-industry interactions. We fit this in along the line of enquiry suggesting a relationship between scientific performance and the willingness to engage in university-industry interaction (Bikard, Vakili, & Teodoridis, 2019). Specifically, we examine how the effect of intrinsic and extrinsic motivational factors is moderated by scientific performance.

A vast amount of literature suggests using publications (Auranen & Nieminen, 2010) and patent applications (Azoulay, Ding, & Stuart, 2009; Libaers, 2017) as proxies for measuring research performance. To assess how research performance moderates motivational factors, we draw on Pablo D'este and Perkmann (2011) who suggests that in line with life cycle theories, junior researchers tend to focus on reputation building (through publishing or patenting) during the early phases of their careers. The expertise and reputation built over the years are then deployed through industry engagements in the later stages of their careers (P. F. Stephan et al., 1992; Zuckerman & Merton, 1972). These industry engagements in turn are often in response to financial incentives (Jensen & Thursby, 2001), leading to an argument that researchers who have achieved a certain academic maturity as demonstrated by their research outcomes would be primarily triggered by extrinsic as compared to intrinsic incentives when it comes to university-industry interactions.

Contrary to this view, it is argued that researchers primarily use their performance (e.g. patenting) as a signal of their academic achievements for reputational gain in industry and the scientific community (Göktepe-Hulten & Mahagaonkar, 2010). However, due to concerns about academic freedom, researchers in engineering faculties across the US are said to be reluctant to engage with industry (Lee, 1996), notwithstanding the fact that researchers tend to support industry engagements that are related to their core areas of research (Lee, 2000) . This logic provides a counter-argument: Following the primary idea of SDT, because researchers who have achieved a certain academic maturity may not have a need to act upon every possible opportunity, and can be substantially more selective regarding their individual engagements, they may look for those university-industry interactions in particular that are in line with their personal interests. This assumption provides a strong argument for a positive interaction between a researcher's performance level and the intrinsic motivational factors for university-industry interaction.

> *Hypothesis 7: The effects of intrinsic motivational factors (extrinsic motivational factors) on the willingness to engage in university-industry interactions is higher (lower) if the professor has high research performance.*

Figure 1 presents a summary of our research model.

Insert figure 1 about here

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3. Methodology

3.1. Sample and selection bias control

Our experiment was conducted during the 2012/2013 academic year. The target population was comprised of engineering professors from U.S.-based universities. Our focus on engineering sciences was a result of the particular demand from industry partners for academic findings within these disciplines (Cohen et al., 2002). Moreover, we targeted U.S. universities because, when compared to European universities, knowledge and technology transfer have here been more strongly promoted over the years, most notably as a consequence of the 1980 Bayh-Dole Act (Czarnitzki, Hussinger, & Schneider, 2012). To identify the relevant target population, we selected the top-ranked 250 U.S. universities (U.S. News, 2012), of which one hundred were randomly selected. We then manually searched the websites of their engineering departments, identifying 4,029 engineering professors and their email addresses. These professors received an email invitation with a personal link to our online survey. After two follow-up reminder mails, we received 250 completed surveys (return rate 6.2%). Our final sample had a structure that is representative for academia. It mainly consisted of male researchers (88.6%) in a leading academic position. 7.8% were chairs, 49.0% full professors, 22.2% associate professors, and 21.0% assistant professors. Furthermore, 34.0% were between 55 and 70 years old, 40.8% between 40 and 54 years old, and 24% under 40 years of age. Further descriptive statistics regarding the professors' engineering disciplines are provided in Table 1.

Insert table 1 about here

To uncover a potential non-response bias, we compared the group of professors we invited to take our survey with the group of those actually participating, comparing university type (public/private) and ranking (see Table 2). We conducted two Mann-Whitney U tests, revealing that the participating group of professors was significantly different from the group of non-responding professors regarding both university type (Asymp. Sig., two-tailed = 0.005) and university ranking (Asymp. Sig., two-tailed = 0.000), indicating a slight overrepresentation of private universities, and slight underrepresentation of top-50 universities. However, as the general proportions appeared to be similar, and no particular group seemed to stand out in our sample, we assumed a rather small potential non-respondent bias. In addition, we followed the suggested approach by Armstrong and Overton (1977), considering the response behavior of early respondents and late respondents, comparing those 95 who responded without having to be reminded with the 72 who responded after the first reminder, and the 83 who responded after the second. A series of independent t-tests on key characteristics such as the pressure to seek external funding, the attitude towards industry collaboration, short-term orientation, and research orientation did not reveal any significant differences.

Insert table 2 about here

3.2. Methodological approach

We chose a conjoint experimental design to investigate professors' willingness to engage in university-industry interactions and analyze their underlying decision-making process.

Originated from marketing, conjoint experiments are well-established and strongly demanded for measuring preferences (Lohrke, Holloway, & Woolley, 2010) in related disciplines such as academic entrepreneurship research. The method is suitable for our purpose, since it approximates real-life decision-making processes, as decisions in reality mostly occur in a complex environment and under uncertainty (Hair, Anderson, Babin, & Black, 2010). During a conjoint experiment, participants are asked to make a series of judgmental decisions based on specific decision profiles, each characterized by a bundle of varying attributes, which in turn allow for analyzing trade-off relationships between competing attributes (Auty, 1995). Each of these bundles comprises a set of all selected attributes and their particular values.

