ERASMUS UNIVERSITY ROTTERDAM
Erasmus School of Economics

Are diverse boards more innovative?

Master Thesis

Eirini Deloudi

Student number: 612415

MSc Accounting, Auditing and Control (AAC)

Track: Accounting and Finance

Supervisor: Dr. Michael Erkens

Second assessor: Dr. Ying Gan

July 2022

Erasmus
University
Rotterdam

ABSTRACT

This paper examines how greater heterogeneity among directors affects the specific firm outcome of corporate innovation. This research is based on a unique hand-collected sample of 176 European firms. A multidimensional diversity index consisting of four cognitive and two demographic aspects of diversity is constructed to examine the effect of diverse boards on innovation input and output. The findings show that the composite diversity index does not produce significant results, and thereby an association between diversity and the firm's R&D spending as well as the number of patents cannot be claimed. However certain components of diversity are found to foster firm innovation. Namely, educational diversity positively influences the innovation input and output, directors with a greater range of nationalities invest more in R&D, firms with board members who have previous experience in other firm's boards generate a higher number of patents and granted patents, and lastly, boards with directors with past professional experience in multiple industries have higher ratios of R&D expenses to total assets. These findings reveal that the benefits of diversity outweigh its costs.

Keywords: board of directors; diversity; demographic diversity; cognitive diversity; innovation

Table of Contents

1. Introduction

Over the past decades, academic literature has extensively examined the role of the board of directors in shaping the firm's corporate governance and influencing various firm outcomes. Beyond the traditional monitoring role of the board, researchers have also explored the importance of diversity among the board members. Specifically, most academic papers choose to investigate the impact of board diversity on firm performance. Advocates of board diversity support the view that heterogeneous directors bring a wide range of viewpoints, ideas, and expertise to the firm and affect therefore positively its performance (Carter et al., 2003, Giannetti et al., 2015). However, when diversity reaches too high levels, opponents of diversity argue that coordination problems appear and the decision-making process, as well as firm performance, may suffer (Talavera et al., 2018, Adams, Akyol, and Verwijmeren, 2018). Therefore, it is apparent that the cost-benefit debate about diversity in the boardroom has yet not been resolved. Even though the relation between board diversity and firm performance has been at the center of academic discussions, the purpose of this paper is to shed some light on a different and less prevalent firm outcome, that of innovation, which is also a key determinant of firm performance. In this thesis, I focus, thereby, on the potential influence of board diversity on corporate innovation, and I examine whether the benefits of diversity on the firm's innovation activities outweigh its costs.

The academic papers that have investigated, mostly during the past decade, the relationship between board diversity and innovation have chosen to focus their research on the U.S. setting. However, this thesis is concentrated on the European setting, and specifically on 176 firms from countries in the European Union, the U.K., and Scandinavian countries. I aim to fill the certain gap in board diversity literature as it would be valuable to examine how firms operate in different geographic regions. Moreover, from a behavioral perspective, studying directors from diverse cultural backgrounds and experiences, would enrich existing literature and increase the generalizability of the findings.

According to a Wall Street Journal article, "Diversity is more important than ever; diverse teams can create a competitive advantage by fueling disruptive innovation", (Prabhakar, Lamar, & Shaikh, 2020). Innovation is an important indicator of the firm's competitive place in the market and is also of interest to a large number of stockholders (Fang et al., 2014). Most academic studies have found that a diverse group of directors can generate new ideas, allocate efficiently the firm's resources, and subsequently influence its innovation strategy. Boards with greater female representation, directors from different ethnic and cultural backgrounds, and members with a variety of professional expertise generally devote more resources to R&D, generate a greater number of patents, and explore new technologies in unfamiliar areas (Chen, Leung, and Evans, 2018, Bernile et al., 2018, Giannetti and Zhao, 2019, Griffin et al., 2021, An et al., 2021).

As stated in the Wall Street Journal article, "One study, published at the Harvard Business Review, identified two types of diversity traits: those that are inherent, such as gender, race, and sexual orientation; and those that are acquired, including educational, geographic, and socioeconomic background. Researchers found that organizations whose leadership teams combine at least three inherent and three acquired diversity traits out-innovated and

outperformed the others", (Prabhakar, Lamar, & Shaikh, 2020). Therefore, to measure board diversity, I construct a multidimensional diversity index that consists of six diversity components; two demographic, i.e., inherent, and four cognitive, i.e., acquired aspects. Director demographic and cognitive characteristics are hand collected from companies' websites, annual reports, and directors' LinkedIn profiles. Based on the hand-collected directors' characteristics, I create the following diversity components: tenure, nationality, educational, professional, director experience, and foreign experience diversity. The sum of the six diversity components scores is the composite board diversity index. I regress four innovation measures against both the composite diversity index and the separate diversity components. In detail, to operationalize corporate innovation, I construct two innovation input and two output proxies. The ratio of R&D to total assets (*R&D/Assets*) and the natural logarithm of the firm's R&D expenditures (*ln(R&D)*) constitute the innovation input measures, and the natural logarithm of the total number of publications (*Patent*) and granted publications (*Granted_patent*) measure the quantity of innovation output. I also control for director and firm characteristics in all the main regression models.

I find that the combined diversity index does not significantly impact the firm's innovation input and output. On the contrary, when I remove the controls from the regression model, the coefficient of the board diversity index is positive and statistically significant, indicating that diverse boards can actually contribute to the firm's innovation activities. Furthermore, I find evidence that certain diversity components matter to corporate innovation. Educational diversity is positively associated with both innovation input and output, directors from different nationality backgrounds invest in more R&D expenses, board members with past director position experience produce a higher number of patents, and lastly, professional diversity is positively related to the ratio of R&D to total assets. The latter findings reveal that individually some diversity components are important determinants of the firm's corporate innovation. Adding thereby to the cost-benefit tradeoff of diversity, this thesis concludes that the benefits of diversity are greater than its drawbacks.

This article contributes to the board diversity and innovation literature in several ways. First of all, this thesis is the first one to examine the association between heterogeneity in the boardroom and corporate innovation in the European setting. Furthermore, the hand-collected sample of director characteristics is a unique feature of this research, as so far other papers extract data from the available datasets. Overall, the results suggest that some diversity aspects actually foster innovation. Companies that aim to improve their position in the market by increasing their innovation levels, can benefit from the thesis's findings and employ directors from certain diverse backgrounds. Namely, mostly the cognitive, and not the inherent aspects of diversity are found to contribute to corporate innovation.

The remainder of this thesis is organized as follows: Section 2 analyzes the theoretical background of board diversity and innovation as well as the hypothesis development, Section 3 describes the sample, variables, and methodology implemented, Section 4 presents the empirical results of the paper, and Section 5 concludes by discussing the contribution of the results and possible limitations.

2. Literature Review and Hypothesis Development

Diversity in the boardroom has received growing attention both from academics and corporations during the past decades. The accelerated phenomenon of globalization has impacted the structure of the workforce, as it has promoted cultural exchanges. Consequently, organizations have started to appoint individuals from ethnic minorities, an increasing number of female directors, and members with diverse backgrounds and expertise. Therefore, the need to study the effect of board diversity on various corporate outcomes has emerged. The current section aims to first provide an assessment of previous literature undertaken on board diversity and understand its various aspects. Additionally, the link between diversity and the specific corporate outcome of innovation will be thoroughly explained, leading to the establishment of the thesis's main hypothesis.

2.1 Board diversity and its aspects

Diversity within the organization and specifically at the board of directors' level has been at the center of most academic discussions during the past years. Organizations are to a large extent subject to numerous dimensions of diversity. Literature has distinguished between two main types of diversity; the observable, demographic part of diversity and the non-observable, cognitive aspect of diversity. While most academics traditionally focus on the surface level, demographic diversity which includes diversity in age, gender, and ethnicity, there has been an emerging need to study how diversity in social backgrounds, values, personality traits, attitudes, and academic and professional skills influences firm outcomes. Therefore, I present in this section evidence from prior studies, which investigate both aspects of diversity.

2.1.1 Demographic diversity

Most academics examine the interaction between the demographic aspect of diversity and various corporate governance outcomes by focusing especially on gender diversity. Adams and Ferreira (2009) were among the first researchers to conclude that a greater number of women in corporate seats enhances the governance of the firm, as female directors are tougher monitors. To control for endogeneity issues, the authors form an instrumental variable which is the proportion of male directors that are also appointed to other boards with female representation. They find that on average gender-diverse boards do not enhance firm value. Only when firms have a weak corporate governance system and no intense monitoring do boards with female directors add value to the firm.

Moreover, a great strand of literature has investigated the effect of the implementation of mandatory gender balancing quotas on several firm outcomes. Norway was the first country to enforce a mandatory gender quota law. In 2003, the Norwegian government imposed a board gender quota which required a minimum of 40% women representation on corporate board seats. By 2008, the law required mandatory compliance by all public-limited firms. Ahern and Dittmar (2012) were the first academics to study the impact of the mandatory gender quota in Norway on firm value and board characteristics. The authors' results suggest that the introduction of the gender balancing quota led to a substantial drop in firm value, as well as a negative stock price reaction. Contrary to the results by Ahern and Dittmar, Eckbo et al. (2019) conclude that the Norwegian quota law changes in firm value and stock returns are insignificant.

