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Board Gender Diversity and Corporate Innovation: International Evidence

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Abstract

Using a novel database of firm patents and board characteristics across 45 countries, we examine both within- and cross-country determinants of board gender diversity and its relation to corporate innovation. Boards are more likely to include women in countries with narrower gender gaps, higher female labor market participation, and less masculine cultures. Firms with gender diverse boards have more patents and novel patents, and a higher innovative efficiency. Further analyses suggest that gender diverse boards are associated with more failure-tolerant and long-term chief executive officer (CEO) incentives, more innovative corporate cultures, and more diverse inventors, characteristics that are conducive to an improved innovative performance.

"Women have a different perspective, which can sometimes lead to better decision-making."

"The point is not to focus on whether one gender is better than the other – it's the mixture that counts."

— Elin Hurvenes, Founder and Chair of the Professional Boards Forum

I. Introduction

In recent years there has been an intense debate among regulators, policy makers, and media on the role of board gender diversity in creating shareholder value. This controversy has led a number of governments to institute mandatory

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gender quotas for corporate boards.[1] The adoption and/or promotion of such quotas rests on two fundamental propositions: i) Board gender diversity promotes public policy objectives such as increasing female labor market participation and female leadership; and ii) board gender diversity encourages better decision making and hence increases firm value. In this paper, we study the value-creation proposition through the lens of corporate innovation, the main engine of firm growth. We examine both within- and cross-country determinants of board gender diversity, and investigate how board gender diversity influences corporate innovation activities, using a novel database that combines firm-level patenting measures with board characteristics across 45 countries and 12,244 firms for the period 2001–2014.

Corporate innovation is known to be a key factor in driving firm competitiveness, productivity, and hence firm value (e.g., Pakes (1985), Austin (1993), Hall, Jaffe, and Trajtenberg (2005), and Kogan, Papanikolaou, Seru, and Stoffman (2017)). Unlike corporate investment in physical assets such as property, plant, and equipment, investment in innovation as measured by research and development (R&D) expenditures is highly risky, characterized by a prolonged period of resource commitment and a high degree of uncertainty. Patents, a common marker for innovation output, take a number of years to develop, and there is no guarantee that granted patents will turn out to be novel and impactful.

Our theoretical framework builds on the established positive link between organizational diversity and creativity (Stahl, Maznevski, Voigt, and Jonsen (2009)), as well as on a number of established gender differences in decision making that have implications for corporate innovation practices (Croson and Gneezy (2009)). These include gender differences in overconfidence, risk aversion, long-term orientation, and personal values (Beyer (1990), Silverman (2003), and Schwartz and Rubel (2005)).

Modern corporations are faced with the constant challenge of mitigating the inherent risk in corporate innovation without sacrificing its long-term value, which comes from its novelty and impact. In particular, excessive managerial risk-taking and overconfidence might lead to choices of risky innovation projects with negative net present values (because of either the low probability of success or the high cost, see, for example, Heaton (2002), and Baker and Wurgler (2013)). On the other hand, management's excessive focus on short-term profits can lead to a refusal to take on innovation projects that are more exploratory with a longer payoff period (Graham, Harvey, and Rajgopal (2005), Krehmeyer, Orsagh, and Schacht (2006)). Given the evidence of gender differences in decision making, we propose that female directors on corporate boards might help mitigate both excessive risk-taking and excessive short-term focus in corporate innovation practices, resulting in lower-cost and more novel innovation.

We first present large-sample evidence on the prevalence of women on corporate boards around the world and then examine within- and cross-country

[1]For example, since 2003 at least 40% of directors in publicly listed Norwegian firms must be women (Ahern and Dittmar (2012), Matsa and Miller (2013), and Eckbo, Nygaard, and Thorburn (2019)). Mandatory quotas were also instituted in Iceland in 2010, Belgium, France, and Italy in 2011, Germany in 2015, and the state of California in the United States in 2018, and voluntary quotas were instituted in Spain in 2007 and the Netherlands in 2009.

determinants of board gender diversity. We show that across the 45 countries in our sample, the fraction of female directors on corporate boards is 8.5%. We further show that corporate boards are more likely to include women in countries with more female CEOs, larger firms, lower asset tangibility, formal regulations promoting gender equity (consistent with Adams and Kirchmaier (2015)), a narrower gender gap, a higher level of female labor market participation, a lower masculinity cultural dimension, and higher gross domestic product (GDP) per capita.

We next examine the link between board gender diversity and corporate innovation. We show that, within a country, the proportion of female directors on a corporate board is associated with more innovation as measured by citation-weighted patent count, more novel (exploratory) innovation as captured by the scope of citations by a firm's patents, and greater innovative efficiency as measured by citation-weighted patent count normalized by R&D capital. These associations largely hold across countries when we examine country averages.

To address the reverse causality concern, we employ a change-on-change specification to assess how the proposed board gender diversity-corporate innovation relation unfolds over time. We find that an increase in gender diversity on boards is followed after 2 or more years by an improvement in innovative performance, and the effect also increases monotonically as we measure changes in innovation outcomes over longer windows, suggesting that reverse causality unlikely drives our results.

We also exploit a reform in Norway as a natural experiment to further strengthen identification. In 2003, Norway introduced a board gender quota that requires 40% of directors in publicly listed Norwegian firms be women. Using an instrumental variables strategy following Ahern and Dittmar (2012) and Eckbo et al. (2019), we find that an increase in the number of women on Norwegian boards is followed by an increase in the innovation output of these firms. This finding again suggests that the effect of gender diversity on corporate innovation is likely to be causal.

Finally, we explore potential mechanisms by which board gender diversity may enhance corporate innovation. Motivated by the literature on incentive design and organization science in corporate innovation (e.g., Hunt and Gauthier-Loiselle (2010), Manso (2011), Díaz-Garcí, González-Moreno, and Sáez-Martínez (2013), and Li, Mai, Shen, and Yan (2020)), we posit that board gender diversity affects corporate innovation through three nonmutually exclusive channels: i) Setting managerial contracts that incentivize innovation; ii) fostering an innovative corporate culture; and iii) increasing diversity among inventors. We show that the proportion of female directors on a corporate board is associated with more failure-tolerant and long-term-oriented CEO incentives. We further show that the proportion of female directors on a corporate board is uniquely associated with the innovation dimension of corporate culture. Finally, we find a positive association between board gender diversity and measures of inventor gender diversity and ethnic diversity.

We conduct a large number of robustness checks on our main findings, including using alternative patenting measures and alternative samples, allowing nonlinear effects, focusing on specific industries, controlling for other dimensions

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of board diversity, and employing a network-based instrumental variable. Overall, our main findings on the positive association between board gender diversity and corporate innovation remain largely unchanged.

Our paper makes the following contributions to the literature. First, using a larger set of countries (and firms) than most prior studies, we provide novel evidence on the important link between board gender diversity and corporate innovation. Our findings contrast prior work showing that risk-seeking and overconfidence unambiguously benefit corporate innovation (Hirshleifer, Low, and Teoh (2012), Sunder, Sunder, and Zhang (2017)), and suggest that a balanced risk attitude induced by board gender diversity helps promote valuable and cost-efficient innovation.

Second, we propose and test potential mechanisms (i.e., CEO incentives, corporate culture, and inventor diversity) by which board gender diversity affects corporate innovation. Our results on the mechanisms highlight that board gender diversity influences corporate innovation through both formal and informal contracts, as well as diversity spillover to rank-and-file inventors.

Finally, we introduce new methodologies to the literature on corporate boards. Our hierarchical linear model (HLM) framework helps distinguish cross- and within-country effects, and allows for cross-level interactions that provide insights into how and why the relation between board gender diversity and corporate innovation varies across countries. Our change-on-change specification helps to address the reverse causality concern and gain a better understanding of the dynamic relation between board gender diversity and innovative performance.

The paper proceeds as follows: Section II develops the hypotheses. We describe our sample and key variables in Section III. Section IV presents the main results on the relation between board gender diversity and corporate innovation and explores the mechanisms. We conduct a large number of robustness checks in Section V. Section VI concludes.

II. Hypothesis Development

Innovation is the main engine of firm growth. Since innovation involves the exploration of new and untested ideas, at every stage of the process it is important for management and the board to deliberate, and for the board to serve as a source of external perspective and to provide timely feedback on the strategic directions for the next stage of development (Balsmeier, Buchwald, and Stiebale (2014), Kang, Liu, Low, and Zhang (2018)).

Research from psychology and management suggests significant gender differences in personal characteristics including long-term orientation (Silverman (2003), Croson and Gneezy (2009)). More gender diverse boards may be more focused on long-term rather than short-term performance, and this may be reflected in CEO incentive schemes that they develop. Manso (2011) proposes that an optimal innovation-motivating incentive scheme includes a combination of stock options with long vesting periods, option repricing, parachutes, and managerial entrenchment. Ederer and Manso (2013) empirically test that corporate innovative performance is responsive to executive compensation contracts that feature tolerance for earlier failure and reward for long-term success. We thus hypothesize that more gender diverse boards are associated with CEO incentive schemes that feature more tolerance for failure and a long-term orientation.

Management theory argues that more diverse boards, including more gender diverse boards, could positively affect corporate innovation practices through their impact on corporate culture. Minority members of a diverse board are more likely to challenge tradition and question status quo and inspire majority members to consider new ways of thinking (Johnson, van de Schoot, Delmar, and Crano (2015)). Corporate culture is "a system of shared values and norms that define appropriate attitudes and behaviors for organizational members" (O'Reilly and Chatman (1996), p. 160). Culture matters because employees will inevitably face choices that cannot be properly regulated ex ante (O'Reilly (1989), Kreps (1990)). Li et al. (2020) show that the innovation dimension of corporate culture from Guiso, Sapienza, and Zingales (2015) is positively associated with better innovation outcomes such as patent count and innovation strength obtained from the Kinder, Lydenberg, and Domini data set (KLD). We thus hypothesize that more gender diverse boards are associated with a corporate culture that promotes innovation.

Management theory also argues that more diverse boards including more gender diverse boards could positively affect corporate innovation practices through their promotion of a more diverse labor force (Dezsö and Ross (2012)). More diverse inventor teams bring different knowledge and perspectives to problem solving (Page (2007)). The presence of team members with different backgrounds can inspire inventor teams to explore novel solutions in uncertain situations that lead to more radical or disruptive innovation. A large number of studies show that more diverse teams, including more gender and ethnically diverse teams at the research and development level, are more creative than more homogeneous teams (e.g., Østergaard, Timmermans, and Kristinsson (2011) and Díaz-García et al. (2013) on gender diversity, and Hunt and Gauthier-Loiselle (2010), Kerr and Lincoln (2010), and Bernstein, Diamond, McQuade, and Pousada (2019) on ethnic diversity). We thus hypothesize that more gender diverse boards are associated with more gender and ethnically diverse inventor teams.

