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Tapping into Industry and Academia: Inbound Mobility, R&D Collaboration and Substitution Effects

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Abstract

This paper studies how different boundary-spanning mechanisms concurrently impact firm innovation. We specifically examine how inbound mobility and R&D collaboration interact when firms use these mechanisms to tap into two distinct knowledge domains: industry and academia. To examine the impacts of simultaneously sourcing academia and industry through hiring and collaboration we utilize a unique Danish dataset which draws on three independent data sources including employer-employee register data, R&D survey data, and patent application data from the European Patent Office. The analysis relies on 13472 firm-year observations, including 12608 hiring events and 691 collaborations, in the period 2001-2004. The results indicate that inbound mobility and collaboration substitute for one another and this result accentuates when firms use both mechanisms to source knowledge from within either the industry or academia domain. We interpret these results as evidence of knowledge redundancies, diseconomies of scope and attention-allocation problems. We contrast prior research on the benefits of involving external partners in a firm?s R&D process by underscoring negative marginal returns from simultaneously sourcing the same type of external organization with a different mechanism.

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ABSTRACT. This paper studies how different boundary-spanning mechanisms concurrently impact firm innovation. We specifically examine how inbound mobility and R&D collaboration interact when firms use these mechanisms to tap into two distinct knowledge domains: industry and academia. To examine the impacts of simultaneously sourcing academia and industry through hiring and collaboration we utilize a unique Danish dataset which draws on three independent data sources including employer-employee register data, R&D survey data, and patent application data from the European Patent Office. The analysis relies on 13472 firm-year observations, including 12608 hiring events and 691 collaborations, in the period 2001-2004. The results indicate that inbound mobility and collaboration substitute for one another and this result accentuates when firms use both mechanisms to source knowledge from within either the industry or academia domain. We interpret these results as evidence of knowledge redundancies, diseconomies of scope and attention-allocation problems. We contrast prior research on the benefits of involving external partners in a firm's R&D process by underscoring negative marginal returns from simultaneously sourcing the same type of external organization with a different mechanism.

KEYWORDS: Hiring, Collaboration, Innovation, Substitution, University-Industry

INTRODUCTION

Organizations increasingly require knowledge inputs that reside outside their organizational boundaries for their research & development (R&D) activities. External knowledge facilitates learning and may bolster firms' innovative capacity in similar or different domains (Lavie & Rosenkopf, 2006; Levin et al., 1987; Mowery, Oxley, & Silverman, 1996). As a result, scholars have underscored the value of different mechanisms to acquire external knowledge, such as R&D alliances and recruitment of skilled individuals (Gulati, 1999; Rosenkopf & Almeida, 2003; Tzabbar, 2009). At the same time, a growing body of literature has alluded to innovation synergies between internal resources and resources that reside outside firms (Cassiman & Veugelers, 2006; Dyer & Singh, 1998; Hess & Rothaermel, 2011; Lavie & Drori, 2012). Yet, little attention has been paid to the interplay among the different boundary-spanning mechanisms that firms utilize to acquire external resources. That is, interdependencies among the different boundary-spanning mechanisms may exist, and they may either strengthen or weaken the combined effect of such mechanisms. In this study we seek to shed light on the interaction between two mechanisms prior research has identified through which firms acquire external knowledge: (1) inbound mobility of scientists and engineers and (2) R&D collaboration. We specifically direct attention to the fact that firms keep multiplex relationships with other organizations (Ozmel, Reuer, & Gulati, 2013; Shipilov & Li, 2012; Somaya, Williamson, & Lorinkova, 2008) and explore how one external sourcing mechanism complements or substitutes for another in terms of innovation output.

We address this underexplored issue by investigating the possible tradeoffs and synergies between hiring and research collaboration for firm innovation. We posit that the learning enabled by these boundary-spanning mechanisms occurs in two domains, namely industry and academia. While prior research has addressed how these mechanisms affects innovation outcomes in a single domain (e.g. Bercovitz & Feldman, 2007; Lacetera, Cockburn, & Henderson, 2004), research addressing the effects of simultaneous collaboration and recruitment in both domains is quite scarce (cf. Hess & Rothaermel, 2011).

Drawing a distinction between industry and academia is crucial for at least two reasons. First, each domain provides a firm with a distinct type of knowledge. Academia primarily focuses on basic science and discovery, and cooperation with, and hiring from, universities provides firms with state-of-the-art knowledge and recent scientific advances (Cockburn & Henderson, 1996). In contrast, inbound mobility from, and collaboration with, industry is likely to be driven by a firm's need for transformation of relevant scientific or technological knowledge into commercially valuable inventions (Gittelman & Kogut, 2003). Thus, universities provide a firm with basic research, while partnering with industry is likely to fuel future development of applied knowledge. Second, firms require different capabilities to maintain relationships and integrate new hires from either industry or academia. Universities follow different incentive systems than firms, which may hamper collaboration efforts or integration of scientists and engineers whom have been working in academia prior to joining a firm. We are thus particularly interested in whether R&D collaboration with firms and universities substitutes or complements recruitment from each organization type.

Drawing on prior research on inbound mobility and R&D collaboration, we posit that simultaneous sourcing external knowledge may on the one hand lead to innovation synergies, for example when hired engineers interpret and implement newly developed knowledge components through joint R&D between firms. On the other hand, simultaneously engaging in hiring and collaboration may also incur negative innovation performance effects. Concurrent sourcing through hiring and collaborating may decrease efficiency of search processes as a result of diseconomies of scope and manager attention problems. Subsequently, we develop the argument that R&D collaboration and recruitment act as substitutes in a particular knowledge domain. In this case, hiring from, and collaboration with either industry or academia provides a firm with similar knowledge which will result in a negative interplay between inbound mobility and collaboration.

Our study draws on a unique database from Denmark for the period 2001-2004. The dataset combines three independent data sources: (1) Danish register employer-employee data, (2) survey data concerning firms' R&D activities (similar to the European Community Innovation Survey, CIS) and (3) European Patent Office (EPO) data. The main advantage of our dataset is the opportunity to identify mobility of all scientists and engineers and distinguish between scientists and engineers who previously worked in industry and those that have academic working experience prior to joining the recipient firm. In addition, the yearly R&D surveys provide us with self-reported answers about the type of firms' R&D collaboration partners. Our zero-inflated negative binomial regression analysis relies on a total of 12608 general inbound mobility events, 691 general collaborations and 13472 firm-year observations across all Danish industries in the period 2001-2004.

Using citation-weighted patents applied for at the EPO to capture innovation performance we primarily find evidence of negative marginal returns when firms simultaneously engage in recruiting skilled workers and collaboration with external organizations. More importantly, our study reveals that substitution effects become even more pronounced when we distinguish between tapping into the industrial and academic knowledge domain. We interpret these results as an indication that firms acquire redundant knowledge, and also experience problems related to diseconomies of scope and attention-allocation, when they concurrently hire and engage in collaboration to fuel internal R&D.