As a result, the findings on the effect of these legislative initiatives on the percentage of women's representation on the board and firm performance appear mixed and inconclusive.

In addition to gender diversity, academics have also chosen to examine other aspects of demographic diversity, such as age diversity. Talavera et al. (2018) focus on the Chinese bank sector and study whether age-diverse boards affect bank performance. Their findings suggest that heterogeneity in age among board members results in difficulties in communication and can lead to intragroup conflicts which negatively affect bank profitability. Furthermore, Hafsi et al. (2013) investigate the link between demographic diversity in the boardroom and corporate social performance. Specifically, while they expect to find that age-diverse boards engage in a more balanced decision-making process and significantly consider the firm's responsibility to its stakeholders, their findings reveal that age diversity is harmful to social performance.

Carter et. al (2003) define board diversity as the percentage of women or minorities (for example African Americans, Hispanics, Asians) on the board of directors. The authors study the association between ethnic diversity and firm performance and point out that firms with a higher percentage of minority directors on their board have greater firm value. According to Carter et. al (2003), diverse team members from different nationalities and backgrounds understand better the level of competition in the marketplace, are more culturally sensitive, and promote effective organizational leadership.

2.1.2 Cognitive diversity

At the same time, researchers choose to investigate the less visible characteristics of directors. Giannetti et al. (2015) examine whether a larger fraction of directors with foreign experience is related to greater firm performance. They choose to study a non-observable aspect of diversity and thereby hand-collect data on directors that received an academic degree from abroad or have work experience in a country outside of China, the country of interest. Organizations that enhance their talent pool by appointing directors with diverse educational and professional backgrounds enhance firm performance and productivity and their corporate governance practices improve. These skilled directors can transmit their knowledge and expertise, embrace cultural differences, and introduce the firm to the international market.

A study by Adams, Akyol, and Verwijmeren (2018) focuses on the cognitive aspect of diversity by examining the effect of diversity in the directors' skill set on firm performance. The authors argue that directors are not one-dimensional but vary primarily on the diversity of the available skills, including academic, and professional qualifications. Following the 2009 amendment to Regulation S-K, U.S. companies are obliged to justify the reasons for nominating directors that are valuable to them. Therefore, the researchers use a Conference Board analysis of 2010 in 30 Dow Jones companies as a guide and construct a dictionary with the most frequent words and phrases for each skill, that companies use in their statements and reports. After that, they code director skills and create several skills categories. They find a negative relation between skill diversity and firm performance. The authors support the view that common ground boards actually perform better as the more diverse the board becomes, the harder it becomes to coordinate all the members and thereby the more frequently the directors have to

meet. As a result, communication among members with different backgrounds and perspectives suffers and the decision-making process becomes slower.

Taking the above into account, the impact of diversity at the board level on various corporate governance outcomes has received growing research attention, but the evidence still remains mixed. While the majority of academic papers use firm value as an outcome variable, it would be very meaningful to understand how board diversity impacts a different corporate outcome, that of innovation, as innovation can later on also influence positively future firm performance.

2.2 Diversity in the boardroom and innovation

Corporate innovation is considered a significant determinant of the firm's level of competitiveness, productivity, and value. Fang et al. (2014) argue that the importance of the firm's innovation productivity is of interest to a large number of stockholders, including shareholders, creditors, managers, and employees. Thereby, the more innovative a firm is the more likely it is to preserve its competitive advantage in the market and to generate more profit for the benefit of its stockholders.

Various studies have highlighted the role of the board in shaping the firm's innovation process. The board of directors influences business decisions and affects the firm's business strategy which is significantly tied to the development of an effective corporate governance system (Matcha and Miller, 2013). Among the various tasks of the board of directors is allocating the firm's resources and presenting ideas that subsequently increase corporate innovation. Heterogeneous boards search for various sources of information, increase the quality of brainstormed ideas, and provide more strategic alternatives (Torchia et al., 2011).

Carter et al. (2003) mention that diversity increases creativity, fosters innovation, and leads to a more effective problem-solving process. A great range of ideas and viewpoints produces a variety of alternative solutions to corporate problems and allows board members to carefully assess the consequences of the alternatives. Diverse boards challenge traditional thinking and promote innovativeness as well as an open and future-oriented organization culture. Furthermore, diverse board teams encourage the appointment of diverse employees who provide different ideas and perspectives to the decision-making process (Griffin et al., 2021). Nonetheless, literature has recognized a potential cost-benefit tradeoff of diversity, as heterogeneous boards can be hard to coordinate. When board members have different backgrounds and different perspectives about important decisions, communication and decision-making may suffer (Adams, Akyol, and Verwijmeren (2018), An et al., 2021). As a result, this paper additionally aims to address the impact of this cost-benefit tradeoff of diversity on firm innovation.

In order, therefore, to understand the association between the board of directors of a firm and its innovation as well as the cost-benefit tradeoff of diversity more extensively, I present in the following two subsections evidence from prior academic studies which investigate various types of board diversity and corporate innovation.

2.2.1 Demographic diversity and innovation

Miller and Triana (2009) were among the first researchers to explore the link between demographic diversity in the boardroom and innovation. Specifically, they examine how two visible aspects of diversity; gender and ethnicity affect firm performance through the mediating role of innovation and reputation. The researchers build their hypotheses on the behavioral theory of a firm and argue that a diverse group of directors generates more innovative ideas, through a more thorough information and decision-making process, which in turn influence positively firm performance. Due to the increased information available among members of a diverse group, board diversity is positively associated with innovative outcomes, measured by the levels of R&D expenditures. When examining the direct relation between racial and gender diversity in the boardroom and innovation, the authors find a positive effect for both types of diversity. However, only racial diversity leads to greater performance when innovation is considered a mediator for firm performance.

Chen, Leung, and Evans (2018) emphasize their research specifically on gender diversity and study whether greater female representation on the board of directors is associated with greater firm innovation. The authors investigate the firm's investment in innovation, measured by the level of R&D expenditures and the level of innovation productivity, measured by the number of patents and citation counts. Given the endogenous relation between board gender composition and innovation output, the authors implement a propensity score matching method and an instrumental variable approach to mitigate any concerns. Their findings reveal that a higher fraction of female directors is positively related to R&D expenditures as well as a greater number of patents and citations. Additionally, the authors point out that the effect of innovation success on firm performance is dependent on the importance of innovation activities for each industry in which the firm operates. They find that greater female board representation is positively associated with firm performance in "IP-intensive" industries, which have high scores in intensity measures regarding patents.

Griffin et al. (2021) also study gender diversity and innovation and find similar results to Chen, Leung, and Evans' paper (2018). The researchers indicate that boards with a higher proportion of female directors positively contribute to the firm's innovative performance through their effect on establishing corporate culture. The presence of female directors in the boardroom helps mitigate excessive risk-taking choices and shifts the firm's focus from short-term profits to long-term value-increasing innovation projects. The authors compare firms within the same country and find that the association between board gender diversity and the citation-weighted number of patents as well as innovation novelty, measured by the number of new citations, is significantly positive. Additionally, higher innovation efficiency is observed in firms with more gender-diverse boards both within the same country as well as across different countries. Griffin et al. (2021) also explore potential mechanisms through which gender board diversity influences innovation. Their results indicate that board gender diversity is associated with CEO long-term incentives and greater failure tolerance compensation contracts, innovative corporate culture, and a greater fraction of minority inventors. These mechanisms are all linked to increased innovative firm performance.

Directors from ethnic minorities foster a culture of innovation and promote collaboration and interaction among members of the organization (Cao et al., 2021). In their recent study, Cao et al. investigate whether firms that employ more ethnically diverse members on their board are more innovative. They perform a difference-in-differences design to account for endogeneity concerns and find that firms after adding minority directors to their boards produce greater innovation outcomes, as the number of their patent applications significantly increases. Moreover, the authors' results indicate a positive relation between board diversity and R&D expenditures which essentially contribute to the production of patents and thereby to the level of corporate innovation. The authors extend their research and conclude that firms with more ethnically diverse boards are more likely to appoint minority inventors and encourage collaboration among inventors from different ethnic minorities who develop as a result a greater number of patents.

Giannetti and Zhao (2019) investigate the costs and benefits of a different demographic aspect of diversity, that of ancestral board diversity, to various firm outcomes. The authors recognize the cost-benefit tradeoff of diversity but conclude that the benefits of diversity in the firms' innovation process outweigh its costs. They support the view that ancestrally diverse boards appear to be more experimental, come up with creative solutions to the firms' problems and thereby contribute to the firm's successful innovation process. Their findings indicate that not only do firms with diverse boards have a higher number of patents, but their patents are also highly cited, revealing a more original innovation outcome.