In line with previous studies, we selected an orthogonal main effect design plan, which by definition contains only attributes that do not correlate (Shepherd & Patzelt, 2015). Each industry project to be evaluated was described along five attributes including (1) research funding, (2) access to in-kind resources, (3) reputational gains, (4) academic freedom, and (5) congruence with the own research focus, of which each varied on two levels, as summarized in Table 3. We developed dichotomous variables for these measures where value 1 represented the "high level" and 0 the "low level" as captured in Table 3. For the *research funding*, the variable took the value 1 if there was substantial research funding, and 0 if otherwise. For *access to in-kind resources*, a value of 1 meant that there was access to in-kind resources, while the value 0 meant there was no access to in-kind resources. For *academic reputation*, a value of 1 meant the comprehensive gain of academic reputation, and 0 otherwise. For *academic freedom*, the variable took a value of 1 if academic freedom was maintained, and 0 otherwise. *Area of research* congruence took a value of 1 if the industry project was in the core area of the professor's research, while the variable took the value 0 if otherwise. The use of dichotomous levels led to robust results, limiting the complexity of the experimental design (Wittink, Krishnamurthi, & Reibstein, 1990). Figure 2 shows an example conjoint scenario that was used for our survey-based experiment.

Insert Table 3 and Figure 2 about here

Instead of using a full factorial experimental design which would require an evaluation of 32 ($=2^5$) industry project profiles, while also bearing the risk of overstraining the respondents and reducing reliability, we used a fractional design of 16 profiles, as suggested by Hahn and Shapiro (1966).

3.3. Measurements

Willingness to conduct university-industry interactions: Because a simple rating of willingness to contribute would be very subjective, we dedicated specific activities to each of the scale levels. These contributions were deduced from Arvanitis et al. (2008), who identified four different kinds of activities between universities and businesses: informal, educational, consulting, and research activities. Via discussions with academic colleagues, we collected a list of 13 specific activities belonging to these four groups: (1) *I have no willingness to participate.* (2) *I provide my already-published publications to the(se) business(es).* (3) *I deliver a guest lecture on the research topics of the(se) business(es).* (4) *I take care of a thesis related to the research topic of the(se) business(es).* (5) *I place graduate students or post-docs in charge of the research topics of the(se) business(es).* (6) *I undertake a joint probing project with the(se) business(es).* (7) *I align an existing project to the requirements of the(se) business(es).* (8) *I undertake a joint new large-scale project with the(se) business(es).* (9) *I assume paid consulting activities in the field of the(se) businesses' research topics.* (10) *I take part in and accept the creation of university-based research centers in the field of the(se) businesses' research topic funded by one or more industrial partners.* (11) *I work directly* *with the(se) business(es) in an effort to commercialize or transfer technology.* (12) *I work directly with the(se) business(es) in an effort to patent or copyright research findings.* (13) *I undertake a joint venture with the(se) business(es) to found a start-up in the field of the(se) business'(es') research topics*. Because these potential contributions did not have a particular order, and differences between scale points need to be equidistant, they were sorted and adjusted during five interviews with professors from engineering sciences. The 13 activities were written on cards, and the professors were asked to sort them, beginning with the lowest realistic contribution to the highest realistic one. Unrealistic activities were sorted out. For example, four of five professors discarded the option "have no willingness to participate," stating that every collaboration request from industry leads to at least some contribution. Comparison of the five sorting results revealed that seven activities were consistently used and sorted in the same order. The final ordinal scale is illustrated in Figure 3, and also considers that academic engagement occurs via more channels than commercialization.

Insert figure 3 about here

Research performance: We used two alternative proxy measures for research performance with the researchers' publications and patents. For the publication measure, we manually calculated for each professor the five-year Hirsch index (Hirsch, 2005) based on only peer-reviewed journal articles (Macri & Sinha, 2006), which we weighted with the five-year journal impact factor (JIF) (Harris, 2008). By weighting it with the year, we ensured that a junior professor's performance would not be downplayed, irrespective of the year of the first published paper of the professor. Additionally, for the patents variable, we created a measure based on a participant's granted patents per year. Here, we manually conducted a patent research for each respondent using the database provided by the United States Patent and Trademark Office.

Short-term orientation: This construct was surveyed by utilizing four items by Ganesan (1994), measured on a five-point Likert scale (1 = 'strongly disagree'; 5 = 'strongly agree'), and allowed us to measure a professor's orientation towards short-term collaboration (Cronbach's alpha = 0.82).

In addition to our key variables in the model, we included several relevant control variables that had previously been shown to exert an influence on a researchers' willingness to engage in university-industry interactions. *Pressure to seek external funding* was measured on a five-point Likert scale with four items from Lee (1998) (Cronbach's alpha = 0.82). To assess a professor's *attitude towards industry collaboration*, we adopted six items from (Lam, 2011) that were measured on a five-point Likert scale (Cronbach's alpha = 0.83). We controlled for a researcher's *research orientation* via four items by Clauss and Kesting (2017) that differentiate the general tendency towards basic or applied research with a five-point semantic differential (Cronbach's alpha = 0.83). *Academic status* took the value 1 if the professor was a chair, full professor, or associate professor. The variable took the value 0 if the professor had the position of assistant professor. The variable *discipline* looked at the six subsumed research disciplines of the professors in our sample. This variable took the value 1 for materials engineering/electrical/electronic/communications engineering and 0 otherwise. We further controlled for *gender* (1= male, 0 = female) and *age* of the professor. For the institutional-level control variables, we included the *university type* that took a value of 1 for public universities and 0 for private universities. *Department R&D* controlled for the department's absolute research expenditures. The *technology transfer rank* referred to the ranking of the university's technology transfer office (TTO). The university TTO ranking data was extracted from the National Science Foundation, the Milken Institute, and the U.S. News ranking from

2012. The appendix provides a detailed overview of the measurement items used to measure the multi-item variables we included.

