Title: Are Female Executives Better Innovators?

Authors: Xiaohu Deng[1], Lei Gao[2,] , Jianlei Han[3]. †

Affiliations:

[1] University of Tasmania, Hobart, TAS 7001, Australia, Email: xiaohu.deng@utas.edu.au

[2] Iowa State University, Ames, IA 50011, United States, Email: lgao@iastate.edu

[3] Macquarie University, Sydney, NSW 2109, Australia, Email: jianlei.han@mq.edu.au

† Author equal contribution.

Abstract

We investigate whether female executives are associated with greater innovative success. We find that firms with female CEOs obtain more patents and citations. A female executive is associated with approximately 50% and 45% standard deviation more patents and citations respectively for given R&D expenditure. We also find that companies led by female CEOs focus more on explorative innovation. Moreover, strengthened human capital (better managerial ability and hiring more inventors) is a plausible channel through which female CEOs positively affects the innovation outcomes. We are not arguing that females are in general more innovative; instead, it does seem that the female executives are more capable of helping the company to become more innovative.

Key Words: Female CEOs; Corporate Innovation; Gender Equity; Innovation Strategies; Human Capital

"Everything in the world is about sex except sex. Sex is about power."

—Oscar Wilde

1. INTRODUCTION

Gender diversity is an integral part of the corporate culture in many countries around the world. Quotas for female board members have become law in many countries, such as France (50%), Italy (30%), Norway, and several other European countries (Ahern and Dittmar, 2012). However, on average 23.3% of board members of the largest publicly listed companies are women. In the United States, there are about 16% of women serving on Fortune 500 company boards in 2011[1], while only about 5.2% CEOs are female. Recent literature also finds supporting evidence that board gender diversify facilitates corporate innovation (e.g., Chen, Leung, and Evans, 2018; Griffin, Li, and Xu, 2020). While the regulator and academia realize the importance of gender diversity in a board, there is little research examining the gender effect of business executives on corporate innovation success.

After all, if the executives labor market and financial markets have biased views on the CEOs' genders, and because labor and financial markets have a substantial impact on firm innovation, the gender of CEOs might impact firms' innovation. One big concern is that there might be few qualified women in the CEO labor market, though it might be possible there are more qualified than incumbent female corporate executives because of the stereotyping of the incompetence of women in the highly competitive working environment. Yavorsky, Keister, Qian, and Nau (2019) show that females' income is sufficient for one percent status in only about 5% households and marrying a man with good income prospects contributes the rest of females' one

[1] According to Catalyst, from the 2010 Catalyst Census: fortune 500 Women Board Directors. www.catalyst.org/knowledge/womenceossp500.

percent status. Our finding of 5.2% female CEOs coincide with their 5%.[2] The low ratio of female CEOs might be a result of the motherhood penalty, England, Bearak, Budig, and Hodges (2016) show that women with high skills and high wages experience the highest total penalties. And we further provide evidence showing the stereotype against females may be the barrier that stops females' march to the top one percentile status, and the discriminating stereotyping results in a group of female CEOs of better quality, who can help the corporates that they serve to become more innovative.

A more gender-equal culture could lead to a diminishing gender gap in several dimensions. E.g., One of the most well-known stereotypes about gender gap is probably in math performance, Guiso, Monte, Sapienza, Zingales (2008) find that gender gap in math scores disappears in countries with a more gender-equal culture. Following a similar idea, regulators tried to increase diversity and equality in the corporate world. Regulations on the fraction of females on boards in Norway create negative consequences (Ahern and Dittmar, 2012), cause criticism, and serve as a reference for regulators following similar regulation policies, such as in California. However, the negative consequences are mostly because of the scarcity of qualified female board members from the demand shock in the requirement of female percentage on board. Also, it is challenging to make laws on CEO position diversification because there is only one CEO for each company (with very few exceptions for two CEOs). Little is known about the economic and innovation consequences of a growing and diverse array of external stakeholders, coupled with the growing diverse internal structures of firms. Literature show negative short term stock returns response to announcements of female CEO compared to male CEOs (e.g., Lee and James, 2007). However,

[2] Back to the years before 2000, the ratio of women CEOs is even lower. The average female executive's ratio is less than 2% during our whole sample period. Fig. 1. illustrates the changes in the percentage of the number of female CEOs among all public firms available in BoardEx dataset. The situation is getting better in the last decade, but it does not seem to be good enough.

the long-term relative performance and the underlying drivers for firms led by female CEOs are under-investigated. We study the long-term impacts of female CEOs. Also, considering innovation is the engine of corporate long-term growth and core competitive advantage in the product market, the innovation yield serves as the main reference for firms' long-term development. Therefore, examining the impacts of female CEOs on corporate innovation mirrors the importance of gender diversity in corporate top management on firms' long-term developments.

The disparate impact and disparate treatment discrimination against female (Benbow and Stanley, 1980) might have existed in the CEO selection process. The "glass ceiling" might have restricted females from stepping up the male-dominated profession, and this might have resulted in a more capable executives' group due to higher qualification standards to break the "glass ceiling". Thus, we should expect firms led by more capable female CEOs yield more innovations and perform better in the long run.

Consistent with our conjecture, we find that firms with female CEOs are associated with more patents and patent citations than male CEOs after controlling for firm size, R&D investment, and other innovation-relevant firm characteristics. To deal with reverse causality and potential endogeneity issues, we rely on the transition from a male CEO to female CEO as a quasi-exogenous change to CEO gender and conduct a Difference-in-Differences (hereafter, DiD) test. Our DiD test is a multi-event DiD test design similar to the one with multiple treatment groups and multiple time periods in Bertrand and Mullainathan (2003) and Imbens and Wooldridge (2009) (different from a traditional DiD test with fixed treatment and control groups and fixed time periods). Our results confirm our baseline results. Furthermore, if the changes in innovation outputs are related to the ongoing effect of CEO gender transition, the results should not be isolated to the period immediately after a female CEO is appointed. We find both the quantity (measured by the raw number of patents) and quality (measured by the number of citation weighted patents) are higher for at least 6 years after a female CEO is appointed. This confirms the notion that the documented effect of female CEOs is not spurious- taking the fruits planted by previous male CEOs is not the case.

Next, we examine the underlying mechanisms through which female CEOs facilitate innovation success. We first look at whether the companies led by female executives employ different innovation strategies. Using internal and external patents classification, we find that firms generate more both internal and external patents. However, the number of external patents increase significantly more than the number of internal patents. According to Akcigit and Kerr (2018), internal patents represent the ones following existing knowledge and technologies and external patents are the ones venturing into new knowledge and technologies. Thus, our results suggest that firms led by female CEOs may focus more on the development of new knowledge and technologies.

Promoting technological innovation, particularly developing new knowledge and technologies, requires human capital (Holmstrom, 1989). We, thus, investigate whether the documented positive effect on innovation is affiliated with strengthened human capital. Chen et al. (2015) and Chemmanur et al. (2019) find evidence that managerial ability can benefit corporate innovation practice. Using the managerial ability score measure developed by Demerjian et al. (2012), we look at the changes in the quality of management teams after the appointment of female CEOs, and we find that the managerial quality significantly increased afterwards. Inventors are the key personnel in the innovation practice. When there is a higher quality management team, the company can provide a more flexible and tolerant environment to the inventors. Following this logic, we test the relationship between CEO gender transition and inflows of inventors, and we find that the management is able to hire more inventors, relative to the period when they have a male CEO.

Our paper contributes to the literature studying gender equity and diversity in the corporate executives' profession. To the best of our knowledge, we are the first one to report the positive association between female CEOs and firms' innovation output. Our findings are based on a general setting with the public firms in the United States. Human is blessed with wonderful potentials. However, we live in a world that is yet to empower all the wonderful potentials completely. Stereotypes and gender discrimination still hold back many extraordinary and talented people from pursuing their dreams, especially for women. Women contribute about 70% of the purchasing power in overall consumer markets. However, they are underrepresented in the executives' roles in corporate management. As businesses, encouraging diversity is a means for us to rouse a tremendous reservoir of untapped potential.

Although the CEO compensation is beyond the scope of our research, the female CEOs' relative outperformance in innovation seems to be consistent with the better monetary compensation findings (Hill, Upadhyay, and Beekun, 2015) in the labor market for these female CEOs. And these seem to be consistent with the anecdotal evidence: "female CEOs of the largest public companies are actually out-earning men" (Fortune 2016, May 10) and "though outnumbered, female CEOs earn more than male chiefs" (WSJ 2017, May 31).