Our study provides a nuanced account of tapping into knowledge sources outside the firm with different mechanisms. Our contribution to the literature on external knowledge sourcing to harness innovation is three-fold. First, this study increases our understanding of the contingency effects of different external sourcing mechanisms on firm innovation. Prior research has either considered independent effects of different mechanisms (e.g. Rosenkopf & Almeida, 2003) or examined complementary or substitution effects between external and internal resources (e.g. Hess & Rothaermel, 2011). However, the combined effect of simultaneously using different boundary-spanning mechanisms on firm-level innovation has not been studied so far. Second, we complement the growing literature on alliances and mobility with distinguishing between industry and academia. Prior work on mobility has investigated recruitment from industry or universities separately (e.g. Lacetera et al., 2004), with few exceptions. Likewise, the alliance literature has examined different types of alliances but has less so focused on the type of organization that firms ally with. We provide evidence that collaborating with, and hiring from, either knowledge domain have differential direct and moderating effects on firm innovation across industries. Third, we complement prior research on open innovation in which claims are made that firms may suffer from too much openness (Laursen & Salter, 2006; Lavie & Drori, 2012). We demonstrate that open strategies may also incur costs and this raises questions on how firms may simultaneously source external knowledge through different mechanisms in an efficient way.

The set-up of this paper is as follows. First we introduce our theoretical framework and develop the hypotheses. The subsequent section discusses the different datasets and variables used in this study. The following section presents our results, and we subsequently discuss the results in light of previous work on external knowledge sourcing mechanisms in the discussion section. We conclude in the final section.

THEORY AND HYPOTHESES

Our aim is to understand how inbound mobility of scientists and engineers, and collaboration with external organizations, concurrently affect firm innovation. We build on the labor mobility and alliance literature, the literature on university-industry interaction, and search for innovation to develop our hypotheses. We also introduce the definitions of complementarity and substitution.

A firm's innovation process involves search and problem-solving and is eventually the result of recombination of existing knowledge components (Fleming, 2001; Hargadon & Sutton, 1997; Schumpeter, 1934). Internal personnel and resources often fail to provide all the relevant knowledge firms need to innovate. In particular firms in high-tech industries therefore access knowledge outside the firm boundary to broaden the available search space, which subsequently increases a firm's innovative performance (Ahuja, 2000; Powell, Koput, & Smith-Doerr, 1996; Rosenkopf & Almeida, 2003). External knowledge acquisition enables firms to combine internal with external resources and this has been shown to result in complementarity (Cassiman & Veugelers, 2006).

Several mechanisms have been studied through which firms cross their boundaries and access sources of external knowledge, including alliances (Arora & Gambardella, 1990; Lavie & Rosenkopf, 2006; Rothaermel, 2001), licensing (Arora & Gambardella, 2010), firm acquisition (Ahuja & Katila, 2001) and hiring of personnel (Ettlie, 1985; Song, Almeida, & Wu, 2003). Two means of external knowledge sourcing have our specific interest in this paper; R&D collaboration and inbound mobility of skilled workers. R&D collaboration is defined as cooperation or active participation in joint projects between a firm and another organization with the intention to conduct joint R&D. Inbound mobility is defined as the recruitment of highlyskilled individuals (i.e. engineers and scientists) by firms to acquire new knowledge and skills to foster internal R&D. Early work on external knowledge sourcing has shown firms simultaneously engage in different mechanisms (Levin et al., 1987).

Simultaneous collaboration and hiring may be complementary to each other or may act as substitutes. Complementarity refers to the idea that the marginal return to one activity (e.g. inbound mobility) increases as the intensity of the other (e.g. collaboration) increases (Cassiman & Veugelers, 2006; Milgrom & Roberts, 1990, 1995; Parmigiani & Mitchell, 2009). Alternatively, resources or activities are substitutes if doing more of one activity reduces the marginal benefit of another. To understand whether collaboration complements or substitutes for inbound mobility the next sections discuss the benefits of inbound mobility and collaboration for innovation and subsequently turn to the contingent relationship of the two mechanisms with firm innovation.

Inbound Mobility

The literature on organizational learning and search has highlighted the role of hiring for firm innovation as firms may adopt processes and products following the inflow of knowledge through mobility (Ettlie, 1985; Groysberg & Lee, 2010; Song et al., 2003). In more general terms hiring exposes firms to new ideas, practices and a novel view on problem-solving (Arrow, 1962). Two main types of employees have been considered in the mobility literature: executives or managers (Boeker, 1997; Kraatz & Moore, 2002), and technical and scientific staff (Palomeras & Melero, 2010; Rosenkopf & Almeida, 2003; Song et al., 2003). We focus on the latter type of worker as they are likely to carry technical or scientific knowledge which fuels the hiring firm's search for innovation.

Recruitment from firms (i.e. industry) has received most attention and follows the definition in the learning-by-hiring literature which states that hiring involves "the acquisition of knowledge from other firms through the hiring of experts" (Song et al., 2003: 352). Hiring away skilled workers from firms affects the hiring firm's innovation performance in three ways. First, industrial scientists and engineers apply their skills obtained through education and on-the-job training (Bidwell & Briscoe, 2010; Bidwell, 2011) and transfer knowledge which can be subsequently recombined with internal knowledge (Rosenkopf & Almeida, 2003). The knowledge and skills of individual workers from industry is mainly of applied nature and positively affects subsequent firm innovation. Second, inbound mobility of skilled workers from other firms allows the hiring firm to tap into the expertise of the worker's prior employer (Corredoira & Rosenkopf, 2010; Song et al., 2003). Hired engineers and scientists maintain informal contact with their previous colleagues and such social ties may act as pipelines, providing up-to-date knowledge of technological developments at the source firm (Song et al., 2003). Third, firm employees also bring social capital in the form of external contacts originating from the time they were still in the prior workplace (Carnahan & Somaya, 2011; Dokko & Rosenkopf, 2009; Somaya et al., 2008). The hiring firm's network of suppliers, customers and other type of partners may thus change through hiring. Taken together, these mechanisms suggest hiring workers from other firms positively affect firm patenting.

Another important type of inbound mobility, hiring of university scientists, has received less attention in the literature on mobility and innovation (see for exceptions: Ejsing, Kaiser, Kongsted, & Laursen, 2012; Lacetera et al., 2004). This is somewhat surprising, since hiring from academia is likely to affect firm innovation differently than firm hiring. The main reason why we expect university and firm hiring to differently impact innovative performance relates to the difference between academia and industry (Gittelman & Kogut, 2003; Zucker &

Darby, 1996). Scientists and engineers with an industry background are likely to carry knowledge which can be readily applied in the hiring firm, while university scientists provide superior state-of-the art basic research.

We identify two main mechanisms through which academic workers affect firm innovation. First, a scientific background provides an individual with strong research skills and a cognitive map for problem-solving (Fleming & Sorenson, 2004; Gibbons & Johnston, 1974). Typically, university scientists hold a PhD and have several years of academic experience before they switch to industry. During their education and academic training they conduct basic research, produce publications and serve the academic community with scientific insights. Scientists thus carry superior research skills and this experience alters their search processes (Fleming & Sorenson, 2004). Second, inbound academic mobility also provides hiring firm's with access to a greater academic community (Gittelman & Kogut, 2003; Lacetera et al., 2004). Hiring academics provides not only access to such a valuable community, but also enables the hiring firm to use the scientist as translator of science into industrial application (Cohen & Levinthal, 1990; Gibbons & Johnston, 1974). The superior problem-solving capabilities of academic hires and access to the scientific research community are expected to lead to higher impact innovations produced by the hiring firm.

R&D Collaboration

Another mechanism to cross firm boundaries and acquire external knowledge is R&D collaboration (Ahuja, 2000; Grant & Baden-Fuller, 2004; Powell, White, Koput, & Owen-Smith, 2005; Uzzi, 1996). General R&D collaboration positively impacts firm innovation in several ways, for instance through knowledge-sharing and access to information about indirect partners (Gulati & Gargiulo, 1999). Moreover, firms can cut costs related to performing internal R&D, for instance through sharing of equipment. In particular when firms have collaboration experience, and therefore a trustworthy relationship with partners, subsequent collaboration becomes more effective (Dyer & Singh, 1998). Similar to our arguments for inbound mobility, we expect that R&D cooperation with industry and academia have distinct effects on firm innovation.