4. Results

4.1 Descriptive statistics

We present our correlations and descriptive statistics in Table 4. Although there were a few noticeably high correlations between the interaction terms and other variables, the variance inflation factor (vif) was far below the conventional rule of the thumb of 10, indicating that multicollinearity was not an issue.

We found that, on average, there were 3.71 engagements with industry by professors in our sample. The patents variable showed a mean of 0.10, indicating the average number of patents granted to professors in our sample; it also showed that they were engaged in inventive activities. The mean of 0.49 of the publications variable showed the average number of publications of professors. The motivation variables all indicated a mean of 0.50, while the short-term orientation variable also showed a mean of 3.60.

Insert table 4 about here

4.2. Regression results

Table 5 presents the results of ordered logit regression models with clustered standard errors, predicting the likelihood of university-industry interactions among engineering professors. The standard errors were clustered at the individual (professor) level because in our experimental design the primary unit of randomization was the individual scientist (Abadie et al, 2017). Hypothesis 1 suggests that access to research funding positively influences a professor's willingness to conduct university-industry interactions. The corresponding co-efficient of the variable *research funding* in Model 3 of Table 5 was positive and statistically significant ($\beta = 1.28$, $p < 0.01$), showing support for Hypothesis 1. We calculated the average marginal effect show its size. Given the ordinal nature of our outcome variable, we calculated the average marginal effects for the different levels of university-industry interactions. Here we referred to the three top forms of interactions, where we observed a direct and active involvement of professors in industry activities (*5- "I align an existing project with the requirements of the(se) business(es)"; 6- "I start a joint new large-scale project with the(se) business(es)"; 7- "I directly work with the(se) business(es) in an effort to commercialize or transfer technology"*). The marginal effect for Model 3 indicates that *research funding* is 8.4 percent more likely to influence a professor's willingness to engage in industry interactions, i.e. to "work directly with the business in an effort to commercialize or transfer technology," which is the highest form of industry interaction. It also shows that a professor is 8.5 percent more likely to "start a new joint large-scale project with the business" given research funding as a motivational factor. Furthermore, the results show that a professor is 4.0 percent more likely to "align an existing project with the requirements of the business" partner. In total, the marginal effect for Model 3 (the three highest forms of university-industry interactions) indicates that research funding is 20.9 percent more likely to influence a professor's willingness to engage directly in industry interactions in comparison to the other identified motivational factors (in-kind resources, academic freedom, academic reputation, and area of research). Hypothesis 2 tests whether in-kind resources influence professors' willingness to conduct university-industry interactions. We found support for this hypothesis, with the corresponding co-efficient of *in-kind resources* in Model 3 of Table 5 showing positive and statistically significant results ($\beta = 0.25$, $p < 0.01$). The average marginal effect shows that in-kind resources are 4.2 percent more likely to influence a professor's willingness to conduct university-industry interactions in comparison to the other identified motivational factors (research funding, academic freedom, academic reputation, and area of research). We also found support for Hypothesis 3 in Model 3 of Table 5 ($\beta = 1.12$, $p < 0.01$). While the result is positive and statistically significant, the effect size shows that a professor is 18.3 percent more likely to be influenced by academic reputation to conduct university-industry interactions compared to the other identified motivational factors (in-kind resources, research funding, academic freedom, and area of research). Regarding Hypothesis 4, our result ($\beta = 2.24$, $p < 0.01$) in Model 3 of Table 5 showed a positive and statistically significant effect of academic freedom on a professor's willingness to conduct university-industry interactions. The average marginal effect shows that a professor is 36.5 percent more likely to conduct industry interactions if there are potential academic freedom gains in comparison to the potential gains in terms of in-kind resources, research funding, academic reputation, and area of research. Hypothesis 5 predicted that the congruence of an industry partner's activities with the research focus of a professor positively influences the willingness to conduct university-industry interactions. As indicated by Model 3 of Table 5 ($\beta = 1.53$, $p < 0.01$), the results are positive and statistically significant. In terms of the effect size, the average marginal effect shows that *area of research congruence* is 25 percent more likely to influence a professor's willingness to conduct an interaction with an industry partner in comparison to research funding, in-kind resources, academic freedom, and academic reputation.

To test Hypotheses 6, we used interaction terms between professors' short-term orientation and the motivational variables. In line with our assumptions, we found negative interactions of the two intrinsic motivational factors and the short-term orientation of a professor in Model 3 of Table 5. Congruence with the research area ($\beta = -0.13$, $p < 0.05$) and academic freedom ($\beta = -0.31$, $p < 0.01$) both yielded a negative interaction effect with short-term orientation, supporting Hypothesis 6. In comparison to the interaction of research funding, in-kind resources and academic reputation, the average marginal effects indicate that congruence of area of research and academic freedom are 1.3 percent and 3.1 percent (respectively), and less likely to influence the willingness to engage in industry projects if a professor has a short-term orientation towards industry projects. However, we did not find opposite positive interactions between a researchers' short-term orientation and extrinsic motivational factors.