2.2.2 Cognitive diversity and innovation

Meanwhile, researchers additionally investigate the relationship between the less visible aspect of diversity and innovation. Kor et al. (2006) focus on cognitive diversity at the top management level and suggest that the composition of the top management team influences the level of a firm's R&D investment intensity, which is used as a proxy for innovation. The authors investigate whether teams whose members have similar "team-specific experience" or have different industry backgrounds allocate larger amounts in R&D investments. The results of the study are in line with the negative side of diversity and reveal that firms that appoint directors with a high level of shared experience have higher R&D investment intensity. The authors support this finding by arguing that top management team members who share similar experiences and are aware of each other's knowledge and skills, develop a common understanding of every situation as well as a sense of trust. Since R&D investments contain a level of risk, these team members can consult each other, handle potential obstacles, and decide collectively on the best strategic decision for the firm.

Bernile et al. (2018) take into account both the observable and the non-observable aspects of diversity by forming a multidimensional diversity index. They explore the extent to which firms with more diverse boards invest in R&D and how efficient their innovation process becomes. To mitigate endogeneity concerns about board composition, they construct a director supply-based instrumental variable, that is the average diversity of potential non-local directors weighted by the frequency of non-stop flights between director home locations and firm headquarters. The instrumented board diversity affects positively the level of R&D investments and leads to greater efficiency in the innovation process. Moreover, the authors suggest that

greater board diversity results in better innovation quality, measured by the number of patents, patent citations, and the originality of these patents.

Shedding light on the benefits of diversity at the board level, An et al. (2021) recognize that directors from different backgrounds bring different strategic resources to the firm which may appear beneficial to the corporate innovation process. The authors also construct a multidimensional index consisting of six diversity components, including demographic and cognitive aspects of diversity. By focusing their study on a large number of public U.S. firms, the authors conclude that firms that appoint directors with diverse characteristics create a higher number of patents, which also receive citations. However, this positive relation diminishes after diversity reaches very high levels, suggesting that the costs of diversity outweigh its benefits. Regarding the quality of the innovative patents, An et al. find that more diverse firms develop new technologies and file a higher number of patents in areas that were previously uncharted. Therefore, firms with a diverse board of directors present more exploratory innovations and implement novel technologies.

The COVID-19 pandemic has drastically shifted the way today's society operates and combined with the already existing rapid economic and technological global transformation it has accelerated overall change. Thereby, there has been an increasing need for researchers to shift their interest to new technologies and innovations that lead to long-term developments. Continuing their study on board diversity and innovation, Bernile et al. (2021) focus on a specific type of innovation, namely disruptive innovation. This type of innovation is associated with technological breakthroughs in previously unfamiliar domains. The authors construct a similar multidimensional diversity index as in their previous work (Bernile et al., 2018) and find that firms with diverse boards produce a higher number and a better quality of disruptive and novel patents. As a result, their findings suggest that diversity in the boardroom is associated with higher R&D intensity and also increased disruptive and overall innovation which has long-term benefits to firm value and significant market impact.

Based on the previous literature discussed above, the link between diversity and innovation has started to receive growing attention only during the past years. However, the evidence on the cost-benefit tradeoff of diversity still remains inconclusive. Thereby, I expect this thesis to contribute to the academic debate about diversity and shed light on whether the benefits of diversity outweigh its costs. Regarding the aspects of diversity discussed, most academics either focus on a particular part of diversity and especially a demographic aspect or they choose to construct a multidimensional index containing both demographic and cognitive characteristics of directors. An et al. (2021) point out that out of all the components that they use to construct the diversity index, professional and educational diversity are the most important in strengthening corporate innovation. Therefore, I aim to enhance prior literature by investigating the association between mainly the cognitive aspects of board diversity and innovation. I expect to test whether board members with different skill sets, including academic and professional experience and expertise, and different backgrounds positively impact the firm's innovation. Taking the above into account, the main hypothesis tested in this paper is the following:

H1: Higher diversity in the boardroom results in more innovative outcomes

3. Research Design

The current section describes the research design and methodology implemented in this thesis. First, the data sample is analyzed, secondly, the operationalization of the dependent and independent variables is discussed as well as the set of control variables taken into account, and lastly, the regression models used to test the thesis' main hypothesis are presented. All variables mentioned in this section are also thoroughly presented in the Appendix table C.

3.1 Sample formation

This research extracts data from numerous sources. Information on patent applications is retrieved from the Orbis database which is provided by Bureau van Dijk (BvD). Orbis reports intellectual property and patent information and specifically discloses the number of publications and granted publications associated with each company. However, Orbis database does not disclose publication information on a yearly basis but provides the total number of the company's publications over the years. To obtain board information as well as board members' characteristics information, I hand collect data from companies' websites, annual reports, and directors' LinkedIn profiles. I choose 2021 as the year of interest as it is the most recent full fiscal year for which annual data is available. Thereby, I examine the composition of the board of directors as it is disclosed in each company's 2021 annual report. This research is focused on the European setting. To construct the final sample, I initially retrieve a larger sample of firms from the European region from the Compustat global database via WRDS (Wharton Research Data Services). After dropping observations with missing values and also removing firms that do not disclose their R&D expenditures on their income statement, 2002 firms from European countries remain in the sample. Next, within each country, I place the remaining firms in a descending order based on their total size and I randomly choose large and medium-size firms to constitute the final sample. Specifically, the final sample consists of 176 companies from the European Union as well as the United Kingdom, Switzerland, and Scandinavian countries and 1600 director observations. In particular, the sample comprises countries from Austria, Belgium, Switzerland, Germany, Spain, France, the United Kingdom, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, and Sweden. An overview table of the hand-collected sample can be found in Appendix B. To obtain firm financial information for the year 2021, such as total assets and liabilities, R&D expenditures, cash, and PPE, I rely on the Compustat global database.

3.2 Key variables

3.2.1 Dependent variable - Corporate innovation

This thesis's key outcome variable is the firm's corporate innovation. To measure the quantity of innovation input I use the firm's R&D expenditures, and to measure both the quantity and quality of innovation output I use patent-based measures. A significant number of past academic studies operationalize the firm's innovation level by using its R&D expenditures (Kor et al., 2006, Miller and Triana, 2009, Chen, Leung, and Evans, 2018, Cao et al., 2021). According to Miller and Triana (2009), R&D intensity accounts for an appropriate proxy of innovation as it shows the number of resources the directors choose to allocate to the firm's innovation process. Furthermore, Cao et al. (2021), support the view that R&D expenses are

considered important resource inputs to generating patents. Therefore, I use two measures of a firm's R&D intensity. *R&D/Assets* is the firm's R&D expenditures in 2021 scaled by its total assets in the same year and *ln(R&D)* is the natural logarithm of 1 plus the firm's R&D expenditures in 2021. Information about the firms' R&D expenditures which are disclosed on the 2021 income statements is retrieved from the Compustat global database.

However, prior literature recognizes that R&D expenses are not always an ideal proxy for the firm's innovation activities. Atanassov (2013) states that R&D expenditures are not the most efficient quality measure of innovation as higher R&D is less likely to result in successful innovation when other inputs are not effectively implemented. Moreover, there is a possibility that managers will overspend the company's resources and substitute R&D for other inputs. For the above reasons, I additionally investigate the effect of board diversity on the firm's total number of patents and granted patents. Patenting has constituted a prevalent choice of corporate innovation measure among academics during the past decade, as it captures how effectively a firm makes use of its innovation inputs (Chen, Leung, and Evans, 2018). I construct, thereby, the third measure of innovation, *Patent,* which is the natural logarithm of 1 plus the firm's total number of publications. After a company has developed a new technology, a patent application is submitted to a patent granting authority so that the invention will be granted. The patent should satisfy certain criteria and therefore there is usually a time lag from the time the invention application is submitted until it is finally granted. Thereby, usually, the number of the firm's granted publications is lower than that of total patent publications. I additionally construct the fourth corporate innovation proxy, G*ranted_patent,* which is calculated as the natural logarithm of 1 plus the total number of granted publications.

3.2.2 Independent variable – Board diversity index

The main independent variable of this thesis is board diversity. I construct a board diversity index which is calculated based on the following six distinct diversity components: i) tenure diversity, ii) nationality diversity, iii) educational diversity, iv) professional experience diversity, v) director experience diversity and vi) foreign experience diversity. As mentioned in the literature review section of the thesis, prior academic studies focus mostly on demographic aspects of diversity. However, the current research's multidimensional index consists mainly of cognitive diversity characteristics (academic, professional, director experience, and foreign experience diversity) and two demographic components (tenure and nationality diversity). The six subcomponents of board diversity are calculated based on the 1600 hand-collected director characteristics from 176 European companies. In detail, I calculate each of the six components of the combined diversity index as follows:

Tenure diversity: Following existing literature (An et al., 2021) directors' tenure diversity is measured based on the number of years the director has been serving on the board (i.e., director tenure). To calculate *Tenure_diversity,* I divide the standard deviation of director tenure to the mean of director tenure.

$$Tenure\_diversity = \frac{standard\ deviation\ of\ director\ tenure}{mean\ of\ director\ tenure}$$

Next, I calculate the median of *Tenure_diversity* of all the firms in the sample. Apart from the above continuous variable, I additionally construct a dummy variable, *Tenure_diversity_dummy*, that is equal to 1 if the firm has *Tenure_diversity* above the sample median, and 0 otherwise.

