APPLIED FINANCE LETTERS

VOLUME 05, ISSUE 02, 2016

BOARD COMPOSITION AND INNOVATION

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Abstract: Corporate boards make key economic and financial decisions. Diversity in the boardroom, on one hand can lead to higher innovation by increasing interaction between heterogeneous agents; on the other hand it can lead to more conflict based on the predictions of social identity theory. In an examination of U.S. firms from 2000 to 2006, this study finds that board members' ascribed characteristics - gender, ethnicity, nationality, age; and acquired characteristics - education and experience are associated with higher innovation in form of patents and quality of innovation in form of citations.

Keywords: Corporate boards; Innovation.

1. Introduction

Recent socio-economic developments have put diversity in the spotlight. For example, the public press regularly bemoans the lack of ethnic and gender diversity in Silicon Valley.[1] Diversity is an important characteristic of corporate boards, benefits of which have been relatively under-examined in academic literature (Broome et al., 2011).[2] Thus far, the lens through which boards of directors have been looked at is board size and proportion of independent directors (Coles et al., 2007; Dennis and Sarin, 1999; Yermack, 1996; Anderson et al., 2000; Borokhovich et al., 1996; Mayers et al., 1997).[3] However, as Coles et al. (2007) point out - one size doesn't fit all and based on firms' business activity the board composition may vary. In this paper, we examine an important characteristic of corporate boards – diversity, and its effect on innovation.

[1] https://www.theguardian.com/money/us-money-blog/2016/mar/06/silicon-valley-women-tech-industry-gender-pay-gap-bias
http://www.nytimes.com/2015/07/26/business/salesforce-makes-strides-toward-gender-equality-in-silicon-valley.html?_r=0
http://www.pbs.org/newshour/bb/how-silicon-valley-is-trying-to-fix-its-diversity-problem/

[2] Broome et al. (2011) interview corporate directors along the benefits of race and gender and generally discover that participants are reluctant to talk about these categories.

[3] Coles et al. (2007) find a U shaped relationship between board size and Tobin's Q.
Denis and Sarin (1999) show that board changes are strongly related to CEO turnover, past performance and threat from market for corporate control and weakly related to firm level factors such as stock return variance, size, leverage and growth opportunities. Yermack (1996) shows firms with small boards with more number of outside directors have higher market valuation. Anderson et al. (2000) also find a positive relationship between outside directors and firm value in diversified firms. Borokhovich et al. (1996) show that outside directors are associated with outside CEO replacement which is further associated with higher stock price returns. Mayers et al. (1997) also find outside directors are more efficient in mutual fund industry.

Schumpeter (1934) has called innovation as the engine of growth. Through innovation firms introduce novel products and processes that help them create new areas of profit or cut costs. Therefore, innovation keeps the businesses alive. However, Holmstrom (1989) defines innovation as risky, long-term and with high rates of failure. Corporate governance mechanisms, both internal and external, play a key role in determining the level and quality of innovation. Previous research looking at corporate governance and innovation has focused on the role of institutional investors (Aghion and Tirole, 2013): CEO incentives (Francis et al., 2016); market for corporate control (Seru, 2014); bank lending (Francis et al., 2012); shareholder rights (Sapra et al., 2014); and regulation (Shadab, 2008).

Corporate boards become relevant in the discussion about innovation because teams are much better at making risky decisions compared to individuals. Cooper and Kagel (2005) note that teams play more strategically and generate more positive synergies. Similarly, Rockenbach et al. (2007), and Blinder and Morgan (2005) study investment decisions by individuals and groups and find that groups make better decisions in terms of risk taking in uncertain environments than individuals. Kugler et al., (2012) conduct review of the literature on group decisions over past 25 years and find that results are widely consistent with rational decision making by groups. In context of innovation, diversity in groups becomes all the more important. Innovation is an interactive process and relies heavily on social cohesion (Lundvall, 1985, 92, 2002). Ostergaard et al., (2011) empirically show that employee diversity makes firms more innovative. A broader cultural and ethnic base leads to a greater knowledge base. Schumpeter (1934) asserts that a boarder knowledge base would produce more innovative ideas. Studies looking at diversity in top management teams also confirm the positive role of diversity in innovation (Williams and O'Reilly, 1998, ver der Vegt and Janssen, 2003; Woodman et al., 1993; Richard et al., 2004).[4] Because major economic decisions are made at the corporate board level, we concentrate on how diverse boards contribute to innovation.

