How horizontal mismatch and educational diversity affects technical innovation of the firm

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Abstract
Innovation by technical employees is an important means of creating sustained competitive advantage for firms in the high-technology sector. The relationship between employee and innovation at the organisation level has been partially described by human capital, in which employee diversity in education and job role is identified as a core component. In this article we use horizontal mismatch as a new lens with which to decompose education/job role diversity effects on organisation innovation. We hypothesise causal relationships between horizontal mismatch at the technical employee and management team levels and innovation at the organisation level, using technical inventions as a proxy for innovation. We find both high educational diversity and low horizontal mismatch to have a positive effect on organisational innovation and that low horizontal mismatch of managers positive moderates the relation between educational diversity and organisational innovation.

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Technical innovation is an important means of creating sustained competitive advantage for firms, particularly in the high-technology sector (A. Joshi & Roh, 2009; Thornhill, 2006). The relationship between employees’ knowledge and skills, and technical innovation at the organisation level has been partially described by human capital (Barrick, Mount, & Li, 2013). From this literature, employee diversity has emerged as a key mechanism driving innovation (Hitt, Biermant, Shimizu, & Kochhar, 2001; Subramaniam & Youndt, 2005), with Unger, Rauch, Frese, & Rosenbusch (2011) highlighting education and job role diversity in particular. However, Laursen, Mahnke, & Vejrup-Hansen (2004) and Carnabuci & Dioszegi (2015) emphasise that significant questions remain as to how these diversity characteristics interact to affect technical innovation.

In the labour economics literature mismatch between field of education and job role (horizontal mismatch) is increasingly recognised as an important predictor of employee satisfaction and productivity related to motivational processes (McGuinness & Sloane, 2011), and thus overall innovation performance (Shipton, West, Parkes, Dawson, & Patterson, 2006). Horizontal mismatch is defined as a lack of alignment between an employee’s field of education and their specific occupation (Nordin, Persson, & Rooth, 2010). Although traditional labour economics studies have focused on the impact of horizontal mismatch on the employee, a number of outcomes relevant to technical innovation at the organisation level have been
identified in relation to this phenomena (Robst, 2007). For example, Østergaard, Timmermans, & Kristinsson (2011) explore the link between mismatch and employee innovation.

In this article we use horizontal mismatch as a new lens with which to decompose education/job role diversity effects on technical innovation in an organisation. We hypothesise causal relationships between horizontal mismatch at the technical employee and management team levels, and resultant technical innovation at the organisation level. Following prior studies, technical inventions are used as a proxy for technical innovation (Ahuja & Katila, 2001; Hall & Ziedonis, 2001; Jaffe & Trajtenberg, 2002). Drawing on the mismatch literature we model two specific causal relationships linked to technical innovation: i) alignment between job role and education at the technical employee and management team levels; ii) interaction between these levels (Note that we do not claim to prove causality, rather we test models that strongly infer causality). In keeping with both human capital literature (A. Joshi & Roh, 2009) and recent research (e.g., Østergaard el al. (2011)), our treatment of education/job role diversity and mismatch is based on organisation level aggregation. Hence our treatment is more specific to the organisational context than is typical of employee focused labour economics literature. Further, we utilise detailed register data on Danish firms and employees from the Danish statistics bureau (Statistics Denmark), which provides in-depth information on both the firm and individual level.