It is not merely a moral position. Our research has practical and policy implications. It is one of the smartest investments we can make in the transformation to a more productive and inspired world. Earlier event study research (Lee and James, 2007) finds that the financial market response on the announcement of female CEO inaugural is negative. However, we do not find that female CEOs underperform in the long-run. Instead, they outperform on average compared to their male peers in firm innovation. We also base our research on a large sample in literature, and thus reflect better coverage of the corporates. Existing literature studying female CEOs relies on relatively small samples, E.g., Lee and James (2007) use 529 announcements of executives' appointments. ExecuComp, the most commonly used dataset that captures gender information of executives, covers only companies in the S&P 1500 index, where there are 400 mid-sized firms and 600 small-sized firms in addition to 500 large firms. We base our analysis on a database with broader coverage of BoardEx, including the vast majority of firms listed on Nasdaq and NYSE. Fortunately, we have observed an upward trend of the female executive ratio in the last two decades, but the percentage is still very low, much lower than other professions.

The rest of the paper is structured as follows: Section 2 presents the data, sample, and construction of variables. Section 3 reports the baseline empirical results. Section 4 presents the results of our identification. Section 5 and Section 6 present additional results. Section 7 concludes.

2. DATA, SAMPLE, & VARIABLES CONSTRUCTION

2.1 Data and sample

We construct our sample using several datasets. Our sample covers the period from 1992-2010. We use BoardEx to collect executive gender information. We extract Firm characteristics data from Compustat. We collect analyst coverage from the Institutional Brokers' Estimate System (I/B/E/S) dataset. We collect institutional holding from the Thomson Reuters 13F database. The variable definitions are available in Supplementary Table S6. Our sample includes 7,739 firm-year observations covering 1,451 firms after excluding financial and utility firms (which is the general practice in the literature because they are in regulated industries).

The dependent variables are the number of patents and the citation adjusted number of patents. The independent variable is the indicator variable Female, which takes one if the firm's CEO is female during the firm-year, and zero otherwise. Following the innovation literature, we control for a vector of managerial and industrial characteristics that could potentially affect corporate innovation outcome. We first control firm size *Log (AT)*, which measures as the natural logarithm of total assets. We also control *Firm Age* (the natural logarithm of number of years since initial public offering), investments in intangible assets, *RD* (R&D expenditure to sales), *Leverage* (the ratio of debt to total assets), *CAPEX* (capital expenditure to total assets from the prior year), and asset tangibility *PPE* (net properties, plants, and equipment scaled by total assets). To control growth opportunity, we compute *Tobin's Q*, as well as profitability *ROA* (return on assets). To control the effect of product market competition on innovation outputs, we control for Herfindahl index *HHI* (sum of squared market shares of firms' sales (sale) at the two-digit SIC industry level) in our regressions. In addition, we control firms' financial constraints using *KZ* index (the Kaplan and Zingales (1997) five-variable KZ index), and institutional ownership *Insownership*, measured as the average ratio of institutional holding to the number of shares outstanding for all quarters during year *t*.

2.2 Measuring corporate innovation

We measure corporate innovation using the firm level total number of patent granted in a fiscal year. We collect patent data from the newly developed patent data collected by Kogan, Papanikolaou, Seru, and Stoffman (2017) (hereafter, KPSS). Following the innovation literature, we use number of patent applications filed in a given year that are eventually granted as the measure of innovation output. The first dependent variable, *Npats* is the total number of patents for year *t*, scaled by 1,000. The second dependent variable, *Cpats* is the scientific value of the patents, which measures the output of innovation. Compared to the raw counts of patents for a company, the scientific value reflects the outcome of the firms' innovative activities. To measure the scientific value of the patents, KPSS uses citation-weighted patents. Similar to *Npats*, we also scale the citation-weighted patents by 1,000.

2.3 Measuring innovation strategies

Following Akcigit and Kerr (2018), we classify patents into external and internal innovations. Internal patents are those in which 50 percent or more of the given citations are self-citations, which are those cited from the patents filed by the same firm. External patents are those in which 50 percent or more of the given citations are non-self-citations. Compared to internal patents, external patents are usually linked with new product lines or new knowledge or technologies. We use *InternalP* to denote the number of internal patents, scaled by 1,000, and *ExternalP* to denote the number of external patents, scaled by 1,000. We take the difference between the *ExternalP* and *InternalP* to gauge the degree of which the company focuses more on existing knowledge and technologies or ventures into new knowledge and technologies.

2.4 Measuring managerial quality

We use *MaScore* developed by Demerjian et al. (2012) to proxy managerial ability. This measure has been extensively used in economics and finance research (see e.g., Demerjian et al., 2012; Albuquerque et al., 2013; Chen et al., 2015). The *MaScore* measure is based on the intuition that management team with higher score can better utilize the firm's inputs, such as labors, capital, and other assets, to generate better output. To obtain the score, Demerjian et al. (2012) first use data envelopment analysis to estimate firm efficiency within each industry, which is assumed to be attributable to both the firm and mangers. The firm specific component of this efficiency is the score of management quality, and is the residual from a Tobit regression by industry which controls specific firm characteristics such as size, free cash flow, competition, and age.

2.5 Measuring inventor mobility

To measure inventor mobility, we collect inventor information of each patent from the Harvard Business School Dataverse – U.S. Patent Inventor database, provided by Li et al (2014). The inventor database includes inventor names, inventor addresses, file and application dates for each patent, using which we are able to identify and track the possible moves of each inventor. Following Marx et al. (2009) and Chemmanur et al. (2019), we identify an inventor as changing employers if she or he has ever filed two consecutive patents which, however, are assigned to two different entities. To identify an inventor's move-in year and move-out year for an employer, we rely on the patent filing year. An inventor's move-in year is the year when he or she filed the first patent with a given employer, and move-out year is the year when he or she filed the first patent in the subsequent employer. [3] After identifying each inventor's move-in and move-out years, we aggregate the number of move-in inventors and move-out inventors at the firm-year level. We define the difference between the number of move-in inventors and the number of move-out inventors, scaled by 1000, as the measure of inflow of mobile inventors, *Inflow*.

3. BASELINE EMPIRICAL RESULTS

3.1 Summary statistics

[3] For robustness check, we shift an inventor's move-in year to 1 or 2 years before he or she filed the first patent with the employer and move-out year to 1 or 2 years after he or she filed the last patent with the employer. Our estimation results are qualitatively similar.

Table 1 provides summary statistics for the variables we use in our study. As our sample includes only firms that generate patents, the overall mean of Female is very low at 0.015, which indicates that very few firms appoint a female CEO. It is consistent with (20) in that only 2% of the CEOs of US public-listed firms are women. The average firm age in our sample is about 22 years. From the comparison, we find that female-CEO firms have a higher average number of patents (0.102) than male-CEO firms (0.052), and the difference is significant. Consistently, female-CEO firms also have a significantly higher citation-weighted number of patents (0.229) than male-CEO firms (0.120). In terms of other firm characteristics, female-CEO firms have lower tangible assets, higher cash flow and cash, higher dividend ratio, lower KZ index, higher institutional ownership, and lower analysts' coverage, and are slightly larger in size.

Table 2 shows the industrial distribution of female CEOs and their innovation outputs in our sample period. We define the industries by Fama-French 12 industry. From the table, we can see that Business Equipment--Computers, Software, and Electronic Equipment has the most female CEO observations and also the most of their patents. The industrial distribution preliminarily indicates that the female CEOs are making most of their innovations in the high tech sectors.

3.2 Baseline results

Table 3 presents baseline OLS regression results that quantify the effect of CEO gender on innovation productivity[4]. The dependent variables are the number of patents, *Npats*, and the citation-weighted number of patents, *Cpats*. Since the innovation process generally takes years, we examine the effect of female CEO on patenting from one year ahead to three years ahead. The

[4] We also include all firms with no patents as a robustness check. The results are qualitatively the same.

key independent variable we focus on is *Female*, which is a dummy variable equals one if the CEO is a woman, and zero otherwise. We control the firm characteristics of firm size, firm age, R&D, capital expenditure, tangible assets, ROA, leverage, Tobin's Q, KZ index, HHI index, and institutional ownership. We include year-fixed effects and industry-fixed effects to account for unobservable time and industry characteristics that might affect a firm's innovation output. In all regressions, we find that the coefficient estimates on *Female* are all positive and statistically significant (β ranges from 0.07 to 0.17, p<0.05 or 0.01). These results strongly support our conjecture that female-CEO firms are associated with significantly higher innovation output. Also, the female-CEO effect is economically significant. For example, the coefficient on *Female* of 0.088 in column (1) means that, after controlling other firm characteristics, female-CEO firms on average have 88 more patents granted than male-CEO firms in the next year.

The coefficients on the control variables also confirm our expectations from prior literature. Firms that are larger, with more R&D expenditure, higher capital expenditure, more tangible assets, lower leverage, higher Tobin's Q, and more institutional ownership are associated with more innovation output. Further, the KZ index is negatively related to innovation, indicating that firms facing lower financial constraint have more innovation output in the future.

4. IDENTIFICATION

4.1 A Difference-in-Differences approach: The case of CEO transition

Concerns of our findings may include reverse causality or endogeneity issues such as some unobservable firm characteristics that simultaneously affect both CEO gender selection and innovation output. To mitigate this concern, similar to Huang and Kisgen (2013) and Faccio et al.