To empirically test the effect of board composition on innovation, we gather data from four different sources – Boardex, RiskMetrics, NBER patent data project and Compustat. After matching these databases we are able to compile a sample of 5,432 U.S. firms spanning from 2000 to 2006. We measure innovation as the number of patents applied for by a firm in a given year. To capture the quality of innovation we use citations. More citations are associated with more radical innovation (Griliches et al., 1987; Hall et al., 2005). Following Ostergaard et al. (2011) and Ruef et al., (2003), we classify board diversity in form of ascribed and achieved characteristics of directors. Ascribed characteristics include gender, nationality, ethnicity, and age; and achieved characteristics include qualifications and experience.

We first look at ascribed characteristics. We find that male dominated boards have a negative relationship with patents. Further, a higher number of foreigners and non-Caucasian members on the corporate board is also associated with higher patents. In case of age, we look at the difference in ages of the oldest and youngest board member and we find that it has a positive relationship with patents. To determine the relationship between board characteristics and quality of innovation we look at their

[4] Williams and O'Reilly, 1998 provide a review of 80 studies over 40 of research on role of diversity in performance and creativity and provide mixed evidence. ver der Vegt and Janssen (2003) conduct a questionnaire study and find a strong correlation between innovation and task interdependence in heterogeneous teams. Woodman et al. (1993) develop a theoretical framework for organizational creativity and interaction.

impact on citations. Again gender has a negative impact, non-Caucasian and foreigners have a positive impact. Age range has a negative relationship with citations. Within the achieved characteristics we find that both education and experience have a positive impact on patents and citations. In general, we find that diversity is associated with higher innovation.

This paper contributes to the literature examining relationship between diversity and innovation in firms. The findings are consistent with those of Ostergaard et al., (2011), who find employee diversity brings in different points of view and adds to the interactive process of innovation.

In the next section we discuss our hypotheses, Section 3 provides an overview of the data, a description of variables and methodology. In Section 4 we discuss the results and conclude in Section 5.

2. Theoretical Background

2.1 Ascribed Characteristics: Gender, Nationality, Ethnicity, and Age

Gender Diversity: Extant research on risk taking behavior of women has mostly been consistent with risk avoidance (Bruce and Johnson, 1994; Hudgens and Fatkin, 1985; Sunden and Surette, 1998; Bernasek and Shwiff, 2001)[5]. However, other studies have shown evidence contrary to the stereotype that women are risk averse. For example, Barber (2001) and Huang (2008) show that men tend to be overconfident and make aggressive and risky decisions; Croson and Gneezy (2004) and Niederle and Vesterlund (2007) argue that women display risk aversion because they prefer less competitive situations; Johnson and Powell (1994) review the literature on male and female decision making and find no difference in risk taking of women, they, however, argue that stereotypes of women in non-managerial roles are imposed on women in managerial roles. Dwyer et al., (2002) suggest that the relationship between gender and risk taking may be a function of knowledge disparities. Weber and Zulehner (2010) show that startups with women have higher chances of survival. Adams and Funk (2011) look at gender differences in directors and find that female directors make more stakeholder oriented decisions but they are not necessarily risk averse. Adams and Ferreira (2009) show that female directors are also better monitors, although they document a negative relationship between gender diversity and firm performance. With already established gender differences in risk taking and economic decisions, gender differences should contribute to diverse points of view and hence should positively impact innovation.

National Cultural Diversity: Frijns et al., (2016) examine the role of national cultural diversity on corporate boards in determining firm outcomes. The authors find that national diversity has a negative relation with Tobin's Q. However, the authors find that the negative relationship disappears for complex firms with significant exposure to international markets. Their findings are consistent with Masulis et al. (2012) who show a negative effect of foreign directors on firm performance. In contrast, Estelyiova and Nisar (2016) show that foreign directors on boards are associated with better performance.

[5] Bruce and Johnson (1994) look at male and female betting behavior and find greater propensity for risk taking for men but better performance and confidence for women. Hudgens and Fatkin (1985) argue that gender differences occur when probably of success is low. Sunden and Surette (1998) also establish gender differences in investment portfolio decisions; Bernasek and Shwiff (2001) also find higher risk aversion in single womens' investment portfolio.

