



## Board diversity and corporate propensity to R&D spending

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### ABSTRACT

Drawing on collective contributions and group performance perspectives, this paper examines the role of board diversity in firms' R&D investment decisions. Building on a fault-line argument about a team's demographic attributes, this study also decomposes the impact of demographic and cognitive diversity on R&D spending. The study sample contains UK data of non-financial companies covering the period between 2005 and 2018. We employ panel data analysis techniques and control for potential endogeneity issues through the application of the two-step system Generalised Method of Moments (GMM) estimations. The findings demonstrate a positive and significant relationship between board diversity and level of corporate R&D spending. The findings also show cognitive diversity as significantly positively associated with corporate R&D investments. Demographic diversity, however, has an insignificant relationship with corporate spending on R&D. The results further show that demographic diversity negatively moderates the relationship between cognitive diversity and spending on R&D. Our main findings document that the board's attributes as a group significantly influence decisions of strategic importance such as, investment in R&D projects. The findings on sub-dimensions of board diversity imply that as compared to demographic diversity, functional/cognitive diversity is more relevant to strategic decisions and related outcomes. The study has practical implications for shareholders in documenting the importance of board diversity, and policy implications for regulators in highlighting the separate roles of behavioural and cognitive diversity in shaping firms' strategic investment decisions.

### 1. Introduction

In its diversity and inclusion policy document Tesco Plc, one of the largest retailers in the UK, reports that, '*...it is the Board's strong belief that a diverse Board with different perspectives, insights and viewpoints in decision-making ultimately benefits the Group's stakeholders through better business performance...*' (Board Diversity and Inclusion Policy, Tesco, 2022).<sup>1</sup> The quote signifies the increased recognition by firms that board diversity plays an important role in the firm's decision-making. Internationally, there has been growing interest in exploring issues concerning corporate board diversity across countries such as, US (e.g., Boulouta, 2013; Carter, Simkins, & Simpson, 2003); UK (e.g., Osmo, 2008; Schopohl, Urquhart, & Zhang, 2021), Australia (e.g., Chapple & Humphrey, 2013), and several other jurisdictions worldwide (e.g., Terjesen, Couto, & Francisco, 2016).

In this regard, evidence in the existing literature documents significant variation across countries in board diversity and suggests that

attributes of directors on the board, such as age, gender, and experience, contribute to improving firms' performance (Carter et al., 2003; Chapple & Humphrey, 2013), strategic innovation (Goodstein, Gautam, & Boeker, 1994), and social achievements (Boulouta, 2013). Other studies found that board diversity contributes to corporate competitiveness (Cox & Blake, 1991), promotes market understanding and increases innovation and creativity (Carter et al., 2003).

In the decision-making process, where team efforts are involved, it is well established that the diversity of members' characteristics is crucial to the quality of the decisions reached (Baranchuk & Dybvig, 2008; Knippenberg, De Dreu, & Homan, 2004; Knippenberg & Schippers, 2007; Sah & Stiglitz, 1991). A corporate board works as a team to make decisions using collective deliberations and relevant information, however, existing evidence on the effectiveness of board diversity in strategic decision making is still scarce. It is therefore important to consider the contributions of the attributes of corporate board as a whole in exploring the role of board diversity in affecting firms' strategic

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<sup>1</sup> <https://www.tescoplac.com/media/759395/board-diversity-and-inclusion-policy-2022-final.pdf>

decisions, such as investment in research and development (R&D hereafter) and innovation (Barker & Mueller, 2002; Ben-Amar, Francoeur, Hafsi, & Labelle, 2013; Chen, 2014). In line with these arguments, this study uses comprehensive board-diversity measures (i.e., directors' gender, age, nationality, education, financial expertise, tenure, and board experience), and examines the role of board diversity in firms' investments on R&D activity. Consistent with agency theory (Jensen & Meckling, 1976), we consider the monitoring role of board diversity in helping achieve goal congruence between managers and shareholders and ensuring that managers employ firms' resources efficiently (e.g., Adams & Ferreira, 2009). Similarly, we also draw on resource dependence theory (Pfeffer & Salancik, 1978) and consider board diversity as a source of critical resources that can shape and influence firms' strategic investment decisions, such as R&D.

Furthermore, organisational and social psychology literature asserts that team members' demographic attributes can result in a divide within the group with individuals standing against each other's opinions and ideas (Bezrukova, Jehn, Zanutto, & Thatcher, 2009; Lau & Murnighan, 1998; Posthuma & Campion, 2009). Such a rift carries the potential to neutralise or lower the positive contribution of members' cognition (Knippenberg & Schippers, 2007). However, corporate board literature lacks evidence from this aspect. Based on the argument of the faultline<sup>2</sup> between groups (Bezrukova et al., 2009; Lau & Murnighan, 1998), this research further examines the moderating role of demographic diversity in the link between cognitive diversity and R&D. In addition, by using a sample of UK listed firms, this research exploits different institutional and corporate governance environments compared with the US to contribute to the extant literature on the role of board diversity in firms' R&D investment decisions.

Spending on R&D projects helps corporations in bringing new processes, products and services to the market which ensures sustained growth and long-run survival (Griliches, 2007; van Pottelsberghe de la Potterie & Guellec, 2004). As investment decisions are solely the discretion of the board, it is argued that corporate boards play a vital role in contributing to strategically important decisions (Kim, Burns, & Prescott, 2009). R&D projects, whilst strategically important, are inherently risky, and thus require expertise, wisdom and optimism to make them successful ventures. Firms' boards therefore hold a key role in the provision of required resources for R&D investment activities.

The existing corporate governance and R&D literature, however, concentrates mainly on the board structure, ownership structure, and CEO characteristics and power (See, e.g., Baysinger, Kosnik, & Turk, 1991; Lee & O'Neill, 2003; Chen & Hsu, 2009; Munari, Oriani, & Sobrero, 2010; Chen, 2014; Guldiken & Darendeli, 2016; Bravo & Reguera-Alvarado, 2017). Similarly, while some studies explore the role of gender-diversity in R&D decisions (e.g., Chen, Ni, & Tong, 2016; Fernandez, 2015), only a handful of studies have attempted to examine the role of board diversity in firms' strategic investments in R&D in the US context (e.g., Bernile, Bhagwat, & Yonker, 2018; Midavaine, Dolfma, & Aalbers, 2016). Bernile et al. (2018), for instance, use a more comprehensive view of board diversity, but they examined the moderating role of R&D spending on the relationship between board diversity and firms' risk. Moreover, most of the existing studies are context-dependent, as the US corporate governance structure and institutional environment differ from those of other countries. These factors therefore warrant further investigation of the role of board diversity in firms' spending on R&D endeavours. In light of the above discussions this study poses the following research questions.

1. How does board diversity affect firms' spending on R&D?

<sup>2</sup> Lau and Murnighan (1998) define the term faultline as combinations of correlated dimensions of diversity that yield a clear basis for differentiation between subgroups. This includes dissimilarity between groups and similarity within groups which lead to division as "them" and "us".

2. Does the board's demographic diversity influence the relationship between cognitive diversity and R&D investment?

Using a sample of non-financial firms listed on the London Stock Exchange (LSE) from 2005 to 2018 and a robust research methodology (two-step System-GMM), this study documents a significantly positive association between board diversity and level of R&D spendings. This finding supports the argument that the attributes of board of directors as a group contribute to improving the quality of decisions making, leading to sustained growth in the long run (Bernile et al., 2018). This research also finds that cognitive diversity has a significant and positive relationship with R&D investment. However, demographic diversity has an insignificant association with firms' spending on R&D projects. Results from this study further validate that demographic diversity negatively moderates the relationship between cognitive diversity and R&D investment.

This study contributes to the extant literature on board diversity and R&D investment in three different ways. First, this is among the first few studies in the UK setting to look at the role of board diversity in the corporate propensity to R&D investment. Earlier studies on board diversity and R&D investment are in the US context (e.g., Bernile et al., 2018; Midavaine et al., 2016). The US corporate governance codes are "rule based" whereas in the UK it is "comply or explain based". Therefore, this study provides empirical evidence in contextually different corporate governance environment than that of US and elsewhere. Second, we complement the R&D and corporate governance literature emphasizing the board contributions as a team (e.g., Barker & Mueller, 2002; Ben-Amar et al., 2013; Chen, 2014). Prior research on board diversity and R&D focuses on gender diversity (e.g., Chen et al., 2016; Fernandez, 2015) or only few of the board members' attributes (e.g., Midavaine et al., 2016). Using a more comprehensive board-diversity index, this research documents that the board's attributes (heterogeneity of team characteristics) as a group significantly influence decisions of strategic importance, such as decisions on R&D investment.

Third, consistent with the 'Faultline Argument' in the organisational and social psychology literature, we make important contribution in board diversity literature. Organisational and social psychology research shows the detrimental effect of demographic attributes of members due to "in-group" and "out-group" thought within team (e.g., Bezrukova et al., 2009; Lau & Murnighan, 1998; Posthuma & Campion, 2009; Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). Wu, Triana, Richard, and Yu (2021) analyse only one demographic characteristic of the board and observe that board gender faultline strength negatively affects strategic change. We provide more comprehensive evidence by empirically documenting that a rift within (group) corporate board emerging from demographic characteristics of directors negatively influences the relationship between cognitive diversity and R&D investment. Previous studies on board diversity and R&D investment (e.g., Bernile et al., 2018; Midavaine et al., 2016) have not considered this aspect. Therefore, consistent with the 'Faultline Argument', our study makes a unique contribution to existing literature on board diversity and R&D investment.

