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Workforce Composition and Innovation: How Diversity in Employees' Ethnic and Educational Backgrounds Facilitates Firm-Level Innovativeness*

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This article studies how workforce composition is related to a firm's success in introducing radical innovations. Previous studies have argued that teams composed of individuals with diverse backgrounds are able to perform more information processing and make deeper use of the information, which is important to accomplish complex tasks. We suggest that this argument can be extended to the level of the aggregate workforce of high-technology firms. In particular, we argue that ethnic and higher education diversity within the workforce is associated with superior performance in radical innovation. Using a sample of 3,888 Swedish firms, this article demonstrates that having greater workforce diversity in terms of both ethnic background and educational disciplinary background is positively correlated to the share of a firm's turnover generated by radical innovation. Having more external collaborations does, however, seem to reduce the importance of educational background diversity. The impact of ethnic diversity is not affected by external collaboration. These findings hold after using alternative measures of dependent and independent variables, alternative sample sizes, and alternative estimation techniques. The research findings presented in this article would seem to have immediate and important practical implications. They would suggest that companies may pursue recruitment policies inspired by greater ethnic and disciplinary diversity as a way to boost the innovativeness of the organization. From a managerial perspective, it may be concluded that workforce disciplinary diversity could be potentially replaced by more external links, while ethnic diversity could not.

Practitioner Points

- Firms whose employees have more heterogeneous ethnic and disciplinary backgrounds are more innovative.
- Disciplinary background diversity can be substituted by an above-average intensity of collaborations with external partners. Ethnic diversity, however, can neither be replaced nor complemented by external sources.
- Disciplinary background diversity is conducive for both radical and incremental innovation, while ethnic diversity primarily facilitates radical innovation.

The more diversity you have around the table, the more likely you are to ask all the questions that need asking. If you are too harmonized or the same type of people, the risk is that there would be fewer questions asked and fewer new initiatives. That's why I think diversity is so crucial.
—Michael Treschow, chairman of Unilever and former chairman of Ericsson.[1]

Introduction

The question of what capabilities allow firms to successfully launch radically new innovations has received substantial attention from scholars. One important element of the scholarly debate in this area concerns the diversity of the knowledge input available to the firm, within and beyond firm boundaries. For example, in March's (1991) model of exploration and exploitation, socialization processes reduce the diversity of knowledge within an organization, which in turn reduces the capacity for exploration. Similarly, Huber (1991) argues that diversity provides an organization with a

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[1]http://m.thelocal.se/20150318/michael-treschow-sweden-cant-be-welcoming-enough-in-a-global-world-connect-sweden-tlccu

broader set of cognitive maps, which is associated with original and creative problem-solving.

However, the literature on firm innovation has paid limited attention to workforce diversity perspectives, focusing instead on investment decisions, innovation strategies, and external networks. The human factor contribution has been difficult to analyze because of the lack of data on single individuals or because the information about employees is crudely aggregated. By contrast, a long-established corpus of scholarly studies of science has devoted attention to the performance of individual scientists and engineers (Antonelli, Franzoni, and Geuna, 2011; Diamond, 1996; Stephan, 1996). These studies typically adopt a fine-grained level of investigation and look at scientists and inventors who work individually or in relatively small teams, in which each member can be characterized in terms of his or her individual attributes. The choice of a small unit of analysis has always been important in the study of science, because of the typical skewness of the achievements in science and innovation, which makes the investigator interested in events that do not represent the average outcome and rather happen at the tail of the distribution.

This article takes inspiration from the studies of science by looking at the human resources that work in companies, with a more fine-grained level of analysis. Individual data on employees are exploited to build measures of human capital composition and study the relationship between the employees' composition and diversity and the firm's innovation performance.

A large body of work on science and technology has investigated the degree to which innovation is related to the knowledge endowment that individuals possess. This literature has a notion of individuals as repositories of unique knowledge sets with limited dissemination capacity, due to tacitness and embeddedness (Allen, 1997; Breschi and Lissoni, 2001; Feldman and Kogler, 2010; Jaffe, Trajtenberg, and Henderson, 1993) and has emphasized the importance of knowledge heterogeneity, knowledge flows, and recombination to sustain innovation processes (Fleming, 2001; Jones, 2008; Katz and Martin, 1997).

The studies of science have built on these insights by studying individual mobility (Agrawal, Kapur, and McHale, 2008; Stephan, 2006) and individual disciplinary background (Adams and Clemmons, 2011) as factors potentially affecting scientific performance.

In this article, we move from these findings to test the extent to which the innovation performance of companies correlates to the characteristics of the company's human capital composition, with respect to diversity in ethnic origin and in higher education (disciplinary) background. Guided by the view that the most ambitious projects of industrial R&D resemble those conducted by scholars in basic science, in terms of novelty and uncertainty, we focus our theoretical interest on the extent to which insights from the literature on science and innovation can be applied to firms' abilities to achieve *radical* innovation. Individual-level data about all employees in positions requiring advanced skills are used to build fine-grained measures of workforce diversity concerning international mobility and higher education background. These data are combined with multiple rounds of the Swedish Community Innovation Survey (CIS) that provides separate accounts for radical and incremental innovation. Moreover, we investigate how the workforce diversity correlates to the employers' innovation outcomes by means of a Tobit model and find that having a greater diversity in workforce international background is positively correlated to the share of the turnover generated by radical innovation, but is neutral to incremental

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innovation. Greater diversity in terms of educational disciplinary background of human capital is positively correlated to both radical and incremental innovation.

We also find evidence of a substitution effect between external collaboration and diversity in disciplinary background. Conversely, ethnic diversity cannot substitute nor complement external collaboration.

To cope with issues of endogeneity, four supplementary analyses are run. These include resorting to a structural equation model, following the approaches taken by Blundell, Griffith, and Van Reenen (1995) and by Lyngsie and Foss (2017) as well as an instrumental variable approach. Furthermore, alternative measures of dependent and independent variables and different samples are used. Finally, the investigation is supplemented with four extensive out-of-sample interviews of human resource specialists in Swedish companies. Collectively, the analyses provide no indication that the main results would be driven by reverse causality and unobserved heterogeneity.

The structure of this article is set out as follows. The following section reviews the literature and develops a set of hypotheses about workforce diversity and innovation. The third section describes the dataset and accounts for methodology and analysis. In the concluding section, a discussion of the findings, contributions, and limitations is offered.

Theory and Hypotheses

Background

The management and organization literature has studied individual diversity and its impact on performance extensively (for a review, see Milliken and Martins, 1996; Stewart, 2006; van Knippenberg and Schippers, 2007; Williams and O'Reilly, 1998). A stylized fact of this literature is that the benefits of diversity increase with the level of complexity and the innovativeness of tasks (Page, 2007). The majority of studies have focused on diversity in groups and teams such as the top management (Bantel and Jackson, 1989; Certo, Lester, Dalton, and Dalton, 2006; Richard, Barnett, Dwyer, and Chadwick, 2004), the board of directors (Campbell and Minguez-Vera, 2008; Miller and Triana, 2009), and inventors or product teams (Ancona and Caldwell, 1992; Fleming, Mingo, and Chen, 2007). These studies usually measure diversity in terms of organizational tenure, functional and educational background, age, gender, and ethnicity. The team-level analysis of diversity uses three primary theories of diversity: social categorization, homophily, and informational diversity in decision-making (Williams and O'Reilly, 1998). The theoretical argument is in essence that individuals with diverse backgrounds have access to a broader range of knowledge, perspectives, and experiences compared to individuals with homogenous backgrounds. This potentially creates more conflict and less cohesion (which reduces the efficiency of work related to routine tasks) but also brings to the discussion more perspectives and more information, ideally spurring problem-solving and creativity (van Knippenberg and Schippers, 2007). Lazear (1999), for example, argues that immigrants' knowledge and information are different than that of the domestic workforce and that multi-cultural teams are often better positioned to contribute to the firms' innovation performance.

The view of diversity as potentially relevant for firms' innovation processes has spurred significant interest among management scholars, often guided by decision-making theory (Williams and O'Reilly, 1998). Research, however, has focused predominantly on teams of few individuals (e.g., top management teams, founding teams of entrepreneurial ventures) or on small functional units (e.g., healthcare units, R&D teams), seeking correlations between the team member characteristics and their knowledge inputs and the broader firm-level innovation outcomes (Klotz, Hmieleski, Bradley, and Busenitz, 2014). One limitation of this approach is that it does not take into account the complex processes whereby inputs of one team or unit translate into broader organizational processes and firm-level actions, overlooking the influence that other parts of the organization, beyond the team analyzed, play in determining the overall effectiveness of the innovation strategy (Certo et al., 2006; Klotz et al., 2014).