Ethnic Diversity: Ethnic diversity brings with it a broad spectrum of ideas in form of differences in attitudes, cognitive development, values and norms. Milliken and Martins (1996) argue that in small numbers ethnic diversity might be detrimental because minority groups may feel dissatisfied. However, on a larger scale, the benefits of new ideas and perspectives outweigh the costs and firms become more innovative. Richard (2000) further enforces the value of racial diversity. Richard et al., (2004) find a curvilinear relationship between cultural diversity and performance for high-risk firms. Richard et al., (2003) argue that racial diversity acts as a knowledge based resource and empirically show that racial diversity has a positive impact on performance only for innovative banks. The extant literature on the impact of racial and national cultural diversity on firm performance is mixed. We conjecture, because specifically innovation benefits from different points of views, its relationship with innovation should be positive.

Age Diversity: Studies on age have shown that younger employees are more innovative (Bantel and Jackson, 1989). Similarly, Wiersema and Bantel (1992) show that younger managers are more receptive to change and willing to more take risk. Compared to young executives, older executives have become more rigid as they age and avoid taking risks (Carlson & Karlsson, 1970; Vroom and Pahl, 1971; Taylor, 1975). Zajac et al., (1991) look at role of internal corporate joint ventures in enhancing innovation, and find that age similarity among members to be a critical factor. Younger boards, with similar age composition, therefore, should have a positive impact on innovation.

2.2 Achieved Characteristics: Qualification & Experience

Both experience and educational background have been documented to have a positive impact on firm performance. Cohen and Levinthal (1990) argue that a firm's investment in R&D is associated with role of diversity and expertise within an organization. Similarly, Murray (1989) shows that heterogeneous teams are more adaptive. Carpenter (2002) shows positive relationship between top management team heterogeneity and performance. The author captures heterogeneity in the form of education, functional experience and tenure. Finkelstien and Hambrick (1990) look at top management team tenure and find that it has a significant impact on corporate strategy and performance. Consistent with previous literature we should find experience and education to positively affect innovation.

3. Data and Methodology

3.1 Data

We obtain our data from three different sources. The information about board of directors comes from Boardex. Boardex is compiled by Management Diagnostic Corporation and contains biographic information about board members and executives. We use NBER patent data constructed by Hall et al., (2001) to get data on innovation. The authors have put together data on patents citations from United States Patent Office (USPTO) patent applications spanning the period 1963- 2006. Due to concerns regarding truncation bias in citations the authors also provide corrected citation data. We gather this data from NBER (see Hall et al., 2001, for details). We also obtain data on ethnicity of directors from RiskMetrics. Finally, we obtain financial and accounting information from Compustat.

We match firms in Boardex with other databases using ticker symbol and CUSIP derived from ISIN code. The patent data ends at 2006 and earliest year in Boardex is 1999. After

matching Boardex with NBER patent database and Compustat we are able to create a sample from 2000 to 2006, with 5432 unique U.S. firms of which 1216 firms applied for a patent during the sample period.

3.2 Description of Variables

We measure innovation as count of patents applied for by a firm. Because count of patents is a discrete variable we take logarithm of count of patents (Log Patents). In order to measure quality of innovation we use forward citations as another dependent variable (Log Citations). Forward citations are the number of citations a patent receives in subsequent years. Hall et al., (2005) show a positive relationship between forward citations firm value. Patent data ends in 2006, therefore there is no measure of citations after 2006 which leads to a truncation bias in the dataset. Hall et al., (2001) provide a corrected measure of citations that addresses the truncation bias.[6] Thus we take logarithm of corrected citations as our measure for quality of innovation.

To capture board diversity we use several variables. We measure %Male as number of males divided by total number of directors on board. %Foreigners is ratio of total number of foreigners to total number of directors on board. %Non-Caucasian is the ratio of non-Caucasian directors divided by to total number of directors on board.[7] Age Range is the difference in age of the oldest and youngest director on the board. Average Education is average number of qualifications of the board members. Time in role is the average number of years as director on the board.

We also control for board and firm level factors that have been shown to affect firm outcomes. For example, Yermack (1996) and Fich and Shivdasani (2006) provide evidence that busy boards are detrimental to firm value. Coles et al. (2007) show that focused on R&D benefit from having fewer independent directors, which is also consistent with previous literature (Fama and Jensen, 1983; Klein, 1998). However, Director's networks have been shown to positively affect innovation (Faleye, 2009). Consequently, we include measures for board size and independence. Board size is total number of directors on the corporate board. %Independent is the ratio of total non-executive independent directors to board size.