Consequently, this study has several implications for human capital and organisation innovation scholarship. First, we examine the role of horizontal mismatch in moderating human capital diversity effects on technical innovation in high-technology sector firms (Thornhill, 2006). Most human capital research has focused on the overall impact of education and diversity on organisational performance, leaving questions regarding the relationships between these elements (McMahon, 2010; Ployhart, Van Iddekinge, & MacKenzie, 2011). Specifically, Barrick
et al. (2013) highlight the difficulties in conceptualising the interaction between numerous individual characteristics and the job environment via person-job fit; as well as the lack of explanations that connect to the underlying motivational processes that drive employee behaviour. Thus, despite robust evidence for education/job role diversity having a significant effect on overall innovation at the organisation level, the exact nature of the relationship remains unclear (Østergaard et al., 2011). Similarly, there is strong evidence for a relationship between education/job role mismatch and individual innovation (McGuinness & Sloane, 2011). Horizontal mismatch thus offers a novel means of exploring these relationships between human capital and technical innovation at the organisation level. Second, we broaden the investigation of the interaction between diversity and mismatch at different levels within the organisation to include technical employee and management team. This extends previous works that have primarily focused on top-management-team diversity (Cannella, Park, & Lee, 2008). Zarutskie (2010), Crook, Todd, Combs, Woehr, & Ketchen (2011) suggest that both employee and management team human capital have specific effects on innovation. However, the role of diversity and mismatch in each group, as well as interaction between them, has not been extensively researched (A. Joshi & Roh, 2009). We thus explore the relationship between these human capital resources and how their interaction contributes to technical innovation at the organisation level (Ployhart et al., 2011). This again broadens the scope of prior person-job fit research (Barrick et al., 2013). Finally, we use longitudinal data to capture the effects of employee education and horizontal mismatch over time. This responds to the review by Joshi & Roh (2009) where only five studies were found to deal explicitly with education, and of these only two reported longitudinal data (following individual teams for six months (Kearney & Gebert, 2009; Kearney, Gebert, & Voelpel, 2009)). This lack of longitudinal examination is
particularly problematic in the dynamic context of the high-technology sector where changing technical demands pose challenges for human capital. We explicitly address this deficit by using a sample covering a 10-year window, which is structured in a balanced panel format, employing a zero inflated negative binomial model common when analysing count data.

**MODEL AND CONTEXT**

Individual innovation is important to organisational success and building sustained competitive advantage in the high-technology sector (A. Joshi & Roh, 2009; Van de Ven, 1986). In this context Ahuja & Katila (2001) show technical inventions, measured via patent applications, to be an appropriate proxy for technical innovation. Technical employees are the primary source of this type of innovation, which is built on specialist educational and job role knowledge (Unger et al., 2011). Thus alignment between these human capital resources is a critical factor in technical employee innovation performance. However, this is little explored due to a general focus on cultural and gender diversity in the management literature (A. Joshi & Roh, 2009; Williams & O’Reilly III, 1998). Further, innovation by technical employees is strongly moderated by factors, including, social capital, leadership, motivation, and recognition of an employee’s skills and contributions in practice (A. Joshi & Roh, 2009; McMahon, 2010). In particular, Barrick et al. (2013) describe how external situational factors, such as social roles, influence motivation and performance. Thus the interaction between technical employees and management team e.g. via role-modelling or stimulation (De Jong & Den Hartog, 2007; Scott & Bruce, 1994), is instrumental in understanding technical innovation performance. Again this has been little explored due to a general focus on Top Management Team effects (Talke, Salomo, & Rost, 2010), and the lack of connection to underlying motivational processes in the person-job fit literature (Barrick et al., 2013).
Technical employees fill roles spanning the range of product and knowledge creation activities (Thornhill, 2006). Thus there is a high degree of teamwork required in the knowledge creation process meaning that individual level characteristics are likely to aggregate to the organisational level (Jiang, Lepak, Hu, & Baer, 2012). Similarly, uniformity of technical management strategy means characteristics of individual managers are also likely able to be aggregated (Subramaniam & Youndt, 2005). Although Stenard & Sauermann (2016) describe how the underlying reasons for mismatch at the individual level affect its overall impact, aggregation at the organisation level partially mitigates this issue.

Figure 1a presents the organisation level model we test in this study. The model is developed for a high-technology sector context but is based more generally on human capital theory. As discussed in more detail below, changes in technical employee and management team human capital (educational diversity and horizontal mismatch) lead to changes in organisational performance (technical innovation measured via patent production). Further, there is an interaction effect between technical employee and management team human capital (educational diversity and horizontal mismatch), which also influences technical innovation at the organisation level. The dimensions of interaction between these characteristics are illustrated in Figure 1b for clarity. This reveals a number of possible interactions, with little theoretical guidance as to which are most favourable for technical innovation. As such, we examine each interaction highlighted in Figure 1b in conjunction with testing the main hypotheses from prior literature in this context.
HYPOTHESES

Technical Employee Educational Diversity and Horizontal Mismatch Impact Technical Innovation at the Organisation Level