Hypothesis 7 tests how research performance moderates the effect of intrinsic and extrinsic motivational factors on university-industry interactions. Using patents as a measure of performance, we found some support for this hypothesis. Our analysis revealed a positive interaction effect of the research performance and academic freedom on university-industry interactions ($\beta = 0.67$, $p < 0.05$) as captured in Model 3 of Table 5. The average marginal effect shows that academic freedom is 11 percent more likely to influence the willingness to engage in university-industry interactions if the performance of the professor is high compared to the other identified motivational factors. In line with our assumptions, the interaction effect between the researchers' performance in terms of patents and two of the extrinsic motivational factors are negative for research funding ($\beta = -0.61$, $p < 0.01$) and academic reputation ($\beta = -0.26$, $p < 0.05$). In terms of the marginal effects, we can see that research funding is 6.1 percent, while academic reputation is 2.4 percent less likely to influence the willingness to engage in industry activities if performance is high compared to the other identified motivational factors. Our analysis as a result provides vast, albeit not yet fully conclusive support for Hypothesis 7.

Insert table 5 about here

Alternatively, using our second proxy for research performance (publications), we did not find any significant effect for our prediction as captured by Model 4 of Table 5. We as a result can only support Hypothesis 7 regarding the performance of the researcher in terms of patents.

As a further robustness check, we used a count measure for *journal publication* and a second variable made up of both *journal publications and conference publications*, with the results similar to the results of the H-index publication variable. The results are available from the authors.

5. Discussion

5.1. Theoretical implications

Knowledge and technology transfer have taken on increasing importance since the commencement of the Bayh-Dole Act, as well as the advent of the entrepreneurial university as a central element of the triple helix model. Due to the specific conditions and particularities in academia, many researchers have proposed that university-industry interactions are not only reflected in commercialization activities such as patent exploitation, but in activities referred to as *academic engagement* as well. As a result, this broader concept of university-industry interactions integrates both modes of interactions, allowing an investigation of a wider range of activities. Against the background of this widened understanding of university-industry interactions, we analyzed which motivational factors primarily drive university professors' willingness to conduct industry projects, furthermore disentangling the complex interaction with the further individual-level factors shaping these motivations. Although prior literature on university-industry collaboration indicates some motivational factors that can determine a researcher's willingness to engage with industry partners, these studies have often restricted their focus to only one of two specific modes of university-industry interactions. Our paper addressed this research gap by pursuing a holistic approach which allowed us to counteract these shortcomings.

Derived from literature, we identified five core motivational factors, finding that all of them positively influence a professor's disposition towards industry. We showed that research funding, access to in-kind resources, academic freedom, reputation, and congruence with the own research focus are indeed relevant factors influencing a professor's willingness to conduct activities with industry partners. Overall, research funding is by far the most important motivational factor, followed by academic freedom, research congruence, reputational gains, and access to in-kind resources. With access to in-kind resources clearly lagging behind the remaining factors, this might indicate engineering professors' level of happiness with modern facilities which enable them to conduct state-of-the-art research, therefore perceiving this factor as a less important incentive for industry engagement.

In line with our prior assumptions, our findings show that researchers' short-term orientation towards industry negatively moderates the effects of intrinsic motivational factors. We interpret this finding to mean that professors with a short-term orientation regarding university-industry relationships seem to have a lower willingness to adapt to the requirements of businesses over the course of such collaboration. Thus, the importance of the intrinsic motivation that drives the interactions with industry seems to be considerably lower if professors are short-term oriented. A further reason for this finding may be that professors in engineering sciences are in particular dependent on equipment and other expensive materials and laboratories (Pablo D'este & Perkmann, 2011; Lee, 2000), so that intrinsic motivation such as congruence of the area of research with industry projects seems to fade into the background when an orientation towards short-term projects is considered. It should be further noted that researchers' short-term orientation in general increases the willingness to engage in university-industry interactions, perhaps indicating that industry projects are regarded as particularly beneficial for achieving short-term results.

With respect to further individually-related factors, our results show that a high research performance in terms of patents does not directly entail activities of academic engagement and commercialization. However, we did find a positive moderation of research performance in terms of patents on the effect of academic freedom on industry engagement. A possible explanation for this is that while it is obvious that patent-holding professors may be predisposed towards industry engagement to exploit the rewards of their research, they also value other performance outcomes such as publications (Lee, 1996), which will require them to have the corresponding freedom to pursue independent of industry projects. This assumption is particularly strengthened by our findings on the negative interactions between extrinsic motivational factors and patents. Researchers who have been successful in commercializing their research results are consequently less inclined by extrinsic motives as compared to intrinsic ones.

Interestingly, our study was unable to identify the direct or moderating effects of a researcher's performance in terms of publications. The absence of a moderating role of publications when compared to publications may be interpreted in how a researcher's focus on more typical academic activities (e.g. basic research) is largely independent of how university-industry engagement is incentivized. This finding may however be influenced by the focus on engineering as an inherently applied research discipline. Furthermore, the absence of a direct effect of publications on university-industry interaction is insofar interesting in how it speaks against previous studies that show negative effects between research ability and researchers' industry engagement (Rentocchini et al., 2014), in particular when it comes to interactions with organizations from the private sector (Fudickar et al., 2018). Furthermore, although this was not hypothesized, patents also do not show a direct effect on the willingness to engage in university-industry interactions. These findings may stimulate future discussion because they speak against the assumption that researchers' career paths are intertwined with industry engagement, and that researchers are either basic research-focused (i.e. focusing on patenting) with comparatively little engagement, or application-focused (i.e. focusing on publications) with rather high industry engagement. In contrast, the moderating effect of patents shows that career orientations may not change the general tendency towards industry engagement, but the importance of the motivational factors that characterize an industry project instead. Less commercially successful and younger researchers (i.e. with fewer patents), despite their overall lower tendency to engage with industry, may be more stimulated by extrinsic motives and less by intrinsic ones when compared to their more established counterparts. This may suggest that the role of university-industry interactions changes during the course of an academic career.