We argue that the evidence documented by this study have policy implications for the corporate sector. From shareholders' perspective, this study provides insights into board diversity as an aggregate of multiple aspects in shaping corporate strategic decisions. Furthermore, firms should aim to focus on bringing diversity of skills and experience on the board to ensure cognitive diversity in board discussions, rather than simply building the demographic diversity.

The rest of this paper is structured as follows. The next section presents theoretical perspectives and prior literature, hypotheses development and conceptual framework for the paper. Section 3 lays out the research design, research model, and measurement of variables. Section 4 provides an overview of the results and related discussions. Finally, section 5 concludes the study with a short summary of the overall content and contributions of the paper.

## 2. Theoretical perspectives and prior literature

The theoretical framework of this study is based on two key theories – agency theory (Jensen & Meckling, 1976) and resource-dependence theory (Barney, 1991; Pfeffer & Salancik, 1978). According to agency theory, the primary role of the board of directors is the monitoring function in the organisation, to regulate the chances of opportunistic (short-termism) behaviour by managers while selecting business projects, which may detract from the motto of wealth maximisation for owners. The role of monitoring is to tackle the moral hazard that may arise from having ownership and control in separate hands (Adams & Ferreira, 2007).

The outcome and success of R&D projects are highly uncertain, and decisions concerning investment in such projects may give rise to conflict between shareholders and managers. A corporate board therefore plays a significant role in aligning shareholders' interests with managers', which eventually boost corporate investment in R&D projects. In particular, a board's characteristics will signify its strengths that is decisive to the monitoring of management, and board diversity can be a vital resource for shaping an improved monitoring and control system. In this regard, Bernile et al. (2018) argue that homogeneity of views, preferences, and approach between directors of the board will lead to increased idiosyncratic conclusions due to a lower level of checks and balances within the board. Therefore, board members' differing views that resulted from board diversity, can be potent in framing a robust system to control and monitor managerial conduct, thereby favouring R&D investments which enhance shareholders' wealth.

Along with monitoring, the board's vital function is to provide strategic resources to the corporation (Johnson, Daily, & Ellstrand, 1996). This role of the board is rooted in the theoretical assertion based on the pioneering work of Pfeffer and Salancik (1978) on resource-dependence. Resource-dependence theory (RDT hereafter) emphasises the board as a source of critical resources, abilities, and skills at the corporation's disposal for enhanced performance (De Villiers, Naiker, & Van Staden, 2011). Based on RDT arguments, board members can assist in the development and implementation of company strategies. This contribution is due to the board's external environment linkage which can empower the organisation to obtain essential resources to reduce the unpredictability and risks associated with strategic efforts (Haynes & Hillman, 2010). The board's resource-provision role may minimise the uncreative behaviour of managers who may pursue short-term objectives (Xie & O'Neill, 2013), and thereby boost R&D activities for a sustained and long term success.

The level of board members' skills and experience will therefore constitute a company's essential resources. These resources can lead to and assist corporate outcomes, such as developing new products and services through innovation due to strategic R&D spending. It is therefore argued that in a situation where all board members have similar attributes, they might make decisions quickly (Marcel, Barr, & Duhaime, 2010) and that their inferences may be based on minimal information, which will result in least effective decision-making processes. In addition, the cognitive conflict emerging from diversity within a board affects the firm's strategic direction in innovative ideas and solutions (Hillman, Cannella, Albert, & Harris, 2002; Rindova, 1999), which guide the firm's R&D initiatives.

It is also argued that spending on R&D projects need rich resources and commitment as these projects are inherently risky and management will be hesitant to spend on such initiatives (Chen, 2014; Wu, Levitas, & Priem, 2005). Furthermore, from management's perspective spending on R&D may decay the firm's performance in the short-run (David, Hitt, & Gimeno, 2001; Sanders & Carpenter, 2003). Therefore, management might cut down investment in R&D activities to maintain or improve the short-run performance. However, corporate board recognises the strategic importance of R&D initiatives and to protect the long-term stakes of shareholders, they monitor and control managers' opportunistic approach (Fama & Jensen, 1983) to R&D spending.

The decisions regarding R&D investment require appropriate resources and control from the board of directors (Xie & O'Neill, 2013). It is also recognised that diversity of members' characteristics is crucial to the quality of the decisions involving group efforts (Baranchuk & Dybvig, 2008; Knippenberg et al., 2004; Knippenberg & Schippers, 2007; Sah & Stiglitz, 1991). Moreover, directors' resources (human and social capital) determine how they perform the monitoring function and provide the necessary guidance to the management of a firm (Dalziel, Gentry, & Bowerman, 2011). Therefore, building on agency and resource-dependency theoretical assertions, this study analyses the role of board diversity in framing corporate propensity to invest in R&D activities.

Investment in R&D projects are vital for bringing innovation; however, such activities involve risks. The board's monitoring and counselling role can overcome the short-term focused behaviour of executives regarding spending on R&D projects and will ensure continuity of the innovation process in generating long term value for shareholders. Existing literature on the role of corporate boards in firms' spending on R&D has considered different aspects of the board. The proportion of independent directors on boards, number of board meetings, and CEO duality have been identified with a positive influence on firms' temptation to spend on R&D activity (Mezghanni, 2011). However, Baysinger et al. (1991) document that a higher number of insider members on boards affect R&D expenditure positively. Similarly, Chen (2014) reported that related-industry experience, education, and social ties of directors promote firm spending on R&D activities.

In addition, Bravo and Reguera-Alvarado (2017) argue that more board sittings by directors of a company contribute positively to the firm's R&D propensity. Female directors' presence on board helps firms avoid unnecessary risks in R&D projects and improve R&D decision quality, which consequently reduces the uncertainty in the future performance of the company (Chen et al., 2016). Moreover, Zona (2016) regards stock options as a tool of interest alignment which is time-dependent in terms of CEO tenure as during the early tenure of the CEO, the increased stock-option awards lead to reduced R&D investment due to the inherent risk factors of these projects. However, in the later part of a CEO's tenure, stock options translate into a positive effect on corporate R&D spending. Guldiken and Darendeli (2016) document that outside directors' firm- and industry-specific experience positively affect the board's monitoring on R&D initiatives. However, at the point where the board-monitoring effect starts to fade, then relevant experience of directors helps them to escape/counter the executives' attempt to persuade those directors regarding R&D investments.

On CEO characteristics, Barker and Mueller (2002) document that R&D investment is higher in firms where the CEO is young, has a higher participation in the firm's equity, and has working experience in the marketing and engineering field. However, CEO's formal undergraduate education does not explain firms' R&D spending, although having higher and specialised qualifications positively affects such investments. Furthermore, Chen et al. (2016) show that presence of female directors on board reduces volatility in firms' performance that emerges from R&D spending. Similarly, Faems and Subramanian (2013) report that diversity attributes in the R&D team result in better technological performance, and argue that gender, and educational and nationality diversity, and field knowledge, work as substitutes for improved technological performance. Fernandez (2015) show that gender diversity in the R&D team has a positive impact on product and service innovation.

In the US context, Bernile et al. (2018) show that board diversity contributes to lower stock return volatility where such relationship is more pronounced for firms with higher R&D spending. They also indicate that board diversity has a positive impact on corporate investment in R&D activities. In contrast, Midavaine et al. (2016) document that presence of a diverse board reduces corporate spending on R&D activities, though they find that gender and educational diversity on board promotes firms' inclination towards R&D spendings.

We argue that evidence in existing corporate governance and R&D literature mainly concentrates on board structure, ownership structure, and CEO characteristics and power (see, e.g., Baysinger et al., 1991; Chen & Hsu, 2009; Chen, 2014; Guldiken & Darendeli, 2016; Bravo & Reguera-Alvarado, 2017). There are only a few studies that examines the role of gender and board diversity in R&D investments (see, e.g., Chen et al., 2016; Midavaine et al., 2016; Bernile et al., 2018). Most of these studies provide evidence in the US context and as the US corporate governance, legal, and institutional structure differ from other countries their results cannot be generalised to other jurisdictions. All these factors warrant further investigation of the role of board diversity in firms' spending on R&D endeavours. This study therefore aims to provide further evidence on this through the application of a more comprehensive view on board diversity by considering directors' cognitive attributes (i.e., education, financial expertise, tenure, and board experience) and directors' demographic characteristics (i.e., gender, age, and nationality).

The gender diversity of a board has been regarded as an asset in providing a variety of perspectives for the corporation and adding to the team's abilities to come up with new ideas and improved solutions to organisational problems (Diaz-Garcia, Gonzalez-Moreno, & Saez-Martinez, 2013). In this regard, Schopohl et al. (2021) examines a sample of UK non-financial firms and report that female CFOs significantly reduce the level of leverage. They further show that the impact become more evident when the board is more diverse in gender, age, and nationality, when a female CFO is externally recruited, and when the CEO is least powerful. Other studies in this area document that board gender diversity is positively associated with the level of corporate innovation (Griffin, Li, & Xu, 2021), human rights and corporate governance dimension of CSR (Beji, Yousfi, Loukil, & Omri, 2021) and tend to have a better monitoring capacity (An, 2022).