(2016), we rely on transition from a male CEO to female CEO as a quasi-exogenous change to CEO gender, and conduct a DiD test. Our DiD test is a multi-event DiD test design (different from a traditional DiD test with fixed treatment and control groups and fixed time periods), following the empirical setting with multiple treatment groups and multiple time periods in Bertrand and Mullainathan (2003) and Imbens and Wooldridge (2009). For this purpose, we include both firm and year fixed effects in our panel regressions to control time-invariant unobservable firm-specific characteristics. We include only firms that experience at least a change from a male CEO to a female CEO during our sample period, as only those firms contribute to the gender effect we are interested in. The final sample has 248 firm-year observations.

We report the regressions results in Table 4. In Table 4, *Female* is equal to 1 if the firm has a female CEO in the year, and zero otherwise. It captures the treatment effect of the transition from a male CEO to a female CEO. Consistent with the baseline results, we find that the transition to female CEO has a significantly positive effect on the firm's R&D outputs in the two and three years ahead.

4.2 Pre-trend test

The assumption of a DiD test is the parallel trends between treatment and control group. Applying to our DiD test, we expect to observe that in the absence of CEO gender transitions, treated firms' innovation outputs should behave the same way as those of control firms. To compare the pre-treatment trend between the treated and control firms, we re-estimate the regression equations reported in Table 8 by replacing the treatment dummy Female with seven new indicator dummies: Female(-3), Female(-2), Female(-1), Female(0), Female(1), Female(2), and Female(3+). These new indicator dummies represent years relative to the year of CEO gender transition from male to female. For example, Female(-2) indicates two years before the year of

CEO gender transition and Female(2) indicates two years after the year of CEO gender transition, while Female(3+) represents three or more years after the gender transition. Female(-3), Female(-2), and Female(-1) are very important because their significance and magnitude suggest whether there is any difference in the corporate innovation outcome between treatment and control group before the gender transition. Table S2 in the supplementary materials reports the results. In Table S2, the coefficients of Female(-3), Female(-2), and Female(-1) are all very small and insignificant from zero, suggesting there is no systematic difference between treated and control firms before the gender transition. Interestingly, the coefficients of Female(3+) are the only dummies statistically significant and positive, indicating that innovation outcome starts climbing up not right after a female CEO takes the office but after she has been in the office for more than 3 years. This is consistent with the common notion that innovation and patents granting usually takes years, and our results also rule out the possibility that the firms choosing female CEOs because they are more innovative ex-ante.

Overall, our DiD test results confirm our findings that female CEO has a positive effect on firm's innovation outcome, and further rule out the endogeneity concerns.

5. IS THE FEMALE EFFECT A DELAYED EFFECT OF MALE CEOs?

To further understand the pattern in which innovation output after a new CEO is appointed, we plot the changes in both the number of patents and the number of citation weighted patents under two scenarios- 2 years and 8 years after a new male CEO is appointed; and after a new female CEO is appointed. The plots are illustrated in Figure 2. Overall, both scenarios exhibit an increase in innovation output after a new CEO is appointed. The average increase in total patents (citation weighted patents) is about 20-25% (12-13%) after a new male CEO is appointed. Interestingly, the average increase in innovation output after a female CEO is appointed is more than 100% (close to 100% for the number of citation weighted patents).

We also formally test the long term effect of new female CEO appointment on innovation output. If the documented effect is not a delayed effect of the past male CEOs' efforts, relative to pre-CEO turnover levels, innovation output levels should be permanently higher. While it is difficult to detect any change over longer horizons, we certainly would not expect the effect to be short-lived. Tables 6 presents the innovation regressions with female treatment indicators for various time periods after the gender transition: years 1 and 2, 3 and 4, 5 and 6, and after 6. We see that the effect is quite persistent with higher number of patents and citation weighted patents documented through the sixth year after the gender transition.

To sum, the results in this section further confirm our findings that female CEOs can facilitate innovation success. More importantly, the gender effect on innovation is long-lived.

6. THE UNDERLYING MECHANISMS

6.1 Female CEOs and innovation strategies

In this subsection, we investigate the effect of CEO gender on innovation strategies. Using the measures and classifications (namely, internal and external patents) we have described in Section 2, we test the relation between CEO gender transistion on the types of innovation strategies the management focuses on, under the same DiD framework. We regress the number of internal and external patents on female indicators, and then regress the difference between the number of external and internal patents on the indicator variable. The coefficients of female indicators are both significant for external and internal patents regressions, suggesting that firms are granted more both internal and external patents. However, the average increase in the granted external patents is about 4 to 5 times more than the incease in the internal patents granted after female CEOs are appointed. As external patents are usually linked with new product lines or new knowledge or technologies, and internal patents are built on the existing knowledge and technologies, our results suggest that the top management and core technology teams emphasize significantly more than developing new products and technologies, after the new female CEOs are appointed.

6.2 Female CEOs, human capital, and innovation success

Innovation requires human capital (Holmstrom, 1989). Therefore, an efficient and high quality management team may facilitate R&D practice.[5] A higher quality management team may provide better resources and more failure-tolerant environment for inventors. Thus, we conjecture that enhanced human capital may be an important channel through which female CEO led companies achieve better innovation success. To formally test this hypothesis, we examine the changes in management quality and inventor hiring and retaining during CEO gender transition.

First, we test whether CEO gender transition affects management quality. As we have discussed in Section 2, we measure management quality by using *MaScore* developed by Demerjian et al. (2012). We estimate the regressions under the same DiD framework with current and future (up to 3 years after the transition) *MaScore* as the dependent variables, and we report the results in Table 8. Consistent with our prior, we find positive and statistically significant

[5] Chen et al. (2015) and Chemmanur et al. (2019) find management quality and ability facilitates corporate innovation success.

coefficients on *Female* across three specifications. The results suggest that one important channel for female CEOs to be more capable to facilitate corporate innovation is because they are able to attract better quality managers and improve the overall management quality.

We, then, test whether improved innovation outputs can be attributable to more inflows of inventors. Similarly, we regress the current and future (up to 3 years after the transition) *Inflow* of inventors measure on *Female* indicators and other control variables under the same DiD framework, and we report the results in Table 9. The coefficients are consistently positive and statistically significant, which confirms our conjecture.

To sum up, the results in this section highlight an important channel through which female CEOs facilitate innovation output- improving the quality of management team and attracting more inventors to join.

7. CONCLUSION

In this study, we investigate an important and hotly debated topic: are female executives are more "productive" than male peers? To answer this question, we study the CEO gender differences in corporate innovation activities. We find that, in general, firms with female CEOs generate better innovation outcome, in terms of both quantity and quality, than firms with male CEOs. Shareholders, whether men or women, might discriminate women without realizing it. Our findings are consistent with the "glass ceiling" prejudice predictions. The widely perceived "glass-ceiling" effects exist in the CEO labor market in the firm executive selection process. Thus, we show that female executives are better innovators.

We use CEO gender transitions as a plausibly exogenous shock on CEO gender, and apply a Difference-in-Difference approach, and are able to confirm our baseline results. In addition, we examine the possible mechanisms through which CEO gender can affect corporate innovation outcome. Companies led by female CEOs are engaging more in new products and technologies, and are able to recruit higher quality management teams, which in turn attracts more inventors to join. The outcome is better innovation outputs.

Gender diversity is a growing issue in modern corporations and the workplace. Our study contributes to the literature as it sheds new light on shaping the importance of gender diversity and contributes to real-world practices. However, our study does not imply any generic conclusion about gender diversity impacts on firm innovations yield. Future studies could further address the issues in the variances between female and male differences in broader areas.

References

Adams, R.B., Barber, M.B., and Odean, T., 2017. Family, values, and women in Finance. Working paper.

Ahern, K.R. and Dittmar, A.K., 2012. The changing of the boards: The impact on firm valuation of mandated female board representation. The Quarterly Journal of Economics, 127(1), pp.137-197.

Akcigit, U., Kerr, W. R. 2018. Growth through heterogeneous innovations. Journal of Political Economy, 126(4), 1374-1443.

Albuquerque, A. M., De Franco, G., Verdi, R. S. 2013. Peer choice in CEO compensation. Journal of Financial Economics, 108(1), 160-181.

Benbow, C.P. and Stanley, J.C., 1980. Sex differences in mathematical ability: Fact or artifact?. Science, 210(4475), pp.1262-1264.

Berenbaum, May R., 2019, Speaking of gender bias. Proceedings of the National Academy of Sciences (2019): 8086-8088.

Bertrand, Marianne, and Sendhil Mullainathan, 2003. Enjoying the quiet life? Corporate governance and managerial preferences. Journal of Political Economy, 111, 1043-1075.

Bertrand, M., Black, S.E., Jensen, S. and Lleras-Muney, A., 2014. Breaking the glass ceiling? The effect of board quotas on female labor market outcomes in Norway. The Review of Economic Studies.