Based on the preceding discussions on the mechanisms by which board gender diversity may affect corporate innovation outcomes, our first hypothesis is as follows:

Hypothesis 1. More gender diverse boards are associated with greater corporate innovation output as measured by more patents and more novel patents.

Research in psychology and economics, largely based on laboratory evidence, has consistently found that women are less overconfident than men whether overconfidence is measured as excessive precision of beliefs or as over-estimation of the likelihood of success (Croson and Gneezy (2009)). This is consistent with studies that examine investment decisions by day traders (Barber and Odean (2001)), corporate financial and investment policies by executives (Huang and Kisgen (2013)), and mergers and acquisitions (M&A) decisions by corporate boards (Levi, Li, and Zhang (2014)).

Surveys in both psychology and economics (Schwartz and Rubel (2005), and Adams and Funk (2012)) indicate that women relative to men tend to score lower on measures of personal values related to success and achievement (e.g., power, stimulation, and self-direction) and higher on personal values related to community (e.g., benevolence and universalism). Similarly, experimental and survey evidence in psychology indicates that women, on average, are more patient and less impulsive than men when trading off present versus future values (Silverman (2003), and McLeish and Oxoby (2007)). Although these personal value differences have not been applied to predict corporate decision-making, they imply that female directors might avoid the overinvestment that comes from an overemphasis on achievement while still pursuing innovative projects for their long-term benefits.

These gender differences imply that female directors in their advisory capacity might require a higher expected payoff and/or a higher likelihood of success to approve investment projects, leading to more efficient innovation.[2] The above discussions lead to our second hypothesis:

Hypothesis 2. More gender diverse boards are associated with higher innovative efficiency.

III. Empirical Framework, Sample Formation, and Key Variables

A. A Hierarchical Linear Model

Our data structure is multilevel. At the country level, we have firms from 45 countries. At the firm level, we have more than 12,000 firms for up to 14 years.

To separate the within-country and cross-country effects of firm-level board gender diversity on innovation outcomes, we employ the following hierarchical linear model specification (HLM; see Greene (2011), Chapter 15.8):

$$y_{i,j,t+1} = \alpha_j + \mathbf{x}'_{i,j,t}\beta + u_{i,j,t}, \quad (1a)$$

$$\alpha_j = \mathbf{w}'_j\gamma + \upsilon_j, \quad (1b)$$

where $y_{i,j,t}$ is an outcome variable such as citation-weighted patent count for firm i from country j in year t. $\mathbf{x}_{i,j,t}$ is a vector of firm-level characteristics such as the fraction of female directors on a board and board size. α_j is a country-level intercept term. To capture the pure firm-level (within-country) relation between $\mathbf{x}_{i,j,t}$ and the outcome variable $y_{i,j,t}$ in β of equation (1a), we remove the country-year means from all firm-level observations in $\mathbf{x}_{i,j,t}$.[3] $\mathbf{w}_j$ is a vector of country-level characteristics including female labor participation and national culture.

[2] It is worth noting that there are a number of studies documenting the dark side of diversity, namely, the presence of dissimilar directors on a board can increase coordination costs and decrease board members' ability to work together as a group on recommendations related to investment projects, acquisitions, and other key decisions (e.g., Goodstein, Gautam, and Boeker (1994), Knyazeva, Knyazeva, and Raheja (2013), Adams, Akyol, and Verwijmeren (2018), Garlappi, Giammarino, and Lazrak (2017), Donaldson, Malenko, and Piacentino (2018), and Giannetti and Zhao (2019)). While diversity may become excessive and cause communication and coordination problems, this concern is unlikely to be severe for board gender diversity when there is only a small minority of women (on average, less than 9% of directors are women).

[3] Note that removing the country-year means from all firm-level observations in $\mathbf{x}_{i,j,t}$ is equivalent to including country and year fixed effects in the within-country model of equation (1a).

To capture the pure country-level relation between $\mathbf{w}_j$ and the country-level intercept term α_j in γ of equation (1b), we include in $\mathbf{w}_j$ both country-level variables and country-year means of firm-level characteristics (as in $\mathbf{x}_{i,j,t}$). We estimate the HLM in equation (1) using the iterative maximum likelihood fitting procedure available in Stata (using the procedure "mixed").

There are two advantages to using the HLM approach in our setting. First, by decomposing firm-level variables in $\mathbf{x}_{i,j,t}$ into country-year means and firm-level deviations and by adding the country-year means to the set of country-level predictors in $\mathbf{w}_j$, we are able to completely separate the within-country and cross-country effects (Raudenbush and Bryk (2002), and Li, Griffin, Yue, and Zhao (2011), (2013)). This decomposition allows us to explore the potentially different associations between the fraction of female directors on a board and patent count both within a country and across countries.

Second, the HLM framework corrects for the distortion introduced by varying sample sizes across countries[4] and for the distortion in standard errors due to within-country clustering (the latter is similar to a country random-effects model where the standard errors are adjusted to reflect the cross-correlation between firms due to common country components).

B. Sample Formation

Our analysis employs data from a number of sources. To obtain data on gender diversity on corporate boards around the world, we rely on BoardEx, a proprietary database that covers more than 20,000 companies in 101 countries with detailed director information including director gender. To obtain data on firm financial characteristics, we rely on the Osiris database provided by Bureau van Dijk (BvD). To obtain data on corporate innovation, we use the patent and citation data from the United States Patent and Trademark Office (USPTO), which covers patents filed in the United States by firms from 230 different countries, and which has been used by Hsu, Tian, and Xu (2014) and Bena, Ferreira, Matos, and Pires (2017) to study corporate innovation around the world.[5] For country-level variables, we employ data from Deloitte, Catalyst, and Adams and Kirchmaier (2015) for national policy initiatives regarding board gender diversity, data from the World Bank for female labor market participation, data from the World Economic Forum for its gender gap index on gender equality, Hofstede's cultural dimension of masculinity from his website (Hofstede (2001)), and data from the World Bank's World Development Indicators Database for economic and financial development measures. Our final sample comprises 12,244 firms with 85,416 firm-year observations from 45 countries over the period 2001–2014. To our knowledge,

[4]Unlike ordinary least squares (OLS), where each firm-level observation receives equal weight, HLM simultaneously models regressions at both the country level and the firm level, with the country-level regression weighted by the precision of the firm-level data.

[5]There are two major reasons for us to employ the USPTO patent data for an international study (see Bena et al. (2017) for more extensive discussions). First, the USPTO provides a common standard for granting patents, while individual national offices might adopt varying standards that makes cross-country comparison difficult or impossible to interpret. Second, patents granted by the USPTO reflect the most important (i.e., economically significant) innovation by firms around the world. Nonetheless, in our robustness check, we will employ "triadic" patents granted by all 3 major patent offices: the USPTO, the European Patent Office, and the Japanese Patent Office.

this is one of the largest data sets ever compiled for the study of corporate directors at the international level. Table IA1 in the Supplementary Material summarizes our sample coverage across countries and over time.[6,7]

C. Key Variables

FEMALE_DIRECTOR_RATIO is the fraction of female directors on a board.

Measures of Corporate Innovation

To capture the quantity of innovation, we use the citation-weighted number of patents applied for by a firm over a 3-year window. To capture the novelty or exploratory nature of innovation, we use SCOPE, which captures the degree to which a firm acquires new knowledge outside of its current expertise (i.e., new citations beyond those citations made by the firm's patents over the past 5 years) (Gao, Hsu, and Li (2018)). To capture the efficiency of innovation, we use the citation-weighted number of patents normalized by R&D capital (i.e., the amount of innovation output per dollar of R&D capital) (Hirshleifer, Hsu, and Li (2013)).

Regulatory and Societal Support for Gender Equity

To characterize the level of national policy initiatives regarding boardroom gender diversity in each country, we use three measures (Adams and Kirchmaier (2015), and see the Appendix for detailed variable definitions and data sources). REGULATION_QUOTA captures whether a country's main stock exchange or securities laws stipulate a minimum quota for either the percentage or number of female directors on a board. REGULATION_CODE captures whether a country's governance code mentions that gender must be considered in director nominations. REGULATION_DISCLOSURE captures whether a country's main stock exchange or securities laws stipulate that board diversity be disclosed.

To characterize the level of a country's informal support for gender equity in the labor force, we use two measures following Adams and Kirchmaier (2015). The gender gap index (GGI) is an annual index published by the World Economic Forum measuring the extent to which women are disadvantaged compared with men in economic participation and opportunity, educational attainment, political empowerment, and health and survival. A higher value of this measure means a larger gender gap between women and men. FEMALE_LABOR_MARKET_PARTICIPATION, from the World Bank, captures the percentage of a country's female population aged 15 and above that participates in the labor force.

National Culture Dimension

The national culture measure that we use in our analyses is Hofstede's (1980), (2001) masculinity dimension. This measure was constructed from answers to a large survey of 117,000 IBM employees across their worldwide subsidiaries in

[6]The number of firm-year observations included by country varies from 5 for the Czech Republic and Malta on the low end to 41,416 for the United States and 14,132 for the United Kingdom on the high end. The sample coverage is increasing over time.

[7]Table IA2 in the Supplementary Material compares our sample firms to the Osiris universe of public firms. We show that our sample firms are fairly representative of the Osiris universe of public firms.

70 countries between 1967 and 1973 (see the Appendix for a detailed discussion). For example, one of the most heavily weighted items (negatively) in the masculinity index is rating the importance of "Work with people who cooperate well with one another," which captures the idea that a masculine culture is instrumental about achievement, with less emphasis on nurturance and mutual support. This item, like others in the index, represents a guideline for appropriate behavior and does not directly translate into corporate decision making (and hence exogenous).[8] Countries high in masculinity emphasize conformity to traditional gender roles, thus in these countries, women should be less likely to choose nontraditional career roles.