Considering a broader organizational involvement appears to be especially relevant when firms engage in radical innovations, i.e., innovations that are not only new to the company but are also unique (new to the market) and have substantial impact on future markets (Dahlin and Behrens, 2005). Radical innovations put organizations under stress because they make the organizations face new and unforeseen problems, and often require learning, problem-solving, and innovation in processes that come into conflict with existing routines and core rigidities (Leonard-Barton, 1992). Incremental innovations also require adaptation at various levels of the company, but the existence of similar products in the market provides a reference point and

a source of inspiration that limits the need to innovate and find solutions to radically new problems. For example, implementing a radical innovation may require identifying customers and market niches that are not immediately visible or not yet existent, outlining new business models, finding sales channels, and pricing policies that would fit the new market and so on. These objectives and activities require an inventive attitude and problem-solving in many functions and organizational levels across the entire company. Consequently, it seems important to investigate the correlation between human resources diversity and radical innovation by looking at the broad workforce of a company, instead of focusing only on the diversity of a few units like R&D teams.

In recent years, many representatives of highly innovative companies have gone on record to express that their firms are striving to have employees with diverse backgrounds and expertise engaged actively in innovation processes. In order to explore current firm practice and test the thesis that workforce diversity facilitates radical innovation, we conducted interviews with centrally placed HR managers in two Swedish firms. These firms were selected on the basis of their renown in terms of innovativeness and on the basis of pre-understanding, suggesting that they differed in their approach to diversity issues in managing their R&D operations.

Sandvik Coromant, a Swedish-based supplier of tools and services to industrial metal-cutting industries worldwide, is the R&D leader in its segment. The R&D process at Sandvik Coromant is organized around expert teams, which are involved all the way from groundbreaking material science research to the development of new products and subsequent product management. In setting up such teams, the firm is actively trying to ensure diversity in terms of different perspectives and experiences among the team members.

Spotify offers a service of music streaming, podcast, and video services to customers worldwide. The firm, which has its R&D headquarters located in Stockholm, is strongly committed to innovation (primarily in the sense of developing its core product). This is manifested in an organization built with some slack, in order to ensure time for experiments. For example, two teams may be set to work on the same task in parallel, in the hope that such redundancy will generate more innovative solutions. In order to get employees from across the firm involved in developing new core products, a plethora of parallel organizational schemes ("tribes," "squads," "chapters," and "guilds") are used simultaneously within the firms.

It is clear that workforce diversity in both these cases is directly linked to team-level diversity. When diversity perspective is deliberately integrated into team-formation processes, such as at Sandvik Coromant, workforce diversity increases the number of possible employee combinations. In contexts where a firm's employees are matched in several parallel groups with partly overlapping tasks, such as at Spotify, workforce diversity ensures that employees will encounter co-workers with different sets of experiences and perspectives than their own in at least some team constellations, even when the teams are not deliberately designed through diversity considerations.

Very few studies have investigated the correlation of the firm's broader workforce diversity and the firm's general performance and even fewer have looked at the firm's innovation performance (Joshi, Liao, and Roh, 2011). Richard and colleagues (2004) focus on the racial and gender heterogeneity of white-collar workers in banks. They find a curvilinear U-shaped relation linking cultural diversity and performance and show that this relation is stronger for firms with an innovation orientation. Ostergaard, Timmermans, and Kristinsson (2011) use employer-employee data on 1,648 Danish companies and show that innovation outcomes, measured as the probability to introduce a new product or service, are positively correlated to the heterogeneity of employees with regard to education and gender. Parrotta, Pozzoli, and Pytlikova (2014), who also use a sample of Danish firms, find a positive relationship between workforce diversity and the probability to apply for a patent as well as the technological breadth of these patents. Aggarwal, Hsu, and Wu (2015) examine a sample of biotechnology firms and show that across-team diversity led to greater firm-level innovation compared to within-team diversity. Our work expands on this line of research by focusing on the firm-level correlation between workforce diversity and radical innovation and speculates on the relative importance of workforce diversity for radical and incremental innovations.

Human Capital, Knowledge Search, and Innovation

A substantial body of literature has looked at the way in which companies access knowledge internally and externally to their boundaries and at how this

knowledge sustains the firm's innovation processes (Cohen, Nelson, and Walsh, 2002; Mansfield, 1991). In recent years, considerable attention has been devoted to the importance of external knowledge sources, especially as drivers of radical innovation. The open innovation literature, for example, has convincingly documented the importance of external sources of ideas and knowledge in supporting a company's innovation processes (Chesbrough, 2003; Katila and Ahuja, 2002). This literature suggests that whereas internal search—typically conducted by the RandD department of a company—is path-dependent and biased in favor of the existing technologies (Almeida and Kogut, 1999; Song, Almeida, and Wu, 2003), external search facilitates access to ideas and technical solutions that would not lie within the perimeter of the company's know-how. External knowledge potentially provided by partners and users, therefore, is seen as especially important for performing "distant search" (as opposed to "local search"), thus potentially leading to more radically new solutions (Laursen and Salter, 2006; Rosenkopf and Almeida, 2003). External knowledge, it is concluded, is a primary ingredient for sustaining the strategic innovation processes of companies, especially where such processes are of an exploratory nature.

While a firm's openness and ability to capitalize on external knowledge flows has been portrayed as being related to the richness of their formal and informal networks, or to their organizational design and corporate culture, human capital aspects have received considerably less attention. The literature on external knowledge sources maintains that employees act both as brokers of external knowledge in search processes (Almeida and Kogut, 1999; Audia and Goncalo, 2007) and as facilitators of knowledge assimilation, by ensuring enough absorptive capacity of the ideas and solutions coming from the outside (Cohen and Levinthal, 1990). Other studies have looked at intra-firm networks and at employees' idea management, highlighting the importance of social capital and internal connectivity (Bjork and Magnusson, 2009; Colombo, Laursen, Magnusson, and Rossi-Lamastra, 2011). Where studies have speculated on the importance of employees as facilitators of external search, they have typically not gone further to connect workforce composition factors and firms' innovation performance.

The relevance of heterogeneous individual backgrounds has conversely been largely emphasized in the studies of science, where the small scale of the typical unit of analysis—the research team—has permitted investigations of the human capital composition at a finer grain of observation. The distinctive contribution of this article is to borrow the approach and insights of this literature to study the broader workforce of firms, by looking at the individual characteristics of their employees. Specifically, the article investigates the correlation of two characteristics—ethnic composition and higher education (disciplinary) background—with performance obtained from radical innovations, where the latter is expressed in terms of the share of turnover drawn from radical (new to the market) products and instances of radical innovations.

Ethnic Composition and Innovation

In the last few years, a growing corpus of works has looked at the geographic mobility of scientists. These studies move from the premises that knowledge usually entails a tacit component that makes ideas prone to be locally developed and difficult to transfer beyond the circles of individuals who work in close proximity (Almeida and Kogut, 1999; Feldman and Kogler, 2010). Although the output of scientific investigation is in part codified into published papers, a large part of the knowledge produced by scientists is known to remain bound within individual brains (Stephan, 1996). This also means that when scientists relocate, they bring with them the unique set of knowledge and skills that they have acquired during their prior training (Stephan, 2006) and while working in partly separated scientific communities (Borjas and Doran, 2012; Ganguli, 2015; Scellato, Franzoni, and Stephan, 2015). Consequently, mobile individuals are assumed to be holding knowledge that is relatively unique in the location of destination. A question of considerable importance that has only recently begun to be analyzed is if the holding of unique knowledge sets translates into more innovation and greater achievements in the person's new location. In this respect, the empirical tests are complicated by the known circumstance that mobile individuals tend to be pre-selected among the best performing *prior* to mobility (Borjas, 1994; Grogger and Hanson, 2011). Ganguli (2015) and Borjas and Doran (2012) attempt to overcome this problem by looking at migration pushed for political reasons, instead of career concerns or skills. The former study finds evidence of a productivity growth after migration. The latter finds a small positive effect, although not statistically significant. Franzoni, Scellato, and Stephan (2014) instrument migration for work or study

with migration in childhood (that is presumably not caused by skills) and find that the work of foreign-born academics has a higher impact than that of non mobile natives. They speculated that the post mobility boost in performance may happen because the individuals moved to locations that provided a special match or complementarity for their knowledge (Jones, 2008) or that the performance boost may happen because heterogeneity unlocks creativity and problem-solving (Fleming, 2001). Recent work by Freeman and Huang (2014) provides evidence in support of the latter view, showing that teams of U.S.-based coauthors who are ethnically diverse outperform teams of coauthors of the same ethnicity, including those entirely comprised of foreign-born scientists. This appears to indicate that the premium is associated with settings in which the knowledge of the foreign-born is somehow recombined with domestic knowledge. Hence, it is knowledge heterogeneity at the final location that appears to spur innovative performance, not the "knowledge arbitrage" ensured by geographic mobility in itself.