There is also evidence that suggests female directors are better able to map consumers' behaviour and needs, and will help to improve the prospects for the corporation to fulfil such needs (Kang, Cheng, & Gray, 2007); which in turn, can place greater focus on R&D investments. In light of all these points we argue that gender diversity on board can help promote improvement in R&D initiatives. In a latest study, Kao, Huang, Fung, and Liu (2020) document that gender diversity on boards plays a vital role in shaping the crash risk behaviour of co-opted/non-co-opted outside directors. Moreover, Gull, Nekhili, Nagati, and Chtioui (2018) report that female directors' demographic attributes are not playing a role in controlling earnings manipulations, and instead it is the functional attributes or expertise of female directors which help in detecting and controlling earnings management practices.

A more diversified corporate board, in terms of its members' age, produces differing views and perspectives (Kang et al., 2007; Walt & Ingle, 2003). Directors of different ages can have various perspectives and views on the need for R&D due to their self-observation and exposure to market prospects. A variety of perspectives on the resource environment induces development and learning. It also engenders creativity and innovation by considering multiple operational and strategic aspects more effectively (Mahadeo, Soobaroyen, & Hanuman, 2012).

Due to growing globalisation, corporate governance structure is changing with the presence of foreign members of boards (Sanders & Carpenter, 1998). The differing opinions of non-ethnic directors, and the flow of information from resources that are not easily reachable by an ethnically homogenous board, can result in an innovative approach and improved outcomes (Hafsi & Turgut, 2013). Directors from different ethnicities can significantly contribute to the decision-making process through their unique viewpoints and perspectives (Westphal & Milton, 2000). It is further argued that directors from different ethnicities can challenge the orthodoxy of wisdom emanating from directors of the same ethnicity (majority). The diverse ethnic background of directors, through their inimitable perspectives and advice, makes significant contributions to shaping decisions concerning strategic matters such as

R&D and innovation.

Individuals' capability to absorb complex situations and capacity to tackle problems by articulating better solutions is probably stronger with a diversity of knowledge grounded in their educational backgrounds (Cohen & Levinthal, 1990). Similarly, drawing upon the resource-based perspective (Chen, 2014) documents that well-educated directors possess better knowledge and capabilities to process information and articulate inferences, thereby shaping effective strategies for corporate R&D commitments. In addition, Beji et al. (2021) argue that directors with business education background are more inclined to improve corporate governance than the environmental aspects of CSR. There is also evidence suggesting that directors with a higher level of education may be better able to assess research projects, understand how to manage innovation, and to improve the approach to seeking corporate R&D endeavours (Dalziel et al., 2011).

Directors' financial expertise gives them more vivid analytical skills in devising well focused and well-proportioned financial support for R&D endeavours. The specialised competence of directors develop awareness about regulations and the competitive environment, building their capacity to make a more effective contribution to the organisation (Certo, 2003; Kor & Sundaramurthy, 2009). For a board's effective contributions to devising strategies, directors' vigilance alone is not sufficient until it is coupled with related field experience (Kroll, Walters, & Wright, 2008). Güner, Malmendier, and Tate (2008) show that directors' financial expertise significantly affects firms' decisions. Similarly, other research findings document that board members' detailed knowledge enables them to come up with better advice and critical scrutiny of management ideas (Carter & Lorsch, 2004; Kor & Sundaramurthy, 2009). Directors equipped with financial expertise are therefore considered to be better at directing R&D spending and enabling innovation.

In another latest study, Zalata, Ntim, Alsohagy, and Malagila (2021) document that presence of female directors on board are negatively associated with earning management, which suggests the importance of financial background of female directors. However, when a financial expert female director sits on three or more boards, they become counterproductive in mitigating earning management practices. It is therefore argued that it is not simply the demographic attributes (gender diversity) of the corporate board, but rather the application of functional/cognitive skills that enables better monitoring or decision quality.

It is also well understood among scholars that multiple directorships would give them experience about corporate matters which will serve the purpose of providing the firm with connections to a rich external environment. Such connections are regarded as a source of social capital and learning that will help in tackling problems and in improving directors' performance (Reeb & Zhao, 2013). It is also argued that presence of directors on different boards is an indicator of their reputation or expertise as independent monitors (Bedard, Chtourou, & Courteau, 2004; Shivdasani, 1993). As a consequence, directors' board experience, from a resource and monitoring point of view, can contribute to decisions on firms' R&D endeavours.

The tenure of board members constitutes a strategic resource to the board. Longer tenured board members have more in-depth understanding and information about the firm's strengths and areas requiring further improvement. Extended tenure, coupled with better knowledge about the strategic concerns of the firm, help to improve monitoring of managerial conduct (Kesner, 1988). Those directors who have not been serving on the board for long contribute as outsiders (new actors) in terms of the strategic decisions of the organisation by finding out what the organisation can do differently in comparison with its past line of actions (Cramton & Hinds, 2004). Therefore, recruitment of fresh blood to the board can innovate its line of thinking. Tenure heterogeneity in board members thus helps in reshaping corporate orientation which not only exploits the firm's short-term prospects but also assists in the accomplishment of the long-term strategic objectives, such as R&D spending.



On the relationship between board diversity and firm performance, Ozdemir (2020) shows a positive relationship between the two, however, the given relationship was subject to lower institutional ownership. Similarly, Haque and Jones (2020) show that board gender diversity is positively associated with firm's initiatives on Biodiversity disclosure and impact assessment. Moreover, Aggarwal, Jindal, and Seth (2019) document that board diversity is positively related with firm performance in case of stand-alone firms, however, this relationship is negative when firms are connected to business groups. In addition, Sarhan, Ntim, and Al-Najjar (2019) find board diversity as positively associated with firm performance and the given relationship gets stronger in better governed organisations. In relation to the role of gender diversity in waste production, Gull, Atif, and Hussain (2022) observe that presence of women on board, particularly, as independent director, is negatively associated with waste production, however, this effect was shown as subject to critical mass.

### 3. Hypotheses development

The characteristics that comprise a team, particularly, the variety of peculiarities among team members, can contribute positively to the performance of that group (Knippenberg & Schippers, 2007). There is also evidence suggesting that racial diversity of workforce in both the low and top level executives is positively associated with firm value (Ellis & Keys, 2015). Other studies also show a positive relationship between board diversity and firm performance (see e.g., Aggarwal et al. (2019); Sarhan et al. (2019), and Ozdemir (2020). Similarly, in a slightly different context, Haque and Jones (2020), show a positive relationship between board gender diversity and firms' initiatives on Biodiversity disclosure and impact assessment. Moreover, the evidence in Gull et al. (2022) suggests that female presence on board particularly as independent directors is negatively related with waste production. On organisational risk and related matters, Zhou, Kara, and Molyneux (2019) report that cognitive conflict that arises from board diversity contribute to a robust monitoring process which reduces firms' risk. They also indicate that age dissimilarity between board chair and CEO increases the cognitive conflict and improves the board's capacity to monitor. There are other studies which regard boardroom diversity as a package of multiple skills and talents that produces decisions in the best interests of the shareholders (Carter et al., 2003; Chapple & Humphrey, 2013) and stakeholders (Boulouta, 2013) at large.

It is therefore evident from the above discussions that most of the recently published studies in this area show a positive relationship between board diversity and different organisational outcomes, such as, performance, firm value etc., and negative relationships with firm outcomes such as risk, waste management etc. Board diversity is therefore regarded as an important attribute for not only the firm shareholders but also a wide range of other stakeholders. However, in the context of this study we argue that investment in R&D projects is not only risky but also requires greater resources and commitment. It is therefore expected that management of organisations will be reluctant in initiating R&D projects (Chen, 2014; Wu et al., 2005).

While looking at the theoretical aspects it is evident that as the decisions concerning R&D investment and innovation need resources and monitoring and control from the board (Xie & O'Neill, 2013), both agency and resource-dependency perspectives are relevant. On the one hand, agency perspective is related to the firm's operations through monitoring, and on the other hand resource-dependency viewpoint is relevant to the firm's resources that can shape corporate strategic decisions, such as R&D and innovation. In the present era of dynamic and complex corporate environment, the main organisational focus is on enhancing the quality of board decisions. As a result, the contributions from directors' viewpoints, knowledge, imagination, and judgement emerging out from a diverse board can be much better than those coming out from a homogenous group. In addition, a diverse base of skills, knowledge and expertise enables board members to be receptive

to new ideas, to build better capacity to absorb information from the external environment (Cohen & Levinthal, 1990), to better exploit private information through collaboration and understanding (Van der Vegt & Janssen, 2003), and to gain advantage by integrating a variety of perspectives and views (Quintana-García & Benavides-Velasco, 2008).