IV. Main Results

A. Descriptive Statistics

Panel A of Table 1 reports country-level descriptive statistics for the explanatory variables. We note that the average proportion of female directors on a board is highest in Norway (27%), and lowest in Malta (2%). The highest GGI is found in Morocco (0.42), and the lowest is in Finland (0.18). Morocco and Turkey have the lowest female labor market participation (0.27), and Peru has the highest (0.67). The country with the highest score in masculinity is Japan (0.95), and the country with the lowest score is Sweden (0.05). As a reference, the United States, with the largest number of firms in the sample, has an average proportion of female directors on a board of 8%, GGI of 0.29, female labor market participation of 58%, and masculinity score of 0.62.

Panel B of Table 1 reports country-level correlations for the explanatory variables. We first show that the proportion of female directors on a board is positively correlated with all three measures of policy initiatives regarding board gender diversity, female labor market participation, and GDP per capita, and negatively correlated with GGI and masculinity. All three measures of policy initiatives regarding board gender diversity and female labor market participation are negatively correlated with masculinity, whereas GGI exhibits a positive correlation with this measure.

Panel A of Table 2 reports summary statistics for the firm-level variables. Panel B reports Pearson correlations among the firm-level variables in 2008 after removing their respective country-year means. Citation-weighted patent count and innovative efficiency are positively and significantly correlated, whereas citation-weighted patent count and scope, and scope and innovative efficiency are negatively and significantly correlated. The proportion of female directors on a board is positively and significantly correlated with citation-weighted patent count, and negatively and significantly correlated with scope.[9]

[8]We note that Hofstede's cultural dimensions were derived from a sample of IBM employees in the 1960s and 1970s, well before the beginning of our sample period and thus mitigating the endogeneity concern. Nonetheless, any changes in cultural values that have occurred over the past 50 years work against our conjectured linkages between the measures of national culture and board gender diversity.

[9]Table IA3 in the Supplementary Material reports Pearson correlations among the country-level variables including the country-year means of the firm-level variables.

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TABLE 1

Country-Level Descriptive Statistics

Table 1 reports the descriptive statistics for key country-level variables from 45 countries. Variable definitions are provided in the Appendix. Panel A presents the mean values of key country-level variables (i.e., country means of country-year observations) for each country in our sample as well as the number of observations in each country. Panel B presents the pairwise correlations between the country mean of female director ratio and country means of other country-level regulatory, cultural, and economic variables. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Mean Values of Key Country-Level Variables

Country Name	FEMALE_ DIRECTOR_ RATIO	REGULATION_ QUOTA	REGULATION_ CODE	REGULATION_ DISCLOSURE	GENDER_GAP_ INDEX	FEMALE_ LABOR_MARKET_ PARTICIPATION	MASCULINITY	No. of Obs.
Argentina	0.03	0.00	0.00	0.00	0.29	0.48	0.56	61
Australia	0.07	0.00	0.33	0.33	0.28	0.58	0.61	4,223
Austria	0.05	0.00	0.56	0.00	0.29	0.53	0.79	248
Belgium	0.08	0.20	0.38	0.20	0.29	0.45	0.54	797
Brazil	0.07	0.00	0.00	0.00	0.32	0.59	0.49	353
Canada	0.06	0.00	0.00	0.00	0.27	0.62	0.52	4,151
Chile	0.05	0.00	0.00	0.00	0.32	0.45	0.28	79
China	0.08	0.00	0.00	0.00	0.32	0.64	0.66	1,450
Colombia	0.09	0.00	0.00	0.00	0.30	0.55	0.64	24
Croatia	0.05	0.00	0.00	0.00	0.29	0.46	0.40	9
Czech Republic	0.03	0.00	0.00	0.00	0.32	0.49	0.57	5
Denmark	0.11	0.11	0.49	0.11	0.24	0.60	0.16	303
Finland	0.21	0.00	0.51	0.51	0.18	0.57	0.26	363
France	0.12	0.34	0.34	0.00	0.33	0.50	0.43	2,913
Germany	0.07	0.00	0.40	0.40	0.25	0.52	0.66	2,009
Greece	0.07	0.00	0.04	0.00	0.33	0.43	0.57	340
Hungary	0.07	0.00	0.00	0.00	0.32	0.43	0.88	6
India	0.05	0.00	0.00	0.00	0.38	0.31	0.56	1,359
Indonesia	0.09	0.00	0.00	0.00	0.34	0.51	0.46	72
Ireland	0.06	0.00	0.00	0.00	0.26	0.51	0.68	779
Israel	0.16	1.00	0.00	0.00	0.31	0.51	0.47	782
Italy	0.07	0.13	0.00	0.00	0.34	0.38	0.70	814
Japan	0.02	0.00	0.00	1.00	0.35	0.48	0.95	759
Luxembourg	0.07	0.00	0.46	0.00	0.30	0.47	0.50	238
Malaysia	0.10	0.00	0.51	0.00	0.35	0.44	0.50	266
Malta	0.02	0.00	0.00	0.00	0.33	0.34	0.47	5
Mexico	0.07	0.00	0.00	0.00	0.34	0.43	0.69	161
Morocco	0.05	0.00	0.00	0.00	0.42	0.27	0.53	11
Netherlands	0.06	0.01	0.35	0.35	0.27	0.57	0.14	1,068
New Zealand	0.14	0.00	0.00	0.03	0.22	0.61	0.58	127

(continued on next page)

TABLE 1 (continued)

Country-Level Descriptive Statistics

Panel A. Mean Values of Key Country-Level Variables (continued)

Country Name	FEMALE_ DIRECTOR_ RATIO	REGULATION_ QUOTA	REGULATION_ CODE	REGULATION_ DISCLOSURE	GENDER_GAP_ INDEX	FEMALE_ LABOR_MARKET_ PARTICIPATION	MASCULINITY	No. of Obs.
Norway	0.27	0.77	0.00	0.77	0.19	0.61	0.08	851
Peru	0.03	0.00	0.00	0.00	0.32	0.67	0.42	14
Philippines	0.04	0.00	0.00	0.00	0.23	0.51	0.64	69
Poland	0.10	0.00	0.00	0.39	0.30	0.48	0.64	108
Portugal	0.05	0.00	0.00	0.00	0.30	0.55	0.31	202
Russia	0.05	0.00	0.00	0.00	0.31	0.57	0.36	180
Singapore	0.07	0.00	0.00	0.00	0.31	0.57	0.48	662
South Africa	0.17	0.00	0.68	0.00	0.25	0.45	0.63	803
Spain	0.08	0.67	0.74	0.00	0.28	0.48	0.42	762
Sweden	0.18	0.00	0.32	0.54	0.20	0.59	0.05	1,493
Switzerland	0.06	0.00	0.00	0.00	0.28	0.60	0.70	831
Thailand	0.07	0.00	0.00	0.00	0.31	0.64	0.34	59
Turkey	0.10	0.00	0.00	0.00	0.40	0.27	0.45	59
United Kingdom	0.06	0.18	0.26	0.10	0.26	0.55	0.66	14,132
United States	0.08	0.00	0.00	0.31	0.29	0.58	0.62	41,416
Total obs.								85,416
Mean (firm-year level)	0.08	0.07	0.11	0.22	0.28	0.56	0.59	
Mean (country-level)	0.08	0.08	0.14	0.11	0.30	0.51	0.51	

Panel B. Correlations of Country-Level Variables

	FEMALE_ DIRECTOR_ RATIO	REGULATION_ QUOTA	REGULATION_ CODE	REGULATION_ DISCLOSURE	GENDER_GAP_ INDEX	FEMALE_ LABOR_MARKET_ PARTICIPATION	MASCULINITY	ln(GDP_ PER_CAPITA)	STOCK_ MKT/GDP
FEMALE_DIRECTOR_RATIO	1.000								
REGULATION_QUOTA	0.445***	1.000							
REGULATION_CODE	0.152***	0.252***	1.000						
REGULATION_DISCLOSURE	0.241***	0.220***	0.219***	1.000					
GENDER_GAP_INDEX	–0.495[a]***	–0.182***	–0.262***	–0.261***	1.000				
FEMALE_LABOR_MARKET_ PARTICIPATION	0.231***	0.047	0.059	0.115***	–0.597***	1.000			
MASCULINITY	–0.399***	–0.196***	–0.130***	–0.118***	0.385***	–0.251***	1.000		
ln(GDP_PER_CAPITA)	0.199***	0.193***	0.255***	0.237***	–0.493***	0.266***	–0.129***	1.000	
STOCK_MKT/GDP	0.023	–0.046	0.113**	–0.026	–0.087*	0.170***	–0.008	0.261***	1.000

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B. Firm- and Country-Level Determinants of Board Gender Diversity

Table 3 reports the estimation results based on equation (1) where the dependent variable is the proportion of female directors on a board. Comparing firms within a country, we show that corporate boards are more likely to include women when boards are larger (consistent with Farrell and Hersch (2005), and Adams and Ferreira (2009)) and more independent, in firms with a female CEO, and in larger and older firms. Comparing across countries, we show that corporate boards are more likely to include women in countries with more female CEOs, in countries with larger firms, and in countries with lower asset tangibility.

Furthermore, in terms of country-level determinants, we show that the average level of board gender diversity is higher in countries with formal quotas, codes, and disclosure requirements promoting gender equity (Adams and Kirchmaier (2015)), lower in countries with a larger gender gap, higher in countries with greater female labor market participation, lower in more masculine countries, and higher in countries with higher GDP per capita.

C. The Relation between Board Gender Diversity and Corporate Innovation

Our general hypothesis is that board gender diversity fosters more novel and more efficient (i.e., lower-cost) innovation. Table 4 reports the results.