Interestingly, the evidence produced by studies of inventors seems to be consistent with this view. A study on historical data by Moser, Voena, and Waldinger (2014) finds that U.S. inventors became more productive after the inflow of German Jewish inventors in the United States post-1933, and that this effect seems to be associated with the attraction of more inventors in the fields where migrants were more active, rather than to a greater productivity of American inventors. Hunt (2011) finds that the migrants that came to the United States for training or employment were, on average, more likely than the natives to file or commercialize a patent and to publish papers in scientific outlets, but the differential was almost entirely explained by the choices of education and area of work, rather than productivity. Similarly, Kerr and Lincoln (2010) analyze the ethnicity of recent U.S. inventors and find that Anglo-Saxon and non-Anglo-Saxon inventors perform at comparable levels. Overall, these results are not conclusive, but would be compatible with the view that foreign born are not necessarily a value added in themselves, but they become so when their knowledge is used *in combination* with that of the natives.

We use insights from this literature to investigate whether the effectiveness of a firm's innovation outcome is higher in companies whose employees are relatively more heterogeneous in terms of their prior ethnic background. Furthermore, we expand on prior research by investigating the context of the firm's aggregated workforces and focused specifically on radical innovations. We see these two elements—radical innovation and aggregate workforce consideration—as going hand-in-hand. We maintain that radical innovations demand a more pervasive problem-solving attitude from the firm's workforce in product development and commercialization, compared to incremental innovations, because radical innovations cannot rely on solutions readily available within the firm or even outside of the firm but rather require innovative efforts, creativity, and learning at various levels and functions within the company. For this reason, the success of radical innovation strategies is largely affected by the firm's dynamic capabilities (Teece, Pisano, and Shuen, 1997) to innovate and manage change throughout the organizational structure. Organizational studies of innovation have extensively documented that the performance of firms confronted with radical change are heavily mediated by the firm's organization, routines, and culture and ultimately by the willingness to accept and manage the change of their human capital (Christensen, 1997, 2003; Leonard-Barton, 1992).

In this article, we posit that the heterogeneity of the human capital that a firm owns constitutes a reservoir of diverse skills, competences, and information that a firm can deploy and use when its innovation strategy requires innovation, problem-solving, and change at multiple organizational levels. Ethnic diversity is expected to lead to better decision-making because of the informational advantages of diversity, which enables decisions to be based on broader information sets, greater capacity to search for solutions beyond the perimeter of the company, and more recombination (Fleming, 2001; Jones, 2008; Katz and Martin, 1997). In other words, ethnic diversity boosts the dynamic capabilities of a company, which in turn increases the capacity to perform well when confronting with innovation and change. Although the causality link between ethnic heterogeneity and radical innovation is hard to prove (as will be discussed later), if this is true, we should observe at least a positive correlation between the two. The first hypothesis is therefore formulated as follows:

H1: Firms with ethnically diverse workforces are more successful in introducing radical innovations.

Education Disciplines Composition and Innovation

A second possible source of background knowledge diversity relates to the field in which an individual has

been trained during higher education. Training diversity relates to the array of knowledge, skills, and abilities that individuals mobilize in their work (Williams and O'Reilly, 1998). In science, where specialization is important (Jones, 2008), most of the research teams are composed of scientists who have been trained in the same or very similar fields. Nonetheless, collaboration between scientists from different disciplines has been known to facilitate major breakthroughs. For example, biotechnology has emerged at the interdisciplinary convergence of molecular biology and medical engineering. A question that has sparked considerable debate is whether or not an interdisciplinary framework may systematically spur greater productivity and/or more radical advances (Schunn, Paulus, Cagan, and Wood, 2006). To the best of our knowledge the implications of interdisciplinarity for innovation have rarely been tested in empirical analyses. An exception is a recent paper by Lee, Walsh, and Wang (2015) who study a large sample of U.S. scientific teams whose team-members were coded into 29 different scientific fields. They find that having a greater field variety of team members is associated with more novel scientific outcomes. Häussler and Sauermann (2014) found that novel fields in science have more division of labor and more interdisciplinary contributions. Adams and Clemmons (2011) showed that interdisciplinary knowledge flows enhance scientific productivity but they do so to a lesser extent compared to the same-field flows and suggests that the costs of sourcing from a distant knowledge domain are greater than those of sourcing from one's own domain. This finding is corroborated by Slavova, Fosfuri, and De Castro (2016), who find that the knowledge spillovers from hiring scientists are relatively more beneficial to other colleagues in a department when the department is relatively more homogenous in terms of background expertise. Finally, Millar (2013) finds that U.S. Ph.D. recipients who graduated with an interdisciplinary dissertation were moderately more productive than those with non-interdisciplinary dissertations after graduation.

We use the insights from this literature to formulate our second research proposition. Thus, we expand previous research by focusing on strategies of radical innovation and by looking at the broad workforce of a firm, rather than at a subset of the firm's employees or units, such as the R&D team or the top management team.

Many of the arguments already discussed concerning ethnic diversity transfer to disciplinary diversity, because both sources of diversity provide informational advantages in decision-making (Dahlin, Weingart, and Hinds, 2005). In line with prior research, we posit that disciplinary diversity, like ethnic diversity, is associated with a broader array of skills, competences, and information usable for decision-making within a firm, especially when decisions require extensive change and innovation (Williams and O'Reilly, 1998). Furthermore, greater disciplinary diversity is usually correlated with greater functional diversity in job-related tasks (van Knippenberg and Schippers, 2007), leading to greater complementarity of the set of skills that the firm owns.

Although both ethnic and disciplinary diversity potentially bring information use advantages, one difference between these two sources of diversity is that the ethnic diversity is more salient and immediately visible in a social environment than disciplinary diversity (van Knippenberg, De Dreu, and Homan, 2004; van Knippenberg and Schippers, 2007). Consequently, disciplinary diversity, unlike ethnic diversity, is less prone to the partial disadvantages of diversity associated with social categorization, such as interpersonal disliking and reduced group cohesion (Joshi et al., 2011). We will keep this in mind when interpreting empirical results.

These arguments lead us to maintain that greater heterogeneity at the firm level should be positively associated with better problem-solving and capacity to perform distant search for multiple functions within the firm. This is especially important when firms have to deal with strategies of radical innovation, which, as we speculated before, require the simultaneous commitment to innovation of many functions and decision-making units within the company.

Again, establishing a clear direction of causality between heterogeneous background and radical innovation may be quite difficult. However, a positive correlation between the two is expected. Consequently, the second hypothesis of this article is formulated as follows:

H2: Firms with a more diverse disciplinary background in their workforce are more successful in introducing radical innovations.

External Search Breadth and Workforce Diversity

The central argument developed thus far is that a firm's workforce diversity facilitates knowledge search and knowledge recombination within a firm. Open innovation strategies, i.e., the capability to systematically search and make use of ideas, knowledge, and innovations developed externally to the company, are also known as an effective means through which firms can enhance their capacity to recombine and innovate

(Chesbrough, 2003; Katila and Ahuja, 2002). External partners can include suppliers, customers, universities, and research organizations (Arora, Cohen, and Walsh, 2016; Cohen et al. 2002), young ventures (Arora and Gambardella, 1990), user groups, and online crowdsourcing communities (Afuah and Tucci, 2012).

One obvious research question at this stage is whether the two sources of distant search—workforce diversity and external partners—complement or substitute one another. In this respect, various and even opposite contentions are plausible. On the one hand, it is possible that both types of distant searches are beneficial to the firm, but either one of the two is sufficient, such that the marginal return from conducting one type of distant search decreases as the firm increases the other type of distant search. On the other hand, it is possible that the value of informational richness produced by external partners can be better captured when firms have enough internal absorptive capacity (Cohen and Levinthal, 1990). In this case, workforce diversity could be complementary to exploiting the benefits of formal collaborations with external partners.

To the best of the authors' knowledge, no prior study has looked precisely at the relationship between internal workforce *diversity* and external collaborations. Several empirical investigations have looked at the interplay between internal and external knowledge sources for innovation outcomes and have generally found a complementary relationship between the two (Caloghirou, Kastelli, and Tsakanikas, 2004; Cassiman and Veugelers, 2006; Lee, Lee, and Pennings, 2001), corroborating the view that maintaining a good basis of knowledge internal to the firm (absorptive capacity) is needed to exploit the knowledge of external sources. Furthermore, there is evidence that inventors that are hired away from a firm in a different country keep an above-normal flow of citations from and to the origin firm (Oettl and Agrawal, 2008), which is compatible with the possibility that international workers keep alive or start long-distance international partnerships after mobility. Conversely, several studies of intra-firm workers' mobility have suggested that the newly acquired stocks of knowledge are less used when the destination company is already knowledgeable in the area (Song et al., 2003; Tzabbar, Silverman, and Aharonson, 2015). These corroborate the idea of a replenishment or crowd-out of internal and external resources, implying that multiple sources of knowledge may not add up and could ultimately be ineffective.

