She-E-Os and innovation: do female CEOs influence firm innovation?

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Abstract

Purpose – This paper empirically investigates whether female CEOs (She-E-Os) have an effect on firm innovation among Chinese listed firms based on patent data. This study also delved further by looking at whether the internal corporate environment moderates the effect of female CEOs on innovation, that is, state ownership. Finally, this study investigates an additional test of financial constraints to examine whether financial constraints also moderate the impact of female CEOs on firm innovation.

Design/methodology/approach – This study used the data of all A-share listed companies on the Shanghai and Shenzhen stock exchanges for the period from 2008 to 2017. The authors use ordinary least squares regression as a baseline methodology, along with firm-fixed effect, lagged measure of female CEOs, alternative measures of innovation, Heckman two-step model and negative binomial regression to check and control the possible issue of endogeneity.

Findings – The authors' findings show that CEO gender plays an important role in producing higher levels of innovation output by improving the governance structure. However, female CEOs have no effect on state-owned enterprises' (SOEs) innovation activities, which suggests that the main goal of SOEs is achieving sociopolitical objectives. Furthermore, female CEOs' influence on innovation output is weaker in firms with financial constraints.

Social implications – This study adds to the emerging global discussion on gender diversity. Many legislative bodies require a quota for women on corporate boards due to gender inequality. This study's findings reinforce such guidelines by emphasizing the economic benefits of including women in top management positions.

Originality/value – This study provides new insights by highlighting the role of female CEOs in increasing firms' innovation activities. Additionally, this study provides evidence on whether the internal corporate environment (state ownership and financial constraints) moderates female CEOs' effect on innovation.

Keywords Female CEOs, Corporate governance, Innovation, Patents, State-owned enterprises, China

Paper type Research paper

1. Introduction

The value of female leadership is demonstrated by the growing number of female CEOs worldwide. Female CEOs have unique characteristics, due to which their performance has been extensively studied. The literature provides evidence that female leaders are more risk-averse (Adams and Funk, 2012; Chen *et al.*, 2016), less overconfident (Croson and Gneezy, 2009; Huang and Kisgen, 2013), provide efficient monitoring (Ullah *et al.*, 2019) and reduce agency costs (Ain *et al.*, 2021d). These findings indicate that top-level female executives have a different effect on company actions and decisions than their male peers (Adams and Ferreira, 2009; Chen *et al.*, 2018b; Vieito, 2012). Female CEOs enhance corporate mechanisms and make decisions that help improve the company's value (Adams and Ferreira, 2009). A

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body of literature shows that female CEOs, compared to male CEOs, have a different effect on investment decisions (Frye and Pham, 2018), leverage, risk and earnings quality (Faccio *et al.*, 2016), the quality of financial information reporting (Peni and Vähämaa, 2010), discrimination lawsuits (Dadanlar and Abebe, 2020), agency conflicts (Jurkus *et al.*, 2011) and the propensity to hoard cash (Sah, 2021). Overall, these studies suggest that top-management gender plays an important role in influencing corporations' decisions.

The present research investigates the impact of female CEOs on innovation because of the enormous relevance of gender disparities in corporate decisions. We investigate the influence of female executives in the Chinese context. Over time, China's attitude toward gender issues has undergone tremendous changes. Women tend to be prevented from achieving their maximum potential due to local culture and social values. However, over time, the culture has changed. In 1950, after the creation of the People's Republic of China in 1949, the National Marriage Law, equalizing men and women's rights, was enacted and promulgated (Chen and Ge, 2018; Ge and Yang, 2014). This enabled Chinese women to join the workforce and provided more significant opportunities in the social, cultural and business sectors, which has resulted in increasing female representation in the corporate sector at the top level. According to data from the World Development Indicators, in 2016, the proportion of companies with the greatest number of female managers in China was 18%, which was higher than the average of 15.8% in Organization for Economic Cooperation and Development (OECD) member countries. In China, the number of female CEOs is on the rise (Fang, 2014). According to Hu (2014), between 2004 and 2013, China had the world's second-highest proportion of female CEOs, with forecasts showing that, by 2040, one-third of CEO appointments will be women. In China's business environment, female leaders have become a significant phenomenon, and women executives in the corporate world cannot be ignored. Over time, women's top-level participation in companies has provided a remarkable opportunity to explore their role in the effective use of resources.

Innovation is widely considered an essential economic growth factor (Kogan *et al.*, 2017; Romer, 1990; Rong *et al.*, 2017; Segerstrom, 1991; Fu, 2019) and also a key source of sustainable development crucial for firms' survival and development (Zhong *et al.*, 2021; He and Shen, 2019). Porter (1992) and Solow (1957) highlighted that innovation is often regarded as the most critical determinant of enterprises' and countries' competitiveness. To clarify differences in economic growth around the world, understanding the motivating factors behind innovation is key. Innovation is regarded, from an enterprise's viewpoint, as one of the most important ways to achieve a competitive advantage (Fu, 2019). The latest research on innovation focuses mainly on developed countries with strong intellectual property rights and good institutional environments. Intellectual property rights in China, however, are poorly developed and implemented, thus providing a valuable environment in which to study firms' innovation drivers in developing economies. Without an institutional environment that includes the protection of property rights, several factors that promote innovation cannot function normally. Findings in the Chinese economy can help shed light on boosting innovation efficiency in various developing countries (Yunhe *et al.*, 2019).