The relationship between technical employees’ knowledge and skills, and technical innovation at the organisation level has been partially described by human capital (Crook et al., 2011). D’Aveni (1996) and more recently Hitt et al. (2001) specifically highlight employee education as a key component of human capital and subsequent innovation at the organisation level across the whole span of an employee’s career. However, critical to realising possible performance benefits from employee education is the fostering and management of educational diversity (McMahon, 2010). This relationship has been highlighted in a range of contexts by Joshi & Roh (2009), Unger et al. (2011), and Certo, Lester, Dalton & Dalton (2006); with van Dijk et al. (2012) showing that diversity is more positively related to innovation performance than in-role performance. For technical employees educational diversity is one of the main correlates of technical innovation at both the organisational level, as described by Kearny et al. (2009) and Østergaard et al. (2011); and at the employee level, particularly in roles where cognitive load is high e.g. in the high-technology sector (Faems & Subramanian, 2013; Post, De Lia, DiTomaso, Tirpak, & Borwankar, 2009). Hypothesis 1a thus addresses the fundamental relationship between educational diversity and technical innovation at the organisation level in the context of the high-technology sector:
**Hypothesis 1a.** High technical employee educational diversity has a positive affect on technical innovation at the organisation level in the high-technology sector.

Decomposing the link between educational diversity and technical innovation performance reveals a non-linear relationship (McMahon, 2010), driven by the conflicting mechanisms of sub-group cohesion and diversity. Lau & Murnighan (2005) show that belonging to a cohesive demographic subgroup has a significant effect on team learning, feelings of psychological safety, and satisfaction, which drive motivation and innovation performance (McMahon, 2010). Thus diversity and demographic cohesion form opposing characteristics, which are both linked to innovation performance (Hitt et al., 2001; Lau & Murnighan, 2005). Critical to balancing these characteristics and thus realising innovation performance gains is effective use of job role and title to help shape employee self-perception. Grant, Berg, & Cable (2014) highlight how job title forms an identity badge, shaping subgroups and feelings of psychological safety, as well as employee self realisation and satisfaction. Employees who identify with their job roles are more able to engage with their job and thus put ‘their full self into a role’ (Rich, Lepine, & Crawford, 2010). This is underpinned by an employee’s confidence in their own worthiness, effectiveness, and capability, allowing for more or less investment of self in role performance (Kahn, 1990). As job role defines many of the measures of worth, effectiveness, and capability it has a profound effect on employee performance, and positively shaping diversity effects. However, Stenard & Sauermann (2016) also highlight how individuals’ draw on their education even in mismatched roles. As such, mismatch complements extant understanding of person-job fit to explain why organisations with similar employee educational diversity still experience performance differences. Jiang et al. (2012) and Bassett-Jones (2005) highlight how properly managing the tension between diversity and job role underpins personal
recognition, motivation, and satisfaction, all of which drive innovation performance (Hitt et al., 2001).

In parallel to the human capital literature motivational mechanisms have been described at a workforce level in research on horizontal mismatch (Nordin et al., 2010). McGuinness & Sloane (2011) specifically connect greater alignment between job role and educational specialisation to improved motivation, and greater satisfaction, which are linked to greater employee innovation by authors such as Shipton et al. (2006). Reduced horizontal mismatch can thus be linked to improved innovation at the organisation level via employee level performance increases, as in the human capital literature (Jiang et al., 2012; Nordin et al., 2010). Further, Nordin et al. (2010) highlights that mismatch builds on the general logic that an individual must be at least able to do their job before motivation, self realisation, and satisfaction become important to their performance. As such, horizontal mismatch provides a lens through which the tensions between diversity and subgroup cohesion can be dissolved. Hypothesis 1b thus addresses the relationship between education diversity and job-role – expressed through horizontal mismatch – and technical innovation.

**Hypothesis 1b.** Low technical employee horizontal mismatch has a positive effect on technical innovation at the organisation level.

Horizontal mismatch and educational diversity share mechanisms linking them to improved innovation performance (Bassett-Jones, 2005). For example, McMahon (2010) and McGuinness & Sloane (2011) highlight increased motivation and job satisfaction stemming from both greater educational diversity and reduced horizontal mismatch. Further, good match between job role and educational background fosters team learning, psychological safety, and overall satisfaction (Grant et al., 2014). This has been highlighted in the human capital and
general management contexts by Lau & Murnighan (2005) and Rich et al. (2010), and in the labour economics literature by, for example, Ho (2015) and Kearney & Gebert (2009).