Comparing firms within a country, we show that board gender diversity is positively associated with citation-weighted patent count. We further show that

TABLE 2

Firm-Level Descriptive Statistics

Table 2 reports the descriptive statistics for key firm-level variables in our analysis. Our main sample consists of 85,416 firm-year observations from 45 countries for the period 2001–2014, for which we have board data from BoardEx and firm data from BvD Osiris. Our innovation sample covers the period 2001–2008 when the measure is ln(CITATION_WEIGHTED_PATENT_COUNT) or EFFICIENCY_CITATION_WEIGHTED_PATENTS, and covers the period 2001–2013 when the measure is SCOPE. All firm-level variables are winsorized at the 1% level in both tails of the distribution. Variable definitions are provided in the Appendix. Panel A presents the summary statistics for firm-level variables. Panel B presents the pairwise correlations between firm-level variables in 2008 after removing country-means. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Summary Statistics of Firm-Level Variables

Variable Name	No. of Obs.	Mean	Std. Dev.	P5	Median	P95
ln(CITATION_WEIGHTED_PATENT_COUNT)	38,892	1.600	2.813	0.000	0.000	7.971
SCOPE	12,534	0.642	0.318	0.069	0.688	1.000
EFFICIENCY_CITATION_WEIGHTED_PATENTS	16,089	4.542	9.043	0.000	0.017	29.013
FEMALE_DIRECTOR_RATIO	85,416	0.085	0.108	0.000	0.000	0.286
ROA	85,416	−0.017	0.196	−0.446	0.031	0.170
STOCK_RETURN	85,416	0.075	0.525	−0.800	0.093	0.892
BOARD_SIZE	85,416	8.101	3.123	4.000	8.000	14.000
BOARD_INDEPENDENCE	85,416	0.737	0.178	0.400	0.800	0.933
FEMALE_CEO	85,416	0.023	0.151	0.000	0.000	0.000
ln(TOTAL_ASSETS)	85,416	12.881	2.467	8.934	12.905	16.803
ln(FIRM_AGE)	85,416	2.877	1.066	1.099	2.890	4.625
TANGIBILITY	85,416	0.258	0.255	0.005	0.166	0.815
ln(K/L)	85,416	5.176	2.058	2.150	5.042	8.720
ln(R&D_CAPITAL)	85,416	4.459	5.427	0.000	0.000	13.141
ln(PATENT_STOCK)	85,416	1.867	2.749	0.000	0.000	7.744
CAPEX	85,416	−0.017	0.086	−0.140	−0.013	0.122
CASH	85,416	0.143	0.172	0.003	0.080	0.519
LEVERAGE	85,416	0.529	0.485	0.098	0.507	0.926
CASH_FLOW_VOLATILITY	85,416	0.100	0.059	0.024	0.084	0.225

(continued on next page)

TABLE 2 (continued)
Firm-Level Descriptive Statistics

Panel B. Correlation of Firm-Level Variables

	ln(CITATION_ WEIGHTED_ PATENT_ COUNT)	SCOPE	EFFICIENCY_ CITATION_ WEIGHTED_ PATENTS	FEMALE_ DIRECTOR_ RATIO	BOARD_ SIZE	BOARD_ INDEPENDENCE	ln(TOTAL_ ASSETS)	ln(FIRM_ AGE)	TANGIBILITY	ln(K/L)	ln(R&D_ CAPITAL)	ln(PATENT_ STOCK)	CAPEX	CASH	LEVERAGE	CASH_ FLOW_ VOLATILITY	ROA	FEMALE_ CEO
ln(CITATION_WEIGHTED_ PATENT_COUNT)	1.000																	
SCOPE	−0.205***	1.000																
EFFICIENCY_CITATION_ WEIGHTED_PATENTS	0.493***	−0.121**	1.000															
FEMALE_DIRECTOR_RATIO	0.115***	−0.076**	0.050	1.000														
BOARD_SIZE	0.333***	0.055	0.153***	0.162***	1.000													
BOARD_INDEPENDENCE	0.123***	−0.130***	0.024	0.225***	−0.025	1.000												
ln(TOTAL_ASSETS)	0.363***	0.058*	−0.185***	0.171***	0.451***	−0.012	1.000											
ln(FIRM_AGE)	0.150***	0.065*	0.038	0.151***	0.405***	−0.075**	0.309***	1.000										
TANGIBILITY	0.052	0.057*	0.124***	0.070**	0.235***	−0.004	0.196***	0.206***	1.000									
ln(K/L)	−0.052	−0.013	−0.463***	−0.007	−0.098***	−0.073**	0.550***	−0.081**	−0.024	1.000								
ln(R&D_CAPITAL)	0.408***	−0.070**	−0.374***	0.085**	0.290***	0.037	0.749***	0.181***	−0.059*	0.531***	1.000							
ln(PATENT_STOCK)	0.823***	−0.170***	0.350***	0.142***	0.444***	0.159***	0.403***	0.293***	0.111***	−0.122***	0.448***	1.000						
CAPEX	−0.058*	0.011	0.039	0.044	0.025	−0.012	0.052	−0.042	0.051	0.080**	−0.091***	−0.120***	1.000					
CASH	−0.085**	−0.105***	−0.069**	−0.119***	−0.302***	−0.014	−0.363***	−0.325***	−0.359***	−0.070**	−0.069**	−0.166***	−0.091***	1.000				
LEVERAGE	0.044	0.043	0.034	0.076**	0.171***	0.046	0.054	0.119***	0.137***	−0.103***	0.049	0.098***	−0.063*	−0.192***	1.000			
CASH_FLOW_VOLATILITY	−0.065*	−0.241***	−0.109***	0.011	−0.168***	0.088**	−0.228***	−0.225***	−0.336***	0.037	0.101***	−0.137***	−0.040	0.301***	0.018	1.000		
ROA	0.142***	0.134***	0.112***	0.082**	0.170***	−0.028	0.365***	0.289***	0.127***	0.036	0.074**	0.167***	0.171***	−0.308***	−0.184***	−0.287***	1.000	
FEMALE_CEO	−0.054	−0.041	−0.015	0.227***	−0.029	0.027	−0.056	0.018	0.016	−0.027	−0.043	−0.040	0.066*	0.025	0.038	0.018	−0.030	1.000

TABLE 3
Explaining Firm-Level Board Gender Diversity

Table 3 reports the estimation results when the dependent variable is the firm-level *female director ratio*. Our sample consists of 85,416 firm-year observations from 45 countries for the period 2001–2014, for which we have board data from BoardEx and firm data from BvD Osiris. Variable definitions are provided in the Appendix. All regressions include year fixed effects and 2-digit standard industry classification (SIC) industry fixed effects (FEs). Standard errors are in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	FEMALE_DIRECTOR_RATIO	
	Within-Country	Cross-Country
Firm Characteristics		
BOARD_SIZE	0.004***	0.001
	[0.000]	[0.001]
BOARD_INDEPENDENCE	0.025***	−0.024
	[0.003]	[0.025]
FEMALE_CEO	0.153***	0.096*
	[0.002]	[0.051]
ln(TOTAL_ASSETS)	0.005***	0.008***
	[0.000]	[0.002]
ln(FIRM_AGE)	0.006***	−0.003
	[0.000]	[0.004]
TANGIBILITY	−0.002	−0.059***
	[0.002]	[0.020]
Country Characteristics		
REGULATION_QUOTA		0.035***
		[0.002]
REGULATION_CODE		0.010***
		[0.002]
REGULATION_DISCLOSURE		0.004***
		[0.001]
GENDER_GAP_INDEX		−0.386***
		[0.028]
FEMALE_LABOR_MARKET_PARTICIPATION		0.091**
		[0.039]
MASCULINITY		−0.080**
		[0.040]
ln(GDP_PER_CAPITA)		0.026***
		[0.003]
STOCK_MKT/GDP		0.001
		[0.001]
Year FEs		Yes
Industry FEs		Yes
No. of countries		45
No. of obs.		85,416

citation-weighted patent count is higher in firms with larger and more independent boards, larger firms, and firms with lower asset tangibility, lower capital-to-labor ratios, and higher R&D capital. In terms of economic significance, a 1-standard-deviation increase in board gender diversity increases citation-weighted patent count by 16.4%, which is a 5.8% standard-deviation increase in ln(CITATION_WEIGHTED_PATENT). In contrast, a 1-standard-deviation increase in board size and firm size increases ln(CITATION_WEIGHTED_PATENT) by 10.3% and 22.8% standard deviations, respectively. Comparing across countries, we show that the average proportion of female directors in a country is positively associated with the average citation-weighted patent count in that country. We further find that citation-weighted patent count is higher in countries with larger boards, larger firms, younger firms, lower asset tangibility, and lower capital-to-labor ratios.

TABLE 4

Board Gender Diversity and Innovation: HLM

Table 4 reports the HLM estimation results when the dependent variables are ln(CITATION_WEIGHTED_PATENT_COUNT), SCOPE, and EFFICIENCY_CITATION_WEIGHTED_PATENTS. When the dependent variable is ln(CITATION_WEIGHTED_PATENT_COUNT), the sample consists of 38,892 firm-year observations from 45 countries for the period 2001–2008, for which we have patent data from the USPTO, board data from BoardEx, and firm data from BvD Osiris. When the dependent variable is SCOPE, the sample consists of 12,534 firm-year observations from 29 countries that have at least 1 patent for the period 2001–2013. When the dependent variable is EFFICIENCY_CITATION_WEIGHTED_PATENTS, the sample consists of 16,089 firm-year observations from 38 countries with nonzero R&D capital for the period 2001–2008. Variable definitions are provided in the Appendix. All regressions include year fixed effects and 2-digit SIC industry fixed effects. Standard errors are in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	ln(CITATION_WEIGHTED_PATENT_COUNT)		SCOPE		EFFICIENCY_CITATION_WEIGHTED_PATENTS	
	Within-Country	Cross-Country	Within-Country	Cross-Country	Within-Country	Cross-Country
Firm Characteristics						
FEMALE_DIRECTOR_RATIO	1.524***	1.793**	0.066**	0.103	3.008***	15.044***
	[0.126]	[0.866]	[0.031]	[0.124]	[0.796]	[4.911]
BOARD_SIZE	0.093***	0.100***	0.002*	0.009***	0.382***	−0.101
	[0.005]	[0.032]	[0.001]	[0.003]	[0.029]	[0.145]
BOARD_INDEPENDENCE	1.010***	0.055	−0.036	−0.187***	2.227***	−3.791
	[0.087]	[0.732]	[0.024]	[0.044]	[0.550]	[3.365]
ln(TOTAL_ASSETS)	0.260***	0.823***	0.030***	0.044***	0.192***	2.797***
	[0.008]	[0.071]	[0.002]	[0.009]	[0.046]	[0.341]
ln(FIRM_AGE)	−0.003	−1.420***	0.012***	−0.010	−0.431***	−6.063***
	[0.010]	[0.138]	[0.003]	[0.015]	[0.065]	[0.637]
TANGIBILITY	−0.595***	−3.945***	0.038*	−0.016	0.479	−10.053***
	[0.058]	[0.763]	[0.019]	[0.089]	[0.446]	[3.864]
ln(K/L)	−0.300***	−0.825***	−0.028***	−0.053***	−1.636***	−3.304***
	[0.008]	[0.092]	[0.002]	[0.011]	[0.051]	[0.442]
ln(R&D_CAPITAL)	0.149***	0.037	−0.003***	0.002		
	[0.003]	[0.034]	[0.001]	[0.003]		
ln(PATENT_STOCK)			−0.044***	−0.049***		
			[0.001]	[0.005]		
Country Characteristics						
FEMALE_LABOR_MARKET_PARTICIPATION		0.044**		−0.004**		0.134
		[0.019]		[0.002]		[0.171]
MASCULINITY		0.017*		−0.001**		0.040
		[0.010]		[0.000]		[0.070]
ln(GDP_PER_CAPITA)		0.812***		0.0004		5.990***
		[0.172]		[0.014]		[1.351]
STOCK_MKT/GDP		−0.007***		0.001***		−0.019
		[0.001]		[0.000]		[0.014]
Cross-Level Interactions		Within-country × Cross-country		Within-country × Cross-country		Within-country × Cross-country
FEMALE_LABOR_MARKET_PARTICIPATION × FEMALE_DIRECTOR_RATIO		0.142***		0.0002		0.095
		[0.031]		[0.009]		[0.089]
MASCULINITY × FEMALE_DIRECTOR_RATIO		0.028***		0.006***		0.038
		[0.008]		[0.002]		[0.039]
Year FEs		Yes		Yes		Yes
Industry FEs		Yes		Yes		Yes
No. of countries		45		29		38
No. of obs.		38,892		12,534		16,089

Furthermore, in terms of purely country-level determinants, we show that citation-weighted patent count is higher in countries with greater female labor market participation, a more masculine culture, higher GDP per capita, and less developed stock markets.