Chemmanur, T. J., Kong, L., Krishnan, K., & Yu, Q. 2019. Top management human capital, inventor mobility, and corporate innovation. Journal of Financial and Quantitative Analysis, 54(6), 2383-2422.

Chen Y., Podolski, E. J., and Veeraraghavan, M., 2015. Does managerial ability facilitate corporate innovation success?. Journal of Empirical Finance, 34, 313-326.

Demerjian, P., Lev, B., McVay, S., 2012. Quantifying managerial ability: A new measure and validity tests. Management Science, 58(7), 1229-1248.

Demerjian, P. R., Lev, B., Lewis, M. F., McVay, S. E. 2012. Managerial ability and earnings quality. The Accounting Review, 88(2), 463-498.

Dezsö, C.L. and Ross, D.G., 2012. Does female representation in top management improve firm performance? A panel data investigation. Strategic Management Journal, 33(9), 1072-1089.

England, P., Bearak, J., Budig, M.J. and Hodges, M.J., 2016. Do highly paid, highly skilled women experience the largest motherhood penalty?. American Sociological Review, 81(6), pp.1161-1189.

Faccio, M., Marchica, M.T., and Mura, R., 2016. CEO gender, corporate risk-taking, and the efficiency of capital allocation, Journal of Corporate Finance 39, p.193-209.

Goldin, C. and Rouse, C., 2000. Orchestrating impartiality: The impact of" blind" auditions on female musicians. American Economic Review, 90(4), pp.715-741.

Goldin, C., Katz, L.F. and Kuziemko, I., 2006. The homecoming of American college women: The reversal of the college gender gap. Journal of Economic Perspectives, 20(4), pp.133-156.

Griffin, D., Li, K., Xu, T. Board Gender Diversity and Corporate Innovation: International Evidence. Journal of Financial and Quantitative Analysis, Forthcoming.

Guiso, L., Monte, F., Sapienza, P. and Zingales, L., 2008. Culture, gender, and math. Science, 320(5880), p.1164-1165.

He, J. and Tian, X., 2013. The dark side of analyst coverage: the case of innovation. Journal of Financial Economics, 109, p.856-878.

Hill, A.D., Upadhyay, A.D., and Beekun, R.I., 2015. Do female and ethnically diverse executives endure inequity in the CEO position or do they benefit from their minority status? An empirical examination. Strategic Management Journal, 36(8), pp.1115-1134.

Huang, J. and Kisgen, D.J., 2013. Gender and corporate finance: are male executives overconfident relative to female executives? Journal of Financial Economics, 108(3), p.822-839.

Imbens, Guido, and Jeffrey Wooldridge, 2009. Recent developments in the econometrics of program evaluation, Journal of Economic Literature, 47, 5-86.

Jensen, K., Kovács, B. and Sorenson, O., 2018. Gender differences in obtaining and maintaining patent rights. Nature Biotechnology, 36(4), p.307.

Khan, B. Zorina. Invisible Women: Entrepreneurship, Innovation and Family Firms in France During Early Industrialization. No. w20854. National Bureau of Economic Research, 2015.

Kogan, L., Papanikolaou, D., Seru, A., and Stoffman, N., 2017. Technological innovation, resource allocation, and growth. The Quarterly Journal of Economics, 132(2), pp.665-712.

Lee, P.M. and James, E.H., 2007. She'-e-os: gender effects and investor reactions to the announcements of top executive appointments. Strategic Management Journal, 28(3), pp.227-241.

Pande, R. and Ford, D., 2011. Gender quotas and female leadership. World Development Report.

Sargis, M. and Lutton, L. P., 2016. Fund managers by gender. Morningstar Research, 1-39.

Weber, A. and Zulehner, C., 2010. Female hires and the success of start-up firms. American Economic Review, 100(2), pp.358-61.

Yavorsky, J.E., Keister, L.A., Qian, Y. and Nau, M., 2019. Women in the One Percent: Gender Dynamics in Top Income Positions. American Sociological Review, 84(1), pp.54-81.

Tables

Table 1: Summary statistics

This table reports the descriptive statistics for all variables used in our study. Npats is the number of patents, scaled by 1000. Cpats is the citation-weighted number of patents, scaled by 1000. Female is a dummy variable, which equals one if the CEO is a female in a given fiscal year, and zero otherwise. CEO Tenure is the tenure of each CEO. Log(AT) is the natural of logarithm of the total assets. Leverage is the ratio of total debt to total assets. Log(firmage) is the natural logarithm of firm age. RD is the ratio of R&D expenditure to sales. CAPEX is the ratio of capital expenditure to tangible assets. PPE is the ration of tangible assets to total assets. ROA is the ratio of income before interest and tax to total asset. Q is the market to book ratio. Cash Flow is the sum of the income before extraordinary items and depreciation and amortization, scaled by the tangible assets. Cash is the ratio of cash and short-term investments, scaled by the tangible assets. Dividend is the ratio of dividend common, scaled by operating income before depreciation. KZ is KZ index. HHI is the sum of squared market shares of firms' sales at the two-digit SIC industry. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Full Sample						Female	Male	Difference
Statistic	N	Mean	STD.	Pctl(25)	Median	Pctl(75)	Mean	Mean	T-stat
Npats	36,002	0.015	0.105	0.000	0.000	0.001	0.019	0.014	0.931
Cpats	36,002	0.035	0.247	0.000	0.000	0.003	0.043	0.034	0.905
Female	36,002	0.024	0.153	0.000	0.000	0.000	1.000	0.000	
CEO Tenure	36,002	4.794	3.811	2.000	4.000	7.000	4.294	4.806	-4.745***
Log(AT)	36,002	7.418	1.651	6.214	7.298	8.500	7.397	7.418	-0.370
Leverage	36,002	0.231	0.187	0.066	0.218	0.349	0.215	0.232	-2.584***
Log(firmage)	36,002	3.065	0.738	2.565	3.135	3.738	3.093	3.065	-1.099
RD	36,002	0.030	0.058	0.000	0.000	0.03	0.021	0.030	-4.497***
CAPEX	36,002	0.238	0.158	0.125	0.197	0.310	0.234	0.238	-0.856
PPE	36,002	0.290	0.236	0.100	0.219	0.434	0.244	0.291	-5.789***
ROA	36,002	0.036	0.105	0.015	0.046	0.084	0.038	0.036	-0.493
Q	36,002	1.976	1.289	1.188	1.546	2.242	1.982	1.976	0.146
Cash Flow	36,002	0.654	0.918	0.145	0.374	0.841	0.677	0.654	0.746
Cash	36,002	2.502	7.161	0.074	0.376	1.682	2.371	2.505	-0.544
Dividend	36,002	0.013	0.040	0.000	0.003	0.018	0.015	0.013	1.393
KZ	36,002	-3.006	9.167	-2.561	-0.349	0.631	- 3.124	-3.003	0.385
HHI	36,002	0.065	0.060	0.032	0.044	0.074	0.066	0.065	0.491

Table 2: Sample distribution among industries

This table reports the industrial distribution of female CEOs and their innovation outputs from 1992 to 2010. The industries are defined by Fama-French 12 industries. No. of Female CEO-year is the total number of firm-year observations with female CEOs. Npats is the number of patents. Cpats is the citation-weighted number of patents.

Industry	No. of Female CEO-year	Npats	Cpats
Consumer NonDurables	31	237	348.5
Consumer Durables	4	33	79.52
Manufacturing	26	242	476.8
Oil, Gas, and Coal Extraction and Products	1	2	2.000
Chemicals and Allied Products	13	903	1,384
Business Equipment-- Computers, Software, and Electronic Equipment	50	14,610	33,795
Telephone and Television Transmission	4	12	21.68
Utilities	2	2	12.25
Wholesale, Retail, and Some Services	3	3	10.77
Healthcare, Medical Equipment, and Drugs	24	438	651.7
Finance	10	50	106.0
Other	5	225	724.0

Table 3: Female CEOs and corporate innovation: Baseline OLS results

In this table, we report the panel regressions results for innovation outcomes from 1 year later to 3 years later. The dependent variables $Npats_{t+i}$ is the number of patents *i* years later. $Cpats_{t+i}$ is the citation-weighted number of patents *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Supplementary S4. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

Panel A: Female CEOs and number of patents

	$Npats_{t+1}$ (1)	$Npats_{t+2}$ (3)	$Npats_{t+3}$ (5)
Female	0.015***	0.017***	0.021***
	(3.869)	(4.088)	(4.260)
Log(AT)	0.020***	0.021***	0.022***
	(44.356)	(42.823)	(41.015)
Log(firmage)	0.006***	0.005***	0.005***
	(6.166)	(5.153)	(4.171)
OMRD	- 0.014***	- 0.014***	- 0.015***
	(- 8.352)	(- 7.833)	(- 7.523)
RD	0.157***	0.173***	0.177***
	(10.883)	(10.893)	(10.029)
CAPEX	0.018***	0.022***	0.025***
	(3.940)	(4.343)	(4.483)
PPE	0.022***	0.024***	0.027***
	(5.046)	(5.143)	(5.172)
ROA	0.002	0.008	0.008
	(0.247)	(1.053)	(0.963)
Leverage	- 0.020***	- 0.022***	- 0.023***
	(- 5.247)	(- 5.193)	(- 5.060)
Q	0.002***	0.003***	0.003***
	(4.472)	(4.288)	(4.604)
KZ	0.0001	0.0001	0.0001
	(1 .085)	(1.004)	(0.781)
HHI	0.010	0.022	0.033
	(0.506)	(0.986)	(1.326)
Year dummy	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes
Observations	32,985	30,086	27,303
R^2	0.117	0.120	0.122
Adjusted R^2	0.115	0.117	0.119