In both domains (human capital and horizontal mismatch) improvement in innovation performance is moderated by factors such as, acceptance and recognition of employees’ skills and contribution to the organisation (Ho, 2015; Kearney & Gebert, 2009). Thus reduced mismatch and greater educational diversity both correlate with improved motivation and satisfaction, and subsequently improved innovation performance. These effects are moderated by acceptance by the management team, and the wider organisation (Alpkan, Bulut, Gunday, Ulusoy, & Kilic, 2010; Chi, Huang, & Lin, 2009). As these underlying motivational mechanisms are shared across the diversity and mismatch literatures their interaction cannot be modelled as a purely additive/offsetting relationship, rather mismatch moderates the performance of a workforce in conjunction with educational diversity. Hypothesis 1c thus links educational diversity and horizontal mismatch, and their interaction in the high-technology sector at the technical employee level:

**Hypothesis 1c.** Horizontal mismatch moderates the affect of technical employee educational diversity on technical innovation at the organisation level. The effects of educational diversity are stronger in more matched settings.

Management Team Educational Diversity and Horizontal Mismatch Impact Technical Innovation at the Organisation Level

As at the employee level, educational diversity in the management team has been linked to improved innovation performance by, for example, Carpenter et al. (2004) and Hitt et al. (2001). This relationship between educational diversity and innovation performance has been decomposed by a number of authors (Talke et al., 2010), and builds on similar mechanisms as
those at the technical employee level. Barkema & Shvyrkov (2007) and Auh & Menguc (2005) explain that greater diversity brings together a wider range of skills, views, and ways of understanding and evaluating. These collectively contribute to higher levels of innovation via a greater diversity in cognition and mental models, and greater scope for the creative development of ideas (Auh & Menguc, 2005; Carpenter & Fredrickson, J, 2001). This is further supported by Dahlin et al. (2005) who explain innovation improvement from diversity in terms of enhanced ability to use information. Based on these findings educational diversity has been shown to have a significant effect on innovation performance distinct from other aspects of diversity (e.g. gender or age) (Dahlin et al., 2005). However, unlike at the at the technical employee level this relationship is yet to be directly demonstrated with respect to the management team. Hypothesis 2a thus addresses the relationship between educational diversity amongst the management team and technical innovation at the organisation level in the context of the high-technology sector:

Hypothesis 2a. High management team educational diversity has a positive affect on technical innovation at the organisation level.

At the management team level alignment between functional role and specific experience (functional and education) correlate with innovation performance (Bassett-Jones, 2005). As at the employee level, recognition of commonalities and awareness of differences are key to effectively leveraging performance benefits from diversity (McMahon, 2010). Carpenter et al. (2004) highlights explicit recognition, incentivisation, and integration of diverse skills team background, and experience as key moderators of management team demographic effects. This translates to the need to actively manage diversity through role assignment and leadership, as highlighted by both Auh & Menguc (2005) and McMahon (2010). As such, it is again possible to build on the labour economics literature to hypothesise a relationship between horizontal
mismatch in the management team and technical innovation at the organisation level. Hypothesis 2b thus links low horizontal mismatch at the management team level to technical innovation at the organisation level in the high-technology sector.

**Hypothesis 2b.** Low management team horizontal mismatch has a positive effect on technical innovation at the organisation level

Finally, as at the employee level, educational diversity and horizontal mismatch can be linked via common mechanisms of empowerment of diversity effects and recognition and incentivisation of individual staff (Carpenter et al., 2004; McMahon, 2010). Building on the same logic as Hypothesis 1c, Hypothesis 2c predicts a moderating relationship between horizontal mismatch and the impact of management team educational diversity effects.

**Hypothesis 2c.** Horizontal mismatch moderates the affect of management team educational diversity on technical innovation at the organisation level. The effects of educational diversity are stronger in more matched settings.