Finally, in terms of interaction effects, we find that the positive association between board gender diversity and citation-weighted patent count is stronger in countries with greater female labor market participation, consistent with the deeper talent pool perspective of Adams and Kirchmaier (2015), and in countries with a more masculine culture.

We next present results for innovation novelty as measured by the scope of citations made by a firm's patents.[10] Comparing firms within a country, we show that board gender diversity is positively associated with innovation novelty. We further show that innovation novelty is higher in firms with larger boards, and in firms that are larger, older, with more tangible assets, lower capital-to-labor ratios, lower R&D capital, and lower patent stock. In terms of economic significance, a 1-standard-deviation increase in board gender diversity increases SCOPE by 2.2% standard deviations. In contrast, a 1-standard-deviation increase in board size and firm size increases SCOPE by 2.0% and 23.3% standard deviations, respectively.

Comparing across countries, we find that the average proportion of female directors in a country is not significantly associated with the average level of innovation novelty in that country. We further show that innovation novelty is higher in countries with larger boards, lower board independence, larger firms, lower capital-to-labor ratios, and lower patent stock.

In terms of purely country-level determinants, we show that innovation novelty is higher in countries with lower female labor market participation, a less masculine culture, and more developed stock markets.

Furthermore, we find that the positive association between board gender diversity and innovation novelty is stronger in countries with a more masculine culture.

Finally, we present results for innovative efficiency as measured by citation-weighted patent count per R&D dollar. Comparing firms within a country, we show that board gender diversity is positively associated with innovative efficiency. We further show that innovative efficiency is higher in firms with larger boards, firms with more independent boards, and larger firms, and lower in older firms and firms with higher capital-to-labor ratios. In terms of economic significance, a 1-standard-deviation increase in board gender diversity increases innovative efficiency by 3.6% standard deviations. In contrast, a 1-standard-deviation increase in board size and firm size increases innovative efficiency by 13.2% and 5.2% standard deviations, respectively.

Comparing across countries, we show that the average proportion of female directors in a country is positively associated with the average level of innovative efficiency in that country. We further find that innovative efficiency is higher in countries with larger and younger firms, firms with less tangible assets, and firms with lower capital-to-labor ratios. In terms of country-level determinants, we show that innovative efficiency is higher in countries with higher GDP per capita. In terms of interaction effects, we show that the positive association between board

[10]The sample requires firms with at least 1 patent over our sample period when the outcome variable is innovation novelty (i.e., SCOPE), and firms with nonzero R&D capital when the outcome variable is innovative efficiency (where R&D capital is the denominator).

gender diversity and innovative efficiency is not influenced by either a country's female labor market participation or its masculinity score.[11]

To address the endogeneity concern related to board gender diversity, we employ an instrumental variables (IV) approach. Following Adams and Ferreira (2009), we use the fraction of male directors on a board who sit on other boards on which there are female directors as an IV. One major impediment to female representation on corporate boards is women executives' lack of business network visibility and hence their lack of connections. The IV captures the degree to which potential female directors are connected to current male directors and therefore we expect a positive association between the IV and the fraction of female directors on a given board. Table IA4 in the Supplementary Material reports the results. We show that the positive effect of board gender diversity on innovation largely remains using the IV approach.

Overall, our findings are consistent with the two hypotheses that more gender diverse boards are associated with higher innovation output, more novel innovation, and higher innovative efficiency.

D. The Change-on-Change Regressions

One way to help assess whether the identified association between board gender diversity and corporate innovation is likely to be causal is to exploit time-series variation in our data.[12] However, a standard firm fixed-effects model is not applicable because of the slow-moving nature of our key variable of interest, namely, the female director ratio. In our sample, about 90% of the firm-year observations do not experience any changes in the ratio compared with the previous year.[13] To tackle this issue, we employ a long-window change-on-change regression specification, which helps maximize temporal variation in the variable of interest, while removing time-invariant firm-level unobservables in a way similar to the firm fixed-effects model:[14]

$$(2) \qquad \Delta_{t\rightarrow t+3}\,\text{Innovation}_{\text{i}} = \alpha + \beta \cdot \Delta_{t-4\rightarrow t-1}\,\text{Female director ratio}_i + \gamma \cdot \Delta_{t-4\rightarrow t-1} X_i + \text{Country} - \text{Year FEs} + \text{Industry FEs} + \varepsilon_{it}.$$

For each firm in our sample, we compute the 3-year rolling window differences in all dependent and independent variables and form a panel of 3-year differences. To maximize temporal variation, we use 1-year patent counts weighted by 3-year forward citations, instead of 3-year patent counts weighted by 5-year forward citations. We also limit our analysis to firm-year observations with

[11] To explore the generality of the relation between board gender diversity and patenting outcome, we classify patents as breakthrough, important, incremental, or failed following Balsmeier, Fleming, and Manso (2017). In untabulated analysis, we find that there remains a positive association between board gender diversity and all 4 categories of patents.

[12] We thank the anonymous referee for suggesting this analysis.

[13] As highlighted in Griliches and Mairesse (1995), Zhou (2001), and Roberts and Whited (2013), using firm fixed effects in a panel with such slow-moving variables will exacerbate measurement error problems and lead to biased estimates.

[14] For example, Autor, Dorn, and Hanson (2013), Bloom, Draca, and Van Reenen (2016), and Bena and Xu (2017) use long-window change-on-change regressions to address the slow-moving nature of technology and ownership structure.

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nonzero changes in the female director ratio over the 3-year change window. Finally, we include country-year and industry fixed effects to absorb unobservable temporal shocks across countries and industry trends. Using this approach, we ask whether temporal changes in the female director ratio are followed by subsequent changes in innovation outcomes. Table 5 reports the results.

We show that as we extend the change window in innovation outcomes, the effect of a change in board gender diversity on the change in innovation outcomes is increasing: i) The addition of female directors does not lead to immediate changes in innovation outcomes, but starts to show an effect from the second or third year; and ii) the magnitudes of those effects also increase monotonically as the change window lengthens. These results suggest that the effect of board gender diversity on corporate innovation is gradual and persistent, and is unlikely to be driven by reserve causality.

E. Evidence from Norway

To further address potential endogeneity concerns, we exploit a reform in Norway that exogenously increased female representation on corporate boards due to the sudden introduction of a gender quota. In 2003, a new law required that 40% of Norwegian firms' directors be women. At the time, only 9% of directors were women.

Our identification strategy follows Ahern and Dittmar (2012) and Eckbo et al. (2019). Specifically, we use pre-reform cross-sectional variation in female board representation to instrument for exogenous changes to corporate boards following the reform. We estimate the following 2-stage least squares (2SLS) regression over the sample period 2003–2012.

$$\text{(3a)} \quad \text{Female director ratio}_{i,t} = \alpha + \sum_{t=2003}^{2012} \beta \times \text{Female director ratio}_{i,2002} \times \text{Year}_t + \text{Year FEs} + \text{Firm FEs} + \varepsilon_{it},$$

$$\text{(3b)} \quad \text{Innovation}_{i,t} = \alpha + \beta \times F\text{emale director ratio}_{i,t} + \text{Year FEs} + \text{Firm FEs} + \varepsilon_{it}.$$

Equation (3a) represents the first-stage regression where we instrument for FEMALE_DIRECTOR_RATIO using a firm's percentage of female directors in 2002 interacted with year indicator variables. As a robustness check, we also use 2001 and 2000 (untabulated) as the pre-reform base year to account for potential anticipation effects (Eckbo et al. (2019)). Equation (3b) is the second-stage regression. We include year and firm fixed effects in both stages of regressions. Table 6 reports the results.

We show that changing the female representation on a board has a significant effect on innovation output, measured by patent count, citation count, and citation-weighted patent count. This finding further suggests that the effect of board gender diversity on innovation outcomes is likely to be causal.