Our control variables include Book leverage, which is defined as is total debt divided by total assets, ROA is defined as net income divided by total assets, R&D/TA is R&D divided by total assets. We also include R&D missing, which is a dummy variable that equals one if R&D is missing and Log assets is log of total assets. All our regressions include year and two-digit SIC industry level controls.

[6] Hall et al. (2001) argue that due to the truncation of data, we do not observe citations beyond 2006. Further, citation intensities vary over time and industry classes. The authors use quasi-structural method, which allows for the separate identification of sources of variation related to time and cohorts. The NBER patent data file includes the corrected measure of patents using weights derived from the quasi-structural method. We use citations corrected using the quasi-structural method as our measure of the quality of innovation.

[7] The data on ethnicity comes from RiskMetrics, which categorizes director's ethnicity as Asian, African-American, Caucasian and Hispanic.

4. Results

4.1 Summary Statistics

Table 1 presents summary statistics for our key variables of interest. Out of 23,315 firm year observations we have patent data available for 3,891 firm years. On average, the firms in our sample applied for 34 patents and average citations received are 3,153. Book leverage is 22% and R&D/TA is at 5%. Average size of a firm in our sample is $7,457 million and ROA is -2%. Percentage of males in boards is about 93%, 5% of board members are foreign nationals, and 12% of board members are non-Caucasian. Average difference between the oldest and youngest board member is 25 years and board members have almost 2 qualifications.[8] The boards are almost 9 members in size and members have spent 6 years in their role as board members.

Table 1: This table presents the summary statistics of our variables of interest at firm level. Patents is total of number of patents applied for by the firm. Citations is number of corrected citations received. Board size is number of directors in the board. %Male is percentage of male members in the board. %Foreigners is percentage of foreign nationals in board. %Non-Caucasian is percentage of non-Caucasian directors on board. Age range is difference in ages of the oldest and youngest board member. Average age, is the average age of a director. Average education is number of qualifications. Board size is total number of directors on the board. % Independent is total Non-Executive Directors divided by total number directors. Time in Role is years spent as a director in the firm. Book Leverage is total debt divided by total assets. ROA is net income divided by total assets. R&D/TA is R&D divided by total assets. Assets is total assets.

	Mean	Median	5th Pctl	95th Pctl	#
Patents	33.68	3.00	1.00	123.00	3891
Citations	3153.45	50.40	0.00	9828.67	3891
%Male	92.60	100.00	75.03	100.00	22667
%Foreigners	0.05	0.00	0.00	0.32	15412
%Non-Caucasian	0.12	0.10	0.07	0.20	4819
Age Range	24.75	24.00	12.00	39.00	23283
Average Education	1.82	1.87	0.78	2.74	23035
Board Size	8.68	8.00	5.00	14.00	23282
%Independent	0.68	0.70	0.36	0.90	23315
Time in Role	5.88	5.33	1.48	11.98	23035
Book Leverage	0.22	0.17	0.00	0.64	23220
ROA	-0.02	0.03	-0.41	0.16	23289
R&D/TA	0.05	0.00	0.00	0.23	23315
Assets	7457.62	673.99	18.99	22284.90	23315

Table 2 shows board characteristics of patenting vs. non-patenting firms. Percentage of males in for patenting firms is slightly lower at 92% compared to non-patenting firms at 93%. Patenting firms also have larger number of foreign nationals. Ratio of foreign directors to board size for patenting firms is at 9% compared to non-patenting firms where it is 4%. There is no significant difference between ratio of non-Caucasian directors on boards, board size and percentage of independent directors of patenting versus non-patenting firms. The age range of directors for patenting firms is slightly lower than non-patenting firms. Directors in patenting firms have longer experience within the company (6.07 years, as compared to 5.83 years for non-patenting firms); they also have longer

[8] Average age of the board members is 58 years.

experience on other boards. R&D/TA for patenting firms is significantly higher and book leverage lower than their non-patenting counterparts.

4.2 Main Results

In this section, we look at the demographic composition of the board and its impact on innovation. Specifically, we look at the gender, nationality, ethnic, and age composition of the board. The results for these estimations are presented in Table 3.