Alignment Between Technical Employee and Management Team Characteristics Impact Technical Innovation at the Organisation Level

Despite significant research at each organisational level Laursen, Mahnke, & Vejrup-Hansen (2004) and Carnabuci & Dioszegi (2015) emphasise that significant questions remain as to how diversity characteristics interact across levels. Auh & Menguc (2005) show that in this context, diversity can have both positive and negative effects on, for example, consensus formation and agreement. Further, Barrick et al. (2013) highlight the limitations of person-job fit in connecting to the motivational processes underlying employee behaviour, which are closely linked to the interaction between technical employees and management team (Kearney & Gebert, 2009). Thus effective management of diversity is underpinned by recognition of commonalities
and awareness of differences within and across levels (McMahon, 2010). Further, Josh et al. (2003) amongst others (Kearney & Gebert, 2009; Raes, Heijltjes, Glunk, & Roe, 2011) emphasise that alignment in strategic vision and understanding of company goals and job roles across organisational levels is key to company performance. Strauss & Connerley (2003) highlight three components essential to developing alignment in understanding when dealing with diversity: realistic appreciation, comfort with difference, and diversity of contact. Thus in order to achieve the performance benefits derived from educational diversity at the employee/management team levels the interaction between levels must be actively managed (Faems & Subramanian, 2013; McMahon, 2010). For example, Milliken & Martins (1996) highlight how the positive effects of diversity on innovation can only be realised when coordination activities are correspondingly increased.

The management of educational diversity across the employee/management team interface builds on employee recognition, trust across levels, engagement, and job satisfaction (McMahon, 2010; Rich et al., 2010). These mechanisms are particularly influential at this interface (M. Joshi et al., 2003; Lankau et al., 2007). Gruman & Saks (2011) and Bassett-Jones (2005) directly link the fostering of employee engagement to job satisfaction and improved innovation performance. Further, Kinicki et al. (2004) show that performance improvement builds on trust in the management team and the employees’ belief that the supervisor knows the job to be done and is in the position to make informed and credible judgements. Here, mutual understanding is key to feelings of acceptance and respect, which underpin psychological safety and contribute to innovation performance (Baer & Frese, 2003). Thus by aligning educational diversity across levels a greater understanding is achieved, increasing both management team’s ability to understand the technical employee’s, and the technical employee’s perception that the
management team are credible (Kinicki et al., 2004; Simpson, 2009); which together contribute to increased technical innovation performance at the organisational level as described with respect to Hypotheses 1 and 2. Hypothesis 3a thus predicts that greater alignment in education diversity across levels will moderate technical innovation performance.

**Hypothesis 3a.** *Alignment between management team and technical employee educational diversity has a positive impact on technical innovation at the organisation level. The effects of educational diversity are stronger in more aligned settings.*

As with Hypotheses 1 and 2 high horizontal mismatch at either level will diminish the beneficial effects of educational diversity, and reduce feelings of psychological safety, recognition, and job satisfaction (Grant et al., 2014; Rich et al., 2010). Further, as these features underpin individuals’ self-realisation and ability to speak out their loss at either level diminishes trust and engagement across levels. For example, Gruman & Saks (2011) highlight how effective coaching by the management team can foster engagement and instil confidence amongst employees. However, in order to achieve such positive effects the management team itself must be comfortable with its own diversity characteristics (McMahon, 2010), and in turn technical employees must also feel recognised and engaged in order to build on management guidance (Carpenter et al., 2004; Strauss & Connerley, 2003). This interpretation is further supported by Hislop et al. (2000) who describe the role of hierarchical authority in empowering and implementing employee innovation, which is contingent on individuals’ confidence in expressing themselves and in managing the exchange relationship across levels (Baer & Frese, 2003). Stenard & Sauermann (2016) also show that mismatch affects human capital development and job satisfaction, but that its impact can vary significantly depending on individuals’ reasons for entering into the mismatch. As such, management of the exchange relationship across levels
becomes particularly important when trying to understand and adapting to each individuals’
particular mismatch effects. Thus horizontal mismatch forms a key moderator of the interface
between levels, by influencing each level’s ability to self realise, as well as their ability to
manage and develop an exchange relationship, and ultimately foster mutual understanding
(Kearney & Gebert, 2009). Hypothesis 3b thus predicts that greater alignment in horizontal
mismatch across levels will moderate technical innovation performance.

**Hypothesis 3b.** Alignment between management team and technical employee horizontal
mismatch has a positive impact on technical innovation at the organisation level. The
effects of horizontal mismatch are stronger in more aligned settings.