Nationality diversity: Firstly, I measure directors' nationality diversity using the number of directors that are from the same country as the country in which the company is located, scaled by the board size (i.e., total number of directors serving on the board).

$$Nationality\_diversity = \frac{number\ of\ directors\ of\ the\ same\ nationality}{total\ number\ of\ directors}$$

A lower number of *Nationality_diversity* indicates a higher degree of diversity in the boardroom. Secondly, I estimate the median of *Nationality_diversity* of all the companies and additionally create a *Nationality_diversity_dummy* variable that is equal to 1 if the firm's *Nationality_diversity* is below the sample median, and 0 otherwise.

Educational diversity: Following a similar procedure as the one developed by An et al. (2021), I measure educational diversity as the percentage of directors across the board that hold a certain type of academic degree. Specifically, *Educational_diversity* is calculated as the ratio of the number of directors that hold a Ph.D. diploma to the total number of directors serving on the board.

$$Educational\_diversity = \frac{number\ of\ directos\ with\ a\ PhD\ diploma}{total\ number\ of\ directors}$$

To additionally construct an *Educational_diversity_dummy* variable, I first calculate the median of *Educational_diversity* of all the firms in the sample, and then I assign *Educational_diversity_dummy* the value of 1 when the firm's *Educational_diversity* is above the median, and 0 otherwise.

Professional experience diversity: I classify directors' previous employment experience and backgrounds into eleven categories: i) industrial, ii) healthcare, iii) telecommunications, iv) IT/technology, v) government, vi) academia, vii) law, viii) finance, ix) consulting, x) banking, and xi) other. The latter categories are determined based on the industry in which the firms that the director was appointed during his/her career belong to. The ratio that determines the *Professional_ diversity* continuous variable for each firm is the following:

$$Professional\_\ diversity = \frac{number\ of\ different\ industries\ existing\ on\ the\ board}{total\ number\ of\ industries\ (=11)}$$

In addition, I construct a professional experience diversity dummy variable, *Professional_ diversity_dummy*, which is equal to 1 if the firm's score of *Professional_ diversity* is above the *Professional_ diversity* median, and 0 otherwise.

Director experience diversity: I measure director experience diversity using the number of directors that have previously held positions on the board of other companies scaled by the board size.

$$Director\_experience\_diversity = \frac{number\ of\ directors\ with\ board\ seats\ in\ other\ firms}{total\ number\ of\ directors}$$

After aggregating the hand collected director experience observations at the company level, I calculate the median of *Director_experience_diversity* of all the firms and form a *Director_experience_diversity_dummy* variable equal to 1 when the firm's *Director_experience_diversity* lies above the sample median, and 0 otherwise.

Foreign experience diversity: I calculate directors' foreign experience diversity by dividing the number of directors that have worked in foreign countries by the total number of directors on the board.

$$Foreign\_experience\_diversity = \frac{number\ of\ directors\ with\ work\ experience\ abroad}{total\ number\ of\ directors}$$

Furthermore, I come up with a *Foreign_experience_diversity_dummy* variable that receives the value of 1 if the value of the firm's *Foreign_experience_diversity* lies above the sample median of *Foreign_experience_diversity*, and 0 if not.

To construct the composite *Brd_diversity* index, I sum the scores of the six corresponding components of board diversity. The *Brd_diversity* index reveals the degree of diversity of the firm. Higher scores of the *Brd_diversity* index indicate higher levels of diversity among the directors serving on the board.

$$Brd\_diversity = \sum_{i=1}^{6} Diversity\_component_i$$

In addition, I construct the composite *Brd_diversity_dummy* index by first adding up the six dummy variables of the corresponding diversity components. Next, I calculate the median of the combined diversity components' dummy variables of all the firms, and finally, I create the *Brd_diversity_dummy* which is equal to 1 if the combined diversity dummy lies above the sample median, and 0 otherwise.

3.2.3 Control variables

Based on existing literature, I control for various board and firm characteristics that are important determinants of firm innovation and are also correlated to board diversity. It is difficult to establish a causal relation between board diversity and corporate innovation due to existing endogeneity concerns. For instance, potential reverse causality concerns arise as it is possible that firms that allocate their resources to R&D or have high patenting activity appoint board members from diverse backgrounds for window-dressing purposes. Moreover, I cannot rule out completely the possibility that the results are not driven by the existence of omitted correlated variables between the independent and the outcome variable. Since I hand collect information about directors who constitute the sample firms' 2021 board, this study is focused only on the year 2021. Therefore, I cannot use a panel regression to test the main hypothesis, and also no firm and time-fixed effect can be incorporated into the model control for unobservable variables that stay constant over time. However, control variables are added to the regression models to ensure that the results are fair and minimize the chances that the changes in the outcome variable are attributed to other causes.

Specifically, I control for the following director characteristics: director executive position, and director dual position. *Executive* is a dummy variable that equals 1 if the firm has at least one executive director on the board, and 0 otherwise. The variable *Dual_position* is also a

dummy variable that receives the value of 1 if the firm's chairman has also an executive position at the company, and 0 otherwise.

Furthermore, based on prior academic papers I control for the following firm characteristics affecting innovation levels: firm size, leverage, tangibility, cash, and profitability. *Firm_size* is calculated as the natural logarithm of the firm's total assets. Firm size is directly and positively related to R&D spending and patenting activity, as the largest firms benefit from greater economies of scale and produce greater innovation outcomes (Chen, Leung, and Evans, 2018, Baysinger and Hoskisson, 1989). Based on a great strand of academic innovation literature, leverage, asset tangibility, profitability, and cash have been documented as important determinants of corporate innovation (He and Tian, 2013, Bernile et al., 2018, Cao et al., 2021, An et al., 2021). *Leverage* is calculated by dividing the firm's total liabilities by its total assets. I measure *Tangibility* by using the firm's net properties, plants, and equipment (PPE) scaled by its total assets. The firm's profitability is captured by its return on assets (*ROA*), which is equal to the operating income before depreciation divided by total assets. Lastly, following An et al., I measure *Cash* by dividing the firm's cash by its total assets.

3.3 Regression model

To examine the effect of board diversity on corporate innovation, I use the following baseline OLS regression model based on the study by An et al., (2021):

$$Innovation_i = \alpha + \beta_1(Board\ Diversity)_i + \sum_{j=2}^{n} \beta_j\ (Control)_i + \varepsilon_i,$$

Specifically, when the dependent variable is the firm *i*'s 2021 innovation input, I use *R&D/Assets* and *ln(R&D)* as innovation input proxies. Moreover, when I measure the firm *i*'s innovation output, I use the following patent-based innovation measures as outcome variables: *Patent*, and *Granted_patent*. On the right side of the regression equation, the main independent variable of interest used is board diversity, measured either by the combined multidimensional *Brd_diversity* index, or the *Brd_diversity_dummy* index. I include in all the regressions the set of control variables explained in the section above.

In addition, I regress the above-mentioned innovation input and output proxies against the six separate diversity components (both the continuous as well as the dummy diversity components' variables) to test which aspects of diversity are the most important to the firm's innovation activities.

4. Empirical Results

4.1 Descriptive statistics and correlation matrix

Before engaging in the regression analysis part of this thesis, I present in Table 1 the summary statistics of all the variables used. All continuous variables are winsorized at the 1st and 99th percentiles in order to mitigate the effects of outliers. It is evident that on average, a firm in the sample produces 8.8 patents and 7.9 granted patents over the years. The average number of granted patents is reasonably slightly lower than that of total patents, since there is some time lag until a patent is granted, and thereby the patents that have not yet passed the granting procedure do not appear in the sample. Furthermore, the board diversity index scores range from 2.71 to 5.11 with an average score of 3.94 and a standard deviation of 0.48. Higher

scores of the board diversity index indicate higher levels of diversity among the firm's board members. The descriptive statistics also reveal that the average board exhibits more diversity in its director experience component, followed by the tenure diversity component. Namely, the mean value of director experience diversity is 0.85, meaning that for the average firm 85% of the board members have held previous director positions in other firms. Additionally, it is interesting to point out that only 37% of the average firm's board members have different nationalities. Out of the six board diversity components, tenure and nationality diversity have the largest standard deviation (0.28), followed by foreign experience diversity (0.25) and educational diversity (0.21). Looking at the statistics for the board characteristics, it is apparent that for an average firm the proportion of directors that have an executive position in the firm is 51%, and there is only 7% probability that the average firm's chairman has also an executive position on the board. Lastly, regarding the firm-level variables, an average firm of the sample has an R&D to assets ratio of 3%, a PPE to assets ratio of 24%, and a leverage ratio of 58%, which indicates that the average company is using mainly its debt to finance its assets.