F. The Mechanisms

In our hypothesis development, we posit that board gender diversity may affect corporate innovation through the following channels: i) Setting CEO

TABLE 5

Board Gender Diversity and Innovation: Change-on-Change Regressions

Table 5 examines the dynamic effect of board gender diversity on innovation using within-firm change regressions. All independent variables (denoted D3) are measured as 3-year changes from year $t-4$ to $t-1$. The dependent variables are 1-year (D1), 2-year (D2), 3-year (D3), and 4-year (D4) changes in innovation outcomes from year t to year $t+1$, $t+2$, $t+3$, and $t+4$, respectively. To increase the number of observations, we use 1-year patent count weighted by 3-year forward citations in computing patent count and efficiency. The sample consists of firm-year observations with nonzero changes in the female director ratio over a 3-year window. All regressions include country-year fixed effects and 2-digit SIC industry fixed effects. Standard errors are in parentheses and are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Change Over	ln(CITATION_WEIGHTED_PATENT_COUNT)				SCOPE				EFFICIENCY_CITATION_WEIGHTED_PATENTS			
Different Periods	D1	D2	D3	D4	D1	D2	D3	D4	D1	D2	D3	D4
D3_FEMALE_DIRECTOR_RATIO	0.044	0.097*	0.119*	0.128*	0.052	0.092*	0.106*	0.184***	0.003	0.230	0.766*	1.002**
	[0.051]	[0.058]	[0.062]	[0.074]	[0.034]	[0.051]	[0.062]	[0.071]	[0.268]	[0.366]	[0.425]	[0.418]
D3_BOARD_SIZE	0.004	0.003	0.002	−0.000	−0.000	−0.001	−0.001	−0.002	−0.034	0.006	0.008	0.009
	[0.003]	[0.004]	[0.004]	[0.003]	[0.002]	[0.002]	[0.003]	[0.003]	[0.029]	[0.045]	[0.048]	[0.068]
D3_BOARD_INDEPENDENCE	0.067	0.029	0.066	0.026	−0.030	0.028	0.044	−0.017	0.230	−0.566	−0.793*	−0.730
	[0.052]	[0.061]	[0.065]	[0.051]	[0.042]	[0.057]	[0.068]	[0.082]	[0.150]	[0.550]	[0.421]	[0.620]
D3_ln(TOTAL_ASSETS)	0.023**	0.034***	0.072***	0.104**	0.004	0.003	0.002	−0.005	0.025	−0.219	−0.024	−0.004
	[0.011]	[0.013]	[0.014]	[0.049]	[0.009]	[0.012]	[0.015]	[0.018]	[0.065]	[0.161]	[0.171]	[0.251]
D3_ln(FIRM_AGE)	0.024	0.073**	0.090***	0.111***	0.014	0.003	0.015	0.035	−0.121	−0.628*	−0.693	−0.954
	[0.027]	[0.031]	[0.033]	[0.023]	[0.016]	[0.021]	[0.026]	[0.037]	[0.127]	[0.367]	[0.500]	[0.651]
D3_TANGIBILITY	−0.020	−0.007	−0.008	−0.001	0.039	−0.015	−0.017	−0.089	−1.024***	−1.105	−0.724	−0.932
	[0.046]	[0.054]	[0.061]	[0.074]	[0.046]	[0.068]	[0.084]	[0.097]	[0.367]	[0.817]	[0.702]	[1.005]
D3_ln(K/L)	−0.004	−0.009	−0.029***	−0.048***	−0.001	0.003	0.007	0.015	−0.101**	−0.143	−0.227	−0.321
	[0.007]	[0.009]	[0.011]	[0.014]	[0.005]	[0.008]	[0.011]	[0.013]	[0.043]	[0.143]	[0.182]	[0.273]
D3_ln(R&D_CAPITAL)	−0.000	0.001	0.006	0.007	−0.001	−0.001	0.000	−0.000				
	[0.004]	[0.004]	[0.004]	[0.005]	[0.001]	[0.002]	[0.002]	[0.002]				
D3_ln(PATENT_STOCK)					−0.026***	−0.049***	−0.078***	−0.089***				
					[0.008]	[0.011]	[0.015]	[0.021]				
Country-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	20,158	19,605	19,572	16,845	3,305	3,217	3,175	2,562	8,145	7,960	7,951	6,565

TABLE 6
Evidence from Norway

Table 6 reports the second-stage results from the 2SLS regressions in equations (3a) and (3b) estimating the effect of female directors on innovation output and other financial outcomes. The female director ratio from year 2003 to 2011 (as the innovation variables are available for 2003 to 2012) is instrumented with the interaction terms between the female director ratio in the pre-reform base year 2002 (2001) and year indicator variables. Panel A presents the results when the pre-reform base year is 2002 (Ahern and Dittmar (2012)). Panel B presents the results when the pre-reform base year is 2001 (Eckbo, Nygaard, and Thorburn (2019)). Variable definitions are provided in the Appendix. All regressions include year fixed effects and firm fixed effects. Standard errors clustered by firm are in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	ln(PATENT_COUNT)	ln(CITATION_COUNT)	ln(CITATION_WEIGHTED_PATENT_COUNT)
Panel A. Instrument: The Female Director Ratio in 2002 Interacted with Year Indicator Variables			
FEMALE_DIRECTOR_RATIO	4.433**	4.134**	6.108**
	[1.955]	[2.041]	[2.699]
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
No. of obs.	526	526	526
Panel B. Instrument: The Female Director Ratio in 2001 Interacted with Year Indicator Variables			
FEMALE_DIRECTOR_RATIO	5.858***	6.294***	8.744***
	[1.812]	[1.849]	[2.491]
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
No. of obs.	443	443	443

employment and compensation contracts that promote more tolerance for failure and a long-term orientation; ii) fostering an innovative corporate culture; and iii) increasing gender and ethnic diversity among inventors, characteristics that are linked to better innovative performance.[15]

Motivated by the literature on incentive schemes in corporate innovation (Manso (2011), and Ederer and Manso (2013)), in Table 7, we examine whether female directors are differentially associated with incentive schemes that encourage innovation. We focus on CEO employment and compensation contracts that promote tolerance for failure and a long-term orientation. In Panel A, we find board gender diversity is associated with lower CEO turnover-performance sensitivity, with performance measured using either return on assets (ROA) or stock returns. This result suggests that boards with female directors offer more downside protection to CEOs and are more tolerant of underperformance should their innovative endeavors stumble. In Panel B, we further find that board gender diversity is associated with a higher fraction of CEO noncash pay, which is typically more long-term in nature than cash pay such as salary and bonus. Board gender diversity is also associated with more frequent use of CEO long-term incentive plans. The results in Table 7 suggest that board gender diversity helps provide CEOs with incentives that are more conducive to innovation.

Next, using novel corporate culture measures from Li et al. (2020), we examine whether and how board gender diversity is related to corporate culture. Following the cultural framework developed by Guiso et al. (2015), Li et al. (2020) measure five corporate culture values, innovation, integrity, quality, respect, and teamwork, from companies' earnings call transcripts using machine-learning

[15]We thank the anonymous referee for encouraging us to investigate these mechanisms.

techniques (available for U.S. firms only). Table 8 reports the results. We find the board gender diversity is uniquely and positively associated with the innovation dimension of corporate culture.

Finally, using inventor-level data, we examine whether board gender diversity also encourages or spills over to gender and ethnic diversity of inventors. Table 9 reports the results. In Panel A, using the Genderize.io database to assign gender categorization probabilities to inventors based on their first names from the USPTO, we find that board gender diversity is positively associated with the fraction of inventors being female. In Panel B, using the NamePrism API that algorithmically assigns ethnicity probabilities to inventors based on their full names, we find that boards with more female directors are associated with greater ethnic diversity of their inventors, that is, lower ethnicity Herfindahl–Hirschman

TABLE 7

Underlying Mechanism: CEO Incentives

Table 7 examines the effect of board gender diversity on CEO incentive schemes to foster innovation. Panel A examines CEO_TURNOVER-performance sensitivity. The dependent variable is the indicator variable CEO_TURNOVER. The sample consists of all firm-year observations in BoardEx from which we obtain information on CEO turnover events. Panel B examines the presence of CEO long-term compensation. The dependent variables are %LT_COMPENSATION, LT_INCENTIVE_PLAN, and %LT_INCENTIVE_PLAN. The sample consists of all firm-year observations Capital IQ from which we obtain information on CEO compensation. Variable definitions are provided in the Appendix. All regressions include country-year fixed effects and 2-digit SIC industry fixed effects. Standard errors are in parentheses and are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. CEO Turnover-Performance Sensitivity

	CEO_TURNOVER			
FEMALE_DIRECTOR_RATIO	0.002 [0.014]	0.0004 [0.014]	−0.012 [0.014]	−0.013 [0.014]
ROA	−0.178*** [0.010]	−0.171*** [0.010]		
ROA × FEMALE_DIRECTOR_RATIO	0.293*** [0.072]	0.290*** [0.073]		
STOCK_RETURN			−0.068*** [0.003]	−0.066*** [0.003]
STOCK_RETURN × FEMALE_DIRECTOR_RATIO			0.056** [0.024]	0.053** [0.024]
BOARD_SIZE	0.005*** [0.001]	0.005*** [0.001]	0.006*** [0.001]	0.005*** [0.001]
BOARD_INDEPENDENCE	0.041*** [0.010]	0.043*** [0.010]	0.046*** [0.010]	0.046*** [0.010]
ln(TOTAL_ASSETS)	0.003*** [0.001]	0.003*** [0.001]	0.000 [0.001]	0.001 [0.001]
ln(FIRM_AGE)	−0.003* [0.002]	−0.005*** [0.002]	−0.006*** [0.002]	−0.007*** [0.002]
TANGIBILITY	−0.011 [0.007]	−0.016** [0.007]	−0.021*** [0.007]	−0.019*** [0.007]
CAPEX		−0.110*** [0.017]		−0.119*** [0.017]
CASH		−0.041*** [0.009]		−0.01 [0.009]
LEVERAGE		0.010** [0.004]		0.017*** [0.004]
CASH_FLOW_VOLATILITY		0.032 [0.042]		0.092** [0.041]
Country-year FEs	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes
No. of countries	41	41	41	41
No. of obs.	82,249	82,249	82,249	82,249

(continued on next page)

TABLE 7 (continued)
Underlying Mechanism: CEO Incentives

Panel B. CEO Long-Term Compensation

	%LT_COMPENSATION	LT_INCENTIVE_PLAN	%LT_INCENTIVE_PLAN
FEMALE_DIRECTOR_RATIO	0.146***	0.114***	0.034***
	[0.033]	[0.017]	[0.005]
ROA	−0.085***	0.025***	0.009***
	[0.017]	[0.007]	[0.002]
BOARD_SIZE	0.004***	0.006***	0.002***
	[0.001]	[0.001]	[0.000]
BOARD_INDEPENDENCE	0.154***	0.051***	0.016***
	[0.024]	[0.011]	[0.003]
ln(TOTAL_ASSETS)	0.007***	0.006***	0.002***
	[0.002]	[0.001]	[0.000]
ln(FIRM_AGE)	−0.003	0.004**	0.000
	[0.003]	[0.002]	[0.001]
TANGIBILITY	0.007	−0.003	−0.002
	[0.017]	[0.008]	[0.003]
CAPEX	0.007	0.009	0.006
	[0.030]	[0.013]	[0.004]
CASH	0.003	−0.002	0.0001
	[0.020]	[0.009]	[0.003]
LEVERAGE	0.003	0.005**	0.002***
	[0.007]	[0.002]	[0.001]
CASH_FLOW_VOLATILITY	0.055	−0.073	−0.003
	[0.096]	[0.053]	[0.015]
Country-year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
No. of countries	45	45	45
No. of obs.	28,869	28,869	28,869

Indices (HHI). The results in Table 9 suggest that inventor gender and ethnic diversity is an important channel through which board gender diversity promotes innovation.