Following a recent call by Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, and Hughes (2013) for a more detailed analysis of individual motivations determining faculty members' engagement with industry partners, we presented an SDT-based framework. This approach allowed us to incorporate the main motivational determinants as well as supplements of individually-related factors into a holistic framework for university-industry interactions. We tested our framework that was derived from literature with a rigorous large-scale study combining a conjoint-based scenario experiment with additional primary and secondary data. Our corresponding empirical findings provide two important and interesting contributions for both research on university-industry relationships, as well as for policies aimed at promoting knowledge and technology transfer for the related entrepreneurial university concept.

First, from a theoretical perspective, our findings contribute to the discussion about incentive mechanisms and motivations among university faculty members for engaging with industry partners (D'Este & Patel, 2007; Lam, 2011). As proposed by Perkmann, Tartari, McKelvey, Autio, Broström, D'Este, Fini, Geuna, Grimaldi, Hughes, et al. (2013), we addressed the research direction that points to a more detailed examination of individual aspects determining researchers' university-industry engagement. Our results are intriguing in comparison to prior studies. Our finding that high research performance in terms of patents positively moderates the influence of intrinsic motivational factors (e.g. academic freedom) and negatively moderates the influence of extrinsic motivational factors (e.g. research funding and academic reputation) on the disposition towards university-industry interaction provides a finer-grained understanding of the nature and context under which certain incentives are successful. It is generally supportive of previous work showing that incentive structures may vary depending on the academics' career trajectory (Roach & Sauermann, 2010). It nevertheless calls for more detailed investigations of "star scientists" (Zucker & Darby, 2001) and their motivational structures. Together with the finding that a short-term orientation negatively interacts with intrinsic motivations, this also provides a more holistic understanding about how university-industry interactions should be designed in an effort to attract the right professors.

Second, we conducted one of the first empirical studies which jointly utilized the concept of academic engagement and commercialization (Perkmann, Tartari, McKelvey, Autio, Broström, D'este, Fini, Geuna, Grimaldi, & Hughes, 2013). In doing so, we measured a professor's disposition towards concrete industry activities on a specifically developed ordered scale, which makes our study considerably more realistic. Moreover, due to the widened understanding of academic engagement, our scale comprised non-commercial, informal, commercial, and formal activities (Abreu & Grinevich, 2013), which also makes our findings valuable for sub-research streams focusing either on university-industry collaboration or academic entrepreneurship.

5.2. Practical implications

Our study also provides practical insights for university administrators and industry managers. First, striking a balance between patenting and traditional publications as they relate to tenure and promotions is an ongoing discussion at many universities. As universities establish departmental or university-wide cultural norms which favor industry projects (Hunter, Perry,

& Currall, 2011), these plans should recognize the value of academic freedom irrespective of the economic value of the extrinsic benefits that these industry engagements may accrue.

Second, the differences in desired collaboration orientations impact industry interaction decisions. That the area of research congruence does not positively influence the willingness of professors to engage in industry projects if professors are short-term oriented is an indication of the value professors place on long-term collaborations. There is the need for industry partners to balance their needs with that of professors in order to take advantage of intrinsically motivated professors who are also long-term oriented towards industry projects.

Third, professors might be using short-term engagements as a way of participating in explorative projects, i.e. projects that are outside their core areas of research, to identify scientifically-relevant basic research questions. In light of this, industry managers should seek out professors with relatively distant backgrounds from the core areas of proposed industry projects for short-term engagements.

5.3. Limitations and future research

Our paper has some limitations, which similarly provide future research avenues. The data for our analysis are drawn from U.S. professors working in the engineering sciences only. Thus, our findings may be restricted solely to engineering disciplines and the U.S. education system. Furthermore, as we drew our sample only from the top 250 universities, our study may not represent the motivational patterns of professors at lower-ranked universities who may have fewer research aspirations and/or higher teaching loads. This is why future studies should also investigate academic behavior among faculty members from other universities and research disciplines, or better yet, should apply an international sampling strategy.

Our paper used a Hirsch index measure as a proxy for publication performance. This is not a perfect measure and thus a limitation of our study, which is why future studies could use alternative measures of research performance to properly capture its essence.

As our results suggest, motivations towards university-industry interactions are highly influenced by individual factors. It would be interesting to investigate if and how faculty members from the same department/university mutually inspire and support each other with respect to collaborative and commercial activities.

Additionally, our results rely on cross-sectional data, which is why longitudinal data could be used in future studies to examine the shift in motivational patterns over time. Another avenue for further research would include examining the effects of different types of activities between academia and industry. While our study considered a variety of activities, future research should also seek to provide more informed judgment on the potential benefits and drawbacks associated with the different activity types when academic researchers participate in industry projects. This also implies that future research should be aimed at identifying in greater detail the common features among researchers who actively engage with industry partners.