Table 2: This table presents the T Tests of our variables of interest at firm level. %Male is percentage of male members in the board. %Foreigners is percentage of foreign nationals in board. %Non-Caucasian is percentage of Non-Caucasian directors on board. Age range is difference in ages of the oldest and youngest board member. Average age, is the average age of a director. Average education is number of qualifications. Board size is total number of directors on the board. % Independent is total Non-Executive Directors divided by total number directors. Time in Role is years spent as a director in the firm. Board size is number of directors in the board. ROA is net income divided by total assets. Book Leverage is total debt divided by total assets. R&D/TA is R&D divided by total assets. R&D missing is a dummy variable that equals one if R&D is missing. Assets is total assets.

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Assets	7457.62	673.99	18.99	22284.90	23315

Column 1 of Table 3 shows the relationship between %Male and Log Patents. The coefficient on %Male is negative and significant. This implies that increasing the number of males on corporate board has a negative impact on innovation. Column 2 shows results for %Foreigners and Log Patents and the coefficient on nationality diversity is positive and significant, therefore increasing the number of foreigners on the board should have a positive impact on innovation. Column 3 shows results for %Non-Caucasian directors on the board, and coefficient is positive and significant. Finally, Column 4 shows the impact of Age Range on Log Patents, the coefficient on Age Range is negative and significant. Columns 5 through 8 show the impact diversity measures on citations. Again, gender diversity has a negative effect, nationality and ethnic diversity has a positive effect on innovation and director age diversity in company has a negative and significant effect on citations. These findings are crucial, because they show that diversity is integral to promoting innovation.

Table 3: This table presents the OLS regression results. Log Patents is log of total number of patents applied for by the firm. Log Citations is log of corrected citations received. Board size is number of directors in the board. %Male is percentage of male members in the board. %Foreigners is percentage of foreign nationals in board. %Non-Caucasian is percentage of Non-Caucasian directors on board. Age range is difference in ages of the oldest and youngest board member. Board size is total number of directors on the board. %Independent is total Non-Executive Directors divided by total number directors. Book Leverage is total debt divided by total assets. ROA is net income divided by total assets. R&D/TA is R&D divided by total assets. R&D missing is a dummy variable that equals one if R&D is missing. Log Assets is log of total assets. All estimations include year and two digit industry fixed effects. Standard errors clustered at firm level are reported in the bracket. The ***, **, *, and + marks denote statistical significance at the 0.1%, 1%, and 5% level respectively

	Log Patents 1	Log Patents 2	Log Patents 3	Log Patents 4	Log Citations 5	Log Citations 6	Log Citations 7	Log Citations 8
%Male	-0.003*** [0.001]				-0.005* [0.002]			
%Foreigners		0.520*** [0.141]				0.749** [0.253]		
%Non-Caucasian			0.664* [0.344]				1.143* [0.684]	
Age Range				-0.002* [0.001]				-0.004* [0.002]
Board Size	-0.105* [0.042]	-0.127* [0.057]	-0.028 [0.112]	-0.077* [0.043]	-0.312*** [0.082]	-0.348** [0.108]	-0.105 [0.210]	-0.260** [0.082]
%Independent	0.187** [0.064]	0.275** [0.084]	0.403* [0.195]	0.191** [0.062]	0.383** [0.126]	0.524** [0.164]	0.817* [0.363]	0.395** [0.123]
Book Leverage	-0.213*** [0.050]	-0.284*** [0.068]	-0.379* [0.149]	-0.207*** [0.050]	-0.453*** [0.101]	-0.563*** [0.139]	-1.197*** [0.290]	-0.443*** [0.098]
ROA	-0.021 [0.048]	0.059 [0.077]	0.273 [0.244]	-0.019 [0.046]	-0.128 [0.107]	-0.053 [0.169]	-0.017 [0.534]	-0.122 [0.102]
R&D/TA	0.459*** [0.126]	0.895*** [0.202]	2.937*** [0.641]	0.460*** [0.122]	0.680** [0.255]	1.518*** [0.405]	5.227*** [1.316]	0.684** [0.246]
R&D Missing	-0.275*** [0.026]	-0.345*** [0.036]	-0.437*** [0.090]	-0.270*** [0.026]	-0.485*** [0.051]	-0.635*** [0.070]	-0.786*** [0.165]	-0.475*** [0.050]
Log Assets	0.141*** [0.010]	0.183*** [0.015]	0.282*** [0.031]	0.143*** [0.010]	0.227*** [0.017]	0.298*** [0.024]	0.443*** [0.050]	0.230*** [0.017]
Intercept	1.113*** [0.246]	0.365* [0.208]	-0.975** [0.304]	0.748*** [0.203]	3.260*** [0.439]	2.081*** [0.371]	-0.238 [0.560]	2.735*** [0.358]
#	22,552	15,323	4,377	23,160	22,552	15,323	4,377	23,160
R-squared	0.329	0.369	0.489	0.328	0.278	0.312	0.423	0.278

Next, we follow the extant literature and look at achieved characteristics of board members such as qualification and experience. These results are presented in Table 4.