The decisions regarding R&D investment are of strategic importance, and diversity on the board can help better frame those decisions given the multiple dimensions and perspectives of the heterogeneous board members. The variety of perspectives from directors serves both the monitoring and resource roles of the board, where a diverse pool of abilities can help to better scrutinise and analyse management's proposal on R&D investment to protect shareholders' long-term interests (see Fig. 1). The diversity of peculiarities among directors can also better guide and mentor the firm's management on contingencies and prospects in the outer environment. As a result, directors as a group serve the organisational-learning objective and improve the quality of strategic decisions made (Ben-Amar et al., 2013). Based on the above discussions, this study hypothesises that:

**Hypothesis 1 (H1).** There is a positive association between board diversity and the level of R&D investment.

The existing body of literature on board diversity categorises it in two groups, demographic/person diversity (observable) and informational/cognitive diversity (unobservable) (Maznevski, 1994; Milliken & Martins, 1996). In this regard, Tasheva and Hillman (2019) argue that different categories of diversity (e.g., demographic, or functional/cognitive) bring varying costs and benefits for an organisation. Moreover, the outcome of each category of diversity differ from one another (Nielsen & Nielsen, 2013). Demographically diverse boards are regarded as more resourceful to support and provide guidance to the management team (Anderson, Reeb, Upadhyay, & Zhao, 2011; Ben-Amar et al., 2013). The demographic attributes of directors bring variety of perspectives and viewpoints and can make the board's deliberations more critical and robust which potentially contribute to better monitoring function. However, adverse outcome of in- and out-group (they and us) caused by demographic diversity may hamper the board's capacity to oversight the management (Tasheva & Hillman, 2019).

Earlier research show that demographic fault-lines are associated with lower exchanges of information on board of directors (Tuggle, Schnatterly, & Johnson, 2010). In normal circumstance it is the nature of human beings that they interact and involve with those members of a group who are familiar and like them. Such a categorization within a team prevents them to perform efficiently (Knippenberg et al., 2004). A strand of empirical research observe negative affect of demographic diversity on firm's outcomes due to challenges in combining and harmonizing diverse pool of resources into an efficient team (Adams & Ferreira, 2009; Erhardt, Werbel, & Shrader, 2003). Moreover, Harjoto, Laksmana, & Yang, (2018) argue that demographically diverse board might face greater challenges to reach a consensus because of the biases emerging from out- and in-group division, which ultimately affect the board performance adversely. We therefore argue that although diversity of the directors' attributes enhances the aggregate resources at disposal of the firm board, it also increases the probability of conflicts, interaction difficulties and coordination among directors, and formulate the following hypothesis:

**Hypothesis 2 (H2).** There is a negative association between board demographic diversity and R&D investment.

Cognitive heterogeneity of board members brings greater breadth of expertise, knowledge and information which make them able to find alternatives to innovatively solve complicated problems and improve the quality of their decisions. On the directors contributions to firms, Nguyen and Nielsen (2010) assert that directors' outputs to firms and shareholders depend on their skills, capabilities, and expertise. There is also evidence suggesting that board members' knowledge and experience acquired in different educational, functional, organisational,

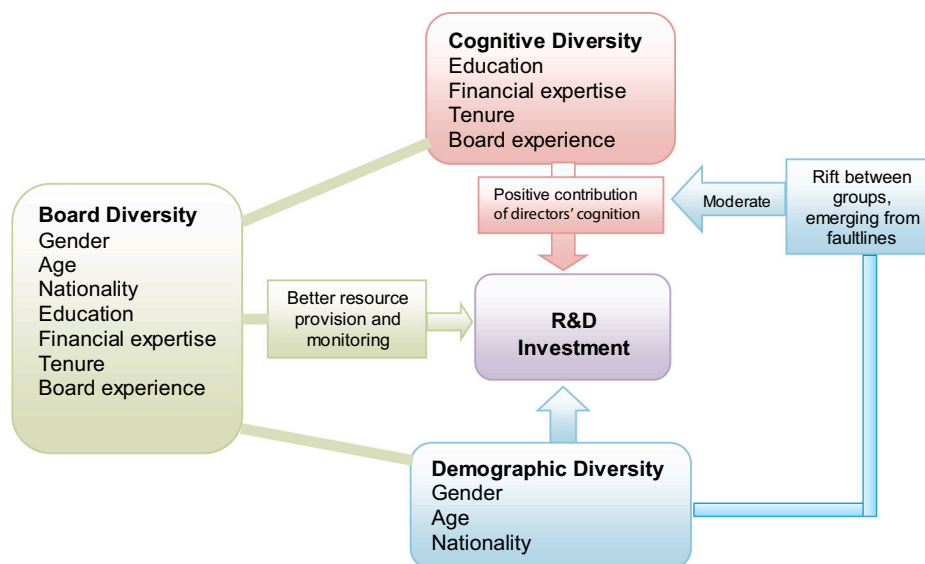


Fig. 1. Conceptual framework.

industrial and country environments enhance their human capital (Haynes & Hillman, 2010). Similarly, team members form cognitive logics based on their experiences shape what they observe, and how they make decisions (Johnson, Schnatterly, & Hill, 2013).

The empirical research document that the presence of outside directors with industry and legal expertise is related to lower earnings manipulation, better quality of accounting and financial information (Cohen, Hoitash, Krishnamoorthy, & Wright, 2013; Krishnan, Wen, & Zhao, 2011; Wang, Xie, & Zhu, 2015) and higher strategic-change (Oehmichen, Schrapp, & Wolff, 2017). An (2022) finds that task related diversity in term of tenure and occupation positively related with board monitoring strength. In the context of high-tech industries, the task related expertise matter more than the demographic diversity of board (Cumming & Leung, 2021). Moreover, Webber and Donahue (2001) argue that task related diversity attributes increase the performance of the team. The above discussion implies that cognitive diversity of board members (originating from knowledge and experience) is positively related with board performance which will translate into better oversight over firm R&D investments. We therefore argue that board cognitive diversity enhances firms' propensity to strategic investment and form the following hypothesis.

**Hypothesis 3 (H3).** There is a positive association between board cognitive diversity and the level of R&D investment.

There is also empirical evidence that suggest that demographic faultlines conceptually substantiate sub-group dynamics within a group and predict team outcomes more accurately than demographic diversity alone (Knippenberg et al., 2004; Knippenberg & Schippers, 2007). Moreover, the demographic-diversity viewpoint holds that differences and resemblances serve the basis of dividing oneself and the others into clusters, ultimately resulting in one's own in-group and one or more out-groups (Lau & Murnighan, 1998). Turner et al. (1987) also argue that division within a team makes people trust and like members who are in-group compared with those from the out-group, eventually ending up in members favouring their own group members more than the others. Moreover, Wu et al. (2021) indicate that board gender faultline strength is negatively associated with strategic change. However, board gender faultline tends to be productive for strategic change when there is higher environmental complexity, munificence, and dynamism.

In the context of organisational and social psychology, person differences within the group can cause unhealthy division among the group members (Bezrukova et al., 2009). Ultimately the sub-groups start ditching one another and eventually kill the very essence of strategic

resource in the shape of person diversity. Person attributes are critical in forming negativity that affect sub-groups of stereotypical thinking within a group (Lau & Murnighan, 1998; Posthuma & Campion, 2009). Furthermore, Tasheva and Hillman (2019) Argue that interaction between different sources of diversity can better explain the impact of diversity on a teams' outcomes. It is therefore argued that a diverse group brings multiple perspectives and ideas to the table which positively influence strategic decisions. However, in the presence of a rift within the group, the consideration or value assigned to ideas might affect the positive contribution when ideas come across a faultline (Knippenberg & Schippers, 2007). We therefore argue that the demographic attributes of directors may affect the contributions made by the board's cognitive diversity and form the following hypothesis.

**Hypothesis 4 (H4).** Diversity of demographic attributes negatively moderates the impact of cognitive diversity on R&D investment.

Source: Prepared by the authors.

## 4. Research methodology and data

### 4.1. Model

In prior corporate governance and related literature endogeneity related issues and their potential impact on results have been highlighted as a cause of concern (see, e.g. Wintoki, Linck, & Netter, 2012; Akbar, Kharabsheh, Poletti-Hughes, & Shah, 2017). This study therefore controls for potential endogeneity problem by using the dynamic generalised method of moments (GMM) estimation approach. In a dynamic panel model, the OLS estimators become biased when the lagged term of the dependent variable is correlated with the firm fixed effect. It is possible to eliminate the firm-level fixed effect through the use of fixed-effects modelling, but the transformation to control the unique effect of the firm will still exhibit the association between the modified lag term of the dependent variable and the error term.

Additionally, when the explanatory variables are endogenous, it will give rise to the possibility of a correlation between explanatory variables and the error term. Hence, the estimators obtained through fixed effect and OLS will be inconsistent. A solution to address these issues is the use of dynamic panel GMM estimators. This approach to analysis can control the firm fixed effects through first difference modification and through adjusting for the bias mentioned above (Arellano & Bond, 1991). It is therefore argued that, in the case of endogeneity, it is more appropriate to use System-GMM than any other methods for panel data analysis (e.g.,

fixed effects, OLS estimators) to avoid inconsistent or biased estimators.

By implementing the two-step System-GMM, this study overcomes the endogeneity issues and produces consistent estimates. The estimation of the GMM system applied in the analyses transforms all the regression factors through differencing. It constructs a system of two equations, one in level and the other in the differences, then combines the conditions of the moment for each of them, in which instruments of endogenous variables are lagging in the level and the differences (Roodman, 2009). This approach relies on the lag terms of the dependent variable and predictor, which are utilised as instruments.