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Figures and Tables

Figure 1: Research model

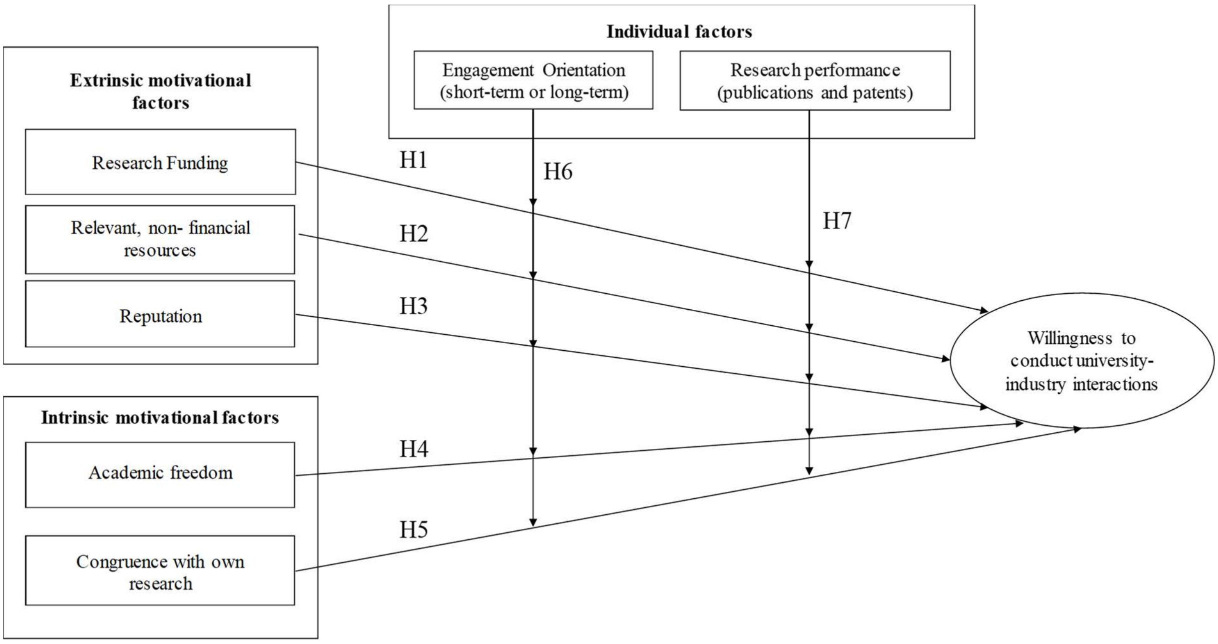

Figure 2: Conjoint scenario example

<u>University-industry Project F</u>

Symbolic research funding

Access to in-kind resources

Restrictions in academic freedom

Comprehensive gain in academic reputation

Peripheral area of research

Figure 3: Rating scale regarding the willingness to conduct university-industry interactions

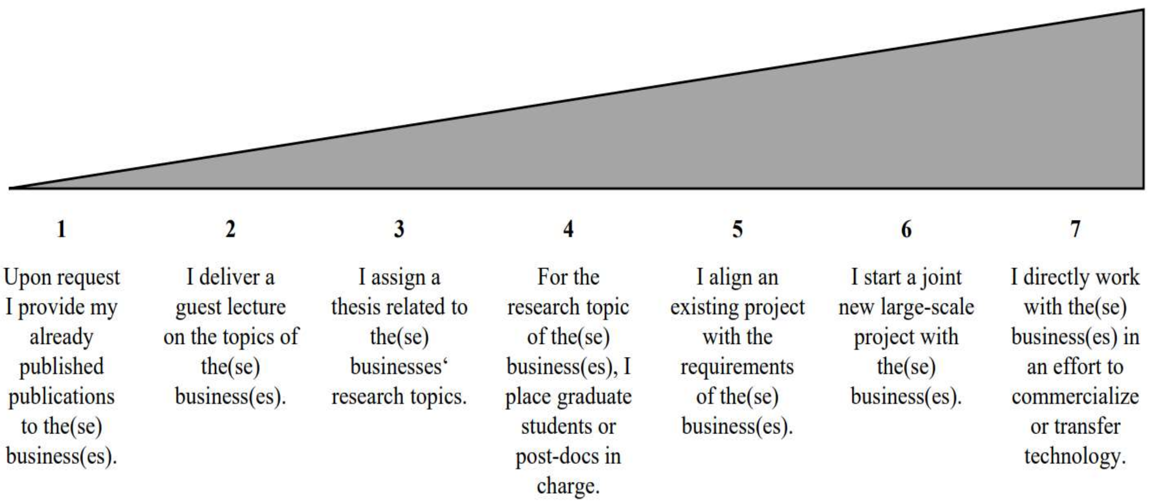

Table 1: Sample characteristics

Research area	Professors	Observations	Proportion
Bioengineering / biomedical engineering / chemical engineering	49	784	19.6
Civil engineering / sustainable engineering	31	496	12.4
Computer engineering	38	608	15.2
Electrical engineering / electronic engineering / communications engineering	44	608	15.2
Mechanical engineering / manufacturing engineering	50	705	17.6
Materials engineering / electrical / electronic / communications engineering	38	800	20.0
Total	250	4000	100%

Table 2: Sample characteristics to control for selection and non-response bias

	Invited professors (n=4029)			**Participating professors (n=250)**	
Attribute	Total number	Proportion		Total number	Proportion
Professors at public universities	883	21.9		37	14.8
Professors at private universities	3146	78.1		213	85.2
University ranked 1 to 50	2284	56.7		118	47.2
University ranked 51 to 100	970	24.1		68	27.2
University ranked 101 to 150	530	13.2		51	20.4
University ranked 151 to 200	0	0		0	0
University ranked 201 to 250	245	6.1		13	5.2
Notes: Classification of universities as per ranking statistic by U.S. News, 2012.					