Two competing hypotheses are formulated to guide further analysis. The first hypothesis contends that external collaborations can prove *more* effective for innovation success in combination with greater workforce diversity, because the latter would ensure a greater absorptive capacity of the former. In the context of workforce diversity, relevant absorptive capacity may relate to the technical and marketing capabilities needed to understand and develop the inputs that come from external partners, as well as to the cultural and social skills necessary to keep well-functioning relationships with these partners. The former—technical and marketing capabilities—would suggest complementarity of external partners and workforce disciplinary diversity in boosting innovation performance, because diversity increases the array of knowledge that firms can use to benefit from collaborations or to scan for fitting external collaborations. The latter—cultural and social skills—implies a more ambiguous outcome. An ethnically diverse workforce can facilitate interaction with a culturally diverse partner. Ethnic diversity, however, may also be associated with language and cultural barriers if the external partners are locals with no or limited cultural diversity. Again, this will be taken into consideration when interpreting the results.

All this considered, a first hypotheses would be as follows.

H3a: *External partnerships increase the positive correlation between workforce diversity and company performance in radical innovation.*

A competing hypothesis contends that external collaborations can prove *less* effective for innovation success in combination with greater workforce diversity, because internal workforce diversity provides firms with a relative abundance of ideas, thereby making them less dependent on an inflow of external contributions and impulses. In this respect, the impact of both ethnic and disciplinary diversity on innovation performance could decrease with the intensity of external collaboration.

H3b: *External partnerships decrease the positive correlation between workforce diversity and company performance in radical innovation.*

Data and Methods

Sample

The three hypotheses are tested using data from Sweden. While investment in innovation and education as well as ethnic diversity are all expected to continue to

increase in most countries, Sweden has a forerunner position in at least two of these three dimensions. First, Sweden is among the most innovative countries in the world. Sweden is one of the top five countries worldwide for research and development spending. In 2012, Swedish R&D expenditure was 3.41 percent of the GDP (European Union average is 1.97% of GDP).[2] Sweden has also been ranked among the top three countries in The Global Innovation Index,[3] throughout the period 2008–2014. Second, Sweden has a very diverse multi-ethnic demography, with over 15% of the inhabitants being foreign born.[4] This share is larger than in the United States (12%)[5] and above the average of the European Union countries (6.5%).[6] Both of these characteristics make the Swedish setting very suitable for testing the hypotheses developed in this article. In particular, this setting provides a sufficient variation in the key variables of interest (radical innovation, ethnic diversity), the lack of which has been identified as problematic in previous studies (Williams and O'Reilly, 1998).

For the purpose of the study, we wish to build a sample of employer-employee-innovation data. In order to do so, data from the Swedish Community Innovation survey (CIS) is utilized.[7] The CIS is administered to firms bi-annually. Firms are asked about the innovative activities that they have conducted in the two years prior to responding. We used five rounds of the CIS: 2004, 2006, 2008, 2010, and 2012. We restrict our sample to respondent firms that: (1) had more than 10 employees and (2) were active in high technology industries, medium high-technology, and knowledge intensive service industries, as coded in NACE (Rev 1.1).[8] Responding to the CIS is mandatory for firms in Sweden, which is reflected in a high response rate (between 66–85%).

The CIS sample is matched with two sources of data provided by Statistics Sweden (SCB). The first source includes information from annual reports of all registered firms in Sweden. The second source includes individual information on the full Swedish workforce, including age, gender, place of birth, education level and type, place of work, position, and wage.

The final sample comprises 7,389 firm-year observations from 3,888 firms. The sample is used as a cross-section.

Variables

Explanatory variables. Ethnic diversity (*EthnDiv*) is based on coding individuals by seven areas of birth. The seven areas included: 1-Sweden (natives), 2-other Nordic countries (Norway, Denmark, Finland, and Iceland), 3-Western Europe (EU15 except Finland and Denmark), 4-other European countries (excluding 1, 2, and 3), 5-North America, 6-Asia, and 7-others. The choice of categories reflects the proportion of individuals with a foreign country of birth. A second, alternative measure of diversity (*ForeignnessDiv*) differentiates individuals by how long they have lived in Sweden: 1-less than 5 years, 2-between 5 and 15 years, and 3-more than 15 years. Higher education background diversity (*EduDiv*) is based on coding individuals by disciplinary area of their university degree: 1-engineering, 2-humanities, 3-health sciences, 4-natural sciences, 5-social science, and 6-others.

Following Harrison and Klein (2007), a measure of diversity that emphasizes the *variety* of the background of the employees is chosen. This is well captured by the Teachman's Entropy Index,[9] also known as the Shannon-Weaver index (Teachman, 1980). The index is calculated as follows:

$-\sum p_i.\ln(p_i)$, where p_i are the shares of employees in the i-th category.

Only diversity among high-skilled workers, i.e., employees in knowledge-intensive positions, is considered.[10] Production workers and employees in standardized administrative support functions are excluded, as such employees are presumably not involved in the

[2]http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?order=wbapi_data_value_2012+wbapi_data_value+wbapi_data_value-last&sort=asc

[3]https://www.globalinnovationindex.org/content.aspx?page=data-analysis

[4]Figures are from 2012. In 2014, the percentage of foreign-born inhabitants in Sweden had further increased over 16%. Since 2008, Sweden has adopted one of the most liberal labor immigration policies in OECD countries, which is expected to increase workforce diversity. This demand-driven model gives Swedish employers the right to unilaterally decide whether or not labor immigrants are needed, provided that pay and working conditions are in accordance with the collective agreements. As a member of the EU, Sweden is also open to migration from other member states.

[5]http://www.census.gov/population/foreign/data/cps.html

[6]http://www.migrationpolicy.org/article/assessing-immigrant-integration-sweden-after-may-2013-riots

[7]The CIS has been used extensively in studying innovation in European firms; a simple search on Google Scholar returned over 7,000 articles that used CIS in their analysis (e.g., Laursen and Salter, 2006; Leiponen and Helfat, 2010).

[8]http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an2.pdf

[9]Alternatively, we used Blau's (1977) index of heterogeneity. The results are similar and available upon request. The correlation between both measures is around 95%.

[10]In robustness check, we also included diversity measure of blue-collar employees.

decision-making relative to new products and services (Page, 2007; Parrotta et al., 2014).

The identification of high-skilled workers is based on the Swedish Standard Classification of Occupations (SSYK). All individuals who are employed as managers (SSYK 1) or professionals[11] (SSYK 2-3) are included, whereas production workers, clerks, and other supporting staff (SSYK 4-9) are excluded.

Since respondents in the CIS were asked information about the innovation activities of the firm over the last two-years, the exploratory variables are measured with a two-year lag. For example, data from the CIS 2004 are combined with a measure of employee diversity in 2002.

As measure of external collaboration, a variable named *Search Breadth* is built. This variable counts the number of different external collaborations that the firms undertook, as in prior studies by Laursen and Salter (2006), Leiponen and Helfat (2010), and Mol and Birkinshaw (2009). The variables takes values from 0 to 5, based on the following categorization of external entities: 1-suppliers, 2-competitors, 3-customers, 4-external subsidiaries of the same company, and 5-knowledge institutes. The latter comprises universities, consultants, governmental research institutes, and commercial R&D labs.

Dependent variables. Two dependent variables, both coming from the CIS, are deployed. Using CIS-based measures provides three advantages. First, it allows comparability with other studies that used these measures as indicators of innovation (e.g., Laursen and Salter, 2006; Leiponen and Helfat, 2010; Ostergaard et al., 2011). Second, CIS-based measures of innovation are applicable to all types of firms, irrespective of the sector (compared to using patent data that are applicable only to a limited set of sectors). Third, CIS-based measures allow us to differentiate between sales from radical innovations and those from incremental ones (e.g., Tödtling, Lehner, and Kaufmann, 2009).[12] The first dependent variable (*Turnradical*) is a self-reported estimate of what proportion of the firm's sales came from products and services that were *new to the market* and could therefore be considered as radical innovations. In the Additional Robustness Analysis section, as an alternative dependent variable, a dummy equal to one if the firm had launched at least one significant radical innovation (*Radical innovation*) is used. This code is drawn from a different answer to the CIS.[13]

Control variables. The set of controls includes variables concerning other characteristics of the workforce composition, such as the share of women employees (*Women share*) and the share of employees with a Ph.D. degree (*Ph.D. share)*. Furthermore, all standard control variables used in previous studies that modeled the share of sales from innovative products and services (e.g., Laursen and Salter, 2006) are included. These are: *R&D intensity*, captured by R&D expenditures divided by sales (Chen and Miller, 2007); firm age, measured by a dummy variable with a value of one if the firm is younger than 10 years old (*Young firm)*[14] and size, which is captured by the natural logarithm of total number of employees (*Firm size*). In view of variations in the firm-level innovativeness across industries (Leiponen and Helfat, 2010) and ownership structures (Dachs, Ebersberger, and Lööf, 2008), a set of industry categorization variables based on the two-digit level NACE industry code is included, along with a set of controls related to the ownership structure of the firm. Four kinds of ownership structures are considered: *Independent*, *Domestic group*, *Domestic multinationals*, and *Foreign multinationals* (omitted category). Firm location, which can potentially affect the access to resources, networks, or markets, is coded by means of a separate dummy variable for each main metropolitan area: *Stockholm, Gothenburg, Malmo*,[15] and non metropolitan locations (omitted category). Finally, the model includes a control for firm performance, by means of return on assets (*ROA* = net profit divided by the average assets value) and for economy-wide time trends, by means of year fixed effects. Table 1 reports all the variables and their definitions.