Table 1: Descriptive Statistics

Table 1 reports the descriptive statistics of the board diversity components, the board diversity index, the innovation measures, and the director and firm characteristics. All the variables are defined in Appendix A.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Tenure_diversity	176	0.82	0.28	0.23	0.64	1.01	1.51
Nationality_diversity	176	0.63	0.28	0.00	0.43	0.86	1.00
Educational_diversity	176	0.20	0.19	0.00	0.00	0.33	0.71
Professional_diversity	176	0.62	0.16	0.27	0.55	0.73	0.91
Director_experience_diversity	176	0.85	0.17	0.00	0.80	1.00	1.00
Foreign_experience_diversity	176	0.60	0.25	0.00	0.40	0.80	1.00
Dual_position	176	0.07	0.25	0.00	0.00	0.00	1.00
Executive	176	0.51	0.50	0.00	0.00	1.00	1.00
Firm_size	176	9.20	1.89	4.78	7.82	10.54	12.85
Leverage	176	0.58	0.18	0.16	0.47	0.71	1.02
Tangibility	176	0.24	0.14	0.03	0.12	0.31	0.62
Cash	176	0.11	0.08	0.01	0.06	0.14	0.46
ROA	176	0.12	0.08	−0.18	0.08	0.14	0.34
R&D/Assets	176	0.03	0.04	0.00	0.00	0.04	0.19
ln(R&D)	176	4.76	2.14	0.31	3.44	5.96	9.48
Patent	176	8.82	1.98	4.42	7.48	10.26	13.05
Granted_patent	176	7.91	2.00	3.38	6.61	9.36	12.14
Brd_diversity	176	3.94	0.48	2.71	3.62	4.29	5.11

Table 2: Pearson correlation matrix

Table 2 presents the Pearson correlations between all the variables used in the regression analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Tenure_diversity	1.00	0.11	-0.03	0.09	-0.01	-0.14	0.11	0.15	0.10	0.01	0.00	-0.19	-0.02	0.00	0.09	0.00	0.00	0.57
(2) Nationality_diversity		1.00	-0.14	0.02	-0.09	-0.50	0.11	0.10	-0.25	0.00	0.07	-0.06	0.01	-0.17	-0.32	-0.25	-0.24	0.30
(3) Educational_diversity			1.00	-0.03	-0.06	0.14	-0.14	-0.26	0.25	0.04	-0.01	0.00	0.00	0.17	0.31	0.30	0.30	0.36
(4) Professional_diversity				1.00	0.06	-0.06	-0.09	0.15	0.53	0.33	0.06	-0.30	-0.14	-0.06	0.28	0.28	0.28	0.37
(5)Director_experience_diversity					1.00	0.07	0.10	-0.11	0.15	0.02	0.04	-0.02	-0.02	-0.09	0.14	0.21	0.21	0.33
(6) Foreign_experience_diversity						1.00	-0.05	-0.09	0.08	0.01	-0.05	0.02	0.02	0.02	0.08	0.08	0.06	0.22
(7) Dual position							1.00	0.27	-0.07	-0.10	0.08	0.01	0.03	-0.11	-0.12	-0.13	-0.13	0.04
(8) Executive								1.00	0.07	0.03	-0.03	-0.09	0.05	-0.05	0.00	-0.05	-0.04	0.01
(9) Firm_size									1.00	0.30	0.10	-0.36	-0.06	-0.13	0.70	0.65	0.65	0.29
(10) Leverage										1.00	0.02	-0.09	-0.29	-0.15	0.14	0.14	0.15	0.15
(11) Tangibility											1.00	-0.19	0.30	-0.36	-0.29	-0.19	-0.17	0.04
(12) Cash												1.00	-0.12	0.33	-0.13	-0.19	-0.21	-0.23
(13) ROA													1.00	0.02	-0.03	0.04	0.05	-0.05
(14) R&D/Assets														1.00	0.45	0.19	0.17	-0.07
(15) ln(R&R)															1.00	0.79	0.77	0.18
(16) Patent																1.00	0.99	0.18
(17) Granted_patent																	1.00	0.18
(18) Brd_diversity																		1.00

Note: The colored coefficient correlations represent the following significance levels. *, **, *** indicate significance at the 10%, 5%, and 1% levels, accordingly.

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

To better understand how the variables interact with each other, Table 2 shows the Pearson correlation matrix of all the variables used. It is evident that in general not very strong correlations exist and thereby no severe multicollinearity problem is observed. In detail, the correlation coefficients between the control variables used in the main regression models are close to 0, indicating that almost no linear correlation exists between them. Additionally, the innovation input and output measures should be significantly associated since they are all used as innovation proxies. Specifically, the natural logarithm of the R&D expenditures (*ln(R&D)*) is strongly positively correlated with both *Patent* and *Granted_patent* (Pearson coefficients of 0.79 and 0.77 accordingly). However, *R&D/Assets* is very poorly associated with both of the patent-based measures. It is also interesting to highlight that there is a very small and insignificant association between *ROA* and the innovation-related dependent variables. In addition, *Executive* has a very low and insignificant correlation with the innovation measures, revealing that it could probably not be included as a control. It is interesting to point out that there is no correlation between *Tenure_diversity* and any of the innovation measures, suggesting that the ratio of tenure diversity, measured based on the years the director has been serving on the board, is not associated with higher or lower levels of the firm's innovation activities. Moreover, *Nationality_diversity* is negatively associated with innovation levels, meaning that as the proportion of directors with the same nationality increases, the firm's corporate innovation decreases.

4.2 Regression results

The results from the main regression models are discussed in the current section. Table 3 reports the regression results where the independent variable is the combined *Brd_diversity* index. In columns 1 and 2 the dependent variable is the firm's innovation input, measured by the ratio of R&D expenditures to total assets (*R&D/Assets*) and the natural logarithm of R&D (*ln(R&D)*) accordingly. Previous academic studies find that firms with more diverse boards allocate higher resources to R&D and engage therefore in a more efficient innovation process (Miller and Triana, 2009, Bernile et al., 2018, Cao et al., 2021). It is evident that the coefficients of the firm's diversity index are positive across the first two columns of Table 3, however, they are insignificant. In columns 3 and 4, I turn my attention to the firm's innovation output, which is measured by the natural logarithm of the firm's total number of publications (*Patent*) as well as granted publications (*Granted_patent*). According to most prior studies, higher levels of board diversity result in a higher number of patents, which also receive citations (Bernile et al., 2018, Griffin et al., 2019, An et al., 2021). As observed, when the board diversity index increases by 1 unit, there is an increase in the total number of patents by 6%, and in the number of granted patents by 2%. Similar to the results reported in the first two columns, the composite board diversity index's coefficients are positive but yet not significant. As a result, I cannot accept or reject the thesis's main hypothesis that firms with more heterogeneous boards become more innovative. In all of the regressions, additional control variables for director and firm characteristics are added. I find that only some of the controls are significantly related to innovation input and output. Specifically, as expected, larger firms devote more resources to R&D expenditures and produce more patents (i.e., significant coefficient of *Firm_size* in columns 2 to 4 at the 1% level). Additionally, both innovation input and output are negatively and significantly related to *Tangibility*, but positively related to the firm's profitability measure,

ROA, at the 1% and 10% significance levels. The highest R-squared (R^2) of 65%, is observed for the model in column 2, indicating a good fit for the model, as 65% of the variance of the R&D expenditures is explained by the firm's board diversity.

Table 3: Board diversity and innovation

Table 3 reports the results of the main regression of this thesis. The dependent variable is the firm's innovation, measured by the following proxies: (1) *R&D/Assets* is the ratio of the firm's 2021 R&D expenditures to its 2021 total assets, (2) *ln(R&D)* is the natural logarithm of the firm's 2021 R&D expenditures, (3) *Patent* is calculated as the natural logarithm of the firm's total number of publications, and (4) *Granted_patent* is the natural logarithm of the firm's total number of publications. The main independent variable of interest is the combined board diversity index, *Brd_diversity*. Controls are added in all of the regressions. The t-statistics are included in the parentheses. *, **, *** correspond to the significance level of 10%, 5%, and 1%, respectively.

	Dependent variable			
	R&D/Assets	ln(R&D)	Patent	Granted_patent
	(1)	(2)	(3)	(4)
Brd_diversity	0.002	0.035	0.061	0.020
	(-0.411)	(-0.162)	(0.259)	(0.087)
Firm_size	0.001	0.893 ***	0.731 ***	0.723 ***
	(-0.429)	(15.026)	(11.387)	(11.036)
Leverage	-0.022	-0.544	-0.114	0.081
	(-1.439)	(-0.895)	(-0.174)	(0.121)
Tangibility	-0.09 ***	-6.003 ***	-4.352 ***	(-4.228) ***
	(-4.568)	(-7.892)	(-5.293)	-5.039
Cash	0.13 ***	2.312 *	0.433	-0.244
	(-3.842)	(1.767)	(0.306)	(-0.170)
ROA	0.061 *	3.81 ***	4.624 ***	4.798 ***
	(-1.678)	(2.688)	(3.018)	(3.069)
Executive	-0.001	-0.217	-0.400 *	-0.360
	(-0.209)	(-1.060)	(-1.802)	(-1.591)
Dual_position	-0.014	-0.231	-0.235	-0.256
	(-1.375)	(-0.565)	(-0.532)	(-0.567)
Controls	Yes	Yes	Yes	Yes
Observations	176	176	176	176
R^2	0.236	0.648	0.552	0.512

However, when the control variables are removed from the regression models, the results suggest that board diversity is positively and statistically significantly associated with corporate innovation. In detail, in Table 4, it is apparent that the estimated coefficient of *Brd_diversity* is

significantly positive across columns 2 to 4 at the 5% level. Therefore, greater diversity in the boardroom is associated with larger innovation input and output. In terms of economic significance, a 1 standard deviation increase in *Brd_diversity* increases, for instance, the value of *Patent* by 0.369 (= 0.77 × 0.48), representing 4.2% (=0.369/8.82) of the mean of *Patent*. The magnitude of the estimated coefficient of *Brd_diversity* is also sizable when the outcome variable is *ln(R&D)* and *Granted_patent* respectively. It is interesting to point out that the point estimate of the board diversity index is only insignificant when the dependent variable is the firm's ratio of R&D to total assets *(R&D/Assets)*. Taking the above into account, while without controls, the board diversity index's estimates are significant, I cannot accept the thesis' hypothesis due to the fact that when I control for board and firm characteristics *Brd_diversity* becomes insignificant.