Table 3: Attributes and levels of the industry project profiles

Attribute of the entrepreneurial project	**Description**	**Low level**	**High level**
Research funding	… is a financial incentive through access to research-related money from the industry partner.	Symbolic research funding	Substantial research funding
Access to in-kind resources	… is a non-financial incentive through access to industry-provided equipment, materials, and data for research.	No access to in-kind resources.	Access to in-kind resources
Reputation	… describes the potential gain in academic reputation through participating in the industry project.	Limited gain in academic reputation	Comprehensive gain in academic reputation
Academic freedom	… is the degree of self-determination possible in the working conditions and research activities of the industry project.	Restrictions in academic freedom	Academic freedom will be maintained
Congruence with own research focus	… describes the degree of thematic proximity between your current research and the topic of the industry project.	Peripheral area of research	Core area of research

Table 4: Correlations and descriptive statistics

No.	Variables	1	2	3	4	5	6	7	8	9	10
1	University-industry interaction	1.00									
2	Research orientation (basic research vs. applied research)	0.05	1.00								
3	Discipline (materials engineering = 1, 0 otherwise)	0.02	0.10	1.00							
4	Attitude towards industry collaboration (traditional vs. entrepreneurial)	-0.01	-0.40	-0.13	1.00						
5	Tech transfer rank	0.01	0.18	0.00	0.00	1.00					
6	Pressure to seek external funding (high pressure = 1, low pressure = 0)	0.07	0.14	-0.07	-0.11	-0.08	1.00				
7	University type (public = 1, private = 0)	-0.05	-0.06	-0.11	0.01	-0.12	-0.06	1.00			
8	Department R&D	0.06	-0.05	0.04	0.00	-0.28	-0.02	-0.17	1.00		
9	Scientific staff	-0.02	-0.18	-0.03	0.02	-0.19	-0.04	-0.05	0.30	1.00	
10	Gender (male = 1, female = 0)	0.05	-0.08	0.08	-0.01	0.09	-0.11	0.03	0.06	-0.11	1.00
11	Age	-0.11	0.00	0.06	-0.01	0.05	-0.11	0.06	0.08	-0.03	0.14
12	Status (chair holder, full prof., or assoc. prof. = 1; assist. prof. = 0)	-0.06	-0.02	0.01	-0.08	0.11	-0.05	0.00	0.10	-0.07	0.14
13	Patents	-0.02	-0.03	-0.13	-0.09	-0.03	-0.04	0.16	0.00	-0.05	0.10
14	Publications	0.08	-0.09	-0.14	0.07	-0.13	0.05	-0.01	-0.07	0.05	-0.06
15	Research funding (substantial = 1, symbolic = 0)	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	In-kind resources (granted = 1, not granted = 0)	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	Academic freedom (maintained = 1, restricted = 0)	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	Academic reputation (high gain = 1, low gain = 0)	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Area of research (high = 1, low = 0)	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Short-term orientation (short-term = 1, long-term = 0)	0.12	0.35	0.05	-0.48	0.03	0.23	-0.05	-0.11	-0.09	0.08
	Mean	3.71	3.10	0.20	2.87	55.90	4.57	0.14	30183.10	34.76	0.89
	SD	1.85	0.88	0.40	0.94	50.24	0.71	0.34	34983.87	38.72	0.32
	Min	1.00	1.00	0.00	1.00	2.00	1.00	0.00	0.00	0.00	0.00
	Max	7.00	5.00	1.00	5.00	226.00	5.00	1.00	176713.00	400.00	1.00

Table 4: Correlations and descriptive statistics (continued)

No.	Variables	11	12	13	14	15	16	17	18	19	20
11	Age	1.00									
12	Status (chair holder, full prof., or assoc. prof. = 1; assist prof.= 0)	0.65	1.00								
13	Patents	0.14	0.11	1.00							
14	Publications	-0.59	-0.52	-0.06	1.00						
15	Research funding (substantial = 1, symbolic = 0)	0.00	0.00	0.00	0.00	1.00					
16	In-kind resources (granted = 1, not granted = 0)	0.00	0.00	0.00	0.00	0.00	1.00				
17	Academic freedom (maintained = 1, restricted = 0)	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
18	Academic reputation (high gain = 1, low gain = 0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00		
19	Area of research (high = 1, low = 0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	
20	Short-term orientation (short-term = 1, long-term = 0)	-0.01	0.02	0.15	0.08	0.00	0.00	0.00	0.00	0.00	1.00
	Mean	20.43	0.77	0.10	0.49	0.50	0.50	0.50	0.50	0.50	3.60
	SD	11.85	0.42	0.28	0.66	0.50	0.50	0.50	0.50	0.50	0.93
	Min	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	Max	51.00	1.00	2.61	4.62	1.00	1.00	1.00	1.00	1.00	5.00

TABLE 5: Ordered-logit regressions predicting the willingness to conduct university-industry interactions