R&D collaboration with industry partners concerns active participation in R&D projects with firms in the same industry, R&D alliances, technology licensing (if including cooperation), consulting and collaboration with suppliers and customers. Collaboration with industry provides knowledge of applied nature, similar to what firms would gain by hiring from industry. Alternatively, R&D collaboration with academia mainly involves R&D projects, alliances and university licensing. University collaboration provides firms with basic research and recent scientific advances, increasing the likelihood that a firm explores new knowledge areas (Lavie & Rosenkopf, 2006; Rothaermel & Deeds, 2004). Thus we find similar advantages for hiring from, and collaboration with respectively industry and academia.

To conclude, we expect both inbound mobility and R&D collaboration to have positive impacts on subsequent innovative performance (i.e. baseline effects).

Combined Effect: Complementary vs. Substitution Effects

Collaboration and inbound mobility may on the one hand complement each other in fueling a firm's innovative capacity. We identify two ways in which collaboration and inbound mobility complement each other. First, each mechanism may breed trust between organizations (Dyer & Singh, 1998; Gulati, 1999) which enhances the influence of the other boundary-spanning mechanism on firm innovation. To illustrate this, a firm's ongoing joint R&D with an external partner may strengthen the effect of hiring an engineer from the same partner as the recipient firm is likely to have trustworthy knowledge on the partner's resources and personnel. Second, hired individuals may act as agents of implementation. That is, scientists and engineers may have the necessary tacit knowledge of technologies to readily implement solutions that have been partly obtained through the collaboration channel. Thus, we hypothesize the following:

Hypothesis 1A: Inbound mobility and R&D collaboration are complements in such a way that the interaction between inbound mobility and R&D collaboration is positive and thus positively *impacts a firm's* innovative performance

On the other hand, both mechanisms may also act as substitutes. Three main arguments can be put forward why this is the case. First, R&D collaboration and hiring provide similar advantages to firms. Firms obtain access to external complementary knowledge when they collaborate (Rothaermel, 2001), and when they engage in hiring (Song et al., 2003). Because R&D collaboration involves intensive interaction between R&D departments of firms, or between university and a firm, knowledge transfer is likely to be safeguarded as is the case with mobility. Second, a firm that simultaneously hires from, and collaborates with external partners runs the risk to experience diseconomies of scope. A firm that recurrently uses one mechanism, for instance R&D collaboration, accumulates collaboration-specific skills, which lowers the marginal cost of a specific mechanism. Simultaneous sourcing through hiring and collaboration may thus involve disadvantages and decrease subsequent firm innovation. Third, another disadvantage is related to the attention-allocation problem (Ocasio, 1997). Incorporating R&D hires and knowledge obtained through collaboration requires substantial management attention. This becomes particularly clear with regard to decision-making by the R&D managers of the firm. Engaging in both mechanisms at the same time leads to attention allocation problems and therefore decreases firm innovation. Based on previous arguments about knowledge redundancy, diseconomies of scope and attention-allocation problems we expect that simultaneous recruitment and collaboration decrease marginal returns to innovation. We therefore alternatively hypothesize:

Hypothesis 1B: Inbound mobility and R&D collaboration are substitutes in such a way that the interaction between inbound mobility and R&D collaboration is negative and thus negatively *impacts a firm's* innovative performance

Combined Effect Within Knowledge Domains

While competing arguments can be made about the complementarity or substitutability of the two knowledge-sourcing mechanisms, we argue that more nuanced effects can be discerned by considering the knowledge domains that the mechanisms tap into. More specifically, the interplay between inbound mobility and R&D collaboration is more likely to be negative when both mechanisms tap into the same knowledge domain. This is because firms acquire redundant knowledge through hiring from, and collaborating with, the same knowledge domain. Accessing external knowledge with a different mechanism from either industry or academia provides a firm with a similar type of knowledge, either of primarily applied or basic nature. In such cases, the interplay between inbound mobility and collaboration shifts towards experiencing problems related to attention allocation of managers and diseconomies of scope. As a result, we suggest a substitutive relationship between inbound mobility and R&D collaboration within the knowledge domain as both mechanisms provide similar knowledge and may lead to suboptimal search processes. Thus, we offer the following two hypotheses:

Hypothesis 2A: Inbound industry mobility and R&D collaboration with industry are substitutes in such a way that the interaction between inbound industry mobility and industry collaboration is negative and thus negatively impacts a *firm's* innovative performance

Hypothesis 2B: Inbound university mobility and R&D collaboration with academia are substitutes in such a way that the interaction between inbound university mobility and university collaboration is negative and thus negatively impacts a *firm's* innovative performance

In summary, our framework considers four sourcing types through which firms tap external knowledge and we examine the contingent effects on firm innovation. Figure 1 visualizes and summarizes the four boundary-spanning mechanisms we examine in this study. Figure 2 shows the conceptual model with the hypothesized relationships.

Insert Figure 1 around here

Insert Figure 2 around here

DATA AND METHODOLOGY

Data. Our research setting is the Danish economy in the period 2001-2004. In order to test our hypotheses concerning the interplay between hiring of skilled workers and research collaboration we rely on a unique longitudinal Danish dataset. The dataset combines three major datasets available in Denmark. First, we use the Danish Integrated Database for Labor Market Research (IDA) which is the Danish employer-employee register database (e.g. Nanda & Sørensen, 2010;

Timmermans, 2010). All persons, establishments and firms are followed annually, from 1980 onwards. The information in the database allows us to directly follow the career of all scientists and engineers in Denmark. Second, we utilize Danish Research and Development surveys in the period 2000-2003. These surveys are annually conducted by the Danish Centre for studies in Research and Research Policy (DCSRRP) and around 3000 cross-industry firms responded each year. The survey is similar to the European Community Innovation Survey (CIS). From the survey we extract information regarding a firm's collaboration partners. Third, patent application data from the European Patent Office provides us with innovation indicators. We merged the three databases on the firm-level and focus on the representative sample of Danish firms that responded to the R&D survey.

Scientists and engineers. In this paper we specifically focus on employees that conduct R&D and add value to a firm's innovativeness. To distinguish employees that are potentially involved in a firm's R&D we utilize individual information available in the employer-employee register data. The definition of a skilled worker is based on three main requirements: education, occupation and age. First, scientists and engineers are employees with at least a vocational or bachelor degree in engineering, natural, veterinary, agricultural or health sciences. Second, they should be employed in a job function which requires a high level of skills following the International Standard Classification of Occupations (ISCO). Such a job position consists "of increasing the existing stock of knowledge, applying scientific and artistic concepts and theories to the solution of problems, and teaching about the foregoing in a systematic manner" (ILO, 2004). Also, we exclude employed individuals younger than 20 years, older than 75 years and retired individuals.

Hiring. We recorded hiring when an individual moved to a firm from either another firm or a university. The data allowed us to distinguish recruitment from firm splits, mergers and spin-offs. Firms in our sample annually hire on average 0.04 university researchers and 0.90 scientists and engineers from other firms (i.e. 0.94 general skilled workers). A total of 12068 inbound industry mobility events and 540 inbound university mobility events are identified.