Column 1 of Table 4 looks at Average Education and the coefficient is also positive and significant. Column 2 looks at Time in Role and the coefficient is positive and significant. Columns 3 and 4 show the impact of these variables on citations. Again education and experience have a positive impact.

Table 4: This table presents the OLS regression results. Log Patents is log of total number of patents applied for by the firm. Log Citations is log of corrected citations received. Average education is number of qualifications. Time in Role is years spent as a director in the firm. Board size is total number of directors on the board. %Independent is total Non-Executive Directors divided by total number directors. Book Leverage is total debt divided by total assets. ROA is net income divided by total assets. R&D/TA is R&D divided by total assets. R&D missing is a dummy variable that equals one if R&D is missing. Log Assets is log of total assets. All estimations include year and two digit industry fixed effects. Standard errors clustered at firm level are reported in the bracket. The ***, **, *, and + marks denote statistical significance at the 0.1%, 1%, and 5% level respectively

	Log Patents **1**	***Log Patents*** **2**	***Log Citations*** **3**	***Log Citations*** **4**
Average Education	0.061***		0.104**	
	[0.017]		[0.034]	
Log(Time in Role)		0.041*		0.067*
		[0.017]		[0.034]
Board Size	-0.090*	-0.093*	-0.284***	-0.288***
	[0.041]	[0.042]	[0.080]	[0.081]
%Independent	0.186**	0.204**	0.381**	0.412***
	[0.064]	[0.063]	[0.125]	[0.124]
Book Leverage	-0.202***	-0.203***	-0.437***	-0.440***
	[0.050]	[0.050]	[0.099]	[0.100]
ROA	-0.009	-0.039	-0.11	-0.159
	[0.047]	[0.047]	[0.105]	[0.104]
R&D/TA	0.412***	0.458***	0.605*	0.683**
	[0.122]	[0.123]	[0.249]	[0.250]
R&D Missing	-0.269***	-0.276***	-0.472***	-0.485***
	[0.026]	[0.026]	[0.051]	[0.051]
Log Assets	0.140***	0.145***	0.224***	0.233***
	[0.010]	[0.010]	[0.017]	[0.017]
Intercept	0.643**	0.646**	2.556***	2.565***
	[0.203]	[0.200]	[0.359]	[0.355]
#	22,920	22,920	22,920	22,920
R-squared	0.329	0.329	0.278	0.278

We combine all the variables of interest in one regression and present the results in Table 5. Column 1 of Table 5 shows results for Log Patents and Column shows results for Log Citations. %Male has a negative impact on our measures of innovation, and %Foreigners and %Non-Caucasian has a positive impact. Age Range and Average Education lose their significance and our measure of experience (Time in Role) has a positive impact. These findings are largely consistent with our previous results and the highlight the importance of ascribed characteristics in motivating innovation.

Table 5: This table presents the OLS regression results. Log Patents is log of total number of patents applied for by the firm. Log Citations is log of corrected citations received. Board size is number of directors in the board. %Male is percentage of male members in the board. %Foreigners is percentage of foreign nationals in board. %Non-Caucasian is percentage of Non-Caucasian directors on board. Age range is difference in ages of the oldest and youngest board member. Average education is number of qualifications. Time in Role is years spent as a director in the firm. Board size is total number of directors on the board. %Independent is total Non-Executive Directors divided by total number directors. Book Leverage is total debt divided by total assets. ROA is net income divided by total assets. R&D/TA is R&D divided by total assets. R&D missing is a dummy variable that equals one if R&D is missing. Log Assets is log of total assets. All estimations include year and two digit industry fixed effects. Robust standard errors are reported in the bracket. The ***, **, *, and + marks denote statistical significance at the 0.1%, 1%, and 5% level respectively