This study considers lag values of R&D expenditures and estimates the dynamic impact of the past occurrence of R&D on the current level of firm spendings on such investment along with governance and financial variables. Hansen's test for over-identifying restrictions is used to ensure the validity of the instruments employed (Hansen, 1982). Hansen test is used instead of the Sargan statistic for instrument validity as it provides a more consistent diagnostic in the presence of heteroscedasticity and autocorrelation (Roodman, 2007). The study also uses Arellano and Bond (1991) AR (1) and AR (2) statistics to decide about first- and second-order serial autocorrelation. The absence of second-order serial autocorrelation is the condition for the goodness of System-GMM estimates.

We employ the following dynamic econometric models for testing the research hypotheses of this study.

$$RnD_{it} = \alpha + \beta_1 RnD_{it-1} + \beta_2 BD_{INDEX}_{it} + \sum_{j=1}^4 \lambda CONT_{it} + \Theta X_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

$$RnD_{it} = \alpha + \beta_1 RnD_{it-1} + \beta_2 Cogn_{Diversity}_{it} + \beta_3 Demo_{Diversity}_{it} + \beta_4 Cogn_{Diversity} \times Demo_{Diversity}_{it} + \sum_{j=1}^4 \lambda CONT_{it} + \Theta X_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

Where "RnD" is R&D expenditure, "RnD<sub>t-1</sub>" is the lag of the dependent variable and "BD\_INDEX" is the board diversity index constructed by using seven different aspects of board diversity. "Cogn\_Diversity" is an index constructed for the cognitive diversity of the board and "Demo\_Diversity" is the demographic diversity of the board. "Cogn\_Diversity × Demo\_Diversity" is an interaction term to capture the moderation effect of demographic diversity on the cognitive diversity of the board. "CONT" control variables (firm age, firm size, leverage, firm performance, board size, board meetings, CEO duality, and board independence). In the above equation, "i" is the cross-section (individual firm), "t" is the time observed in the two models, and "β" is the loading factor (coefficient) of the independent variables. In both the equations, "λ" represents the coefficient of firm-level control variables and "X<sub>it</sub>" represents the exogenous variables (governance and financial variables). Moreover, "μ<sub>i</sub>" captures the unobserved firm effect, and "ε" represents the error term. This study winsorises all continuous variables at 1 and 99 percentiles to control the extreme observation cases (outliers) in the dataset.

The econometric models include firm-specific governance and financial attributes as the control variables. Independent directors (INDs) being impartial monitors and having the resource capacity serve to regulate myopic managerial behaviour that reduces the flow of finances towards R&D activities (Osma, 2008) and favour spending on R&D (Kor, 2006). A larger board will bring more expertise and is better able to review the tasks under consideration, thereby reducing the chances of error and improving the decision efficacy (Klein, 2002).

However, due to coordination and consensus problems a larger board may take a long time in decision making, could be least effective, and without the directions of an independent leader it will be difficult for the board to operate effectively (Jensen, 1993). In addition, directors' objective evaluation of an investment proposal from the management is likely to be impossible when the CEO holds the dual role (Dalton, Hitt,

Certo, & Dalton, 2007). Therefore, in the case of the CEO dual roles, the top executives' self-interest orientation may strengthen which will lower the investment level in R&D endeavours.

Empirical evidence in this area shows that, as activities of a business expand, the propensity to spend on R&D activities increases. On the one hand, older organisations are more conscious about value-spending on activities related to R&D (Midavaine et al., 2016). On the other hand, freshly established corporate entities feel their newness gives them a duty to thrive and therefore show greater propensity to initiate R&D investments (Stinchcombe & March, 1965). Moreover, when a firm increases its leverage, its propensity to invest in R&D and innovation goes down (Czarnitzki & Kraft, 2009), because servicing of debt requires a stable stream of funds, and increased financing through debt puts constraint on firm's ability to allocate funds to R&D. However, better financial performance enables firms to devote more resources to R&D (Zona, 2016) which helps them to gain a competitive advantage.

#### 4.2. Variables measurement

Following prior literature, the dependent variable (R&D expenditures) is measured by the total value of R&D expenses in a financial year scaled by sales revenue (see, e.g., Lee & O'Neill, 2003; Munari et al., 2010; Chen, 2014; Chen et al., 2016; Chu, Yang, & Yang, 2016; Guldiken & Darendeli, 2016; Midavaine et al., 2016; Bravo & Reguera-Alvarado, 2017). For the board diversity index, this study uses seven different aspects of diversity, namely directors' gender, age, nationality, tenure, education, financial expertise, and board experience. Gender diversity is measured by the ratio of female and male directors on the board (Harjoto et al., 2018). To measure age diversity, this study categorised directors into four age groups i.e., below 46 years, 46–55, 56–65, and above 65 (Harjoto et al., 2018). For diversity of nationality, directors are grouped into two categories, domestic and foreign, where domestic category contains those directors who have nationality of the same country as the company's headquarter (i.e., country of incorporation), and all the other directors are categorised as foreign directors (Hoang, Abeysekera, & Ma, 2017).

For directors' tenure diversity, directors are grouped into three categories (≤ 3 years, >3 but ≤ 6 years, and > 6 years) according to their length of tenure on the board of the firm (Harjoto et al., 2018). Following Hafsi and Turgut (2013); Hoang, Abeysekera, and Ma (2018), this study measures education diversity by categorising directors into four groups of qualification, i.e. PhD, Master, Bachelor, and Other. To capture the diversity of financial expertise, directors are categorised into two groups, i.e., financial expert and not financial expert. Following Minton, Taillard, and Williamson (2014), directors are categorised as financial experts if they have worked in an executive position in financial institutions (such as, banks, insurance companies, investment companies, investment funds), or worked in non-financial firms in key finance positions (such as, treasurer, CFO, accountant, finance executive, vice president finance). To measure diversity in boards' experience, directors are categorised into three categories based on number of their board sittings at other companies ((i) ≤ 3, (ii) >3 but ≤ 6, and (iii) >6). A detailed explanation of all the variables used in this study is given in Appendix A.

Following Bernile et al. (2018) and Hoang et al. (2018), this study uses Blau's Index to construct the board diversity index. Blau's index is regarded as optimal measure to capture the variation within a team (Harrison & Klein, 2007). Each component of the index is measured using the following formula  $1 - \sum (P_i)^2$ , where "P" represents the proportion of the directors in the "ith" category. The sum of the square term of each category's ratio is deducted from "1" and the outcome represents the heterogeneity of each component of the overall board diversity index. This study normalises each aspect of the diversity index by their mean and standard deviation so that the scale of each component is comparable. Further, to test the second hypothesis, this study



constructed two separate indexes for (i) cognitive diversity and (ii) demographic diversity. The board gender, nationality and age diversity are combined to construct a demographic diversity index. The cognitive diversity index is comprised of education, tenure, board-experience, and financial-expertise diversity. An overall board diversity index is constructed using the following equation.

$$BD_{INDEX} = Z_{GenderDiversity} + Z_{AgeDiversity} + Z_{NationalityDiversity} + Z_{FinanXPDiversity} + Z_{TenureDiversity} + Z_{EducationDiversity} + Z_{BoardsExpDiversity} \quad (3)$$

### 4.3. Sample description

An initial sample of UK-listed (FTSE All Share) firms has been selected. After excluding firms from financial, utilities and real-estate industries, the initial sample of 340 non-financial firms is considered. The study drops those firms which did not report R&D expenditure over the entire sample period, from 2005 to 2018. After merging financial data with governance data obtained from BoardEx, the final sample is reduced to 245 firms and 2813 firm-year observations. All financial, and some of the corporate-governance variables data (board independence, CEO duality, board size and board meetings) data have been extracted from Thomson Eikon/Datastream. Data for board diversity measures (directors' tenure, board sittings, gender, age, financial expertise, nationality, and education) have been extracted from BoardEx.

The sample is extracted from eight industries. Table 1 presents the distribution of the sample across the industries. The industrials sector has a major representation (29.01%) in the sample, followed by the basic material and technology sectors (15.75 and 15.11% respectively). The energy sector has the lowest representation (5.08%). The full sample is further divided into sub-samples to ensure the consistency and robustness of the results. First, the sample is categorised into small and large firms. To identify the small and large firms' sample groups, this study compares a firm's total assets with the median value of total assets in the respective industry. Firms whose total assets value is higher than the industry median are classified as large firms, and those with total assets lower than the industry median are grouped as small firms. Second, the sample is divided into manufacturing and non-manufacturing firms and this division is based on the first two digits of the SIC codes. SIC codes in the range of 20 to 39 are classified as manufacturing and the rest are all classed as non-manufacturing.

## 5. Results and discussions

### 5.1. Descriptive statistics

The descriptive statistics of all variables for the full sample and the four sub-samples (large and small firms, manufacturing and non-manufacturing firms) of the study are presented in Table 2. The average proportion of R&D spending to sales is 0.053 for all sampled firms. On average, the R&D expenditure of large firms (0.055) is higher than that of small firms (0.049) and non-manufacturing firms spend less on R&D endeavours (0.046) than manufacturing companies (0.056). The average value of gender diversity (as measured by Blau's Index) for

**Table 1**  
Sample distribution across industry.

Industry Name	No. of Firms	Firm-Year Obs	Percentage
Basic Materials	39	443	15.75
Consumer Discretionary	20	221	7.86
Consumer Staples	29	329	11.70
Energy	13	143	5.08
Healthcare	22	274	9.74
Industrials	68	816	29.01
Technology	40	425	15.11
Telecommunications	14	162	5.76
<b>Total</b>	<b>245</b>	<b>2813</b>	<b>100</b>

all sampled firms is 0.21, and it is 0.25 for large firms and 0.16 for small firms. The average value of age diversity is 0.58. The mean values of directors' nationality, education and tenure diversity are 0.29, 0.59 and 0.52 respectively.