Collaboration. In the Danish R&D survey firms self-report the use of collaboration partners for their innovation process. Collaboration with regard to a firm's innovation process includes active cooperation in projects regarding R&D, and other innovative activities. Licensing or other ties with external partners that involve no active collaboration with external partners is not part of R&D collaboration. In the four-year period a total of 273 unique firms collaborate at least once only with industry, a number of 328 firms collaborate at least once only with academia, and 219 firms collaborate with both industry and university in the same year. Overall, 691 firms collaborate with external organizations, regardless of the organization type.

Firms. The sample of Danish firms that responded to the R&D survey was matched with the employer-employee register data through the national identification number. Patent applications applied for by Danish firms at the EPO were matched to firm identifiers based on assignee name. We excluded governmental organizations from the analysis. The final dataset includes 8966 across-industry firms and 13472 firm-year observations in the period 2001-2004 (See Figure 3 for the number of observations with each type of inbound mobility and collaboration per year).

Insert Figure 3 around here

The panel data is unbalanced, since the waves of R&D surveys target a representative sample of firms, but not necessarily the same firms. As a result, firms occur on average 1.5 times in the four-year period.

Measures

Dependent variable: Citation-weighted patents. Firm innovative performance is measured using a count of the number of patents a firm applied for at the EPO, weighted by the number of forward citation in a three-year moving window. We used patent application data as the application date is the point in time which is closest to the firm's innovation process. Citation-weighted patents are widely used to measure innovative performance (e.g. Ahuja, 2000; Sampson, 2007) as it indicates the number of innovations and quality of innovations that firms produce (Trajtenberg, 1990). Firms in our sample apply on average for 0.26 citation-weighted patents per year.

Focal independent variables. We measure hiring or inbound mobility as the log number of new R&D recruits. Three variables are constructed to examine the impact of hiring on firm innovativeness. First, we pool all inbound mobility regardless of source organization (Pooled inbound mobility). Then we distinguish between individuals hired from firms (Inbound industry mobility) and universities (Inbound university mobility). The main difference between the two types of employees is that university workers have been employed at a university. Typically university scientists hold a master or PhD degree and have worked for several years at the university as doctoral student or post-doc. We assume university hires bring more fundamental and abstract knowledge to firms compared to firm hires through their scientific background.

We obtain information on collaboration partners from the Danish R&D survey. In the period 2000-2003 firms were asked to which extent they use a set of collaboration partners. Firms were asked which types of external partners they collaborated with in the past year. In this paper we focus on collaboration with Danish firms and universities. Again, three variables regarding collaboration are constructed. We distinguish between collaboration in general (Pooled collaboration), collaboration with industry (Industry collaboration) and academia (University collaboration). The variables are dummies with the value 1 if a firm collaborates at all, or with each of the external partner types.

To capture the combined effect of hiring and collaboration we center and interact the inbound mobility and collaboration variables (Aiken & West, 1991). We construct three interaction variables: general hiring with general collaboration (Pooled inbound mobility x pooled collaboration), hiring from firms with firm collaboration (Inbound industry mobility x collaboration) and likewise for university hiring and collaboration with academia (Inbound university mobility x collaboration).

Control Variables. To control for unobserved heterogeneity among firms we followed the pre-sample patent approach from Blundell, Griffith, & Reenen (1995) to proxy a firm's likelihood to patent. The pre-sample patent stock thus acts as a "fixed-effect". To do so, we included the pre-sample mean number of patent applications per firm (Pre-sample mean estimator) and a dummy variable which captures whether a firm patented in t-1 (Patent dummy). We added the log number of employees to control for firm size (Firm size) and the log number of years since the firm was established (Firm age) since old and large firms are more likely to patent. To control for executive hiring and strategy change (Boeker, 1997) we added a variable which measures the number of recruited top management team (TMT) members (Inbound TMT mobility). Skilled workers that leave the hiring or recipient firm are accounted for by a dummy variable (Outbound mobility) indicating whether a firm lost a scientist or engineer due to retirement or job change. Employees that leave a firm may indirectly affect firm-level search processes (Corredoira & Rosenkopf, 2010). We control for a firm's R&D spending to account for its investment in creation of knowledge and absorptive capacity (R&D intensity). We measured R&D spending by dividing the number of scientists and engineers by the total number of employees. In addition to these control variables we add industry, regional and year dummies to capture sectoral, regional and time differences in innovative output.

Model Specification and Estimation

We estimate firms' innovative performance as a function of scientist and engineer recruitment, collaboration and the control variables. To investigate the relationships between innovative performance and hiring and collaboration we perform a firm-level study in which we explain the number of citation-weighted patent applications. The dependent variable is a count with an excess of zeroes (97% of the observations have zero patent applications) and we therefore considered zero-inflated models. The likelihood-ratio test indicates the presence of over-dispersion and the significant Vuong statistic indicates that we should chose a zero-inflated negative binomial model. The zero-inflated model handles over-dispersion by estimating the likelihood of observing a zero using the logit specification and secondly estimating the count of citation-weighted patent applications by a negative binomial model. The observed distribution of the dependent variable and the zero-inflated negative binomial model thus enables us to estimate two distinct processes. First, we are able to examine the predictors of the likelihood that firms patent at all with the logit model. At the same time, this model allows us to infer patent value, because the count model estimates the number of forward citations in a subsequent three year period. We cluster the standard-errors by firm to allow for within-group correlation, because observations for the same firm are likely to be correlated. The estimations are robust using the Huber-White-sandwich standard errors to correct for heteroskedasticity. All independent variables are lagged one year to avoid issues related to reverse causality.

RESULTS

Table 1 provides the descriptive statistics and correlations. Each of the individual VIF values are below the maximum value 10 (Belsley, Kuh, & Welsch, 1980), and the mean variance inflation factor (VIF) is 1.96. No correlations are high (>0.6), except the correlation between the pre-sample mean estimator and the patent dummy. The results do not alter when we remove the patent dummy. Thus, we do not find reasons that our results are unduly affected by multicollinearity. We follow a hierarchical or stepwise estimation procedure.

Insert Table 1 around here

Table 2 reports the results of the zero-inflated negative binomial model with clustered robust standard errors explaining innovative performance. As mentioned earlier, each model reports two models explaining the number of forward citations, or innovation value, (i.e. count model) and the likelihood that a firm does not patent, or has the value 0 (i.e. zero-inflated model). Model I reports the estimators for the control variables. In model II and III we added pooled inbound mobility and collaboration. Subsequently, we added both variables in model IV. The interaction between pooled inbound mobility and pooled collaboration is added in model V. In model VI to IX we added one-by-one each of the specific four mechanisms through which firms acquire external knowledge. The control variables plus all four main independent variables are added in model X. In model XI and XII we subsequently added the interactions between inbound industry mobility and industry collaboration, and inbound university mobility and university collaboration. The final model reports the coefficients of all variables.

Insert Table 2 around here

Hypothesis 1A posits that inbound mobility and R&D collaboration are complements with regard to a firm's innovative performance. Alternatively, hypothesis 1B predicts that both boundary-spanning mechanisms act as substitutes. Model V presents the interaction between pooled inbound mobility and pooled collaboration in both the count and zero-inflated model. We find partial support for hypothesis 1B. The interaction between pooled inbound mobility and pooled collaboration shows a positive and significant effect ($p<0.05$, two-sided) in the zero-inflated model. Substitution corresponds to a positive interaction in the estimations, since we predict the likelihood to observe a zero (Cohen, Cohen, West, & Aiken, 2003). Thus, the result indicates that simultaneously engaging in general recruitment and general collaboration decreases the likelihood of patenting.