Results

Summary Statistics and Univariate Analysis

Table 2 reports descriptive statistics, including the mean and standard deviation in addition to the correlations between the variables.

[11]The definition of this category is that the position requires advanced tertiary education and training.

[12]We wish to thank an anonymous reviewer for this point.

[13]In an alternative analysis, in order to test whether diversity measures have a different effect on incremental innovation, we used what proportion of the firm's sales came from products and services that were *new to the firm* and could therefore be considered incremental innovations. The results are reported in the supplementary appendix.

[14]We are not able to use a continuous measure of age due to reporting limitations in the database, as those firms established before 1986 given a value of "1986" regardless of when they were established.

[15]These are the most densely populated areas in Sweden in which more than 60 percent of the population lives, while it occupies only 5% of the land (SCB, 2014, Folkmängd i riket, län och kommuner).

Table 1. Variables Definitions

Variables	Definition
Explanatory Variable	
EthnDiv	Entropy index considering place of birth in Sweden, Nordic, Western Europe, Other Europe, North America, Asia, and others
EduDiv	Entropy index of education among educated employees considering 6 different subjects of engineering, social science, humanities, health science, natural science, and other fields
ForeignnessDiv	Entropy index considering number of years living in Sweden, less than 5 years, 5–15 years, and more than 15 years
Dependent Variable	
Turnradical	Turnover from new product/services new to the market
Radical innovation	A dummy equal to 1 if firm had at least one new product/process new to the market
Search breadth	Number of external sources of knowledge; a value between 0 and 5
Control Variables	
Women share	Share of female professionals
Ph.D. share	Share of professionals with Ph.D. degree
R&D intensity	R&D investment divided by sales
ROA	Net profit divided by total assets
Young firm	A dummy=1 if firm is less than 10 years old
Firm size	Natural of logarithm of number of employees
Ownership	Four dummies indicating whether firm is independent, part of a domestic group, part of a domestic multinational, or a foreign multinational
Location fixed effect	Four dummies showing firm is located in Stockholm, Gothenburg, Malmo, or other

On average, 6.1% of the firms' turnover is related to the sales generated from radical innovations (products new to the market). The entropy measure of diversity grows with the relative diversity of the workforce. The average firm ethnic diversity is 0.27, the average firm educational disciplinary diversity is 0.51, and the average firm foreignness diversity is 0.19. The average firm had established relationships with external partners in one category (*Search breadth*). Women represent 25.3% of the firms' (qualified) workers, and 2.4% of the workers had a Ph.D. degree. On average, firms spent the equivalent of 6.2% of their sales on R&D (*Research intensity*) and yielded a 3.8% return on assets (*ROA*). About 46.5% of the firms were coded as *young*. The average firm had 51 employees. The shares for *Independent*,

Table 2. Correlation Matrix and Descriptive Statistics

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1. Turnradical	0.061	0.155	1.00													
2. EthnDiv[a]	0.275	0.269	0.08	1.00												
3. EduDiv	0.512	0.464	0.10	0.33	1.00											
4. ForeignnessDiv[a]	0.194	0.215	0.13	0.60	0.34	1.00										
5. Search breadth	0.938	1.574	0.24	0.12	0.18	0.14	1.00									
6. Women share	0.253	0.204	−0.04	0.17	0.27	0.15	0.02	1.00								
7. Ph.D. share	0.024	0.074	0.15	0.21	0.20	0.24	0.21	0.18	1.00							
8. Research intensity	0.062	0.254	0.24	0.08	0.10	0.13	0.16	0.06	0.29	1.00						
9. ROA	0.038	0.339	−0.13	−0.04	−0.06	−0.06	−0.04	−0.01	−0.17	−0.20	1.00					
10. Firm size[b]	3.927	1.366	0.01	0.24	0.45	0.19	0.26	0.06	−0.03	−0.07	0.03	1.00				
11. Young firm	0.465	0.499	0.07	0.02	0.00	0.09	−0.06	0.07	0.02	0.07	−0.06	−0.15	1.00			
12. Independent	0.200	0.400	−0.02	−0.12	−0.25	−0.12	−0.12	−0.07	−0.03	−0.01	0.00	−0.31	0.08	1.00		
13. Domestic group	0.274	0.446	−0.05	−0.12	−0.17	−0.14	−0.09	−0.02	−0.01	−0.02	0.02	−0.25	0.00	−0.31	1.00	
14. Domestic multinationals	0.272	0.445	0.07	0.03	0.16	0.10	0.11	0.02	0.05	0.04	−0.02	0.21	−0.04	−0.31	−0.37	1.00

[a]EthnDiv and ForeignessDiv do not appear in the same regression mode.
[b]This variable is logged.

Domestic group, and *Domestic multinationals* were 20.0%, 27.4%, and 27.2%, respectively.

Multivariate Analysis

Across the entire sample, the mean variance inflated factor (VIF) is under 2 for all our main variables of observation (average VIF = 2.45), showing that our model does not have multi collinearity problems.

Recall that we are interested in studying the effect of workforce diversity on firm radical innovation and the moderation effect of ethnic and higher education diversity on the effect of external search on radical innovation. The general estimation model is specified as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Search\ breadth_{it} + \beta_3 Search\ breadth_{it} * X_{it} + \beta_4 Z_{it} + \beta_5 Y_t + \varepsilon_{it}$$

where the subscript *i* refers to firms, and the subscript *t* refers to time.

Y_{it} is the dependent variable, expressed as the share of the turnover generated by radical innovation (*Turnradical*). X_{it} is a vector of independent variables concerning employee diversity. H3 is tested through the inclusion of the interaction terms of *Search breadth* and each of the two diversity measures. Z_{it} is a vector of control variables and Y_t includes dummies representing the year fixed effects.

Since the dependent variable (*Turnradical*) is a censored variable, a Tobit model estimator is used. Furthermore, since there is more than one observation for some firms, potentially generating serial correlation of the error term, clustered robust standard errors are used.

Table 3 shows the results of the multivariate analysis. Controls for industry, location, and year fixed effect are applied in all models.

Model 1 includes only the three main variables of observation: ethnic diversity (*EthnDiv*), higher education diversity (*EduDiv*), and external search (*Search breadth*), useful for testing H1 and H2. Models 2 and 3 add the interaction terms between search breadth and ethnic diversity and search breadth and higher education diversity, respectively, useful for testing H3. Models 4 and 5 are reported for comparison and include the *ForeignnessDiv* measure instead of our preferred measure of ethnic diversity.

The results of model 1 show that ethnic diversity is positively correlated to the dependent variable ($b = 0.05$, $p < 0.05$) and so is higher education diversity ($b = 0.11$, $p < 0.01$), giving support to H1 and H2. An increase of one standard deviation in ethnic diversity and education diversity increase the sales from radical innovation by 1.3 and 5 percentage points, respectively. In model 2, the interaction between *Search breadth and* education diversity (*EduDiv)* is included. The coefficient is negative and statistically significant ($b = -0.02$, $p < 0.01$), giving support to the substitution effect as in H3b. In model 3, the interaction term between *Search breadth* and ethnic diversity (*EthnDiv*) is included. The coefficient is negative, but it is not statistically significant ($b = -0.01$, n.s.), which means that we do not find support for H3a nor H3b. The results of models 4 and 5 mirror those reported in models 1 and 3. In model 4, the coefficient of *ForeignnessDiv* is positive and statistically significant ($b = 0.13$, $p < 0.01$). This implies that an increase of one standard deviation in *ForeignnessDiv* increase the sales from radical innovation by 2.8 percentage points. Model 5 includes the interaction between *Search breadth* and *ForeignnessDiv*. Parallel to the result on *EthnDiv* in model 3, the coefficient is not statistically significant.

Overall, the results support H1 and H2, indicating that workforce ethnic and education diversity are positively correlated with the intensity of radical innovation. There is also evidence supporting a substitution effect between *EduDiv* and *Search breadth*, as in H3b, but not for any complementarity or substitution effect between *EthnDiv* and *Search breadth*. We are uncertain as to what causes this result. However, one plausible interpretation is that ethnic diversity, unlike educational diversity, is associated with greater cultural and language barriers that lower the capability of the company to establish well-functioning collaborations with external partners, especially if these partners are locals with no or limited ethnically diverse backgrounds.