V. Additional Investigation

A. Using Alternative Measures of Innovation

Table IA5 in the Supplementary Material reports our main results in Table 4 using a 3-year window (instead of a 5-year window) to capture forward citations in constructing two of the three innovation variables: citation-weighted patent count and innovative efficiency. As such, our sample size increases by almost 40%. Table IA6 in the Supplementary Material reports our main results in Table 4 by using alternative measures of innovation and innovative efficiency: patent count, citation count,[16] and their corresponding efficiency measures. We show that our main findings in Table 4 remain unchanged.

[16]We do not adjust citation counts for truncation bias or cross-technology class differences in citation practices as recommended by Hall, Jaffe, and Trajtenberg (2001) for two reasons. First, the USPTO patent data does not have a long time series or sufficient cross-technology class coverage for patents filed by foreign firms as examined by our paper. Second, it is not obvious to us that board gender diversity is systematically related to truncation biases or cross-technology class differences in citation practices. Nonetheless, in our robustness check (see Table IA9 in the Supplementary Material), we repeat our main analysis for different industries to address any potential differences in industry-level citation practices.

TABLE 8
Underlying Mechanism: Corporate Culture

Table 8 examines the effect of board gender diversity on the innovation dimension of corporate culture (Guiso et al. (2015)). The corporate culture values are from Li et al. (2020) and are measured from earnings call transcripts using machine learning techniques. The sample consists of all U.S. firm-year observations for which we have data on the innovation dimension of corporate culture. Variable definitions are provided in the Appendix. All regressions include year fixed effects and 2-digit SIC industry fixed effects. Standard errors are in parentheses and are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	INNOVATION		INTEGRITY		QUALITY		RESPECT		TEAMWORK	
FEMALE_DIRECTOR_RATIO	0.368***	0.298***	0.019	0.029*	0.084	0.026	0.024	0.029	–0.013	–0.015
	[0.077]	[0.077]	[0.017]	[0.017]	[0.072]	[0.072]	[0.030]	[0.030]	[0.026]	[0.025]
BOARD_SIZE	0.007*	0.010***	0.002**	0.002	–0.005	–0.002	0.003**	0.003**	0.004***	0.004***
	[0.004]	[0.004]	[0.001]	[0.001]	[0.004]	[0.004]	[0.002]	[0.002]	[0.001]	[0.001]
BOARD_INDEPENDENCE	0.293***	0.309***	0.047***	0.040**	0.158**	0.156**	–0.008	–0.008	0.048*	0.040
	[0.078]	[0.078]	[0.018]	[0.018]	[0.071]	[0.070]	[0.031]	[0.031]	[0.026]	[0.025]
ln(TOTAL_ASSETS)	0.038***	0.044***	–0.011***	–0.008***	–0.011*	–0.004	–0.012***	–0.007***	–0.025***	–0.015***
	[0.007]	[0.007]	[0.002]	[0.002]	[0.006]	[0.006]	[0.002]	[0.002]	[0.002]	[0.002]
ln(FIRM_AGE)	–0.015*	0.002	0.002	0.002	–0.021***	–0.005	–0.008**	–0.004	–0.015***	–0.007**
	[0.008]	[0.008]	[0.003]	[0.003]	[0.007]	[0.008]	[0.003]	[0.003]	[0.003]	[0.003]
TANGIBILITY	–0.454***	–0.404***	–0.100***	–0.090***	–0.181***	–0.097**	–0.056***	–0.033*	–0.175***	–0.139***
	[0.046]	[0.047]	[0.010]	[0.011]	[0.042]	[0.043]	[0.019]	[0.019]	[0.015]	[0.015]
ln(K/L)	–0.037***	–0.040***	0.006***	0.005***	–0.004	–0.003	–0.000	–0.001	0.014***	0.010***
	[0.007]	[0.007]	[0.001]	[0.001]	[0.006]	[0.006]	[0.003]	[0.003]	[0.002]	[0.002]
ln(TRANSCRIPT_LENGTH)	0.101***	0.102***	0.008***	0.011***	0.093***	0.096***	0.023***	0.026***	0.008**	0.015***
	[0.011]	[0.011]	[0.003]	[0.003]	[0.010]	[0.010]	[0.004]	[0.004]	[0.004]	[0.003]
ROA		0.036		–0.085***		0.032		–0.104***		–0.230***
		[0.039]		[0.012]		[0.036]		[0.016]		[0.015]
CAPEX		–0.180***		0.025		–0.358***		0.092***		0.031
		[0.065]		[0.017]		[0.062]		[0.029]		[0.023]
CASH		0.079		0.043***		0.258***		0.123***		0.119***
		[0.051]		[0.014]		[0.047]		[0.019]		[0.019]
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	30,301	30,301	30,301	30,301	30,301	30,301	30,301	30,301	30,301	30,301

B. Using "Triadic" Patents

To address the concern that our main findings are based on patents granted by the USPTO which may bias our sample of patents against non-U.S. firms (Bena et al. (2017)), we replicate our analysis using "triadic" patents, namely patents applied for simultaneously at all 3 major patent offices: the USPTO, the European Patent Office (EPO), and the Japanese Patent Office (JPO) (OECD Triadic Patent Families Database, Mar. 2018). Table IA7 reports the results and we show that our main findings remain unchanged.

C. The Nonlinear Effect of Board Gender Diversity

To examine any possible nonlinear effect of the number of women on a board, we introduce indicator variables representing 1 woman (versus 0), 2 women (versus 1), and 3 or more women (versus 2) on a board. Table IA8 in the Supplementary Material reports the results.

TABLE 9

Underlying Mechanism: Inventor Gender and Ethnic Diversity

Table 9 examines the effect of board gender diversity on inventor gender and ethnic diversity. Panel A presents the results on inventor gender diversity. The dependent variable is FRACTION_FEMALE_INVENTORS. Panel B presents the results on inventor ethnic diversity. The dependent variable is INVENTOR_ETHNICITY_HHI. In both panels the samples consist of all firm-year observations that have at least 1 patent application. Variable definitions are provided in the Appendix. All regressions include country-year fixed effects and 2-digit SIC industry fixed effects. Standard errors are in parentheses and are clustered at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Inventor Gender Diversity

	FRACTION_FEMALE_INVENTORS		
FEMALE_DIRECTOR_RATIO	0.045** [0.019]	0.044** [0.019]	0.037* [0.020]
BOARD_SIZE	0.001* [0.001]	0.001** [0.001]	0.001 [0.001]
BOARD_INDEPENDENCE	0.043*** [0.015]	0.048*** [0.015]	0.042*** [0.015]
ln(TOTAL_ASSETS)	0.000 [0.001]	0.002 [0.001]	−0.001 [0.001]
ln(FIRM_AGE)	−0.003** [0.002]	−0.002 [0.002]	−0.003* [0.002]
TANGIBILITY	−0.039*** [0.012]	−0.029** [0.012]	−0.023* [0.012]
ln(K/L)	0.000 [0.001]	−0.000 [0.001]	0.001 [0.002]
ROA		−0.010 [0.009]	−0.010 [0.009]
CAPEX		−0.010 [0.021]	0.001 [0.021]
CASH		0.027** [0.011]	0.025** [0.011]
ln(R&D_CAPITAL)			0.001** [0.000]
ln(PATENT_STOCK)			0.005*** [0.001]
Country-year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
No. of countries	30	30	30
No. of obs.	18,444	18,444	18,444

(continued on next page)

TABLE 9 (continued)
Underlying Mechanism: Inventor Gender and Ethnic Diversity

Panel B. Inventor Ethnic Diversity

	INVENTOR_ETHNICITY_HHI		
FEMALE_DIRECTOR_RATIO	−0.099***	−0.101***	−0.046*
	[0.028]	[0.028]	[0.026]
BOARD_SIZE	−0.003***	−0.003**	0.001
	[0.001]	[0.001]	[0.001]
BOARD_INDEPENDENCE	−0.076***	−0.071***	−0.023
	[0.023]	[0.024]	[0.022]
ln(TOTAL_ASSETS)	−0.019***	−0.020***	−0.003
	[0.002]	[0.002]	[0.002]
ln(FIRM_AGE)	0.005*	0.006*	0.011***
	[0.003]	[0.003]	[0.003]
TANGIBILITY	0.140***	0.136***	0.103***
	[0.030]	[0.030]	[0.027]
ln(K/L)	0.017***	0.018***	0.002
	[0.002]	[0.002]	[0.002]
ROA		0.008	0.006
		[0.014]	[0.013]
CAPEX		−0.027	−0.110***
		[0.034]	[0.032]
CASH		−0.014	−0.014
		[0.015]	[0.014]
ln(R&D_CAPITAL)			−0.003***
			[0.001]
ln(PATENT_STOCK)			−0.037***
			[0.002]
Country-year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
No. of countries	30	30	30
No. of obs.	18,508	18,508	18,508

Comparing firms within a country, we show that having 1 woman on a board (versus 0) is positively and significantly related to 2 out of the 3 innovation measures (citation-weighted patent count and innovative efficiency). Similarly, we show that having 2 women on a board (versus 1) is positively and significantly related to 2 out of the 3 innovation measures (citation-weighted patent count and scope). In contrast, we show that having 3 or more women on a board (versus 2) is unrelated to any innovation outcomes. Note that the presence of 3 or more women on a board is extremely rare in this data set, so this finding is not surprising. Comparing across countries, we show that having 1 woman on a board (versus 0) in a country is positively and significantly related to all 3 innovation measures. Overall, these results suggest that the effect of female directors on innovation is most significant when there is 1 female director.

D. Innovative Industries

To examine the generality of our findings on the relation between board gender diversity and corporate innovation, particularly between innovative and non-innovative industries (Hirshleifer et al. (2012)), we repeat our analysis across 5 Fama-French industries. Table IA9 reports the results. We show that the positive association between board gender diversity and patenting output is found largely in manufacturing, business equipment, and healthcare industries that are known to be innovative.

E. Subsample Analyses

According to Table IA1 in the Supplementary Material, U.S. firms contribute almost 50% of the sample. Thus, it is important to check whether our main findings remain if we exclude firms from this single dominant country. Table IA10 in the Supplementary Material reports the results after excluding U.S. firms.[17] Our main findings largely remain.