Panel B: Female CEOs and number of citation adjusted patents

	$Cpats_{t+1}$ (1)	$Cpats_{t+2}$ (3)	$Cpats_{t+3}$ (5)
Female	0.032***	0.037***	0.042***
	(3.517)	(3.642)	(3.704)
Log(AT)	0.047***	0.049***	0.051***
	(44.225)	(42.558)	(40.598)
Log(firmage)	0.011***	0.009***	0.008***
	(4.785)	(3.899)	(3.034)
OMRD	- 0.033***	- 0.034***	- 0.035***
	(- 8.271)	(- 7.769)	(- 7.425)
RD	0.380***	0.418***	0.429***
	(11.150)	(11.110)	(10.320)
CAPEX	0.047***	0.056***	0.063***
	(4.254)	(4.708)	(4.748)
PPE	0.044***	0.050***	0.054***
	(4.358)	(4.471)	(4.434)
ROA	- 0.002	0.013	0.017
	(- 0.118)	(0.752)	(0.859)
Leverage	- 0.053***	- 0.057***	- 0.061***
	(- 5.923)	(- 5.781)	(- 5.593)
Q	0.008***	0.008***	0.009***
	(5.911)	(5.713)	(5.976)
KZ	0.0002	0.0002	0.0001
	(0.848)	(0.766)	(0.591)
HHI	0.046	0.075	0.102*
	(0.937)	(1.410)	(1.730)
Year dummy	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes
Observations	32,985	30,086	27,303
R^2	0.112	0.115	0.117
Adjusted R^2	0.110	0.112	0.113

Table 4: DiD Regression results from the CEO turnovers

In this table, we report the panel regressions results of CEO turnover sample for innovation outcomes from 1 year later to 3 years later. We include only firms that experience a turnover, and their observations 8 years before and after the turnover. We include firm fixed effects and year fixed effects for this identification. The dependent variables $Npats_{t+i}$ are number of patents *i* years later. $Cpats_{t+i}$ are citation-weighted number of patents *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Appendix 1. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:					
	$Npats_{t+1}$	$Cpats_{t+1}$	$Npats_{t+2}$	$Cpats_{t+2}$	$Npats_{t+3}$	$Cpats_{t+3}$
	(1)	(2)	(3)	(4)	(5)	(6)
Female	- 0.011	- 0.025	0.033**	0.056*	0.069***	0.124***
	(- 0.946)	(- 0.942)	(2.556)	(1.913)	(4.795)	(3.895)
Log(AT)	0.028***	0.064***	0.028***	0.062***	0.026***	0.055***
	(9.632)	(9.692)	(8.918)	(8.765)	(7.515)	(7.198)
Log(firmage)	0.003	0.017	0.003	0.018	0.005	0.024
	(0.380)	(0.947)	(0.370)	(0.950)	(0.553)	(1.201)
OMRD	0.004	0.003	0.003	0.001	- 0.001	- 0.008
	(0.440)	(0.158)	(0.277)	(0.051)	(- 0.128)	(- 0.342)
RD	0.137***	0.264***	0.163***	0.328***	0.129***	0.247**
	(3.246)	(2.765)	(3.635)	(3.251)	(2.644)	(2.286)
CAPEX	- 0.010	- 0.032	- 0.006	- 0.017	0.005	0.008
	(- 0.985)	(- 1.338)	(- 0.537)	(- 0.677)	(0.415)	(0.277)
PPE	0.085***	0.207***	0.100***	0.242***	0.113***	0.249***
	(4.522)	(4.848)	(4.959)	(5.311)	(5.112)	(5.107)
ROA	- 0.016	- 0.052*	- 0.003	- 0.015	- 0.012	- 0.025
	(- 1.219)	(- 1.766)	(- 0.235)	(- 0.493)	(- 0.813)	(- 0.755)
Leverage	- 0.033***	- 0.073***	- 0.042***	- 0.085***	- 0.045***	- 0.088***
	(- 3.146)	(- 3.068)	(- 3.697)	(- 3.351)	(- 3.668)	(- 3.255)
Q	0.002	0.005*	0.001	0.002	- 0.0002	0.0004
	(1.589)	(1.866)	(0.556)	(0.808)	(- 0.114)	(0.130)
KZ	- 0.001***	- 0.002***	- 0.001***	- 0.002***	- 0.001***	- 0.002***
	(- 2.807)	(- 3.098)	(- 2.983)	(- 3.312)	(- 3.101)	(- 3.064)
HHI	- 0.211***	- 0.498***	- 0.222***	- 0.512***	- 0.230***	- 0.503***
	(- 3.316)	(- 3.440)	(- 3.293)	(- 3.369)	(- 3.190)	(- 3.158)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Firm dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,651	6,651	6,437	6,437	6,197	6,197
R^2	0.832	0.857	0.836	0.862	0.836	0.867
Adjusted R^2	0.809	0.837	0.812	0.842	0.811	0.847

Table 5: Pre-treatment trends test

In this table, we report the pre-treatment trends test results of CEO transition sample for innovation outcomes. We include only firms that experience a change from a male CEO to a female CEO or vice versa. We include firm fixed effects for the identification. The dependent variables $Npats_{t+i}$ are number of patents *i* years later. $Cpats_{t+i}$ are citation-weighted number of patents *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Appendix 1. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:	
	$Npats_{t+1}$	$Cpats_{t+1}$
	(1)	(2)
Female(-3)	0.035	0.054
	(0.816)	(0.614)
Female(-2)	0.037	0.063
	(0.856)	(0.710)
Female(-1)	0.033	0.070
	(0.714)	(0.731)
Female(0)	0.049	0.092
	(1.032)	(0.931)
Female(1)	0.033	0.035
	(0.608)	(0.314)
Female(2)	0.052	0.064
	(0.923)	(0.543)
Female(3+)	0.166**	0.222**
	(2.583)	(2.464)
With Controls	Yes	Yes
Year dummy	Yes	Yes
Firm dummy	Yes	Yes
Observations	591	591
R^2	0.867	0.888
Adjusted R^2	0.835	0.861

Table 6: The long term effect of Female CEO Appointment

In this table, we report the panel regressions results of CEO turnover sample for innovation outcomes from 1 year later to 3 years later. We define a series of indicators Famale[1,2], Female[3,4], Female[5,6], Female[7,) representing 1-2 years, 3-4 years, 5-6 years, and over 7 years after the appointment of a female CEO. We include only firms that experience a turnover, and their observations 8 years before and after the turnover. The dependent variables $Npats_t$ is number of patents at year *t*. $Cpats_t$ is citation-weighted number of patents at year *t*. Control variables are defined in Appendix 1. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:	
	$Npats_t$	$Cpats_t$
	(1)	(2)
Famale[1,2]	0.026	0.061
	(0.693)	(0.650)
Female[3,4]	0.163***	0.417***
	(3.393)	(3.466)
Female[5,6]	0.098**	0.237**
	(2.479)	(2.388)
Female[7,)	0.053	0.102
	(0.976)	(0.752)
Log(AT)	0.055***	0.132***
	(39.660)	(37.796)
Log(firmage)	0.010***	0.017**
	(3.125)	(2.193)
OMRD	- 0.020***	- 0.052***
	(- 3.192)	(- 3.255)
RD	0.378***	0.883***
	(10.129)	(9.436)
CAPEX	0.037**	0.095**
	(2.539)	(2.565)
PPE	0.077***	0.170***
	(5.207)	(4.610)
ROA	- 0.044**	- 0.114**
	(- 2.419)	(- 2.525)
Leverage	- 0.054***	- 0.150***
	(- 4.494)	(- 4.977)
Q	0.002	0.009**
	(1.072)	(2.464)
KZ	- 0.0005	- 0.001
	(- 1.505)	(- 1.617)
HHI	0.039	0.245
	(0.386)	(0.964)
Year dummy	Yes	Yes
Industry dummy	Yes	Yes
Observations	6,858	6,858
R^2	0.287	0.259
Adjusted R^2	0.279	0.250