The mean values of directors' board experience diversity and financial expertise diversity are 0.46 and 0.32 respectively. On average, boards of the sampled firms show higher diversity in directors' age, education, tenure, and experience on other boards, while diversity in gender, nationality and financial expertise are low. Overall, the mean value of the board diversity index for the full sample is 0.05. The mean value of the board diversity index for non-manufacturing firms is low compared to that of manufacturing firms.

The average age (measure as natural logarithms) of all the sample firms is 3.75, 3.82 years for large firms and 3.67 for small firms, 3.94 for manufacturing firms and 3.39 for non-manufacturing firms. On average, the performance (ROA) of the sample firms is 0.07. Large firms are better performers than smaller ones, and the ROA of non-manufacturing firms is higher than of the manufacturing firms. The average leverage is 0.15 for the full sample. The average board size is approximately 10 directors for the entire sample. On average, 63.61% directors on the board are independent for the full sample. Comparatively, large firms have more independent boards than small firms. Similarly, manufacturing firms have more independent directors on their boards than non-manufacturing companies. On average, the directors meet approximately nine times in a financial year.

We carefully checked all correlations among variables and the variance inflation factor (VIF) of the explanatory variables to examine any multicollinearity concerns for model specification. All correlation coefficients were well below the threshold of 0.80. Hence, multicollinearity is not an issue for concern. This was further supported by the results of VIFs, that were well below the critical value of 5.

### 5.2. Multivariate results and discussions

The relationship between board diversity and corporate R&D spending is analysed using the two-step System-GMM. Table 3 presents the results for the full sample of the study, where three models are estimated. **Model 1** analysed the overall board diversity index to test **Hypothesis 1** (H1) of the study. **Model 2** examined the moderating role of demographic diversity on the association between cognitive diversity of the board and R&D investment to test **Hypothesis 2** (H2). **Model 3** examined separately the association of each aspect of the board diversity index with firms' R&D spending.

The results of **Model 1** for board diversity confirm that there is a significant and positive association between board diversity and corporate propensity to invest in R&D projects. This finding supports **hypothesis 1** that aggregate diversity on board, emerging from different features of directors, boost corporate R&D spending. This result is also consistent with the findings of **Bernile et al. (2018)** that a more diverse board is associated with higher R&D investment. This finding is also in line with the argument that directors, as a group, serve the organisational learning objective and help to improve the quality of the strategic decisions (**Ben-Amar et al., 2013**).

In **Model 2**, board demographic and cognitive diversity indexes are included, along with the interaction term of the two variables. The results show a significant and positive relationship between board cognitive diversity and firm R&D spending which support the **hypothesis 3** of the study. This finding supports the argument that a broader and more diverse information/cognition base on the board improves the quality of strategic and long-term decisions through better guidance and monitoring of corporate actions (**An, 2022; Haynes & Hillman, 2010; Johnson et al., 2013**). The association between R&D investment and demographic diversity is however insignificant and coefficient is positive therefore our **hypothesis 2** is not supported by empirical evidence. The interaction term of demographic and cognitive diversity is significant and negative, which supports **hypothesis 4** of the study. This finding



**Table 2**  
Descriptive analysis.

Variable	Full Sample (Panel A)					Large Firms (Panel B)		Small Firms (Panel C)		Manufacturing Firms (Panel D)		Non-Manufacturing Firms (Panel E)	
	Mean	Std. Dev.	Median	Min	Max	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
RnD	0.053	0.07	0.021	0	0.323	0.055	0.08	0.049	0.07	0.056	0.09	0.046	0.07
Gender_Diversity	0.21	0.15	0.22	0	0.49	0.25	0.13	0.16	0.16	0.21	0.16	0.21	0.15
Age_diversity	0.58	0.1	0.59	0.24	0.75	0.58	0.09	0.58	0.11	0.57	0.1	0.59	0.1
Nationality_Diversity	0.29	0.2	0.37	0	0.50	0.32	0.18	0.26	0.22	0.29	0.2	0.31	0.2
Education_Diversity	0.59	0.11	0.61	0.16	0.75	0.59	0.11	0.58	0.12	0.58	0.12	0.61	0.1
Tenure_Diversity	0.52	0.17	0.58	0	0.72	0.55	0.15	0.48	0.19	0.53	0.16	0.49	0.2
BoardsExp_Diversity	0.46	0.18	0.49	0	0.71	0.51	0.14	0.4	0.19	0.45	0.18	0.47	0.18
FinanXp_Diversity	0.32	0.14	0.34	0	0.50	0.29	0.14	0.35	0.14	0.32	0.15	0.32	0.13
BD_INDEX	0.05	2.88	0.31	-8.26	5.55	0.01	2.96	0.01	2.76	0.02	2.99	0.001	2.77
Firm_Age	3.75	0.95	3.71	1.39	5.54	3.82	0.97	3.67	0.92	3.94	0.93	3.39	0.88
ROA	0.07	0.08	0.06	-0.19	0.31	0.08	0.06	0.05	0.09	0.06	0.07	0.07	0.08
LEV	0.15	0.12	0.14	0	0.49	0.19	0.11	0.12	0.12	0.16	0.12	0.15	0.13
SIZE	14.68	2	14.53	10.69	18.98	16.18	1.37	12.99	1.04	13.58	1.97	14.87	2.05
Brd_Size	9.59	2.73	9	5	18	10.95	2.54	8.12	2.09	9.6	2.73	8.19	2.72
Brd_IND	63.61	16.79	62.5	23.53	92.86	69.78	16.8	56.87	13.94	64.86	17.14	61.26	15.85
Brd_Meet	8.67	2.83	8	4	17	8.74	2.98	8.59	2.67	8.74	2.78	8.54	2.91
Firms Years Obs.	2813					1467		1346		1832		981	
No. of Firms	245					120		125		159		86	

Note: This table provides the descriptive view of variables of the study for the full (Panel A) sample and the four sub-samples (Panels B to E), where “RnD” is proportionate R&D, “BoardsExp\_Diversity” is the diversity of directors’ experience on other boards, “FinanXp\_Diversity” is the diversity of directors’ financial expertise, “BD\_INDEX” is the board diversity index, “ROA” is the return on assets, “LEV” is the leverage structure of the firm, “Brd\_Size” is board size, “Brd\_IND” is board independence, “Brd\_Meet” is the number of board meetings.

confirms that demographic diversity negatively moderates the relationship between board cognitive diversity and the level of R&D spending. This finding is consistent with the faultline argument that demographic features of a group are critical in forming, negatively affecting subgroups of stereotypical thinking within a group (Lau & Murnighan, 1998; Posthuma & Campion, 2009). A diverse group brings multiple perspectives and ideas to the table before reaching the final decisions. But in the presence of a rift in the group, the consideration or value assigned to ideas might affect their positive contribution when ideas come across a faultline (Knippenberg & Schippers, 2007).

**Model 3** analyses the relationship between R&D investment and each component of board diversity individually. The results show that board tenure diversity has a significant and positive association with the level of R&D investment. A more diverse board in terms of directors’ tenure has the benefit of a better understanding of firm strategic concerns (due to long tenure) and out-of-the-box thinking (due to short tenure) to find new ways to do things differently in comparison to its past line of actions (Cramton & Hinds, 2004; Kesner, 1988). Gender diversity has a significant and negative relationship with a firm’s propensity to invest in R&D. This finding is consistent with the argument that female directors are more risk averse and conservative while deciding about R&D investment to avoid aggressive risk taking behaviour (Chen et al., 2016). As R&D projects are inherently risky, the presence of female directors on board reduces corporate spending on R&D projects. The results for individual aspects of aggregate board diversity confirm that these features on their own do not explain corporate propensity to invest in R&D projects.

In **Model 3**, most of the disaggregated diversity index components are insignificant apart from tenure and gender diversity. These findings are therefore consistent with the argument that it is not a single feature of the board of directors, but instead, it is the board’s characteristics as a group that contribute to producing quality decisions and eventually result in improved organisational outcomes (Bernile et al., 2018).

The results for control variables in **Table 3** show that firm age has a significant and negative association with the level of R&D spending, consistent with the findings of published literature (Choi, Zahra, Yoshikawa, & Han, 2015; Midavaine et al., 2016). This finding confirms that firms at an early age are more prone to spend on R&D activities as growth is pivotal for their survival. Older, more matured firms are more conscious of value spending and are generally not receptive to

aggressive risk-taking, and thus tend to spend less on R&D projects.

Firm performance (ROA) has a significant and negative association with R&D investment which is consistent with a strand of literature (e.g., Chen & Hsu, 2009; Dalziel et al., 2011; Sung, Lee, & Ahn, 2017) and support the assertion that firms with higher financial performance invest less in R&D probably due to lower competitive pressure (Sung et al., 2017). Leverage has a significant and negative relationship with R&D spending suggesting that highly leveraged firms prefer to remain solvent and consider debt payment as their priority over and above risky R&D investments. Moreover, board independence has a significant and positive association with firms’ R&D spending. This result is consistent with the findings of Osma (2008) in the UK that firms with more independent boards are less likely to apply cuts to their R&D spending. The results for CEO duality show a significant and negative relationship with R&D investment, consistent with existing literature (Bravo & Reguera-Alvarado, 2017; Guldiken & Darendeli, 2016), which confirm that when the CEO is also the chairman of the company, corporate investment in R&D activities is reduced due to the myopic approach of top executives.