Despite the strength of the general hypotheses (3a and 3b) associated with interaction
between the management team and technical employees, there is little research describing the
range of possible interactions illustrated in Figure 1b. As such, we also examine how each type
of interaction affects innovation performance. In particular, this is necessary as both the human
capital and labour economics literatures tend to focus on the effects of diversity and mismatch at
a single level, despite common underlying motivational mechanisms, which point to interactions
between levels.

**SAMPLE AND ORGANIZATION**

We base our study on a longitudinal dataset of 8,350 Danish firms. The firms are
observed from 2001 to 2010 and thus containing a panel structure. The data is sampled from the
Integrated Labor Market database (IDA) supplied by the national Danish statistics bureau
(Statistics Denmark) and provides firm and employee level register data. The firm level register
data contain information on industry, export activities, the size of the firm, geographical location,
revenue and profits. The employee level data contains information on education, salary, primary
and secondary workplace, type of job and degree of unemployment. Merging firm and employee level data allows us to create firm level variables that describe the levels of education and horizontal mismatch within the firm. We observe firms with more than 20 full time employees to remove home offices and cottage industry. This provides us with 60,217 observations divided between 8,350 unique firms.

To measure the innovative performance of the firm we rely on patents as a proxy for innovation output. The patent data is provided by the Danish Patent and Trademark Office (DKPTO) and is matched to the firm level data using a unique firm identifier. The matching to IDA register data was done by DKPTO to ensure a high validity of the data.

**Measures**

**Organizational innovation:** The annual patent production of the firm is used as a proxy for organizational innovation. Patent data does not capture all innovation of the firm, but does provide an indication of the innovative output of the firm, particularly in technical industries. Unfortunately we do not have citation data not available, whereby we are unable to assess the quality or impact of firm innovation.

**Horizontal mismatch:** We use the employee level data on education and job title aggregated to the firm level to generate indicators on the overall level of educational diversity and horizontal mismatch on the firm level. Horizontal mismatch is calculated both for employees and managers separately. The IDA database provides both distinct education codes describing the title of the highest completed education, and a descriptive job title for each employee. The level of horizontal mismatch for managers is calculated as the share of employees in a management job with an education in business administration or management. For
employees we focus on the horizontal mismatch of engineers. Engineers contribute highly to technical innovation, and provide a clear identification of education and job title. Similar to managers, the horizontal mismatch of engineers is calculated as the share of engineering jobs staffed by an employee with an engineering education. This is a ratio variable ranging from 0 to 1 in which high values indicate low levels of horizontal mismatch. We do not take engineering specialization into account as a large share of engineers has an education classified as ‘general engineering’ or simply ‘Engineering Masters’, rather than as falling within a specific technical domain.

**Educational diversity:** For educational diversity we calculate a normalized Herfindahl-Hirschman Index (HHI) using education codes for employees and managers separately. For managers we focus those with a relevant education in business administration or management and classify each manager to their specific education. Similarly for employees, we classify each engineer in a non-management job to their specific education using the education codes from the IDA database. The HHI for educational diversity is normalized in order to present a higher value for high values of educational diversity.

**Alignment of horizontal mismatch:** Alignment between managers and employees is represented as the difference between the levels of horizontal mismatch. As horizontal mismatch is a ratio variable ranging from 0 to 1 these can be compared directly. We compute the alignment of horizontal mismatch as the difference between the ratio of horizontal mismatch of managers to that of employees. This value is normalized in order for the variable to show a high value for a strong alignment of horizontal mismatch between managers and employees.

**Alignment of educational diversity:** Similarly to the alignment of horizontal mismatch, the alignment of educational diversity compares the difference between two ratio variables
ranging from 0 to 1. The alignment of educational diversity is computed as the difference between the ratio of educational diversity for managers and employees. Again this is normalized to provide a high value for stronger alignment of educational diversity.

**Control variables:** We employ a number of control variables across all models. We include the size of the firm (\textit{firmsize}) measured as number of employees. This allows for an even comparison between firms of varying sizes and eliminates the effect of larger firms potentially producing more patents. As our dependent variable is the patent production of the firm, we include controls for the number of lawyers in relation to the size of the firm (\textit{share_lawyers}) as firms with a higher number of lawyers employed could potentially be more active in patenting. In addition we control for the share of employees with a doctorate in natural science (\textit{share_science}) as this group of employees can contribute significantly to the patent production of the firm.