Table 4: Board diversity and innovation without controls

Table 4 reflects the relation between board diversity and innovation, without taking into account director and firm characteristics. The dependent variable is the firm's innovation, measured by *R&D/Assets* in column 1, *ln(R&D)* in column 2, *Patent* in column 3, and *Granted_patent* in column 4. The only independent variable is the *Brd_diversity* index. The t-statistics are included in the parentheses. *, **, *** correspond to the significance level of 10%, 5%, and 1%, respectively.

	Dependent variable			
	R&D/Assets	ln(R&D)	Patent	Granted_patent
	(1)	(2)	(3)	(4)
Brd_diversity	-0.005	0.810 **	0.770**	0.759**
	(-0.901)	(2.431)	(2.476)	(2.415)
Controls	No	No	No	No
Observations	176	176	176	176
R^2	0.004	0.032	0.034	0.032

I additionally regress the innovation input and output proxies against the composite board diversity's index dummy variable *(Brd_diversity_dummy)*. Table 5 presents the results which are mostly similar to those of the board diversity's continuous variable. The point estimates of the *Brd_diversity_dummy* are positive and higher than those of *Brd_diversity*, however, they are still not significant. Regarding the controls added to the regressions, it is evident that *Firm_size*, *Tangibility*, and *ROA* remain significantly related to corporate innovation. Also, although the coefficients are not very high, *Cash* seems to positively influence the ratio of R&D expenses to total assets and *Executive* negatively influences the innovation output proxy of *Patent*.

Table 5: Board diversity indicator and innovation

Table 5 reports the results of the regression where the main variable of interest is the *Brd_diversity_dummy* variable and the dependent variable is the firm's innovation. *Brd_diversity_dummy* is a dummy variable that equals 1 if the firm's combined diversity dummy lies above the sample median, and 0 otherwise. Innovation is measured by: (1) *R&D/Assets*, (2) *ln(R&D)*, (3) *Patent*, and (4) *Granted_patent*. Controls are added in all of the regressions. The t-statistics are included in the parentheses. *, **, *** correspond to the significance level of 10%, 5%, and 1%, respectively.

	Dependent variable			
	R&D/Assets	ln(R&D)	Patent	Granted_patent
	(1)	(2)	(3)	(4)
Brd_diversity_dummy	0.003	0.218	0.257	0.229
	(0.733)	(1.080)	(1.176)	(1.025)
Firm_size	0.001	0.880 ***	0.717 ***	0.709 ***
	(0.343)	(14.779)	(11.152)	(10.793)
Leverage	-0.022	-0.542	-0.107	0.080
	(-1.420)	(-0.897)	(-0.165)	(0.121)
Tangibility	-0.089 ***	-5.968 ***	-4.311 ***	-4.191 ***
	(-4.539)	(-7.865)	(-5.259)	(-5.006)
Cash	0.129 ***	2.352	0.463	-0.187
	(3.860)	(1.822)	(0.332)	(-0.132)
ROA	0.060	3.793 ***	4.537 ***	4.727 ***
	(1.636)	(2.646)	(2.971)	(3.031)
Executive	-0.001	-0.225	-0.410 *	-0.367
	(-0.246)	(-1.101)	(-1.853)	(-1.628)
Dual_position	-0.014	-0.232	-0.234	-0.259
	(-1.358)	(-0.571)	(-0.533)	(-0.578)
Controls	Yes	Yes	Yes	Yes
Observations	176	176	176	176
R^2	0.238	0.650	0.526	0.515

To sum up, while I find that board diversity is positively associated with the firm's innovation levels, I cannot confirm prior literature findings since the results are insignificant. Considering that I hand collect board characteristics information, I focus only on one year of data and on a limited number of firms, which could result in insignificant findings. However, following An et al. (2021), I regress the four innovation measures against each of the six diversity components to examine whether a certain aspect of diversity alone can significantly influence corporate innovation.

Table 6 presents the results. Contrary to the findings of the composite board diversity index, it is apparent that the estimated coefficients of the educational diversity component are positive and statistically significant at the 10% level across all four columns. As described in section 3, educational diversity is the proportion of directors serving on the board who hold a Ph.D. diploma. The results suggest that, in line with the findings by An et al., (2021), the educational component of diversity notably positively affects both the firm's R&D spending and the generation of a higher number of patents. For instance, in terms of economic magnitude, a 1

standard deviation increase in educational diversity results in a 0.268 (= 0.19 × 1.4111) increase in *Granted_patent*, which represents 3.4% (= 0.268/7.91) of its mean. Furthermore, nationality diversity appears to significantly matter for the firm's innovation input. The point estimates of *Nationality_diversity* are -0.0026 in column 1, and -2.418 in column 2 respectively. Nationality diversity is calculated as the ratio of the directors who have the same nationality to the total number of directors in the boardroom. Therefore, the negative coefficients indicate that nationality diversity has actually a positive impact on innovation input. The findings suggest that diverse nationality backgrounds contribute to the investment in R&D expenditures. In addition, the coefficients of the director experience component of diversity are positive and statistically significant at the 10% level in columns 3 and 4. These results indicate that firms with directors who have previously held positions on other companies' boards generate more patents and granted patents. Lastly, even though the point estimate of professional diversity in column 1 is relatively small, it is still positive and statistically significant, revealing that diverse professional backgrounds and expertise positively influence the firm's R&D spending. I include in all of the regressions the same set of control variables used in the models where the independent variable is the board diversity index. Similar to the findings in Tables 3 and 5, *Tangibility* is negatively associated with corporate innovation, *ROA* positively influences the firm's innovation and lastly, larger firms produce a greater number of patents and invest in R&D.

Table 6: Diversity components and innovation

Table 6 presents the impact of the six diversity components on firm innovation. The dependent variable is the firm's innovation, measured by *R&D/Assets* in column 1, *ln(R&D)* in column 2, *Patent* in column 3, and *Granted_patent* in column 4. The main variables of interest are the six components of board diversity. Controls are added in all of the regressions. The t-statistics are included in the parentheses. *, **, *** indicate the statistical significance level of 10%, 5%, and 1%, respectively.

	Dependent variable			
	R&D/Assets (1)	ln(R&D) (2)	Patent (3)	Granted_patent (4)
Tenure_diversity	0.011	0.329	-0.353	-0.436
	(1.150)	(0.923)	(-0.911)	(-1.105)
Nationality_diversity	-0.026 *	-1.007 *	-0.481	-0.493
	(-2.396)	(-2.418)	(-1.062)	(-1.070)
Educational_diversity	0.037 *	1.385 *	1.365 *	1.411 *
	(2.575)	(2.501)	(2.266)	(2.301)
Professional_diversity	0.041 *	-0.490	-0.285	-0.324
	(2.038)	(-0.629)	(-0.336)	(-0.375)
Director_experience_diversity	-0.010	0.760	1.650 *	1.693 *
	(-0.675)	(1.289)	(2.572)	(2.592)
Foreign_experience_diversity	-0.013	-0.699	-0.499	-0.668
	(-1.164)	(-1.566)	(-1.026)	(-1.352)

Firm_size	-0.003		0.815	***	0.662	***	0.653	***
	(-1.504)		(11.589)		(8.649)		(8.391)	
Leverage	-0.023		-0.303		0.026		0.217	
	(-1.509)		(-0.505)		0.039		(0.327)	
Tangibility	-0.087	***	-5.835	***	-4.311	***	-4.206	***
	(-4.501)		(-7.859)		-5.338		(-5.118)	
Cash	0.127	***	1.604		-0.469		-1.163	
	(3.759)		(1.232)		-0.331		(-0.807)	
ROA	0.066		3.611	*	4.398	**	4.580	**
	(1.841)		(2.602)		2.914		(2.982)	
Executive	0.000		-0.017		-0.140		-0.092	
	(0.065)		(-0.080)		-0.604		(-0.391)	
Dual_position	-0.009		-0.245		-0.297		-0.321	
	(-0.892)		(-0.605)		(-0.672)		(-0.716)	
Controls	Yes		Yes		Yes		Yes	
Observations	176		176		176		176	
R^2	0.305		0.678		0.557		0.551	

Finally, I employ regression models where the explanatory variable is each of the diversity component's dummy variable. As the results in Table 7 show, only educational diversity significantly affects the firm's innovation output as well as its R&D expenditures. The estimated coefficient of the educational diversity categorical variable is positive and significant at the 10% level across columns 2 to 4. Namely, the point estimate of 0.494 of educational diversity in column 2, reflects that there is a 63.6% (= $100 \times (e^{0.494} - 1)$) increase in R&D expenditures associated with switching *Educational_diversity_dummy* from 0 to 1. Similarly, the estimated coefficient of the educational diversity component is 0.512 in column 3, with a t-statistic of 2.287, and 0.53 in column 5, with a t-statistic of 2.317, indicating that, variation in academic degrees fosters innovation output.