Table 7: Female CEOs and external patents

In this table, we report the panel regressions results of CEO turnover sample. We include only firms that experience a turnover, and their observations 8 years before and after the turnover. We include firm fixed effects and year fixed effects for this identification. The dependent variable ExternalP $_{t+3}$ is the number of non-self-cited patents 3 years later. The dependent variables InternalP $_{t+3}$ is the number of self-cited patents 3 years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Appendix 1. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:		
	ExternalP $_{t+3}$	InternalP $_{t+3}$	ExternalP $_{t+3}$-InternalP $_{t+3}$
	(1)	(2)	(3)
Female	0.101***	0.024***	0.077***
	(5.189)	(6.749)	(4.556)
Log(AT)	0.061***	0.008***	0.053***
	(36.113)	(37.373)	(35.771)
Log(firmage)	-0.001	0.003***	-0.004
	(-0.395)	(3.979)	(-1.277)
OMRD	-0.024***	-0.004***	- 0.020***
	(-2.897)	(-2.792)	(-2.746)
RD	0.414***	0.046***	0.368***
	(8.804)	(5.439)	(8.977)
CAPEX	0.053***	0.005	0.048***
	(2.903)	(1.447)	(3.032)
PPE	0.113***	0.010***	0.103***
	(6.228)	(3.117)	(6.501)
ROA	- 0.016	- 0.002	- 0.014
	(- 0.704)	(- 0.512)	(- 0.701)
Leverage	- 0.068***	- 0.004	- 0.068***
	(-4.513)	(-0.151)	(-5.147)
Q	0.002	0.001*	0.001
	(1.051)	(1.835)	(0.826)
KZ	- 0.0005	- 0.0001	- 0.0004
	(-1.114)	(-0.800)	(-1.112)
HHI	0.130	- 0.001	0.131
	(0.926)	(-0.038)	(1.070)
Year dummy	Yes	Yes	Yes
Firm dummy	Yes	Yes	Yes
Observations	5,460	5,460	5,460
R^2	0.863	0.889	0.849
Adjusted R^2	0.840	0.870	0.825

Table 8: Female CEOs and managerial ability

In this table, we report the panel regressions results of CEO turnover sample. We include only firms that experience a turnover, and their observations 8 years before and after the turnover. We include firm fixed effects and year fixed effects for this identification. The dependent variable MaScore $_{t+i}$ is the score of managerial quality *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Appendix 1. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:		
	MaScore $_{t+1}$	MaScore $_{t+2}$	MaScore $_{t+3}$
	(1)	(2)	(3)
Female	0.054***	0.060***	0.054***
	(3.426)	(3.616)	(3.268)
Log(AT)	0.031***	0.030***	0.028***
	(23.428)	(22.029)	(20.604)
Log(firmage)	0.003	0.003	0.003
	(1.086)	(0.893)	(1.026)
OMRD	0.017***	0.016***	0.020***
	(2.776)	(2.538)	(3.066)
RD	0.475***	0.514***	0.530***
	(12.886)	(13.526)	(13.521)
CAPEX	0.0003	-0.026*	-0.018
	(0.018)	(-1.731)	(-1.170)
PPE	-0.078***	-0.086***	-0.087***
	(-5.354)	(-5.789)	(-5.705)
ROA	0.057***	0.041**	0.027
	(3.152)	(2.139)	(1.398)
Leverage	-0.015	- 0.011	- 0.011
	(-1.291)	(-0.879)	(-0.903)
Q	0.029***	0.030***	0.030***
	(20.315)	(20.451)	(19.855)
KZ	- 0.003***	- 0.003***	- 0.003***
	(-8.094)	(-8.888)	(-7.675)
HHI	-0.025	- 0.015	-0.050
	(-0.267)	(-0.161)	(-0.519)
Year dummy	Yes	Yes	Yes
Firm dummy	Yes	Yes	Yes
Observations	6,014	6,014	6,014
R^2	0.704	0.703	0.721
Adjusted R^2	0.661	0.660	0.681

Table 9: Female CEOs and inventor mobility

In this table, we report the panel regressions results of CEO turnover sample. We include only firms that experience a turnover, and their observations 8 years before and after the turnover. We include firm fixed effects and year fixed effects for this identification. The dependent variable Inflow $_{t+i}$ is the measure of inventor mobility for *i* years later. Higher value of Inflow measure indicates the fact that the new hires of inventors are more than the departed inventors. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Appendix 1. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:		
	Inflow $_{t+1}$	Inflow $_{t+2}$	Inflow $_{t+3}$
	(1)	(2)	(3)
Female	0.001**	0.003***	0.003***
	(2.304)	(4.781)	(3.682)
Log(AT)	0.001***	0.001***	0.0002
	(7.082)	(3.781)	(1.015)
Log(firmage)	-0.003***	-0.002***	-0.002***
	(-8.035)	(-4.643)	(-3.138)
OMRD	0.001	0.001	0.0001
	(1.290)	(0.983)	(0.149)
RD	0.005***	0.004	-0.005*
	(2.344)	(1.576)	(-1.844)
CAPEX	-0.001*	-0.0001	0.001
	(-1.858)	(-0.154)	(1.111)
PPE	0.002*	0.003**	0.002*
	(1.818)	(2.450)	(1.839)
ROA	-0.00004	0.0003	0-0.001
	(-0.059)	(0.405)	(-0.829)
Leverage	0.0001	- 0.0003	- 0.010
	(0.205)	(-0.603)	(-0.809)
Q	-0.0001	0.0002	0.00001
	(-0.863)	(0.369)	(0.123)
KZ	- 0.0003*	- 0.0002	- 0.00001
	(-2.199)	(-1.396)	(-0.469)
HHI	0.003	0.005	0.002
	(0.717)	(1.225)	(0.460)
Year dummy	Yes	Yes	Yes
Firm dummy	Yes	Yes	Yes
Observations	4,212	3,873	3,538
R^2	0.288	0.286	0.301
Adjusted R^2	0.160	0.157	0.174