### 5.3. Additional analyses

For robustness and to check the consistency of the results obtained from the full sample (Panel-A in **Table 2**), the analyses are repeated for the four sub-samples, i.e., large versus small firms, and manufacturing versus non-manufacturing firms. **Table 4** shows the results for large firms (Panel-B, **Table 2**) and small firms (Panel-C, **Table 2**). **Table 5** presents the results for manufacturing (Panel-D, **Table 2**) and non-manufacturing firms (Panel-E, **Table 2**). The results for aggregate board diversity (BD\_INDEX), cognitive diversity, and the interaction term between demographic diversity and cognitive diversity in the sub-sample models are all consistent with the results from the full sample. The findings are therefore similar across all the (four) sub-samples.

Taken together, the empirical results reported in **Tables 3, 4 & 5**, hypotheses 1, 3, & 4 of this study are supported. The results obtained from the two-step System-GMM confirm that board diversity is positively associated with firms’ R&D spending. This finding advocates the argument that the board of directors’ characteristics as a group contribute to improving the quality of decisions made that eventually lead to sustained growth in the long run (Bernile et al., 2018). Cognitive

**Table 3**  
GMM results for Panel A (Full Sample).

Variable	Model 1	Model 2	Model 3
BD_INDEX	<b>0.0514**</b> (0.036)		
Cogn_Diversity		<b>0.0622**</b> (0.037)	
Demo_Diversity		0.0340 (0.383)	
Cogn_Diversity × Demo_Diversity		<b>-0.0257**</b> (0.036)	
BoardsExp_Diversity			0.0689 (0.466)
Tenure_Diversity			<b>0.1918**</b> (0.029)
Gender_Diversity			<b>-0.1557*</b> (0.100)
Nationality_Diversity			-0.0220 (0.803)
Education_Diversity			0.0315 (0.661)
FinanXp_Diversity			0.0557 (0.492)
Age_diversity			0.0363 (0.537)
Firm_Age	<b>-0.0267***</b> (0.002)	<b>-0.0192***</b> (0.008)	<b>-0.0297***</b> (0.005)
ROA	<b>-2.1450**</b> (0.041)	<b>-1.8637***</b> (0.010)	<b>-2.2225**</b> (0.047)
LEV	<b>-1.5802**</b> (0.038)	-0.4094 (0.567)	-2.3015 (0.135)
SIZE	0.1260 (0.153)	0.0648 (0.963)	0.1711 (0.104)
Brd_Size	0.0142 (0.675)	0.0125 (0.981)	0.0236 (0.542)
Brd_IND	<b>0.0116*</b> (0.071)	<b>0.0122**</b> (0.025)	0.0094 (0.106)
Brd_Meet	0.0131 (0.553)	0.0238 (0.225)	0.0065 (0.780)
CEO_DUAL	<b>-0.4516*</b> (0.054)	<b>-0.2998*</b> (0.080)	<b>-0.4579**</b> (0.036)
RnD <sub>t-1</sub>	<b>0.7506***</b> (0.000)	<b>0.6828***</b> (0.000)	<b>0.7653***</b> (0.000)
F-Stat (Prob)	143.59 (0.000)	215.19 (0.000)	135.92 (0.000)
Groups/Instruments	245/208	245/104	245/203
AR (1) (Prob-Value)	0.001	0.000	0.000
AR (2) (Prob-Value)	0.435	0.431	0.442
Hansen test (Prob)	0.391	0.212	0.326
Industry and Year FE	Yes	Yes	Yes

**Note:** This table shows the two-step System-GMM results for the full sample (Panel A). All results reported are based on robust (heteroscedasticity- and autocorrelation-consistent) standard errors. \*, \*\*, \*\*\* indicate the significance of variables at 10%, 5% and 1% level, respectively. “BD\_INDEX” is the board diversity index measured by seven (three demographic and four cognitive features of the firm board) different components/features of the board, “Cogn\_Diversity” is the board cognitive diversity index measured by four different features of the board, “Demo\_Diversity” is the board demographic diversity index measured by three different features of the board, “BoardsExp\_Diversity” is diversity in the directors’ other board experience, “FinanXp\_Diversity” is the diversity in directors’ financial expertise, “ROA” is the return on assets, “LEV” is leverage, “SIZE” is the size of the firm, “Brd\_Size” is board size, “Brd\_IND” is board independence, “Brd\_Meet” is board meetings in a financial year, “CEO\_DUAL” is CEO duality.

diversity is found to have a significantly positive association with R&D investment. However, demographic diversity does not have a significant relationship with firms’ R&D spending. The results further suggest that demographic diversity negatively moderates the relationship between cognitive diversity and R&D investment, supporting hypothesis 2. This finding supports the “Faultline Argument” that a rift within groups emerging from demographic differences lowers group performance (Knippenberg & Schippers, 2007). We have also tested the hypotheses through fixed/random effects estimations for the full sample and all sub-

**Table 4**  
GMM Results for Panels B & C (Large and Small Firms).

Variable	Large Firms Sample		Small Firms Sample	
	Model 1	Model 2	Model 1	Model 2
BD_INDEX	<b>0.1770***</b> (0.003)		<b>0.1716**</b> (0.022)	
Cogn_Diversity		<b>0.0686**</b> (0.043)		<b>0.2164**</b> (0.027)
Demo_Diversity		0.0676 (0.114)		0.0432 (0.583)
Cogn_Diversity × Demo_Diversity		<b>-0.0293**</b> (0.036)		<b>-0.1090**</b> (0.023)
Firm_Age	<b>-0.0700**</b> (0.030)	<b>-0.0156**</b> (0.027)	<b>-0.2371***</b> (0.010)	<b>-0.1877**</b> (0.011)
ROA	-1.060 (0.545)	<b>-1.5685***</b> (0.000)	-3.3601 (0.318)	-1.9920 (0.377)
LEV	-0.0234 (0.991)	<b>-1.1422***</b> (0.000)	<b>-2.1027*</b> (0.061)	<b>-3.0441**</b> (0.045)
SIZE	0.4096 (0.213)	<b>0.5524***</b> (0.003)	<b>0.9620**</b> (0.012)	<b>0.7563*</b> (0.051)
Brd_Size	0.0296 (0.782)	<b>0.1330**</b> (0.011)	0.0709 (0.456)	0.1032 (0.416)
Brd_IND	0.0035 (0.859)	<b>0.0348***</b> (0.000)	<b>0.0471**</b> (0.014)	<b>0.0374**</b> (0.043)
Brd_Meet	<b>0.1287**</b> (0.014)	0.0175 (0.427)	0.1944 (0.115)	<b>0.1458</b> (0.075)
CEO_DUAL	-0.7394 (0.326)	<b>-0.4400*</b> (0.082)	<b>-3.5243***</b> (0.005)	<b>-2.9642**</b> (0.012)
RnD <sub>t-1</sub>	<b>0.5197***</b> (0.000)	<b>0.5275***</b> (0.000)	<b>0.8870***</b> (0.000)	<b>0.8490***</b> (0.000)
F-Stat (Prob)	44.77 (0.000)	36.32 (0.000)	42.80 (0.000)	32.88 (0.000)
Groups/ Instruments	122/54	122/93	123/42	123/44
AR (1) (Prob- Value)	0.008	0.010	0.014	0.007
AR (2) (Prob- Value)	0.151	0.187	0.354	0.331
Hansen test (Prob)	0.372	0.208	0.554	0.465
Industry and Year FE	Yes	Yes	Yes	Yes

**Note:** This table presents the two-step System-GMM results for the sub-sample of large and small firms (Panels B & C). All results reported are based on robust (heteroscedasticity- and autocorrelation-consistent) standard errors. \*, \*\*, \*\*\* indicate the significance of variables at 10%, 5% and 1% level, respectively.

samples. The results are similar to those estimated by two-step System-GMM methods.<sup>3</sup>

## 6. Conclusion

The corporate propensity to invest in R&D is critical for firms’ growth in the long run, and allocation of funds to R&D projects is a key strategic decision. As R&D projects are inherently risky, management might refrain from investing in such activities, particularly when they have a myopic approach. Such an approach by the management potentially halts the firm’s growth, which is not in shareholders’ interests. To protect shareholders’ stake, a corporate board plays a crucial role by employing the right level of monitoring and providing resources to improve the quality of strategically important decisions such as R&D investment.

The board of directors of a firm work as a team and make decisions which are based on their collective deliberations and wisdom. It is thus appropriate to consider the contributions of different attributes of the corporate board as a whole (Barker & Mueller, 2002; Chen, 2014). The current study examines the relationship between board diversity and a

<sup>3</sup> The results from fixed/random effects estimations for the full sample and all sub-samples are not reported in the paper due to reason of space but are available from the corresponding author upon request.