**ANALYTICAL METHOD**

Our dependent variable was the number of patents produced by the firm annually and following prior literature using this data we turned to count models for estimation (e.g. Hausman et al (1984)). The annual production of patents by the firm is estimated as an exponential function of the knowledge stock of firm employees and other characteristics \(X_{it}^i\):

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E[p_{it} | X_{it}^i] = \lambda_{it} = \exp(X_{it}^i\beta + y_t)
\]

In which \(i\) identifies the firm, \(t\) the year, and \(y_t\) measuring the mean overall patent production across time. The data is tested for overdispersion using the LaGrange Multiplier test as suggested by Cameron and Trivedi (1986), and for zero inflation using the Vuong test (Greene, 2012). As our data is overdispersed we find the negative binomial estimation to have a better fit in comparison to the Poisson estimation. The Vuong test points to an issue of zero
inflation and hence we rely on a zero inflated negative binomial estimation to analyse our data. We test our hypotheses in four separate models; Model 1 focus on the educational diversity of managers and engineers, whereas models 2 and 3 focus on the interaction effects between educational diversity and horizontal mismatch for engineers and managers respectively. Model 4 focus on the alignment of educational diversity and horizontal mismatch.

RESULTS

We present the descriptive statistics in table 1. Within our sample, the median firm has a size of 206 employees and produces 0.3 patents annually. The indicators for educational diversity differs slightly between managers and engineers, however both normalized HHI show a substantial educational diversity in both job types. The pairwise correlations are presented in table 2, with no signs of high correlation between variables.

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Table 3 presents the results of our regression models, separated into 4 models. Model 1 focus on the direct effects of educational diversity and horizontal mismatch on organizational innovation. We find that increasing levels of educational diversity of both engineers and managers have a positive effect on organizational innovation, lending support to hypotheses 1a and 2a. Hypotheses 1b and 2b finds also support in model 1 as we find a positive and significant
effect of low horizontal mismatch of both employees and managers on organizational innovation. Model 2 presents the interaction effect between horizontal mismatch and educational diversity for employees, however this does not produce any significant results. Hence we do not find any support for hypothesis 1c. Model 3 presents the interaction effect between horizontal mismatch and educational diversity for managers. In this we find a positive and significant result of the interaction, which indicates that lower levels of horizontal mismatch positively moderates the relation between educational diversity of managers and organizational innovation. Interestingly when including the interacted term in the model, we find a negative and significant estimation of horizontal mismatch of managers. This contradicts our results in the remaining models and indicates that the benefits of low horizontal mismatch of managers are only present in firms with higher levels of educational diversity among the management. Model 4 is structured similar to model 1, however includes two variables for the alignment between educational diversity for managers and employees, and alignment between horizontal mismatch for managers and employees. We find a positive, significant result for the effect of both types of alignment on organizational innovation, supporting hypotheses 3a and 3b.

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**DISCUSSION**

The purpose of this study was to examine, both theoretically and empirically, the interconnected nature of educational diversity and horizontal mismatch across organisational levels, and their effect of innovation at the organisation level. In keeping with recent arguments (e.g. Hitt et al. (2001); Unger et al. (2011)), we conceptualise these factors as interconnected and
significantly related to innovation performance. By considering these both amongst technical employees and the management team, we provide a more detailed examination of the interrelationships and consequences of educational diversity and horizontal mismatch on innovation. This closes a significant empirical gap in the human capital literature by employing a longitudinal dataset to identify time specific variations of educational diversity and horizontal mismatch and their effect on organizational innovation.

**Theoretical Implications**

First, we demonstrate that both high educational diversity and low horizontal mismatch amongst technical employees and the management team have a strong positive effect on innovation at the organisation level. This confirms and extends prior research on the effects of educational diversity amongst technical employees. In particular, the findings align with and extend studies of individual teams (Kearney & Gebert, 2009; Kearney et al., 2009), as well as studies of diversity across the entire employee base (Østergaard et al., 2011). This closes the major empirical gap highlighted by both the review of Joshi & Roh (2009) and Østergaard et al. (2011). By demonstrating the link between horizontal mismatch and innovation at the organisation level this study explicitly connects horizontal mismatch and human capital theory. Despite the logical link between these areas implied by e.g. McGuinness & Sloane (2011), this relationship has not previously been described theoretically or empirically demonstrated. Here, findings align with studies at the workforce level (Nordin et al., 2010) but explicitly highlight the importance of horizontal alignment for organisations and human capital. This extends prior work on the affects of educational diversity and job role by introducing a additional dimension not previously described by human capital theory (Jiang et al., 2012). The interconnectedness between educational diversity and horizontal mismatch makes these factors even more inimitable
than either in isolation. Failing to understand these interrelationships and their specific significance amongst technical employees and the management team, it is possible to misattribute antecedents of innovation within an organisation. Research should further study the relationships between different types of human capital and their alignment with job role.