FIGURES

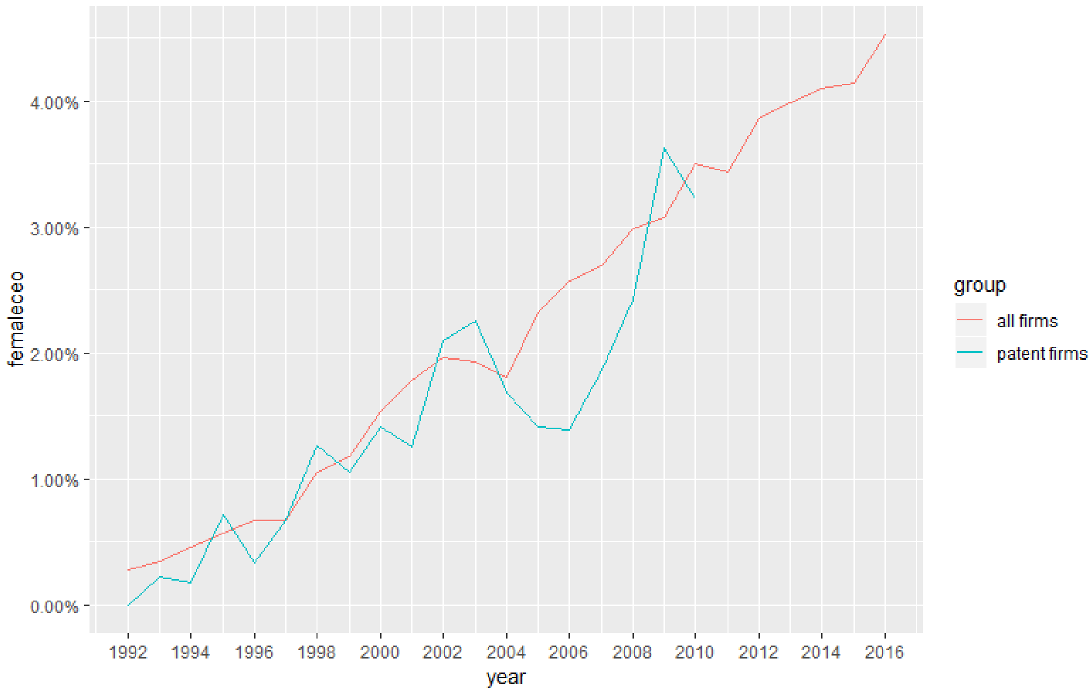
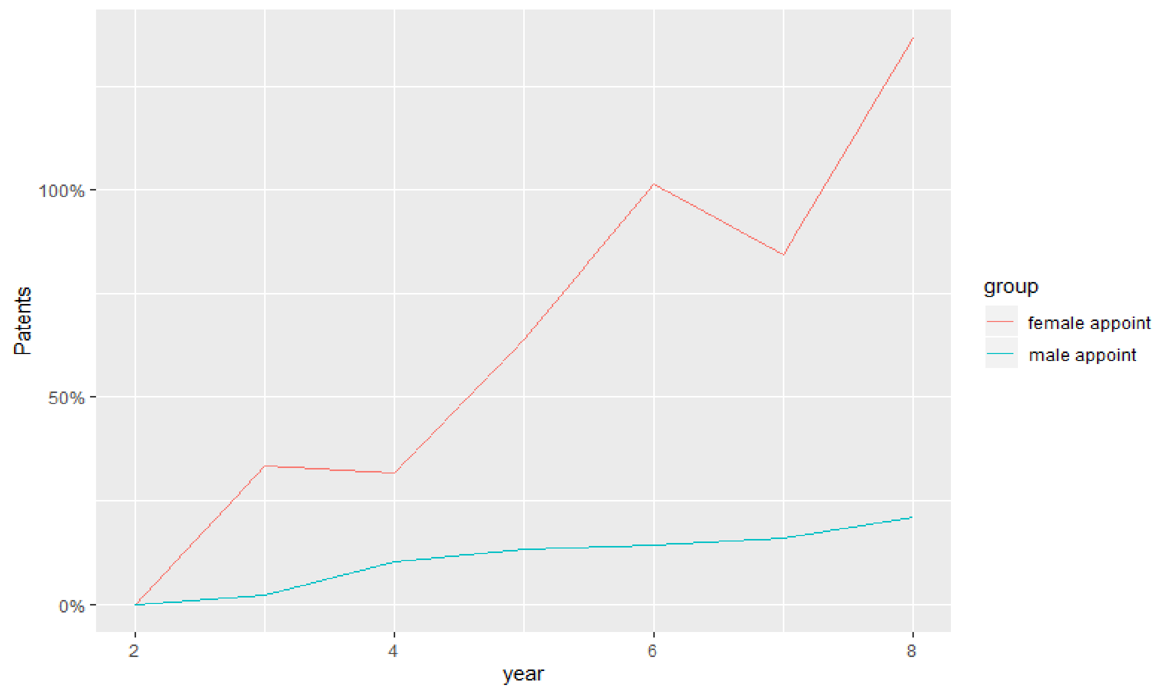
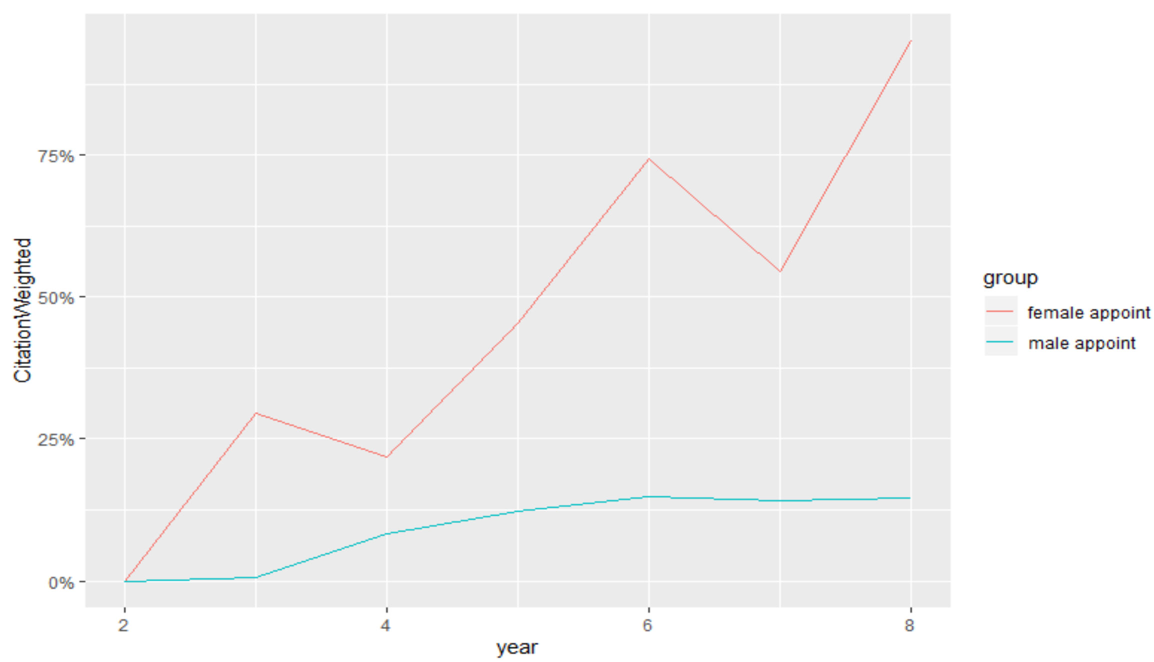


Fig. 1: Female CEOs since 1992

This figure illustrates the changes in the percentage of female CEOs among most public firms listed on NASDAQ and NYSE from 1992 to 2016. The blue-line is for firms that generate patents in a given year, and the red-line for all firms available in BoardEx dataset.



Panel A: Changes in the number of patents



Panel B: Changes in the number of citation-weighted patents

Fig. 2: Patents output after CEO appointment

This figure illustrates the average percentage change of patent number and citation-weighted patent number from 2 years to 8 years after the appointment of a CEO. The redline is for a female CEO appointment, while the blue line is for a male CEO appointment.

Appendix

Appendix 1: Variables definitions

Variables	Definition
Npats	Number of patents, scaled by 1000
Cpats	Citation-weighted number of patents, scaled by 1000
Female	A dummy variable equals to one if the CEO is a female, and zero otherwise
InternalP	Number of patents which have more self-citations than external citations, scaled by 1000 Self-citations are identified if the cited patent was applied by the same firm
ExternalP	Number of patents which have fewer self-citations than external citations, scaled by 1000 Self-citations are identified if the cited patent was applied by the same firm
MaScore	The score of managerial quality, provided by Demerjian et al. (2012)
Inflow	The number of newly recruited inventors minus the number of departed inventors, scaled by 1000
CEO Tenure	The tenure (the number of years in office) of each CEO
Log(AT)	The natural logarithm of the total assets (at)
Leverage	The ratio of total debt (dlc+dltt) to total assets (at)
Log(firm age)	Log of firm age (From the first year in Compustat)
RD	The ratio of R&D expenditure (xrd) to sales (sale)
OMRD	A dummy variable equals to one if the R&D expenditure (xrd) is missing
CAPEX	The ratio of capital expenditure (capx) to tangible assets (ppent)
PPE	The ratio of tangible assets (ppent) to total assets(at)
ROA	The ratio of income before interest and tax (ib) to total asset(at)
Q	The ratio of the market value of equity (csho*prcc_f) + book value of assets-the book value of common equity - deferred taxes scaled by the book value of assets
Cash Flow	The sum of the income before extraordinary items (ib) and depreciation and amortization (dp) scaled by the tangible assets (ppent)
Cash	The ratio of cash and short-term investments (che) scaled by the tangible assets (ppent)
Dividend	The ratio of dividend common (dvc) scaled by operating income before depreciation(oibdp)
KZ	KZ index $= -1002 * Cashflow + 0.283 * Q + 3.139 * Leverage - 39.368 * Dividend - 1.315 * Cash$
HHI	Sum of squared market shares of firms'sales (sale) at the two-digit SIC industry
Outboard	The proportion of outside boards that current male board members serve on which the CEO is a female
Inboard	The proportion of the board members that sits on another board that has a female CEO

Appendix 2: Robustness Tests

Table 2A: DiD Regression results from the CEO gender transitions

In this table, we report the panel regressions results of CEO transition sample for innovation outcomes from 1 year later to 3 years later. We include only firms that experience a change from a male CEO to a female CEO or vice versa. We include firm fixed effects for the identification. The dependent variables $Npats_{t+i}$ is the number of patents *i* years later. $Cpats_{t+i}$ is the citation-weighted number of patents *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Supplementary S4. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Dependent variable:					
	$Npats_{t+1}$	$Cpats_{t+1}$	$Npats_{t+2}$	$Cpats_{t+2}$	$Npats_{t+3}$	$Cpats_{t+3}$
	(1)	(2)	(3)	(4)	(5)	(6)
Female	- 0.034	- 0.021	0.058	0.161	0.137**	0.323***
	(- 0.795)	(- 0.247)	(1.209)	(1.598)	(2.548)	(2.784)
Log(AT)	0.051	0.125**	0.035	0.087	0.018	0.048
	(1.629)	(1.983)	(0.998)	(1.195)	(0.483)	(0.587)
Log(firmage)	- 0.120	- 0.125	- 0.032	0.078	0.028	0.213
	(- 1.344)	(- 0.693)	(- 0.316)	(0.375)	(0.256)	(0.909)
OMRD	- 0.069	- 0.144	- 0.054	- 0.096	- 0.053	- 0.095
	(- 0.704)	(- 0.727)	(- 0.474)	(- 0.406)	(- 0.442)	(- 0.364)
RD	- 0.423	- 0.591	- 0.203	- 0.240	- 0.076	- 0.069
	(- 0.782)	(- 0.543)	(- 0.337)	(- 0.190)	(- 0.116)	(- 0.049)
CAPEX	0.081	0.259	0.105	0.259	0.127	0.236
	(0.603)	(0.961)	(0.686)	(0.806)	(0.756)	(0.653)
PPE	0.214	0.512	0.154	0.407	0.157	0.379
	(0.884)	(1.052)	(0.578)	(0.731)	(0.549)	(0.614)
ROA	0.117	0.180	0.165	0.333	0.117	0.297
	(0.677)	(0.515)	(0.851)	(0.818)	(0.560)	(0.658)
Leverage	- 0.164	- 0.232	- 0.094	- 0.049	- 0.054	0.028
	(- 1.242)	(- 0.871)	(- 0.637)	(- 0.159)	(- 0.341)	(0.081)
Q	0.011	0.024	0.001	0.002	- 0.007	- 0.018
	(0.749)	(0.794)	(0.088)	(0.047)	(- 0.394)	(- 0.456)
KZ	0.002	0.005	0.003	0.007	0.003	0.009
	(0.658)	(0.893)	(0.958)	(1.169)	(1.115)	(1.335)
HHI	- 3.037***	- 5.138***	- 2.000**	- 2.704	- 1.007	- 0.276
	(- 3.726)	(- 3.132)	(- 2.237)	(- 1.443)	(- 1.051)	(- 0.134)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Firm dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	610	610	601	601	591	591
R^2	0.827	0.875	0.796	0.839	0.768	0.806
Adjusted R^2	0.793	0.850	0.754	0.806	0.720	0.766