**Table 5**  
GMM Results for Panels D & E (Manufacturing and Non-Manufacturing Firms).

Variable	Manufacturing Firms Sample		Non-Manufacturing Firms Sample	
	Model-1	Model-2	Model-1	Model-2
BD_INDEX	<b>0.0738***</b> (0.007)		<b>0.1109**</b> (0.024)	
Cogn_Diversity		<b>0.0700**</b> (0.049)		<b>0.1107***</b> (0.008)
Demo_Diversity		0.1619 (0.879)		0.0208 (0.721)
Cogn_Diversity × Demo_Diversity		<b>-0.0630***</b> (0.006)		<b>-0.0663***</b> (0.000)
Firm_Age	<b>-0.0380***</b> (0.008)	<b>-0.0159*</b> (0.088)	<b>-0.0787***</b> (0.006)	<b>-0.0483***</b> (0.000)
ROA	-1.3804 (0.275)	-1.2869 (0.220)	<b>-3.2579***</b> (0.004)	<b>-3.7458***</b> (0.000)
LEV	-0.3541 (0.725)	-0.0287 (0.963)	-0.2847 (0.848)	-1.1143 (0.147)
SIZE	<b>0.2356*</b> (0.077)	0.1912 (0.201)	<b>0.3364*</b> (0.078)	0.2612 (0.706)
Brd_Size	0.0211 (0.701)	0.0444 (0.431)	<b>0.1591*</b> (0.058)	0.4363 (0.516)
Brd_IND	0.0020 (0.790)	<b>0.0168**</b> (0.025)	0.0030 (0.728)	<b>0.0193***</b> (0.007)
Brd_Meet	0.0212 (0.550)	0.0042 (0.881)	0.0373 (0.279)	<b>0.0564**</b> (0.049)
CEO_DUAL	<b>-0.8253**</b> (0.044)	-0.3780 (0.134)	-0.2499 (0.673)	-0.0320 (0.908)
RnD <sub>t-1</sub>	<b>0.7847***</b> (0.000)	<b>0.7366***</b> (0.000)	<b>0.5603***</b> (0.000)	<b>0.5865***</b> (0.000)
F-Stat (Prob)	57.14 (0.000)	36.80 (0.000)	30.42 (0.000)	66.56 (0.000)
Groups/Instruments	159/129	159/79	86/65	86/63
AR (1) (Prob-Value)	0.000	0.000	0.013	0.006
AR (2) (Prob-Value)	0.290	0.300	0.594	0.548
Hansen test (Prob)	0.169	0.181	0.131	0.498
Industry and Year FE	Yes	Yes	Yes	Yes

**Note:** This table presents the two-step System-GMM results for the sub-sample of manufacturing and non-manufacturing firms (Panels D & E). All results reported are based on robust (heteroscedasticity- and autocorrelation-consistent) standard errors. \*, \*\*, \*\*\* indicate the significance of variables at 10%, 5% and 1% level, respectively.

firm's propensity to R&D investment. It also probes the moderating role of the corporate board's demographic diversity in the relationship between cognitive diversity and the level of spendings on R&D activity.

By analysing a sample of UK-listed non-financial firms, this study observes a significant positive relationship between board diversity and the level of R&D investment. A more diverse board draws its conclusions from a variety of inputs and richer information, which helps the firm to better position its strategic directions and leads to sustained growth in the long run. This supports the argument that the corporate board functions as a group and the board members' characteristics collectively influence the quality of its decisions. Cognitive diversity is found to have a significant and positive association with R&D investment.

The findings of our study, however, show an insignificant relationship between demographic diversity and firms' spending on R&D. We therefore argue that board functional/ cognitive diversity is more relevant to influencing corporate decisions regarding R&D investment than demographic diversity. The findings of our research also show that demographic diversity negatively moderates the association between cognitive diversity and R&D investment. These findings thus supports the "Faultline Argument" that suggest that rifts within groups, emerging from demographic differences, lower group performance (Knippenberg & Schippers, 2007). The results obtained from the full sample also hold for the sub-samples of large and small firms and for manufacturing and non-manufacturing firms.

Overall, the findings of this paper make the following contributions to the board diversity and R&D investment literature. In the UK context, this study is among the first studies, that document empirical evidence on the role of board diversity in corporate R&D spending. Further, consistent with the argument of group contribution, this study develops a comprehensive board diversity index by considering a range of

cognitive and demographic attributes. It provides empirical evidence that directors' characteristics collectively contribute to firms' strategic decisions, such as R&D investment. In line with the "Faultline Argument" in the organisational and social psychology literature, this study adds to the existing body of knowledge on board diversity and R&D investment by providing evidence that suggests unproductive division within board members, arising from demographic attributes (demographic diversity), negatively affects the association between cognitive diversity and R&D investment.

The findings of this study have implications for the corporate sector, regulators, and policy makers. From the shareholders' point of view, our findings provide insight into which aspects of board diversity are more relevant to influencing the decisions made by top executives. Our findings document that while deciding and recommending on the composition of the board companies and regulators and policy makers should consider two important aspects. First, they should focus on the board attributes as a whole, rather than a particular characteristic. Second, firms should put more emphasis on functional/cognitive diversity on their boards and carefully harness demographic composition from skills and experience perspective to enhance boards' performance.

Despite its significant contributions, this study also has limitations, which will serve as an avenue for future research. The research has been conducted in the UK settings, where corporate governance codes are based on the "comply or explain" concept. Therefore, the findings may only be applicable to countries with principle-based governance codes and not to countries where corporate governance codes are based on a rules-based system. Moreover, this study uses research and development investment (input side of innovation) as the dependent variable which has limitations. Future research can be conducted using patents (output) as measure of innovation, provided that reliable data on patents in the



UK context is available. In addition, the use of a multi-country sample is warranted for more generalizability of findings regarding the role of board diversity in corporate strategic decisions, such as R&D investment. Further exploring the finding of the current study in an emerging market context can also be regarded as another useful avenue for future

research.

#### Data availability

Data will be made available on request.

### Appendix A. Measurement of variables

Variable	Symbol	Measurement Proxy
<b>Dependent Variable</b>		
R&D Investment	RnD	Corporate research and development spending divided by total sales (missing data is recorded as "0")
<b>Independent Variables</b>		
Board Diversity Index	BD_INDEX	For every company in the sample, board diversity index is calculated as $[Z_{Gender\_Diversity} + Z_{Age\_diversity} + Z_{Nationality\_Diversity} + Z_{FinanXp\_Diversity} + Z_{Tenure\_Diversity} + Z_{Education\_Diversity} + Z_{BoardsExp\_Diversity}]$ . The prefix "Z" with each component of diversity shows that these are standardised measures
Demographic Diversity Index	Demo_Diversity	The demographic diversity index is measured as $[Z_{Gender\_Diversity} + Z_{Age\_diversity} + Z_{Nationality\_Diversity}]$
Cognitive Diversity Index	Cogn_Diversity	The cognitive diversity index is constructed as $[Z_{FinanXp\_Diversity} + Z_{Tenure\_Diversity} + Z_{Education\_Diversity} + Z_{BoardsExp\_Diversity}]$
Directors' Gender Diversity	Gender_Diversity	Gender diversity is measured by the ratio of male and female directors on the board
Directors' Age Diversity	Age_diversity	Age diversity is captured by categorising directors in four age groups, i.e. (i) below 46 years, (ii) 46–55, (iii) 56–65, and (iv) above 65
Directors' Nationality Diversity	Nationality_Diversity	Directors are categorised as domestic and foreign directors to construct diversity of nationality. Directors are recoded as domestic if their nationality and firm-headquarters country (country of incorporation) is the same; otherwise, they are considered as foreigners
Directors' Financial Expertise Diversity	FinanXp_Diversity	Directors' financial expertise diversity is measured by dividing them into two groups: (i) financially expert directors; (ii) not financially expert directors
Directors' Tenure Diversity	Tenure_Diversity	Tenure diversity is constructed by categorising directors in three groups based on the length of their tenure on the firm's board: (i) directors having tenure $\leq 3$ years; (ii) directors whose tenure is $> 3$ but $\leq 6$ years; (iii) directors having tenure $> 6$ years
Directors' Education Diversity	Education_Diversity	For measuring education diversity, directors are placed into four groups based on their level of qualification, i.e. PhD, Master, Bachelor, Other
Directors' Board Experience Diversity	BoardsExp_Diversity	For constructing board experience diversity, directors are categorised into three groups on the basis of their sitting on other firms' boards: (i) number of directors sitting on $\leq 3$ boards; (ii) number of directors sitting on $> 3$ but $\leq 6$ boards; (iii) number of directors sitting on $> 6$ boards
<b>Control Variables</b>		
Firm Size	SIZE	The size of the firm is proxied by the log value of total assets
Firm Age	Firm_Age	The age of the firm is proxied by the log value of number of years since its incorporation (when it was founded)
Firm Performance	ROA	Proxied by return on total assets (ROA)
Leverage	LEV	Leverage is proxied by proportionate long-term debt to the total assets of the firm
Board Independence	Brd_IND	Proportion of directors that are independent and have no connection to the company except through the board directorship
Board Size	Brd_Size	The number of directors on the board of a firm in a year
Board Meetings	Brd_Meet	The number of board meetings in a year
CEO Duality	CEO_DUAL	Binary variable recording value "1" if the CEO is also serving as chair of the board; otherwise "0"

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