Table 7: Diversity components indicators and innovation

Table 7 shows the effect of the dummy variables of the six diversity components on corporate innovation. The dependent variable is the firm's innovation, measured by the following proxies: (1) *R&D/Assets*, (2) *ln(R&D)*, (3) *Patent*, and (4) *Granted_patent*. Controls are added in all of the regressions. The t-statistics are included in the parentheses. *, **, *** indicate the statistical significance level of 10%, 5%, and 1%, respectively.

	Dependent variable			
	R&D/Assets	ln(R&D)	Patent	Granted_patent
	(1)	(2)	(3)	(4)
Tenure_diversity_dummy	0.006	0.333	-0.032	-0.072
	(1.233)	(1.685)	(-0.149)	-0.324

Nationality_diversity_dummy	0.007		0.348		0.289		0.276	
	(1.295)		(1.661)		(1.253)		1.171	
Educational_diversity_dummy	0.010		0.494	*	0.512	*	0.530	*
	(1.851)		(2.432)		(2.287)		2.317	
Professional_diversity_dummy	0.001		-0.386		-0.127		-0.125	
	(0.228)		(-1.691)		(-0.507)		-0.488	
Director_experience_diversity_dummy	-0.006		(0.021)		0.040		0.068	
	(-1.146)		0.107		(0.184)		0.310	
Foreign_experience_diversity_dummy	-0.001		-0.154		0.020		-0.043	
	(-0.204)		(-0.756)		(0.090)		-0.189	
Firm_size	-0.001		0.859	***	0.686	***	0.676	***
	(-0.352)		(13.438)		(9.730)		9.392	
Leverage	-0.020		-0.321		-0.040		0.123	
	(-1.287)		(-0.535)		(-0.061)		0.182	
Tangibility	-0.090	***	-5.899	***	-4.263	***	-4.153	***
	(-4.560)		(-7.933)		(-5.202)		(-4.962)	
Cash	0.131	***	2.064		0.020		-0.653	
	(3.890)		(1.617)		(0.014)		(-0.455)	
ROA	0.061		3.377	*	4.207	**	4.372	**
	(1.644)		(2.423)		(2.739)		(2.786)	
Executive	-0.001		-0.119		-0.287		-0.241	
	(-0.204)		(-0.572)		(-1.258)		(-1.034)	
Dual_position	-0.009		-0.108		-0.126		-0.159	
	(-0.819)		(-0.266)		(-0.282)		(-0.349)	
Controls	Yes		Yes		Yes		Yes	
Observations	176		176		176		176	
R^2	0.277		0.678		0.545		0.535	

Taking the above findings into consideration, while the composite board diversity index does not produce significant results, it is obvious that some components of board diversity do in fact positively impact the firm's corporate innovation. Therefore, addressing the cost-benefit trade-off of diversity, this research concludes that the benefits of board diversity outweigh its costs.

5. Discussion and Conclusion

This thesis studies the relationship between board diversity and corporate innovation. While academics have investigated board diversity and its impact on various firm outcomes over the

years, it is not until recently that their attention has shifted to the firm's innovation outcome. Innovation is considered an important determinant of the firm's level of competitiveness and thereby its growth in the market. The board of directors can play a crucial role in determining the firm's innovation process and building its strategy. Prior researchers argue that when the board consists of diverse team members from different backgrounds who bring a variety of expertise and perspectives, the firm's innovation levels increase. At the same time, opponents of diversity state that when diversity reaches very high levels, the decision-making process becomes slower and coordination problems exist, resulting in lower levels of innovation outcomes.

To address the above-mentioned empirical issue, I regress four different measures of innovation input and output against a multidimensional diversity index. I construct the board diversity index based on six diversity components, four cognitive aspects, and two demographic aspects. The combined diversity index and consequently the diversity components are measured based on the hand-collected director characteristics from the 176 firms consisting of this thesis's final sample. I find that the composite diversity index is not significantly associated with either innovation input or output. While the estimated coefficients of the board diversity index are positive, they are yet insignificant. The same results are observed when I construct a dummy variable of the board diversity index. As a result, I cannot accept or reject the thesis's main hypothesis that diversity in the boardroom fosters innovation. However, I find evidence to suggest that certain diversity components significantly matter to the firm's innovation levels. Specifically, the board's educational diversity is the one diversity aspect that matters both for innovation input as well as output. In addition, firms that employ directors of multiple nationalities devote more resources to R&D, and directors with past experience in other firms' boards bring expertise to their companies and produce a greater quantity of innovation output. Lastly, diversity based on the variation in professional backgrounds affects positively only the efficient allocation of the firm's R&D resources. To summarize, it is evident that mainly the cognitive aspects of diversity influence the firm's innovation levels, with the exception of nationality diversity which affects only the firm's R&D spending. Overall, my findings suggest that certain types of diverse backgrounds lead to an optimal innovation process and consequently it is evident that the benefits of board diversity offset any of its drawbacks.

I address some of the limitations of this study that could possibly explain the insignificant findings. First of all, I hand collect director characteristics information from the directors who constitute the 2021 board of directors. Therefore, I only focus on one year of data, limiting the year range and the number of observations. In addition, even though the hand collection sample is a unique aspect of this research, it consists of a specific number of firms from certain European countries. Due to time constraints and information availability, the hand collection sample is relatively smaller than a research sample retrieved from any available database. The latter remarks suggest that due to the smaller sample size and the focus on only the year 2021, the real effect of board diversity on innovation might not be captured.

Moreover, the thesis's regression models are subject to endogeneity problems. Both omitted correlated variables could exist as well as reverse causality concerns. To partially account for omitted correlated variables bias, I control for director and firm characteristics that

are potential determinants of corporate innovation. As I use only information for one year, I cannot perform a panel study and add firm and time-fixed effects to control for any unobservable variables. Therefore, this research is just an association study and does not generate causal inferences.

An additional shortcoming of this research is the fact that Orbis database does not provide intellectual property and patent information on a yearly basis. Thereby, I have access only to the firm's total number of publications and granted publications over the years. As a result, even though for the innovation input proxy I obtain the firm's 2021 R&D expenditures, for the innovation output proxies I retrieve collective publication information for more than one year.

Taken together, while I was not able to overcome the above-mentioned limitations, the thesis's findings still remain relevant. Firms that are aiming to gain a competitive advantage by developing new innovation strategies, find the information that directors from different nationalities, with high-level educational backgrounds, past director position experience, and professional expertise in multiple industries significantly add value to the firm's innovation process, valuable. Thereby, directors that are not one-dimensional and have diverse characteristics are able to promote efficient R&D spending and produce a greater number of patents.

Appendix A

Overview table of key academic papers on board diversity and innovation

Author	Year	Journal	Research Question	Main Results
Miller, T., & Triana, M. d.	2009	Journal of Management Studies	Does demographic board diversity, through reputation and innovation, impact firm performance?	There is a positive relationship between gender and racial board diversity and innovation. Reputation and innovation mediate the relationship between racial diversity in the boardroom and firm performance.
Chen, J., Leung, W., & Evans, K. P.	2018	Journal of Empirical Finance	Does the fraction of female directors on the board affect corporate innovation?	Boards with a higher proportion of female representation have higher R&D expenditures and patenting activity. The positive relationship between gender board diversity and innovation is more profound in "innovation-intensive" industries.
Griffin, D., Li, K., & Xu, T.	2021	Journal of Financial and Quantitative Analysis	Are gender-diverse boards more innovative?	Within a country, boards with a higher fraction of women produce more patents that also receive citations, are associated with more exploratory innovation, and have higher innovation efficiency. Board gender diversity is associated with CEO long-term incentives and greater failure tolerance compensation contracts, innovative corporate culture, and a greater fraction of minority inventors.
Cao, C., Li, X., Li, X., Zeng, C., & Zhou, X.	2021	Journal of Empirical Finance	Do firms with more ethnically diverse boards attract more minority inventors and produce more innovative outcomes?	Firms with more ethnically diverse boards recruit more minority inventors and promote collaboration between inventors from different ethnic backgrounds. There is a positive association between minority directors and the firm's innovation outputs. Diverse boards are significantly positively related to higher R&D spending.
Giannetti, M., & Zhao, M.	2019	Journal of Financial and Quantitative Analysis	Is there a cost-benefit tradeoff between ancestral board diversity and firm outcomes?	Ancestrally diverse boards have a more successful innovation process.