Second, we found that horizontal mismatch, particularly within the management team, moderates the effects of educational diversity. This points to interplay between human capital factors not fully described by current theoretical models. This aligns with the arguments outlined by Ployhart & Moliterno (2011) who describe the human capital literature as theoretically fractured. A further finding in this context is that the relationship between horizontal mismatch and educational diversity is not consistent across the two groups of employees (contrast H1c and H2c). This points to the need for further exploration of how employee heterogeneity affects the emergence of particular aspects of organisational performance. Prior studies have tended to focus one or other group of employees e.g. top management teams (Carpenter et al., 2004). The interrelationship between these factors across employee groups suggests a more complex picture of human capital and highlights the need for greater connectivity within human capital theory. Research should further study the varying impact of human capital factors as well as their changing interactions across employee groups.

Finally, we have argued and shown that the interplay between horizontal mismatch and educational diversity in the management team and amongst technical employees has a significant impact on innovation at an organisation level. However, this relationship is not currently described by human capital theory. This is of particular significance given the conflicting affects of diversity, leadership, and alignment across organisational levels demonstrated by e.g. Faems & Subramaniam (2013), Kinicki et al. (2004), and Kearney & Gebert (2009). This extends prior
studies, which have focused on the impact of the top management team exclusively, as well as pointing to a more complex model of human capital across organisational levels. Research is needed to explore the variety of possible factors affecting this relationship.

**Managerial Implications**

The challenge of managing educational diversity, particularly, across organisational levels, is that its effects are both significant for innovation and also highly interconnected with other aspects of human capital. Consequently educational diversity and horizontal mismatch cannot easily be separated and are also dependant on alignment across organisational levels.

One important implication is that leveraging educational diversity as a means of innovation requires more than simply employing a diverse population of technical employees. It requires careful consideration of how these employees are matched to their job roles, how these roles are balanced across the population, and how this aligns with diversity and mismatch within the management team. This leaves the manager with the challenge of having to align diversity and mismatch across multiple dimensions, while still integrating more traditional guidelines, such as transformational leadership. For example an organisation with a highly diverse group of technical employees must consider if alignment is needed across organisational levels, within the technical employees only, or within both the management team and technical employee population. By modelling the moderating affects of these factors we showed that the practical consequences of alignment within and across these two groups of employees is critical to the innovation performance of an organisation.

**Limitations and Directions for Future Research**

In the current iteration of our estimations we do not correct for potential issues of endogeneity. In future research this should be investigated and any issues identified corrected.
Due to the nature of the data and availability of data, the application of instrumental variable regression could solve potential issues. Alternatively a matched sample can be employed. In addition multiple robustness checks are required to test the validity of the findings presented in this paper. Potential robustness checks include standardizing the dependent variable and employing a linear regression model, a zero inflated Poisson model or a panel-level fixed effects specification with firm-level fixed effects.

Conclusion

In conclusion, the present study confirms the importance of educational diversity for innovation at the organisation level and identifies horizontal mismatch as a key construct not previously described by human capital theory. Importantly these factors both independently influence innovation and interact within and across organisational levels. This points to a more complex understanding of interconnected human capital within an organisation. We hope this study prompts researchers towards finer-grained examination of different forms of human capital, their interactions, and their moderating effects across organisational levels. In particular, the relationship between management team and educational diversity/horizontal mismatch within the technical employee group requires further investigation in order to derive potential best practices.
REFERENCES


Figure 1a: Causal model linking human capital and mismatch characteristics to organizational innovation

Figure 1b: Dimensions of mismatch and alignment considered in this study
Table 1 – Descriptive statistics

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Table 2 – Pairwise correlation matrix

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Table 3 – Results of zero inflated negative binomial regression

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* p<0.1, ** p<0.05, *** p<0.01