	Log Patents **1**	***Log Patents*** **2**
%Male	-0.005*	-0.009*
	[0.002]	[0.005]
%Foreigners	0.674***	1.006**
	[0.172]	[0.370]
%Non-Caucasian	0.684*	1.534*
	[0.290]	[0.612]
Age Range	-0.001	-0.005
	[0.002]	[0.005]
Average Education	0.052	0.122
	[0.040]	[0.086]
Log(Time in Role)	0.167***	0.298***
	[0.038]	[0.082]
Board Size	-0.065	-0.191
	[0.084]	[0.179]
% Independent	0.423**	0.779**
	[0.141]	[0.277]
Book Leverage	-0.465***	-1.358***
	[0.108]	[0.233]
ROA	0.177	-0.402
	[0.222]	[0.509]
R&D/TA	2.597***	4.574***
	[0.517]	[1.133]
R&D Missing	-0.458***	-0.836***
	[0.057]	[0.125]
Log Assets	0.264***	0.413***
	[0.019]	[0.037]
Intercept	-0.680*	0.258
	[0.386]	[0.779]
#	3,743	3,743
R-squared	0.511	0.448

4.3 Robustness

In this section, we focus our attention again on gender, nationality and ethnic diversity. We look at changes in diversity scores. We create a dummy variable called %Male ↓Dummy, which equals 1 for negative changes in percentage of males and 0 otherwise. %Foreigner↑Dummy is a dummy variable, which equals 1 for positive changes in foreigners on boards and 0 otherwise. %Non-Caucasian↑Dummy is a dummy variable, which equals 1 for positive changes in non-Caucasians on boards and 0 otherwise. These results are presented in Table 6.

Table 6: This table presents the OLS regression results. Log Patents is log of total number of patents applied for by the firm. %Male↓Dummy is a dummy variable that equals one if the change in %Male is negative. %Male is percentage of male members in the board. %Foreigner↑Dummy is a dummy variable that equals 1 if change in %Foreigners positive. % Foreigners is percentage of foreign nationals in board. %Non-Caucasian↑Dummy is a dummy variable that equals 1 if change %Non-Caucasian is positive. %Non-Caucasian is percentage of Non-Caucasian directors on board. Board size is total number of directors on the board. %Independent is total Non-Executive Directors divided by total number directors. Book Leverage is total debt divided by total assets. ROA is net income divided by total assets. R&D/TA is R&D divided by total assets. R&D missing is a dummy variable that equals one if R&D is missing. Log Assets is log of total assets. All estimations include year and two digit industry fixed effects. Standard errors clustered at firm level are reported in the bracket. The ***, **, *, and + marks denote statistical significance at the 0.1%, 1%, and 5% level respectively

	***Log Patents* 1**	***Log Patents* 2**	***Log Patents* 3**
%Male↓Dummy	0.044**		
	[0.016]		
%Foreigner↑Dummy		0.125**	
		[0.047]	
%Non-Caucasian↑Dummy			0.229***
			[0.056]
Board Size	-0.103*	-0.099*	-0.105**
	[0.040]	[0.040]	[0.040]
%Independent	0.202**	0.209***	0.192**
	[0.062]	[0.062]	[0.062]
Book Leverage	-0.208***	-0.207***	-0.204***
	[0.049]	[0.049]	[0.049]
ROA	-0.017	-0.015	-0.012
	[0.046]	[0.046]	[0.046]
R&D/TA	0.462***	0.462***	0.462***
	[0.122]	[0.122]	[0.121]
R&D Missing	-0.271***	-0.271***	-0.269***
	[0.026]	[0.026]	[0.026]
Log Assets	0.143***	0.143***	0.140***
	[0.010]	[0.010]	[0.010]
Intercept	0.765***	0.757***	0.810***
	[0.204]	[0.203]	[0.202]
#	23,162	23,162	23,162
R-squared	0.328	0.329	0.33

Column 1 of Table 6 shows results for %Male↓Dummy regressed on Log Patents. We find that increases in women in corporate boards are associated with higher innovation. Similarly %Foreigner↑Dummy and %Non-Caucasian↑Dummy is also associated with higher innovation.

The findings in the paper support our initial predictions about a positive relation between gender, national culture and ethnic diversity on innovation.

5. Conclusion

We look at how diversity in form of ascribed and achieved characteristics of directors on the corporate board impact innovation. We find that ethnicity and nationality mix has a positive impact on innovation and age dissimilarity and lack of women has a negative impact. Qualifications and experience also contribute to higher innovation.

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