In hypothesis 2A we predict that inbound mobility from, and collaboration with, industry leads to negative returns at the margin. In the full model XII we find support for this prediction in the zero-inflated part of the regression model. The interaction is significant and positively associated ($p<0.05$, two-tailed) to a firm's likelihood to obtain zero patent applications.

Model XII also served for testing hypothesis 2B. We predict that inbound mobility from academia and collaboration with universities are substitutes and that the interaction negatively impacts a firm's innovative performance. Consistent with our prediction in hypothesis 2B we find that the interaction between university hiring and collaboration with universities is negative and significant in the count model ($p<0.05$, two-tailed). Simultaneous hiring from, and collaborating with, academia thus has a negative impact on innovation quality.

Regarding the main effects of the focal independent variables we find differential effects. First, when we consider all inbound mobility and collaboration, regardless of the type of source firm, we find a negative and significant effect (respectively $p<0.05$ and $p<0.001$, two-tailed) on the likelihood to obtain zero patents in model V. Thus, in the absence of general inbound mobility and collaboration firms are less likely to produce an innovation. When we distinguish between industry and academia we find different effects. The final model reports on all variables and shows that inbound mobility from university has a positive and significant effect ($p<0.001$, two-tailed) on the number of forward citations. Indeed, this suggests hiring university researchers increases a firm's capacity to produce valuable patents. Furthermore, inbound industry mobility, collaboration with industry and collaboration with academia all have a negative and significant effect on the likelihood to apply for zero patents (respectively $p<0.05$, $p<0.05$, and $p<0.10$, two-tailed). These results suggest that these boundary-spanning mechanisms increase a firm's likelihood to apply for a patent.

With regard to the control variables we find in the zero-inflated negative binomial models that the pre-sample mean estimator negatively and significantly predicts zero patent applications in all models (at least $p<0.05$). In addition, the pre-sample mean estimator has a positive and statistically significant effect on the number of forward citations in all models. This suggests its importance as a control for unobserved heterogeneity at the firm-level. Also, firm size is positive and significant in most count models, which indicates that large firms are more likely to produce valuable patents. In some models we also find evidence that firm size increases the likelihood that firms apply for a patent at the EPO. Yet, this finding disappears when we include all boundary-spanning mechanisms. This may indicate that large firms engage more in boundary-spanning, which finds support in the correlation table. It may also be the case that this finding hints at the idea that large firms are better able to incorporate several boundary-spanning mechanisms at the same time. Firm age, inbound TMT mobility, general outbound mobility and R&D intensity do not affect either forward citations or the likelihood to apply for patents.

DISCUSSION

The present study was motivated by the two gaps in the management literature. First, studies have overlooked the common practice that firms simultaneously utilize different boundary-spanning mechanisms to source external knowledge, raising the question whether different boundary-spanning mechanisms complement or rather substitute for one another. Second, few studies have addressed the fact that firms hire from, and collaborate, with industry and academia, while each knowledge domain may have differential effects on firm innovation. In this study we addressed these shortcomings and explore the joint and contingent effects of scientist and engineer recruitment and R&D collaboration on subsequent firm-level innovation. We specifically examined the interplay between hiring and collaboration in general and in each knowledge domain (i.e. industry vs. academia).

Drawing on a unique cross-industry dataset which combines register employer-employee data, R&D survey data and EPO patent application data we find partial support for our hypotheses. First, we find no evidence of possible complementary effects between inbound mobility and collaboration, but rather emphasize the prediction that inbound mobility and R&D collaboration act as substitutes in terms of innovative performance. Next, we develop a framework in which we not only consider inbound mobility from university and industry, but also R&D collaboration with academia and industry. We hypothesize and find support for the idea that the simultaneous pursuit of hiring and collaboration in each knowledge domain leads to a marginal decrease in firm-level innovation performance.

Our findings have implications for different bodies of literature. First, our study provides insight in the costs and benefits related to the use of external knowledge and the development of open innovation practices (Chesbrough, Vanhaverbeke, & West, 2006; Owen-Smith & Powell, 2004). Paradoxically, the erosion of internal R&D as a result of for example the increase in mobility of skilled workers has directed firms to both make and buy R&D (Parmigiani & Mitchell, 2009), yet too much emphasis on external partners may paralyze firms' innovative performance. In our paper we uncover boundaries in the extent to which firms should engage in scientist and engineer recruitment and joint research participation as part of their R&D strategy. Delicate decision-making on which boundary-spanning mechanism is beneficial for which stage of the R&D process may counteract negative effects of simultaneous sourcing (e.g. Hess & Rothaermel, 2011).

Second, to our knowledge this is the first study in the alliance and learning-by-hiring literature which demonstrates the contingent effects between two alternative external knowledge sourcing mechanisms: inbound mobility and R&D collaboration. Simply controlling for alternative sourcing mechanisms or comparison of boundary-spanning channels (e.g. Al-Laham, Tzabbar, & Amburgey, 2011; Rosenkopf & Almeida, 2003; Tzabbar, Aharonson, & Amburgey, 2012) is not sufficient; our findings strengthen the idea that the contingent relationships between a variety of boundary-spanning mechanisms need to be examined.

We also extend the literature on university-industry interaction (Agrawal & Henderson, 2002; Audretsch & Maryann P Feldman, 2003; Rosenberg, 1990; Stuart & Ding, 2006) by our attempt to uncover complementarities or substitution effects between hiring of experienced academics and joint research cooperation. Previous research has suggested star scientists may act as translators of science and function as linchpin between basic research and for instance application in drug-development (Lacetera et al., 2004; Zucker & Darby, 1996). This would suggest firms can benefit from possible complementarities between having in-house scientists and maintaining joint research projects with universities. Going beyond an external-internal framework we find that a firm acquires redundant knowledge by engaging in two different types of university-industry interaction.

In an attempt to uncover independent and contingent relationships between inbound mobility and research collaboration we acknowledge that our study is limited in the following ways. First, recruitment and joint R&D collaboration between organizations are two of many alternative boundary-spanning mechanisms. Firms engage in a myriad of external sourcing mechanisms and our study is an initial attempt to reveal contingent effects between two channels. In addition, our data has limited self-reported information on collaboration practices. Future research can shed more light on contingencies by looking into the size and specific content of research collaboration and other mechanisms. Moreover, another possible extension may be to distinguish between different types of industrial and academic partners.

Second, our research setting raises questions about the generalization of our results. Even though we identify mobility of all skilled workers active in a cross-industry setting in the period 2000-2004, our findings may be specific to the Danish context. Being a small country, characterized by high mobility rates, Denmark and its firms may be unique. Nevertheless, the longitudinal analysis which draws on three independent data sources strengthens our confidence in the results.

CONCLUSION

In conclusion, our study reveals the contingent nature of simultaneous engagement in different external sourcing mechanisms. Extending current literature on complementarities between internal and external R&D, our study reinforces the need to consider substitution effects between hiring scientists or engineers and alternative mechanisms to tap external knowledge, such as joint R&D collaboration. In this way, research in the field of innovation management can improve our understanding of how firms can optimize the process of harnessing external knowledge to fuel future innovative activity.