Investigating Alternative Explanations: Recruitment Patterns of Innovative Firms

In this study, we hypothesize an association between workforce diversity and radical innovation. We are nonetheless aware that the correlations observed between diversity and radical innovation in the empirical analyses may not necessarily imply causality. Alternative explanations to the empirical findings reported above are clearly conceivable. In particular, firms with higher ambitions regarding innovation may be more likely to recruit individuals with a foreign background as a result of a more active international search for specialized technical competence in their

Table 3. Tobit Analysis of Effect of Ethnic and Education Diversity on Radical Innovation Sales

	(1)	(2)	(3)	(4)	(5)
EthnDiv	0.05** (0.02)	0.05** (0.02)	0.05** (0.03)		
EthnDiv × Search breadth			−0.01 (0.01)		
EduDiv	0.11*** (0.02)	0.13*** (0.02)	0.11*** (0.02)	0.10*** (0.02)	0.10*** (0.02)
EduDiv × Search breadth		−0.02*** (0.01)			
ForeignnessDiv				0.13*** (0.03)	0.13*** (0.03)
ForeignnessDiv × Search breadth					−0.00 (0.01)
Search breadth	0.07*** (0.00)	0.08*** (0.01)	0.07*** (0.00)	0.07*** (0.00)	0.07*** (0.00)
Women share	−0.20*** (0.03)	−0.20*** (0.03)	−0.20*** (0.03)	−0.20*** (0.03)	−0.20*** (0.03)
PhD share	0.07 (0.12)	0.07 (0.12)	0.07 (0.12)	0.03 (0.12)	0.03 (0.12)
Research intensity	0.19*** (0.03)	0.19*** (0.03)	0.19*** (0.03)	0.18*** (0.03)	0.18*** (0.03)
ROA	−0.03 (0.02)	−0.03 (0.02)	−0.03 (0.02)	−0.03 (0.02)	−0.03 (0.02)
Firm size[a]	−0.01** (0.00)	−0.01** (0.00)	−0.01** (0.00)	−0.01** (0.00)	−0.01** (0.00)
Young firm	0.03*** (0.01)	0.03*** (0.01)	0.03*** (0.01)	0.03*** (0.01)	0.03*** (0.01)
Independent	−0.00 (0.02)	0.00 (0.02)	−0.00 (0.02)	0.00 (0.02)	0.00 (0.02)
Domestic group	−0.02 (0.02)	−0.02 (0.02)	−0.02 (0.02)	−0.02 (0.02)	−0.02 (0.02)
Domestic multinationals	0.03** (0.01)	0.04** (0.01)	0.04** (0.01)	0.03** (0.01)	0.03** (0.01)
Industry	Yes	Yes	Yes	Yes	Yes
Location	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Constant	−0.21*** (0.06)	−0.23*** (0.06)	−0.21*** (0.06)	−0.21*** (0.06)	−0.22*** (0.06)
Sigma	0.31*** (0.01)	0.31*** (0.01)	0.31*** (0.01)	0.31*** (0.01)	0.31*** (0.01)
Observations	7389	7389	7389	7389	7389
left censored	4980	4980	4980	4980	4980
right censored	74	74	74	74	74
Log lik.	−2771.6	−2765.9	−2771.5	−2759.5	−2759.5

Note: In all models, robust standard error is reported in parentheses; *, **, or *** indicates statistical significance at the 10%, 5%, 1% level, respectively.
[a]This variable is logged.

recruitment processes. An ethnically and educationally diverse workforce could also be the result of a tendency among innovative firms to intentionally recruit diverse employees, as the quote reported in the beginning of our article suggests. These possibilities suggest that greater workforce diversity could be a consequence—rather than a cause—of the firm's strategic dedication to innovation.

This section reports additional analyses conducted to investigate the knowledge-related advantages of diversity for innovation processes in parallel to recruitment-oriented explanations.

A first step in this direction is to explicitly model the firm's decision regarding investment in innovation input activities (R&D, external search intensity) and workforce diversity. Thereby, we relax the assumption of our two diversity variables being independent of the firm's R&D investment and external search. To this end, these linkages are modelled using a structural equation model (SEM), where we also explicitly frame the firm's decisions about R&D investment and formal external interactions, following the standard literature on R&D and innovation (Crépon, Duguet, and Mairesse, 1998; Lööf and Broström, 2008). Beyond the controls used in Table 3, the level of investment in innovation input is modeled as being driven by the firm's financial strength. Firms with strong internal finances are able to overcome the constraints associated with funding investments in R&D through external sources (Czarnitzki and Hottenrott, 2011). In a second step, workforce diversity is modeled as a function of the level of innovation input. In addition to the full set of controls, we add a variable capturing the breadth of the firm's recruitment. This is measured by an entropy index that captures the variety of regional origins of the newly recruited employees that re locate within Sweden to work for the focal firm. This variable, referred to as *Mobility-Div*, is not correlated with *Turnradical* (0.00, n.s.). Figure 1 shows a path diagram illustrating the SEM model with the estimated results. While not shown in the figure, the full set of controls used in Table 3 is included in all three stages of the structural model. Covariation between the error terms of the separate equations within each step explicitly modeled (and found to be significant). As before, stage 3 is estimated using a Tobit model. Detailed results are reported in Supporting Information Appendix S1.

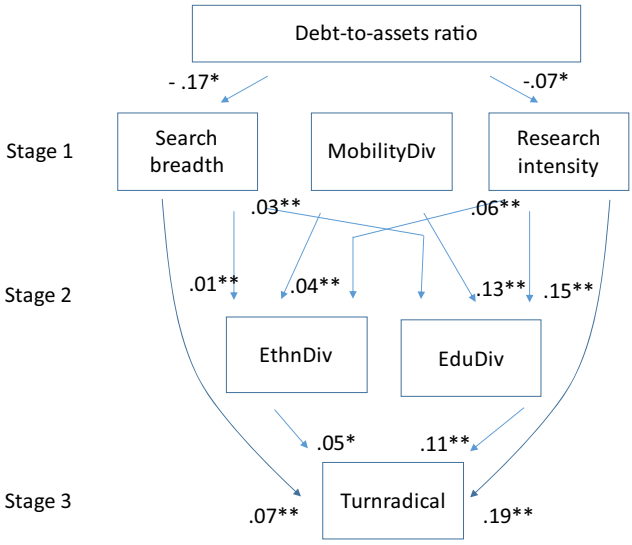

Figure 1. Structural Equation Model—Path Diagram Coefficient estimates. * or ** indicate statistical significance at the 5% or 1% level, respectively. [Color figure can be viewed at wileyonlinelibrary.com]

Results of the SEM show that the innovation input variables are associated with diversity. This confirms that the level of the firm's innovation input is indeed related to the workforce diversity. The estimated relationships between both types of workforce diversity and radical innovation (stage 3 of Figure 1) are very close to those of the main analyses (Table 3). Still, it is not possible to rule out the existence of non-observed heterogeneity correlated with diversity and with innovation (i.e., the standard errors of the stage 3 Tobit model equation) if firms which are more innovative—conditional on observable innovation inputs—are more prone to recruiting employees with different disciplinary and ethnic backgrounds. In order to investigate this possibility, additional analyses are conducted.

We begin by adopting a qualitative method and investigate recruitment practices by conducting a limited set of interviews. We talked to the heads of (global) recruitment of Sandvik Coromant and Spotify, the two Swedish firms whose mechanisms of R&D organization were described in the Theory section. In addition, we talked to senior experts at two leading Swedish recruitment agencies (TNG, K2 search). Interviewees were keen to stress that they saw workforce diversity as positive for white-collar jobs in general, but also pointed out that they experience a general conservativeness in recruitment which persists in many settings. In particular, managers often hesitate to hire candidates from backgrounds that they are not familiar with. To counteract this tendency, recruitment experts in many cases invite managers to identify prioritized competence-based criteria for each opening, especially for managerial and specialist positions.

The interviewed headhunters stressed that less conservative firms in hiring could be found occasionally and that they were of no specific sector or size. However, they thought it was plausible that ambitious firms, in terms of R&D, employ a greater share of specialists, and therefore could be less prone to homophily in recruitment. Our interviews, however, do not provide indications that firms which are more innovative (conditional on innovation input) would be more prone than other firms to actively pursue workforce diversity in their recruitment processes.

We further investigate potential unobserved heterogeneity and reverse causality using several empirical methodologies. First, a method proposed by Blundell et al. (1995) is used, where pre-sample history is used in order to take into account unobserved firm heterogeneity. For this test, pre-sample data on the firms' patent application activities in the period 1997–2002 is used.[16] A dummy variable equal to one if the firm had any patent application in the pre-sample period is inserted into the main model. Alternatively, we use the average number of patent applications per year in the pre-sample period (Blundell et al., 1995). Results are reported in Supporting Information Appendix S2 and are very similar to those shown in Table 3.

Second, we adopt a methodology suggested by Lyngsie and Foss (2017), by introducing alternative diversity measures for the set of employees that were hired in the end of each CIS survey period. This variable is regressed on *Turnradical* using the full set of control variables from Table 3. The results are shown in Table 4 with alternative specifications and indicate that *Turnradical* is not significantly related to the firms' recruitment.[17]

[16]Unfortunately, we do not have access to data on patent citations, which would provide more qualified information about the level of innovativeness in the pre-sample period.