Table 2B: Regression results with Propensity-Score matched sample

In this table, we report the panel regressions results of the matched sample, using Propensity-Score matching technique, for 1 year and 3-year lead innovation outcomes. Panel A reports the descriptive statistics for the matched sample, and Panel B reports the regression results with the matched sample. The dependent variables $Npats_{t+i}$ is the number of patents *i* years later. $Cpats_{t+i}$ is the citation-weighted number of patents *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. Control variables are defined in Appendix A. *T*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

Panel A. Propensity-score matching results

		Female CEOs sample		Matched sample		Difference
Variables	N	Mean	Median	Mean	median	t-stats
Log(AT)	554	7.608	7.336	7.618	7.542	- 0.102
Leverage	554	0.206	0.190	0.204	0.185	0.155
ROA	554	0.044	0.049	0.049	0.053	- 0.919
Q	554	1.877	1.496	1.951	1.570	- 1.037
Cash	554	2.221	0.654	2.436	0.521	- 0.430
RD	554	0.019	0.000	0.017	0.000	0.942
Dividend	554	0.016	0.01	0.017	0.006	- 0.153

Table 2B, cont'd

Panel B: Regression results with the matched sample

	Dependent variable:					
	$Npats_{t+1}$ (1)	$Cpats_{t+1}$ (2)	$Npats_{t+2}$ (3)	$Cpats_{t+2}$ (4)	$Npats_{t+3}$ (5)	$Cpats_{t+3}$ (6)
Female	0.020***	0.042***	0.019**	0.040**	0.022**	0.045**
	(2.901)	(2.763)	(2.440)	(2.377)	(2.431)	(2.346)
Log(AT)	0.021***	0.048***	0.021***	0.047***	0.023***	0.050***
	(7.130)	(7.273)	(6.321)	(6.458)	(5.942)	(6.055)
Log(firmage)	0.017***	0.035**	0.019***	0.040**	0.023***	0.047***
	(2.736)	(2.527)	(2.703)	(2.554)	(2.829)	(2.728)
OMRD	- 0.015	- 0.032	- 0.015	- 0.033	- 0.015	- 0.033
	(- 1.465)	(- 1.431)	(- 1.347)	(- 1.319)	(- 1.185)	(- 1.197)
RD	0.112	0.295	0.080	0.214	0.163	0.364
	(0.958)	(1.129)	(0.589)	(0.724)	(1.007)	(1.057)
CAPEX	0.015	0.041	0.049	0.115	0.068	0.153*
	(0.465)	(0.579)	(1.347)	(1.444)	(1.605)	(1.695)
PPE	- 0.027	- 0.056	- 0.021	- 0.041	- 0.018	- 0.037
	(- 0.884)	(- 0.821)	(- 0.598)	(- 0.549)	(- 0.458)	(- 0.429)
ROA	- 0.036	- 0.109	- 0.039	- 0.111	- 0.048	- 0.133
	(- 0.704)	(- 0.956)	(- 0.670)	(- 0.887)	(- 0.717)	(- 0.943)
Leverage	- 0.030	- 0.069	- 0.047	- 0.104	- 0.078**	- 0.173**
	(- 1.134)	(- 1.176)	(- 1.554)	(- 1.605)	(- 2.282)	(- 2.373)
Q	0.001	0.003	0.001	0.003	0.002	0.005
	(0.236)	(0.420)	(0.191)	(0.315)	(0.338)	(0.501)
KZ	- 0.0001	- 0.0001	- 0.0003	- 0.001	- 0.0003	- 0.0005
	(- 0.133)	(- 0.098)	(- 0.436)	(- 0.393)	(- 0.337)	(- 0.299)
HHI	0.165	0.364	0.176	0.381	0.139	0.287
	(0.893)	(0.881)	(0.824)	(0.822)	(0.561)	(0.545)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,064	1,064	1,017	1,017	889	889
R^2	0.250	0.247	0.232	0.230	0.246	0.242
Adjusted R^2	0.199	0.197	0.178	0.175	0.185	0.181

Table 2C: Female CEOs and corporate innovation: Two-stage regressions

In this table, we report the two-stage regressions results for innovation outcomes 1 year later. Regression (1) and (2) are first stage regressions using instrument variables. Regression (3) to (6) are second stage regressions. The dependent variables $Npats_{t+i}$ is the number of patents *i* years later. $Cpats_{t+i}$ is the citation-weighted number of patents *i* years later. Female is an indicator variable which equals 1 if the CEO is a woman and 0 otherwise. The instrument variable Outboard is the proportion of outside boards that current male board members serve on which the CEO is a female, and Inboard is the proportion of the board members that sits on another board that has a female CEO. All variables are defined in Supplementary S4. *t*-statistics are reported in brackets below the coefficients. *, ** and *** indicate statistical significance levels of 10%, 5% and 1%.

	Stage1:		*Stage2:*			
	Female		Npats1	Cpats1	Npats1	Cpats1
	(1)	(2)	(3)	(4)	(5)	(6)
Outboard	2.531***					
	(3.720)					
Inboard		1.589***				
		(3.851)				
fit1			0.316***	0.751***		
			(4.523)	(4.613)		
fit2					0.302***	0.719***
					(4.314)	(4.405)
Log(AT)	-0.013	-0.015	0.026***	0.059***	0.026***	0.059***
	(-0.761)	(-0.882)	(34.304)	(33.996)	(34.291)	(33.983)
Log(firmage)	-0.013	-0.012	0.006***	0.009**	0.006***	0.009**
	(-0.356)	(-0.340)	(3.525)	(2.330)	(3.510)	(2.314)
OMRD	-0.110*	-0.111*	-0.014***	-0.033***	-0.014***	-0.033***
	(-1.901)	(-1.900)	(-5.151)	(-5.104)	(-5.176)	(-5.129)
RD	-1.226**	-1.224**	0.251***	0.590***	0.250***	0.589***
	(-2.005)	(-2.000)	(9.244)	(9.318)	(9.214)	(9.288)
CAPEX	-0.095	-0.094	0.032***	0.080***	0.032***	0.080***
	(-0.528)	(-0.524)	(3.913)	(4.239)	(3.908)	(4.234)
PPE	-0.645***	-0.641***	0.050***	0.105***	0.049***	0.104***
	(-3.940)	(-3.913)	(6.654)	(6.067)	(6.599)	(6.012)
ROA	-0.560**	-0.559**	0.019	0.040	0.018	0.039
	(-2.165)	(-2.161)	(1.449)	(1.327)	(1.417)	(1.296)
Leverage	-0.280**	-0.280**	-0.029***	-0.074***	-0.029***	-0.074***
	(-1.989)	(-1.985)	(-4.260)	(-4.700)	(-4.278)	(-4.718)
Q	-0.036	-0.037*	0.004***	0.013***	0.004***	0.013***
	(-1.640)	(-1.665)	(4.441)	(5.739)	(4.415)	(5.713)
KZ	-0.001	-0.001	0.0002	0.0004	0.0002	0.0004
	(-0.259)	(-0.260)	(1.536)	(1.248)	(1.529)	(1.242)
HHI	-0.015	0.002	0.054	0.146	0.054	0.147
	(-0.015)	(0.002)	(1.324)	(1.544)	(1.335)	(1.555)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,746	22,746	18,756	18,756	18,756	18,756

Table 2C, cont'd

Weak Instrument	37.34***	29.37***				
Wu-Hausman	16.51***	14.88***				
Sargan	0.691	0.686				
R^2	0.024	0.024	0.131	0.124	0.130	0.124
Adjusted R^2	0.011	0.011	0.126	0.119	0.126	0.119
F-Statistic	3.367***	3.340***	29.580***	27.925***	29.616***	27.966***