				Ancestral board diversity is associated with higher firm performance volatility and negatively associated with firm profitability.
Bernile, G., Bhagwat, V., & Yonker, S.	2018	Journal of Financial Economics	How is diversity in the boardroom related to firm risk and corporate policies?	Heterogeneity in the boardroom is associated with lower stock return volatility. Diverse boards implement more moderate corporate policies. Greater board diversity affects positively the level of R&D investments and results in better innovation quality.
An, H., Chen, C., Wu, Q., & Zhang, T.	2021	Journal of Financial and Quantitative Analysis	Does board diversity positively affect the level of corporate innovation?	Diversity at the board of directors' level is positively related to firm innovation, measured by the number of patents and patent citations.
Bernile, G., Bhagwat, V., Genin, A., & Ma, W.	2021	University of Miami Business School Research Paper	Does board diversity impact disruptive innovation?	Diverse boards generate technological breakthroughs in previously unfamiliar domains and produce a higher number and a better quality of disruptive and novel patents.

Appendix B

Overview table of hand-collected sample

Country	Number of Companies	Number of Directors
Austria	12	84
Belgium	15	142
Switzerland	15	119
Deutschland	19	171
Spain	15	166
France	14	159
United Kingdom	14	162
Greece	3	28
Ireland	6	60
Italy	12	130
Luxembourg	6	45
Netherlands	15	111
Norway	15	91
Sweden	15	132
Total	**176**	**1600**

Appendix C

Variable definitions table

Variable name	Description	Source
Tenure_diversity	Standard deviation of director tenure divided by mean of director tenure	Hand collection data
Nationality_diversity	Fraction of directors that are from the same country as the country in which the firm is located	Hand collection data
Educational_diversity	Fraction of directors holding either an MBA or a PhD diploma	Hand collection data
Professional_diversity	Number of different industries existing on the board divided by the total number of industries available	Hand collection data
Director_experience_diversity	Fraction of directors that have previous director positions in other firms	Hand collection data
Foreign_experience_diversity	Fraction of directors that have past professional experience abroad	Hand collection data
Tenure_diversity_dummy	Dummy variable that equals 1 if the firm has Tenure_diversity above the sample median of Tenure_diversity, and 0 otherwise	Hand collection data
Nationality_diversity_dummy	Dummy variable that equals 1 if the firm's Nationality_diversity is below the sample median of Nationality_diversity, and 0 otherwise.	Hand collection data
Educational_diversity_dummy	Dummy variable that equals 1 if the firm's Educational_diveristy is above the sample median of Educational_diveristy, and 0 otherwise	Hand collection data
Professional_diversity_dummy	Dummy variable that equals 1 if the firm's score of Professional_diversity is above the sample median of Professional_diversity, and 0 otherwise.	Hand collection data
Director_experience_diversity_dummy	Dummy variable that equals 1 if the firm's Director_experience_diversity lies above the sample median of	Hand collection data

	Director_experience_diversity, and 0 otherwise	
Foreign_experience_diversity_dummy	Dummy variable that equals 1 if the value of the firm's Foreign_experience_diversity lies above the sample median of Foreign_experience_diversity, and 0 if not	Hand collection data
Brd_diversity	Sum of the six board diversity components	Hand collection data
Brd_diversity_dummy	Dummy variable that equals 1 if firm's combined diversity dummy lies above the sample median, and 0 otherwise	Hand collection data
R&D/Assets	R&D expenditures divided by total assets	Compustat
ln(R&D)	ln(R&D expenditures + 1)	Compustat
Patent	ln(Total number of publications + 1)	Orbis
Granted_patent	ln(Total number of granted publications + 1)	Orbis
Executive	Dummy variable that equals 1 if the firm has at least one executive director on the board, and 0 otherwise	Hand collection data
Dual_position	Proportion of directors that have both a chairman and an executive position within the firm	Hand collection data
Firm_size	Natural logarithm of the total assets	Compustat
Leverage	Total liabilities divided by total assets	Compustat
Tangibility	Property, plants, and equipment (PPE) divided by total assets	Compustat
ROA	Operating income before depreciation divided by total assets	Compustat
Cash	Cash divided by total assets	Compustat

References

Adams, R. B., & Ferreira, D. (2009). Women in the boardroom and their impact on governance and performance. *Journal of Financial Economics, 94*, 291-309.

Adams, R. B., Akyol, A. C., & Verwijmeren, P. (2018). Director Skill Sets. *Journal of Financial Economics, 130*(3), 641-662.

Ahern, K. R., & Dittmar, A. K. (2012). The Changing of the Boards: The Impact on Firm Valuation of Mandated Female Board Representation. *The Quartely Journal of Economics, 127*(1), 137-197.

An, H., Chen, C., Wu, Q., & Zhang, T. (2021). Corporate Innovation: Do Diverse Boards Help? *Journal of Financial and Quantitative Analysis, 56*(1), 155-182.

Atanassov, Julian. "Do Hostile Takeovers Stifle Innovation ? Evidence from Antitakeover Legislation and Corporate patenting." *The Journal of Finance* 68.3 (2013): 1097-1131.

Baysinger, B., & Hoskisson, R. E. (1989). Diversification Strategy and R&D Intensity in Multiproduct Firms. *Academy of Management Journal, 32*(2), 310-332.

Bernile, G., Bhagwat, V., & Yonker, S. (2018). Board diversity, firm risk, and corporate policies. *Journal of Financial Economics, 127*(3), 588-612.

Bernile, G., Bhagwat, V., Genin, A., & Ma, W. (2021, January). Does Board Diversity Promote Disruptive Knowledge Diversity and Radical Innovation. University of Miami Business School Research Paper No.3908606. Retrieved from https://ssrn.com/abstract=3908606

Cao, C., Li, X., Li, X., Zeng, C., & Zhou, X. (2021). Diversity and inclusion: Evidence from corporate inventors. *Journal of Empirical Finance, 64*, 295-316.

Carter, D., Simkins, B., & Simpson, W. (2003). Corporate Governance, Board Diversity and Firm Value. *The Financial Review, 38*(1), 33-53.

Chen, J., Leung, W., & Evans, K. P. (2018). Female board representation, corporate innovation and firm performance. *Journal of Empirical Finance, 48*, 236-254.

Eckbo, B. E., Nygaard, K., & Thorburn, K. S. (2019). Board Gender-Balancing and Firm Value. ECGI Working Paper Series in Finance. Working Paper N° 463/2016. Retrieved from http://ssrn.com/abstract_id=2746786

Fang, V. W., Tian, X., & Tice, S. (2014). Does Stock Liquidity Enhance or Impede Firm Innovation? *The Journal of Finance, 69*(5), 2085-2125.

Giannetti, M., & Zhao, M. (2019). Board Ancestral Diversity and Firm-Performance Volatility. *Journal of Financial and Quantitative Analysis, 54*(3), 1117-1155.

Giannetti, M., Liao, G., & Yu, X. (2015). The Brain Gain of Corporate Boards: Evidence from China. *The Journal of Finance, 70*(4), 1629-1682.

Griffin, D., Li, K., & Xu, T. (2019, September). Board Gender Diversity and Corporate Innovation: International Evidence. Retrieved from https://ssrn.com/abstract=3266080

Griffin, D., Li, K., & Xu, T. (2021, February). Board Gender Diversity and Corporate Innovation: International Evidence. *Journal of Financial and Quantitative Analysis, 56*(1), 123-154.

Hafsi, T., & Turgut, G. (2013). Boardroom Diversity and its Effect on Social Performance: Conceptualization and Empirical Evidence. *Journal of Business Ethics*, 463-479.

He, J., & Tian, X. (2013). The dark side of analyst coverage:The case of innovation. *Journal of Financial Economics, 109*(3), 856-878.

Kor, Y. Y. (2006). Direct and Interaction Effects of Top Management Team and Board Compositions on R&D Investment Strategy. *Strategic Management Journal, 27*(11), 1081-1099.

Ma, W., Genin, A., Bernile, G., & Bhagwat, V. (2021, January). Does Board Diversity Promote Disruptive Knowledge Diversity and Radical Innovation. University of Miami Business School Research Paper No.3908606. Retrieved from https://ssrn.com/abstract=3908606

Matsa, D. A., & Miller, A. R. (2013). A Female Style in Corporate Leadership? Evidence from Quotas. *American Economic Journal: Applied Economics, 5*(3), 136-169.

Miller, T., & Triana, M. d. (2009). Demographic Diversity in the Boardroom: Mediators of the Board Diversity-Firm Performace Relationship. *Journal of Management Studies, 45*(5), 755-786.

Østergaard, C., Timmermans, B., & Kristinsson, K. (2011). Does a different view create something new? The effect of employee diversity on innovation. *Research Policy, 40*(3), 500-509.

Prabhakar, K., Lamar, K., & Shaikh, A. (2020, January 13). Foster Innovation, Ethical Tech With Diverse Teams. *The Wall Street Journal*.

Talavera, O., Yin, S., & Zhang, M. (2021). Tournament incentives, age diversity and firm performance. *Journal of Empirical Finance*, 139-162.

Torchia, M., Calabro, A., & Huse, M. (2011). Women Directors on Corporate Boards: From Tokenism to Critical Mass. *Journal of Business Ethics, 102*(2), 299-317.