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APPENDIX

Figure 1. Pooled and Specific Boundary-Spanning Mechanisms (N=13472)

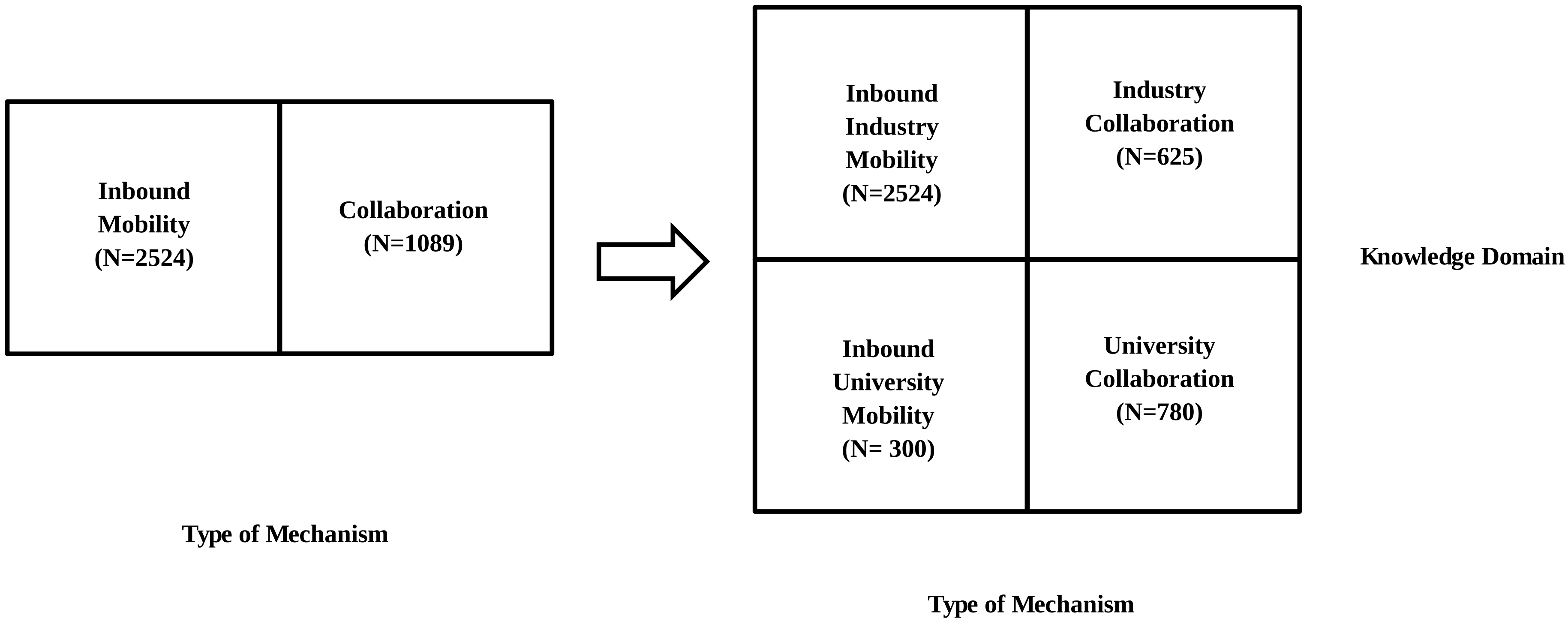

Figure 2. Conceptual Model

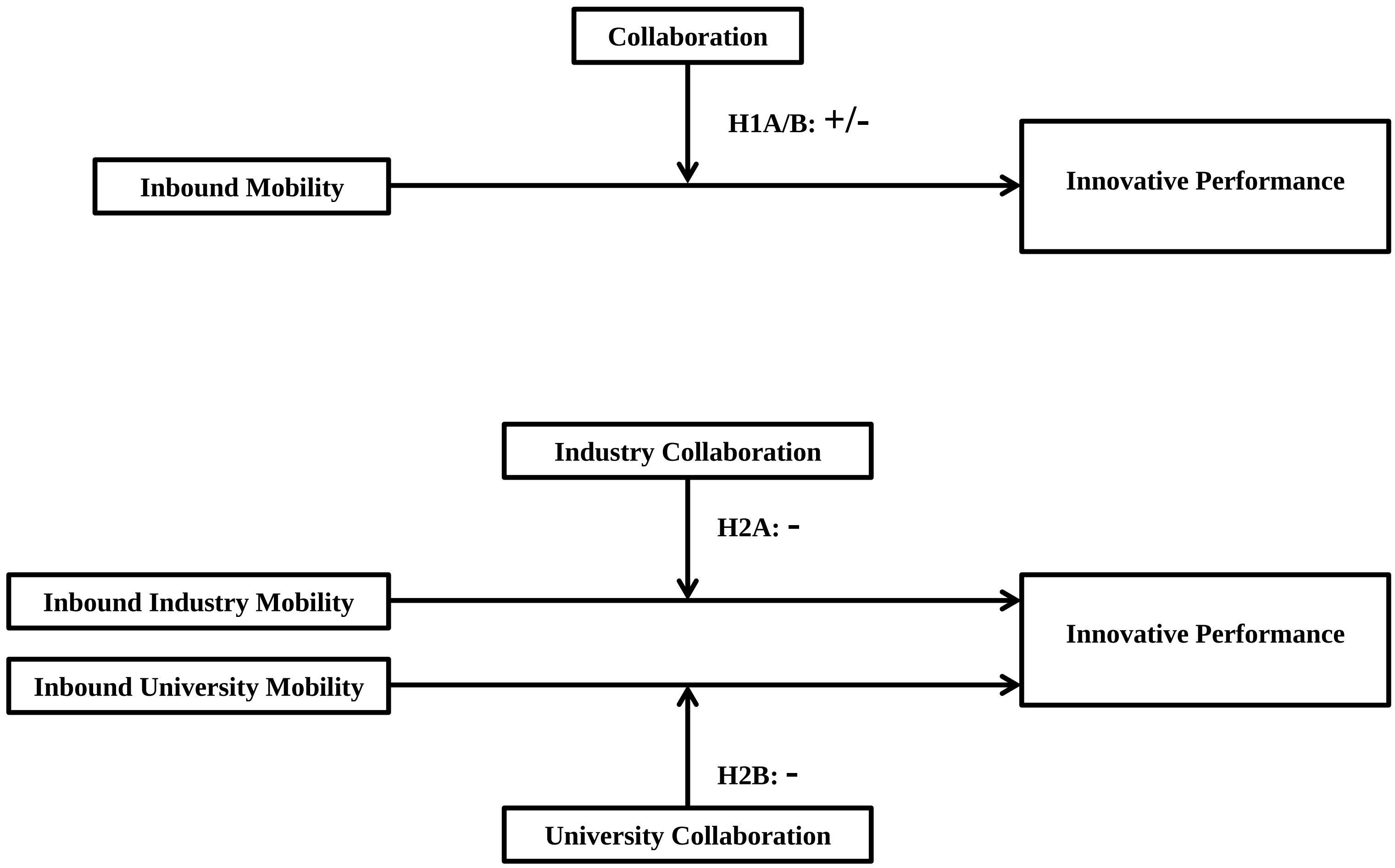

Figure 3. Frequency Counts of Observations with Inbound Mobility and Collaboration in the Period 2001-2004 (N=13472)