[17]An interesting observation from Table 4 is that EthnDiv and EduDiv are highly correlated to the diversity of firms' new recruitments. This suggests that existing patterns of workforce diversity are reproduced through recruitment. In additional investigation of this phenomenon, we examine the temporal variation of key variables (we would like to thank an anonymous referee for this suggestion). The results, which are not reported elsewhere in the article, show that almost all of the variance in our independent and dependent variables comes from variation between firms (30%-80%). Variation within firms over time only amounts to about 1%. It would seem that there is a great deal of inertia in the processes shaping firms' workforce diversity (cf. Chen and Rider, 2015). This result would seem to suggest that workforce diversity may be a source of lasting differences in firms' innovation performance.

Table 4. Effect of Radical Innovation Sales on Ethnic and Education Diversity of New Employees

	(1)	(2)	(3)	(4)
	EthnDiv of new recruits		EduDiv of new recruits	
Turnradical	0.01	−0.01	−0.00	−0.03
	(0.01)	(0.01)	(0.02)	(0.02)
Search breadth	−0.00	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Women share	0.03***	0.01	0.07***	0.03*
	(0.01)	(0.01)	(0.01)	(0.01)
Ph.D. share	0.13***	0.04	0.09*	−0.01
	(0.04)	(0.04)	(0.05)	(0.05)
Research intensity	0.01	0.00	0.01	0.00
	(0.01)	(0.01)	(0.02)	(0.02)
ROA	−0.00	−0.00	−0.01	−0.00
	(0.01)	(0.01)	(0.01)	(0.01)
Firm size[a]	0.01***	0.00	0.03***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)
Young firm	0.02***	0.02***	0.03***	0.03***
	(0.00)	(0.00)	(0.01)	(0.01)
Independent	−0.01	0.01	0.00	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)
Domestic group	−0.01*	0.00	−0.01	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
Domestic multinationals	−0.01**	−0.00	−0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
EthnDiv		0.16***		0.02**
		(0.01)		(0.01)
EduDiv		0.02***		0.14***
		(0.01)		(0.01)
Industry	Yes	Yes	Yes	Yes
Location	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Constant	−0.01	−0.00	−0.01	−0.00
	(0.02)	(0.02)	(0.03)	(0.03)
Observations	7389	7389	7389	7389
Log lik.	2893.0	3125.8	225.6	396.9
R-square	0.035	0.094	0.057	0.100

Note: In all models, robust standard error is reported in parentheses; *, ** or *** indicates statistical significance at the 10%, 5%, 1% level, respectively.
[a]This variable is logged.

Third, we use a 2-stage least square model (2SLS) instrumenting *EthnDiv* and *ForeignnessDiv* in the first stage. The instrument here is the "*Share of foreign born*" in the active workforce, irrespective of skills and education, in the firm's region in the last 5 years. This measure is likely a result of demography and migratory moves rather than an output of diversity-minded company recruiting. The instrument is significantly correlated with *EthnDiv* and *ForeignnessDiv* (29% and 24%, $p < 0.001$), and is uncorrelated with the dependent variable *Turnradical* (1%, n.s.). Thus, it conforms well to the exclusion restrictions. The F-statistics of the first stage is larger than 10, suggesting that the instrument is not weak (Bascle, 2008). Results are presented in Table 5 and support H1.

Taken together, the set of additional analyses described would seem to offer evidence reassuring us that the results presented in Table 3 are not crudely affected by endogeneity problems.

Additional Robustness Analysis

The robustness of our analysis is explored along different dimensions. This section provides a brief account. The related tables are provided in a Supporting Information Appendix.

First, we check the robustness of our estimates to replacing the dependent variable *Turnradical* with a dummy taking value 1 if the firm launched at least one significant radical innovation in the period, according to the CIS data. The resulting Probit model, as reported in Supporting Information Appendix S3, confirms the consistency with the findings presented in Table 3.

Second, we provide a comparison between radical and incremental innovation using as an alternative dependent variable the estimate of the proportion of a firm's sales from products and services that were *new to the firm*, and can therefore be considered incremental innovations (*Turnincremental*). The results (Supporting Information Appendix S4) show that while educational disciplinary diversity is also positively correlated to incremental innovation (albeit with a weaker relationship), ethnic diversity (and foreignness diversity) is not correlated to incremental innovation. Recall from the Theory section that ethnic diversity is associated with greater costs compared to educational diversity, because it is on average associated with more conflicts and less cohesion of the workforce (Joshi et al., 2011). Based on this, the finding may be interpreted as evidence that the problem-solving benefits associated with ethnic diversity are large enough to counterbalance its conflict-related costs only when the workforce is tasked with goals, like radical innovation, which makes problem-solving truly essential.

Third, extending the main analysis where only the high-skilled workers are included, the diversity of blue-collar workers are introduced as control variables (Supporting Information Appendix S5, Model 1). The result is consistent with the main analysis.

Fourth, in order to be able to compare our independent variable across industries and years, in addition to industry fixed effects, we control for the average sales

Table 5. Two-Stage Instrumental Variable Regression (Instrument: Share of Foreign Born)

	(1)	(2)	(3)	(4)
	EthnDiv	Turnradical	ForeignnessDiv	Turnradical
EthnDiv		0.08*** (0.03)		
Foreignness diversity				0.15*** (0.06)
Share of foreign born	1.37*** (0.10)		0.75*** (0.07)	
Search breadth	0.01** (0.00)	0.02*** (0.00)	0.01*** (0.00)	0.02*** (0.00)
Women share	0.06*** (0.02)	−0.05*** (0.01)	0.03** (0.02)	−0.05*** (0.01)
Ph.D. share	0.50*** (0.07)	0.02 (0.07)	0.50*** (0.06)	−0.01 (0.08)
Research intensity	0.03* (0.02)	0.10*** (0.02)	0.05*** (0.01)	0.10*** (0.02)
ROA	−0.00 (0.01)	−0.03*** (0.01)	−0.01 (0.01)	−0.03*** (0.01)
Firm size[a]	0.04*** (0.00)	−0.01** (0.00)	0.02*** (0.00)	−0.01** (0.00)
Young firm	0.01 (0.01)	0.02*** (0.00)	0.03*** (0.01)	0.02*** (0.00)
Independent	−0.07*** (0.01)	0.00 (0.01)	−0.07*** (0.01)	0.01 (0.01)
Domestic group	−0.08*** (0.01)	−0.00 (0.01)	−0.08*** (0.01)	0.01 (0.01)
Domestic multinationals	−0.06*** (0.01)	0.02*** (0.01)	−0.02** (0.01)	0.02*** (0.01)
Industry	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Constant	−0.10*** (0.03)	0.05*** (0.02)	0.01 (0.03)	0.04** (0.02)
Observations	7389	7389	7389	7389
F-Value	54.93***		50.44***	
R-Square	0.207	0.124	0.194	0.122

Note: In all models, robust standard error is reported in parentheses; *, ** or *** indicates statistical significance at the 10%, 5%, 1% level, respectively.
[a]This variable is logged.

from radical innovation at the industry level (2-digit NACE). The results (Supporting Information Appendix S5, Model 2) are very similar to the main analysis.

Fifth, we experiment with introducing alternative measures of diversity. These tests include using two alternative measures of education diversity; a measure proposed by Ostergaard et al. (2011) that takes into consideration both field and level of education (Supporting Information Appendix S5, model 3) and diversity in industry experience (Supporting Information Appendix S5, model 4). Similarly, two alternative measures of workforce age diversity are examined (Supporting Information Appendix S6). Results are similar to the main analysis.

Sixth, in the main analysis, the diversity variables were measured with a 2-year lag. However, in consideration that the timing for radical innovation strategies might be longer, these variables were re defined using a 3- and 4-year lag (Supporting Information Appendix S5, Models 5 and 6). While the coefficient for ethnic diversity is not statistically significant (available upon request), the results for foreignness diversity and education diversity are very similar to our main analyses.

Finally, the analysis was restricted to firms that answered at least three rounds of the CIS, using 4,025 observations on 1,239 firms. Once again, the results (Supporting Information Appendix S7) were very similar to those shown in Table 3. As before, *EthnDiv, ForeignnessDiv*, and *EduDiv* are positively and significantly correlated to *Turnradical*. Regarding H3, results are found to be consistent with Table 3, where a substitution effect for *EduDiv*, but not for *EthnDiv and ForeignnessDiv*, was observed.

Discussion

This work was motivated by a desire to inform the innovation activity of firms that pursue radical innovation, i.e., innovation that is both new to the market and the firm. We were especially interested in understanding the relationship between the diversity of the firm's workforce and the capability to succeed in radical innovation. Prior management studies of diversity and innovation have focused attention on a few specific units within the company deemed to play a forefront role in the innovation processes, such as the top management (Bantel and Jackson, 1989; Certo et al., 2006; Richard et al., 2004), the board of directors (Campbell and Minguez-Vera, 2008; Miller and Triana, 2009), or the product teams (Ancona and Caldwell, 1992; Fleming et al., 2007). We speculated instead that the link between the workers' diversity and the firm capability to conduct radical innovation relates and should consequently be investigated at the level of the entire firm's workforce.