Variables	Model 1	Model 2	Model 3	Model 4
Research orientation (basic research vs. applied research)	0.10	0.10	0.10	0.10
	(0.10)	(0.10)	(0.10)	(0.10)
Discipline (materials engineering = 1, 0 otherwise)	0.08	0.08	0.08	0.08
	(0.17)	(0.17)	(0.17)	(0.17)
Attitude towards industry collaboration (traditional vs. entrepreneurial)	0.18*	0.18*	0.18*	0.18*
	(0.10)	(0.10)	(0.10)	(0.10)
Tech transfer rank	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Pressure to seek external funding (low pressure vs. high pressure)	0.07	0.07	0.08	0.07
	(0.08)	(0.08)	(0.08)	(0.08)
University type (public = 1, private =0)	-0.10	-0.10	-0.10	-0.10
	(0.15)	(0.16)	(0.16)	(0.16)
Department R&D	0.00**	0.00**	0.00**	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)
Scientific staff	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Gender (male = 1, female = 0)	0.39*	0.39*	0.40**	0.39*
	(0.20)	(0.20)	(0.20)	(0.20)
Age	-0.02***	-0.02***	-0.02***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.01)
Status (chair holder, full prof., or assoc. prof. = 1; assist. prof. = 0)	0.05	0.07	0.07	0.07
	(0.19)	(0.19)	(0.19)	(0.19)
Patents	-0.25	-0.25	-0.04	-0.25
	(0.29)	(0.29)	(0.60)	(0.29)
Publications	0.01	0.01	0.01	0.11
	(0.12)	(0.12)	(0.12)	(0.19)
Research funding (substantial = 1, symbolic = 0)	1.78***	1.31***	1.28***	1.33***
	(0.10)	(0.35)	(0.35)	(0.36)
In-kind resources (granted = 1, not granted = 0)	0.39***	0.27*	0.25*	0.30**
	(0.04)	(0.15)	(0.15)	(0.15)
Academic freedom (maintained = 1, restricted = 0)	1.18***	2.20***	2.24***	2.22***
	(0.08)	(0.38)	(0.38)	(0.38)
Academic reputation (high gain = 1, low gain = 0)	0.87***	1.14***	1.12***	1.13***
	(0.06)	(0.22)	(0.22)	(0.22)
Area of research congruence (high = 1, low = 0)	1.06***	1.54***	1.53***	1.55***
	(0.07)	(0.24)	(0.24)	(0.24)
Short-term orientation (Short-term vs. long-term)	0.32***	0.49***	0.47***	0.48***
	(0.09)	(0.16)	(0.16)	(0.16)

Co-efficients are reported, standard errors in parentheses

*p < .10 **p < .05 ***p < .01

TABLE 5: Ordered-logit regressions predicting the willingness to conduct university-industry interactions (continued)

Variables	Model 1	Model 2	Model 3	Model 4
Research funding*short-term orientation		0.13	0.16	0.14
		(0.10)	(0.10)	(0.10)
Area of research*short-term orientation		-0.13**	-0.13**	-0.13**
		(0.06)	(0.06)	(0.06)
In-kind resources*short-term orientation		0.03	0.04	0.04
		(0.04)	(0.04)	(0.04)
Academic reputation*short-term orientation		-0.07	-0.06	-0.07
		(0.06)	(0.06)	(0.06)
Academic freedom*short-term orientation		-0.28***	-0.31***	-0.28***
		(0.10)	(0.10)	(0.10)
Area of research*patents			-0.07	
			(0.14)	
Academic freedom*patents			0.67**	
			(0.30)	
Research funding*patents			-0.61**	
			(0.24)	
Academic reputation*patents			-0.26**	
			(0.12)	
In-kind resource*patents			-0.20	
			(0.18)	
Area of research*publications				-0.03
				(0.10)
Academic freedom*publications				-0.05
				(0.08)
Research funding*publications				-0.07
				(0.11)
Academic reputation*publications				0.04
				(0.06)
In-kind resource*publications				-0.08
				(0.05)
Observations	4000	4000	4000	4000
Log-Likelihood	-6727.10	-6711.36	-6701.92	-6710.23

Co-efficients are reported, standard errors in parentheses

*p < .10 **p < .05 ***p < .01

Appendix: Multi Item Measures

Construct	Measurement Item(s)	Scale	Cronbach's Alpha
Pressure to seek external funding	(1) *At our university, we give priority to acquiring external research funding to obtain additional resources for department funding.* (2) *My university regards external research funding as an academic achievement considered in annual performance evaluations and salary increases.* (3) *Seeking external research funding is perceived as an integral part of academic advancement in terms of recognition and prestige*.	Likert scale 1 = *strongly disagree;* 5 = *strongly agree*	0.82
Attitude towards industry collaboration	(1) *I believe in the fundamental importance of academic-industry collaboration for scientific advancement.* (2) *I believe that the benefits of collaboration with industry usually outweigh the inconveniences and costs of such work.* (3) *Because of my collaboration with industry, I have an increased understanding of what my own research brings to others.* (4) *I am confident that collaborating with industry will yield valuable scientific outcomes.* (5) *I try to combine industrial ways of working with my research methods to foster the outcome of my research.* (6) *I believe in the fundamental importance of academic-industry collaboration for application and commercial exploitation.*	Likert scale 1 = *strongly disagree;* 5 = *strongly agree*	0.83
Short-term orientation	*(1) I believe that over the long run my collaboration with industry will be profitable. (2) Maintaining long-term collaborations with industry is important to me. (3) I focus on long-term goals in my collaborations with industry. (4) I am willing to make sacrifices to help my collaboration partner from time to time. (5) Any concession we make to help out this resource will even out in the long run.*	Likert scale 1 = *strongly disagree;* 5 = *strongly agree*	0.82
Research orientation	*(1) My research activities primarily aim at the investigation of general principles and theories … My research activities primarily aim at the exploration of well-founded guidelines for practical actions. (2) The goal of my research activities is to acquire new knowledge about phenomena and observable facts. ... The goal of my research activities is to determine the possible use of new knowledge for achieving specific objectives. (3) My research is conducted for the advancement of knowledge without seeking economic or social benefits. ... My research is with the expectation to solve particular problems. (4) My research efforts are focused on studying phenomena in order to obtain information. ... My research efforts are focused on optimizing predetermined processes and methods.*	Five-point semantic differential 1=left statement fully applies 5= right statement fully applies.	0.83