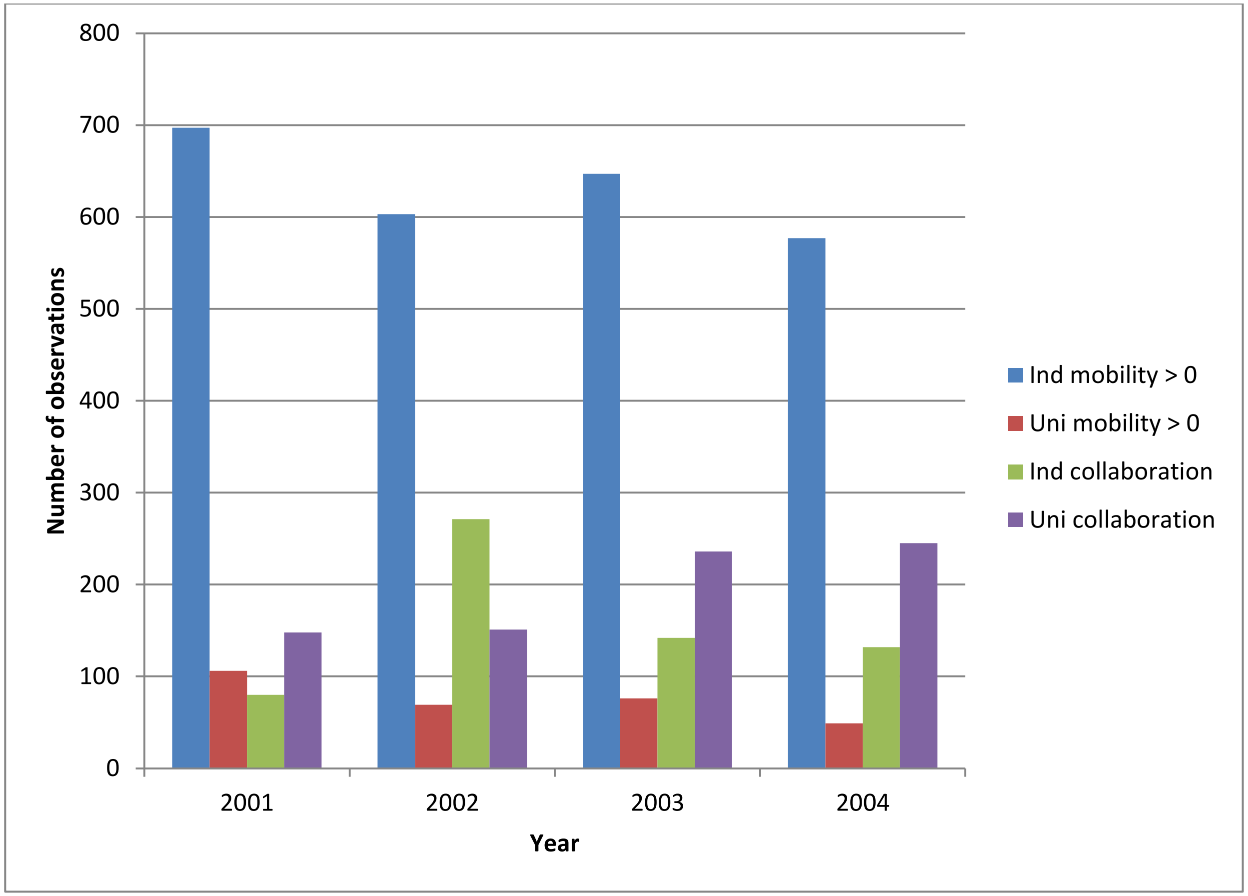

Table 1. Descriptive Statistics and Correlations

Variable	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable																		
(1) Citation-weighted patent appl.	0.257	4.537	0.000	325.000	1.00													
Independent variables pooled																		
(2) Pooled inbound mobility	0.239	0.603	0.000	6.433	0.27	1.00												
(3) Pooled collaboration	0.081	0.273	0.000	1.000	0.14	0.32	1.00											
Independent variables specified																		
(4) Inbound industry mobility	0.235	0.592	0.000	6.392	0.27	1.00	0.31	1.00										
(5) Inbound university mobility	0.020	0.147	0.000	3.258	0.44	0.56	0.23	0.53	1.00									
(6) Industry collaboration	0.046	0.210	0.000	1.000	0.15	0.24	0.74	0.23	0.19	1.00								
(7) University collaboration	0.058	0.234	0.000	1.000	0.16	0.33	0.84	0.32	0.25	0.42	1.00							
Control variables																		
(8) Firm age	2.759	0.768	0.693	5.489	0.05	0.08	0.05	0.08	0.04	0.03	0.05	1.00						
(9) Firm size	3.730	1.503	0.000	10.228	0.13	0.45	0.23	0.45	0.23	0.16	0.23	0.27	1.00					
(10) Inbound TMT mobility	0.039	0.203	0.000	7.000	-0.00	0.05	0.01	0.05	0.02	0.02	0.00	0.02	0.08	1.00				
(11) Outbound mobility	0.234	0.423	0.000	1.000	0.09	0.55	0.25	0.55	0.23	0.17	0.25	0.07	0.39	0.04	1.00			
(12) R&D intensity	0.048	0.119	0.000	1.000	0.05	0.37	0.19	0.37	0.19	0.14	0.19	-0.06	-0.04	-0.00	0.40	1.00		
(13) Pre-sample mean estimator	-11.173	1.152	-11.513	-2.249	0.27	0.39	0.33	0.38	0.28	0.23	0.35	0.15	0.30	0.04	0.30	0.13	1.00	
(14) Patent dummy	0.089	0.285	0.000	1.000	0.15	0.31	0.29	0.31	0.19	0.19	0.30	0.15	0.29	0.04	0.28	0.10	0.94	1.00

Correlations above 0.02 are significant on the 1% level

Table 2. Zero-Inflated Negative Binomial Models Explaining Citation-Weighted Patent Applications

VARIABLES	Model I		Model II		Model III		Model IV		Model V	
	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated
Pooled inbound mobility x pooled collaboration									0.036	0.656**
									(0.146)	(0.245)
Pooled inbound mobility			0.337*	-0.311			0.309+	-0.336	0.307	-0.598*
			(0.165)	(0.235)			(0.186)	(0.326)	(0.189)	(0.245)
Pooled collaboration					0.021	-1.186**	0.015	-1.142*	-0.099	-1.850***
					(0.205)	(0.396)	(0.201)	(0.484)	(0.332)	(0.480)
Inbound ind mobility x ind coll										
Inbound uni mobility x uni coll										
Inbound industry mobility										
Inbound university mobility										
Industry collaboration										
University collaboration										
Firm age	-0.220	-0.065	-0.140	-0.033	-0.208	-0.077	-0.137	-0.049	-0.128	-0.041
	(0.169)	(0.212)	(0.171)	(0.220)	(0.151)	(0.208)	(0.163)	(0.226)	(0.160)	(0.209)
Firm size	0.590***	-0.302+	0.416*	-0.213	0.542***	-0.269	0.382+	-0.172	0.407*	-0.144
	(0.143)	(0.155)	(0.182)	(0.169)	(0.162)	(0.181)	(0.195)	(0.184)	(0.179)	(0.170)
Inbound TMT mobility	-0.364	-0.722	-0.404	-0.773	-0.378	-0.880+	-0.414	-0.916	-0.395	-0.845+
	(0.362)	(0.520)	(0.371)	(0.528)	(0.343)	(0.514)	(0.375)	(0.585)	(0.355)	(0.500)
Outbound mobility	-0.395	-0.775	-0.567	-0.746	-0.260	-0.628	-0.435	-0.608	-0.464	-0.569