In developing this proposition, we find inspiration and insights in the studies of science project organization. In this literature, a common approach is to look at the characteristics of each individual scientist that takes part in a research project, irrespective of the position or task performed in the research, under the assumption that everyone, from the project leader to the trainee, is instrumental in increasing the likelihood to achieve a breakthrough. Equally important are the formal and informal relationships of scientists with the broader network of colleagues and experts working in their environment, which provide constant feedback and insights in the spirit of the "invisible colleges" (de Solla Price and Beaver, 1966; Guimera, Uzzi, Spiro, and Amaral, 2005).

We imported the view that a broader human capital, and not just the circle of direct collaborators, is important to nurture scientific progress into the study of radical innovation in private firms. In particular, while a rich literature has established that firms' maintaining linkages with diverse external partners are more innovative than other firms (Laursen and Salter, 2006), significantly less explored is the innovative potential brought by the internal firm workforce. Thinking about the firm as a network of individuals (Van den Bulte and Moenaert, 1998), within which teams are formed and re-formed and within which teams interact with other teams, it may be argued that this particular form is better suited than many other forms of networks to harness the potential of diversity. This is because the organizational structure of the firm can provide an institutional embedding within which the frictions of cognitive and cultural diversity may be reduced. Thereby, the firm may exploit the inherent advantages of diversity—within and across teams of direct coworkers—to increase its capabilities for radical innovation and continuous change throughout the entire organization (Christensen, 1997, 2003; Leonard-Barton, 1992).

Drawing further inspiration from the studies of science, this research has focused on two individual characteristics: ethnic and higher education (disciplinary) background. The theoretical basis of this article is built on a view that diversity acts as a facilitator of knowledge search and recombination. We hypothesize that firms whose employees have more heterogeneous ethnic and disciplinary backgrounds are more likely to be innovative because they obtain more benefits when conducting distant search.

The sample used to test this hypothesis was based on matching several waves of CIS with employer-employee data from Sweden. One primary result of our analysis is that having an ethnically diverse workforce composition is positively correlated to greater turnover generated by radical innovation. A second result is that also having employees with diverse disciplinary background (expressed by the subject of their higher education degrees) is positively correlated with the turnover generated by radical innovation and with more instances of radical innovation.

Higher education diversity is also positively correlated to more incremental innovation. Ethnic diversity, however, does not seem to be correlated to incremental innovation. This outcome could be rationalized by recent findings that suggest that ethnic diversity is more exposed to generating conflicts due to social categorization compared to educational diversity, because of its greater salience/visibility (Joshi et al., 2014). Therefore, the problem-solving benefits of ethnic diversity may be large enough to outbalance the greater costs of social conflict, only when the innovation strategy is a primary concern of the organization, like for radical innovation.

A third result is that the positive effect of education diversity is reduced when the collaboration with the range of external partners outside of the firm boundaries increases, suggesting that disciplinary diversity can be replaced by a broader set of external links. Conversely, no positive or negative interaction effects between external collaboration and ethnic diversity were observed. This suggests that while disciplinary background diversity can be replaced by collaborations with external partners, ethnic diversity can neither be replaced nor complemented by external sources.

Theoretical Implication

This study contributes to two important streams of literature. First, it contributes to the literature on the consequences of diversity for the performance of organizations, and does so in a number of ways. While previous studies focused extensively on team composition, very few studies have studied diversity across the entire company's workforce. This article provides evidence on the existence of aggregate-level impacts of diversity. By investigating two dimensions of diversity—ethnic diversity and disciplinary diversity—the study also contributes to an existing discussion on ethnicity and multidisciplinarity, and corroborates prior findings of a positive linkage between diversity and firm performance (Herring, 2009; Parrotta et al., 2014;

Richard, 2000). Furthermore, the study empirically explores the extent to which the hypothesized influence of diversity on radical innovation extends to a successful innovation of an incremental type, recognizing that these outcomes are related to markedly different types of knowledge and search strategies.

A second literature where this study offers interesting contributions is scholarly work on innovation, in particular those studies that address the role of different types of knowledge on the innovative performance of firms. By studying diversity as a source of knowledge and information input, it was shown that internal knowledge plays an important role in radical innovation. We further showed that internal diversity can only in part be replaced by external knowledge search. More specifically, while disciplinary diversity can be replaced if the firm is active in keeping external connections (e.g., nurturing an open innovation strategy), ethnic diversity appears to offer a distinctive source of innovation advantage that cannot be replaced by external links.

While prior literature focused on how employee skill levels and R&D activities created the absorptive capacity to assimilate and use external knowledge, we argue that workforce diversity—especially ethnic diversity—enhances these capabilities and expands distant search.

Managerial Implications

Our research also has other important implications for managers and organizations. Ambidexterity is known to be an important determinant of organizational survival and success (Raisch and Birkinshaw, 2008). Ambidexterity is achieved when firms pursue both exploitation and exploration activities (March, 1991; Tushman and O'Reilly, 1997). In this research, we have shown that ethnic diversity and education diversity have different implications for radical and incremental innovation. Radical and incremental innovations are resonant with exploration and exploitation, respectively (Tushman and Smith, 2002). Organizational ambidexterity can be achieved by creating separate units that pursue either exploitation or exploration (Raisch and Birkinshaw, 2008). Our result shows that while education diversity is helpful in both units, ethnic diversity can be more important in units pursuing exploration.

Despite its limitations, our work suggests that having a diversified workforce is a plus for firms engaging in radical innovation. Future work is called upon to investigate what managerial practices are best suited to garner the advantages of workforce diversity.

Limitations and Future Research

The article has some limitations that could be addressed in future research. First, using aggregate data on all high-skill workers employed by firms creates certain limitations to our analysis. We do not, for example, have any information on how and to what extent different employees are directly involved in the innovation process. A related limitation of the current study is that we are not able to capture team-level effects of diversity. For example, we expect that a firm that has divisions with large within-unit workforce homogeneity but significant between-unit differences in education and ethnic background may have a different outcome than a firm where all the units have diversified workforces, even if both firms have identical aggregate workforce diversity. Further research that is able to incorporate team-level data may be able to find even stronger total effects of workforce diversity on innovation than in the present study.

Second, our empirical setting does not allow us to make strong causal inferences since the workforce compositions may be non randomly assigned. To cope with this known problem, we performed a set of tailored interviews with recruiters of off-sample firms and headhunters. We also used a broad set of control variables (time variant and time invariant), and performed a set of additional analyses. These include using a structural equation model that allows simultaneous estimation of diversity and R&D intensity, as well as analyses utilizing pre-sample (Blundell et al., 1995) and post-sample (Lyngsie and Foss, 2017) data. An instrumental variable approach was also used for ethnic diversity. The findings do not point at endogeneity or reverse causality and thereby corroborate the main findings that diversity positively impacts innovation. However, since a final causal interpretation cannot be possible here, we advise caution and invite further analyses. Repeating the test on other samples, as well as employing further instrumental variable or natural experiment techniques could be helpful to shed definitive light on this issue.

If confirmed by further analyses, the finding that ethnic and disciplinary diversity increase the success of radical innovation would bring immediate and important practical implications. They would suggest that companies may pursue recruitment policies inspired by greater ethnic and disciplinary diversity as

a way to boost the innovativeness of the organization. It would further imply that disciplinary diversity could be potentially replaced by more external links, while ethnic diversity could not.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website.

Appendix S1. Structural equation model presented in Figure 1.

Appendix S2. Using pre-sample patent history in order to take into account unobserved firm heterogeneity as proposed by Blundell et al. (1995).

Appendix S3. Probit analysis of effect of ethnical and education diversity on likelihood of having a radical innovation.

Appendix S4. Cross-sectional Tobit analysis of effect of ethnical and education diversity on sale of incremental innovation.

Appendix S5. Additional robustness check. In model 1 we also include ethnical and education diversity of blue collar employees. In model 2 we control for innovation from radical innovation at industry level (2-digit NACE). In model 3 we use an alternative measure of education diversity (EduDiv1) which take into consideration both field and level of education. In model 4 we use industry background instead of education. In model 5 and 6 we use diversity measures with 3 and 4 years time lag.

Appendix S6. Additional robustness check by including control for age diversity and standard deviation coefficient (standard deviation divided by average, age sd-coeff) as additional control variable.

Appendix S7. Random effect Tobit regression on effect of ethnical and education diversity on radical innovation sales.

Appendix S8. Interaction between EduDiv and Search Breadth in Tobit model (margins are calculated based on model 2 in Table 3).

Appendix S9. Interaction between EduDiv and Search Breadth in Probit model (margins are calculated based on model 2 in Appendix S3).