F. Controlling for Other Dimensions of Board Diversity

To examine whether the association between board gender diversity and corporate innovation reflects the effect of other dimensions of board diversity, we include 6 other board diversity measures following Bernile, Bhagwat, and Yonker (2018) and Giannetti and Zhao (2019): director age, the number of directorships, board tenure, industry experience, nationality, and educational background. Table IA11 reports the results. We find that our main findings within a country remain unchanged after controlling for these alternative dimensions of diversity. In contrast, none of these alternative diversity measures have a consistently strong effect on our outcome variables. This suggest that the effect of gender diversity is distinct and economically important.

VI. Conclusions

In this paper, we examine the determinants of board gender diversity and its effect on an important driver of firm value creation, corporate innovation, in an international setting. We show that firms with gender diverse boards have more patents, more novel patents, and higher innovative efficiency.

To address the reverse causality concern, we employ a change-on-change specification to assess how the relation between board gender diversity and corporate innovation unfolds over time. We find that an increase in gender diversity on boards is followed after 2 or more years by an improvement in innovative performance. Moreover, the positive effect of gender diversity on corporate innovation is also found for the natural experiment of introducing board gender quotas in Norway.

Finally, we explore potential mechanisms by which board gender diversity may enhance corporate innovation. We find that board gender diversity is associated with more failure-tolerant and long-term executive compensation, a more innovative corporate culture, and more diverse inventors, characteristics that are conducive to better innovative performance.

We conclude that the results in our paper provide strong support for the hypothesis that board gender diversity positively influences corporate innovation.

Appendix. Variable Definitions and Data Sources

Country-Level Control Variables

REGULATION_QUOTA: A country-year level indicator variable that takes the value of 1 if a country's main stock exchange or securities laws stipulate minimum quota

[17] In untabulated analysis, we remove U.K. firms that contribute about 17% of our sample, and show that our main findings largely remain.

for either the percentage or number of female directors on a board, and 0 otherwise. *Source:* Adams and Kirchmaier (2015), Catalyst (2012), (2014), and Deloitte (2010–2014).

REGULATION_CODE: A country-year level indicator variable that takes the value of 1 if a country's governance code mentions that gender must be considered by a board in nominations, and 0 otherwise. *Source:* Adams and Kirchmaier (2015), Catalyst (2012), (2014), and Deloitte (2010–2014).

REGULATION_DISCLOSURE: A country-year level indicator variable that takes the value of 1 if the main stock exchange or securities laws stipulate that board diversity should be disclosed, and 0 otherwise. *Source:* Adams and Kirchmaier (2015), Catalyst (2012), (2014), and Deloitte (2010–2014).

GENDER_GAP_INDEX (GGI): An annual index measuring the extent to which women are disadvantaged compared with men in the following 4 overall areas: i) Economic participation and opportunity (i.e., outcomes on salaries, participation levels, and access to high-skilled employment); ii) educational attainment (i.e., outcomes on access to basic and higher level education); iii) political empowerment (i.e., outcomes on representation in decision-making structures); and iv) health and survival (i.e., outcomes on life expectancy and sex ratio). A higher value of this measures means a larger gender gap between women and men. *Source:* World Economic Forum.

FEMALE_LABOR_MARKET_PARTICIPATION: A country-year level variable measuring the percentage of a country's female population aged 15 and above that participates in the labor force. *Source:* World Bank's World Development Indicators Database.

MASCULINITY: The index is a weighted sum of the following four statements: i) Work with people who cooperate well with one another; ii) have an opportunity for advancement to higher level jobs; iii) most people can be trusted; and iv) when people have failed in life it is often their own fault. High masculinity is indicated by ratings of "of very little or no importance" to items (i) and (iii), and ratings of "of utmost importance" to items (ii) and (iv). MASCULINITY stands for a society in which emotional gender roles are clearly distinct: Men are supposed to be assertive, tough, and focused on material success; women are supposed to be more modest, tender, and concerned with the quality of life. Femininity stands for a society in which emotional gender roles overlap: Both men and women are supposed to be modest, tender, and concerned with the quality of life. The masculinity side of this dimension represents a preference in society for achievement, heroism, assertiveness, and material rewards for success. Society at large is more competitive. Its opposite, femininity, stands for a preference for cooperation, modesty, caring for the weak, and quality of life. Society at large is more consensus-oriented. In the business context masculinity versus femininity is sometimes also referred to as "tough versus tender" cultures. *Source:* Hofstede (2001).

ln(GDP_PER_CAPITA): Natural logarithm of GDP per capita. *Source:* World Bank's World Development Indicators Database.

STOCK_MKT/GDP: Stock market capitalization as a percentage of GDP. *Source:* World Bank's World Development Indicators Database.

Firm-Level Variables

FEMALE_DIRECTOR_RATIO: The fraction of female directors on a board. *Source:* BoardEx.

IV_CONNECTION: The fraction of male directors on a board who sit on other boards on which there are female directors. *Source:* BoardEx.

ln(CITATION_WEIGHTED_PATENT_COUNT): Natural logarithm of the number of patents applied by a firm in years t to $t+2$, with each patent weighted by the number of citations it receives from the application year to 4 years after.

SCOPE: The number of new citations made by patents applied for in years t to $t+2$ divided by the number of citations made by patents applied for in years t to $t+2$. New citations are citations that have never been made by a firm in the past 5 years.

EFFICIENCY_CITATION_WEIGHTED_PATENTS: The number of citation-weighted patents applied by a firm in years t to $t+2$ divided by its R&D capital in year $t-1$, with citation weight being the number of citations a patent receives from the application year to 4 years after.

ln(PATENT_COUNT): Natural logarithm of the number of patents applied by a firm in years t to $t+2$.

ln(CITATION_COUNT): Natural logarithm of the number of citations received in years t to $t+4$ by patents applied by a firm in year t.

CEO_TURNOVER: An indicator variable that takes the value of 1 if a firm experiences CEO_TURNOVER in a given year, and 0 otherwise. *Source:* BoardEx.

%LT_COMPENSATION: The fraction of noncash compensation (i.e., stock, stock options, etc.) in a CEO's compensation package. *Source:* Capital IQ.

LT_INCENTIVE_PLAN: An indicator variable that takes the value of 1 if a CEO's compensation package contains a long-term incentive plan, and 0 otherwise. *Source:* Capital IQ.

%LT_INCENTIVE_PLAN: The value of a CEO's long-term incentive plan as a fraction of her total compensation. *Source:* Capital IQ.

INNOVATION: Ratio of the number of innovation-related words to the total number of words in the questions and answers (QA) section of earnings calls averaged over a 3-year window. *Source:* Li et al. (2020).

INTEGRITY: Ratio of the number of integrity-related words to the total number of words in the QA section of earnings calls averaged over a 3-year window. *Source:* Li et al. (2020).

QUALITY: Ratio of the number of quality-related words to the total number of words in the QA section of earnings calls averaged over a 3-year window. *Source:* Li et al. (2020).

RESPECT: Ratio of the number of respect-related words to the total number of words in the QA section of earnings calls averaged over a 3-year window. *Source:* Li et al. (2020).

TEAMWORK: Ratio of the number of teamwork-related words to the total number of words in the QA section of earnings calls averaged over a 3-year window. *Source:* Li et al. (2020).

FRACTION_FEMALE_INVENTORS: The estimated fraction of female inventors of patents applied for by a firm in a given year. We compute the probability that an inventor is female based on the inventor's first name using the Genderize.io database. We then sum up these probabilities and divide the sum by the total number of inventors in a given firm-patent application year to obtain the estimated fraction of female inventors in a firm. *Source:* USPTO, Genderize.io.

INVENTOR_ETHNICITY_HHI: The Herfindahl–Hirschman Index (HHI) of the estimated fraction of inventors belonging to 10 different ethnic/cultural groups: African, Celtic, East Asian, South Asian, European, Nordic, Greek, Hispanic, Jewish, and Muslim. We algorithmically compute the probabilities that an inventor belongs to each of the 10 ethnic/cultural groups based on the inventor's full name and the NamePrism API.

We then sum up these probabilities for each ethnic/cultural group and divide the sum by the total number of inventors in a given firm-patent application year to obtain the estimated fraction of investors belonging to each ethnic/cultural group. Finally, we compute the HHI over the 10 ethnic/cultural groups for each firm. *Source:* USPTO, NamePrism.

ROA: Ratio of net income to total assets. *Source:* Osiris.

STOCK_RETURN: Cumulative monthly stock return over the past 12 months. *Source:* Osiris.

BOARD_SIZE: The number of directors on a board. *Source:* BoardEx.

BOARD_INDEPENDENCE: The fraction of independent directors on a board. *Source:* BoardEx.

FEMALE_CEO: An indicator variable that takes the value of 1 if a firm has a female CEO in a given year, and 0 otherwise. *Source:* BoardEx.

ln(TOTAL_ASSETS): Natural logarithm of total assets. *Source:* Osiris.

ln(FIRM_AGE): Natural logarithm of firm age. *Source:* Osiris.

TANGIBILITY: Ratio of fixed assets to total assets. *Source:* Osiris.

ln(K/L): Natural logarithm of the ratio of fixed assets to the number of employees. *Source:* Osiris.

ln(R&D_CAPITAL): Natural logarithm of R&D capital S. $S_t = R_t + (1-\delta)S_{t-1}$, where S_t is R&D capital in year t, R_t is R&D expenditures in year t, and $\delta = 0.15$ is the depreciation rate of R&D capital.

ln(PATENT_STOCK): Natural logarithm of patent stock PS. $PS_t = P_t + (1-\theta)PS_{t-1}$, where PS_t is patent stock in year t, P_t is the number of patents applied by a firm in year t, and $\theta = 0.05$ is the depreciation rate of patents (based on an average patent term of 20 years).

CAPEX: Ratio of capital expenditures to total assets. *Source:* Osiris.

CASH: Ratio of cash or cash equivalent to total assets. *Source:* Osiris

LEVERAGE: Ratio of total debt to total assets. *Source:* Osiris.

CASH_FLOW_VOLATILITY: The standard deviation of free cash flows over the past 3 years. *Source:* Osiris.

ln(TRANSCRIPT_LENGTH): Natural logarithm of the number of words in a firm's earnings call transcripts in a given year. *Source:* StreetEvents.

Supplementary Material

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