	(0.457)	(0.476)	(0.421)	(0.498)	(0.500)	(0.551)	(0.633)	(0.731)	(0.387)	(0.496)
R&D intensity	1.478	-1.302	1.075	-0.583	1.180	-1.166	0.782	-0.462	1.320	0.156
	(2.850)	(2.507)	(2.550)	(2.232)	(2.597)	(2.438)	(2.771)	(2.649)	(2.156)	(1.826)
Pre-sample mean estimator	0.406**	-0.805*	0.341*	-0.773*	0.431**	-0.735**	0.374+	-0.697*	0.346**	-0.675**
	(0.135)	(0.323)	(0.137)	(0.317)	(0.141)	(0.266)	(0.196)	(0.281)	(0.121)	(0.218)
Patent dummy	-1.455+	0.230	-1.122	0.233	-1.614+	-0.054	-1.303	-0.071	-1.212+	-0.095
	(0.852)	(1.094)	(0.776)	(1.111)	(0.853)	(1.069)	(1.091)	(1.148)	(0.670)	(0.953)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	13,472		13,472		13,472		13,472		13,472	
Number of zeros	13,093		13,093		13,093		13,093		13,093	
Log pseudolikelihood	-1798.018		-1786.243		-1785.228		-1774.457		-1768.939	
Wald Chi2	448.932***		491.429***		417.004***		432.258***		475.382***	

Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.10

Table 2. Zero-Inflated Negative Binomial Models Explaining Citation-Weighted Patent Applications (Continued)

VARIABLES	Model VI		Model VII		Model VIII		Model IX		Model X	
	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated
Pooled inbound mobility x pooled collaboration										
Pooled inbound mobility										
Pooled collaboration										
Inbound ind mobility x ind coll										
Inbound uni mobility x uni coll										
Inbound industry mobility	0.331*	-0.320							0.085	-0.446
	(0.168)	(0.238)							(0.164)	(0.279)
Inbound university mobility			1.082***	-0.051					0.939***	0.419
			(0.222)	(0.484)					(0.220)	(0.556)
Industry collaboration					0.373+	-0.900			0.354	-0.450
					(0.219)	(0.605)			(0.216)	(0.397)
University collaboration							-0.071	-1.433*	-0.033	-0.846
							(0.200)	(0.585)	(0.195)	(0.524)
Firm age	-0.144	-0.033	-0.192	-0.057	-0.236	-0.082	-0.201	-0.068	-0.192	-0.074
	(0.174)	(0.223)	(0.140)	(0.190)	(0.164)	(0.211)	(0.157)	(0.214)	(0.150)	(0.208)
Firm size	0.422*	-0.211	0.463***	-0.322**	0.551***	-0.304	0.517**	-0.318	0.397*	-0.167
	(0.183)	(0.169)	(0.121)	(0.122)	(0.160)	(0.186)	(0.175)	(0.210)	(0.156)	(0.148)
Inbound TMT mobility	-0.404	-0.772	-0.265	-0.591	-0.358	-0.716	-0.330	-0.821+	-0.263	-0.626
	(0.369)	(0.525)	(0.308)	(0.484)	(0.365)	(0.564)	(0.343)	(0.478)	(0.302)	(0.518)
Outbound mobility	-0.553	-0.736	-0.460	-0.782+	-0.324	-0.699	-0.149	-0.503	-0.441	-0.606

	(0.425)	(0.502)	(0.374)	(0.457)	(0.646)	(0.630)	(0.523)	(0.635)	(0.457)	(0.547)
R&D intensity	1.107	-0.572	1.977	-0.579	1.190	-1.255	1.003	-1.450	1.206	-0.042
	(2.558)	(2.255)	(2.344)	(1.780)	(2.951)	(2.711)	(2.435)	(2.433)	(2.150)	(1.927)
Pre-sample mean estimator	0.344*	-0.778*	0.272*	-0.813***	0.399*	-0.849*	0.469**	-0.782*	0.267+	-0.778**
	(0.139)	(0.322)	(0.106)	(0.226)	(0.168)	(0.420)	(0.149)	(0.313)	(0.154)	(0.297)
Patent dummy	-1.141	0.237	-0.789	0.546	-1.515	0.284	-1.773*	-0.111	-0.765	0.446
	(0.786)	(1.120)	(0.608)	(0.901)	(1.183)	(1.210)	(0.864)	(1.276)	(0.853)	(1.000)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	13,472		13,472		13,472		13,472		13,472	
Number of zeros	13,093		13,093		13,093		13,093		13,093	
Log pseudolikelihood	-1786.650		-1782.212		-1788.146		-1786.154		-1763.096	
Wald Chi2	485.328***		441.313***		449.348***		401.115***		426.290***	

Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.10

Table 2. Zero-Inflated Negative Binomial Models Explaining Citation-Weighted Patent Applications (Continued)

VARIABLES	Model XI		Model XII		Model XII	
	Count model	Zero-inflated	Count model	Zero-inflated	Count model	Zero-inflated
Pooled inbound mobility x pooled collaboration						
Pooled inbound mobility						
Pooled collaboration						
Inbound ind mobility x ind coll	0.060	0.583*			0.153	0.549*
	(0.130)	(0.281)			(0.143)	(0.273)
Inbound uni mobility x uni coll			-0.562+	0.914	-0.675*	0.572
			(0.301)	(0.779)	(0.322)	(0.683)
Inbound industry mobility	0.071	-0.563*	0.128	-0.396	0.091	-0.514*
	(0.167)	(0.239)	(0.172)	(0.271)	(0.170)	(0.240)
Inbound university mobility	0.944***	0.378	1.268***	0.041	1.303***	0.139
	(0.209)	(0.482)	(0.203)	(0.513)	(0.206)	(0.481)
Industry collaboration	0.213	-1.151*	0.416+	-0.369	0.127	-1.109*
	(0.358)	(0.518)	(0.223)	(0.374)	(0.371)	(0.538)
University collaboration	-0.023	-0.819+	0.090	-0.962+	0.129	-0.868+
	(0.188)	(0.428)	(0.232)	(0.533)	(0.229)	(0.492)
Firm age	-0.194	-0.092	-0.162	-0.061	-0.162	-0.075
	(0.148)	(0.199)	(0.150)	(0.205)	(0.147)	(0.201)
Firm size	0.392**	-0.176	0.341*	-0.197	0.328*	-0.212
	(0.149)	(0.141)	(0.166)	(0.157)	(0.159)	(0.151)
Inbound TMT mobility	-0.285	-0.672	-0.213	-0.609	-0.232	-0.652
	(0.281)	(0.447)	(0.305)	(0.481)	(0.290)	(0.449)
Outbound mobility	-0.409	-0.524	-0.513	-0.678	-0.462	-0.586

	(0.373)	(0.471)	(0.440)	(0.542)	(0.388)	(0.493)
R&D intensity	1.105	-0.118	1.119	-0.017	0.881	-0.196
	(1.924)	(1.733)	(2.029)	(1.799)	(1.970)	(1.785)
Pre-sample mean estimator	0.262*	-0.752**	0.310*	-0.735**	0.308**	-0.720**
	(0.112)	(0.252)	(0.130)	(0.283)	(0.114)	(0.247)
Patent dummy	-0.775	0.359	-0.902	0.305	-0.924	0.250
	(0.618)	(0.931)	(0.691)	(0.993)	(0.602)	(0.918)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	13,472		13,472		13,472	
Number of zeros	13,093		13,093		13,093	
Log pseudolikelihood	-1759.917		-1759.228		-1756.566	
Wald Chi2	399.159***		537.190***		496.675***	

Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.10