Moreover, China's Patent Law, last revised in 2008, has strengthened the protection of intellectual property rights, from almost nonexistent to extremely powerful. Therefore, corporations have more incentives to invest in innovation and patents (to obtain economic benefits from them). Although the mechanism of firm innovation is complex, requiring a large amount of capital and labor input while providing unpredictable outcomes, it is critical to enterprises' long-term growth. Consequently, it is essential to analyze which factors influence companies' innovation activities (Porter, 1992). In this paper, the factor we analyze, which has mostly been overlooked in previous literature, is females in top-level positions (F_CEOs).

We find that female CEOs positively affected firm innovation practices using panel data for Chinese A-listed companies from 2008 to 2017. These findings suggest that firms led by female CEOs have better monitoring than firms led by their male counterparts because female CEOs

resolve agency problems more effectively, leading to greater innovation. Therefore, monitoring must be strengthened to improve the governance of innovation. Our research also examines whether the internal corporate environment, that is, state ownership, moderates the female CEOs' effect on enterprise innovation. Additionally, we include a test for financial constraints. Our findings show the insignificant relationship between female CEOs and innovation efficiency in state-owned enterprises (SOEs), which suggests that SOEs' main goal is the achievement of sociopolitical objectives. The findings also reveal that financial constraints tend to reduce female CEOs' impact on firm innovation (measured by patents count).

Our paper makes several key contributions. First, extending previous studies that have studied the influence of CEO gender on firms' financial situation and performance (Faccio *et al.*, 2016; Martín-Ugedo *et al.*, 2018; Strøm *et al.*, 2014), we explore novel evidence regarding whether CEO gender enhances firm innovation. This research extends our perception of how gender differences affect (male-dominated) corporate decision-making processes. Second, our results enhance the SOE literature by exploring whether state ownership moderates female CEOs' effect on enterprise innovation. Third, we extend the empirical literature by proving that female CEOs' impact is more noticeable in firms that have substantial access to external capital markets. Finally, we also contribute to the literature by researching the Chinese institutional environment. Although the Chinese economy is the second largest economy in the world, it is still considered an emerging market. Thus, our study has significant implications for emerging economies. Therefore, this research has implications for formulating guidelines and provides recommendations for greater women's engagement in business.

The remainder of this paper is organized as follows. In Section 2, we develop several hypotheses. Section 3 explains the data and measures used in this study. The analytical findings are described in Section 4. In Section 5, we present an additional test, followed by robustness tests in Section 6. Finally, Section 7 concludes the paper and outlines avenues for future research.

2. Literature review and hypothesis development

2.1 Female CEOs and corporate innovation

Studies on female CEOs are limited for a simple reason: there have been very few of them. However, given regulators' increased attention toward the presence of women on top management position, the number of female CEOs is growing (e.g. the proportion of women-led firms in our sample rose from 4.18% in 2008 to 5.012% in 2017), eliciting much scholarly attention (Wei, 2018). Numerous studies have shown that female leaders enhance firm performance and economic value. For example, financial decisions made by female executives are better and help companies to grow steadily (Huang and Kisgen, 2013). Vieito (2012) found that companies run by women perform better than companies run by male counterparts and have a better return on assets (ROA) (Jalbert *et al.*, 2013). Similarly, Khan and Vieito (2013) showed that firms led by female executives have more stable earnings and ROA consistency, as well as lower volatility in stocks.

Several studies have shown the risk-averse behavior of female CEOs (Francis *et al.*, 2014; Palvia *et al.*, 2015): they enhance firms' long-term financial performance and sustainable growth (Jeong and Harrison, 2017; Ain *et al.*, 2021c); are considered more conservative than male executives (Palvia *et al.*, 2015); have higher corporate cash holdings (Zeng and Wang, 2015); and require more conservative accounting (Francis *et al.*, 2015). Earlier studies have also suggested that female CEOs provide more efficient monitoring than male counterparts (Frye and Pham, 2018). Female leadership also tends to reduce agency conflicts and information asymmetry between shareholders and managers through control mechanisms (Ain *et al.*, 2021d; Chen *et al.*, 2018a, b). Female CEOs encourage strong corporate governance practices, resulting in better investment choices (Nielsen and Huse, 2010) and pay less for

credit (Usman *et al.*, 2018). Female executives are often related to improved corporate-level monitoring (Adams and Ferreira, 2009).

Prior literature has documented the effect of gender diversity on firm innovation (Chen *et al.*, 2018b; Galia and Zenou, 2012; Miller and Triana, 2009; Ruiz-Jimenez and Fuentes-Fuentes, 2016). For example, Chen *et al.* (2005) reported that effective top management teams enhance organizational innovation. Similarly, Chen *et al.* (2018b) and Miller and Triana (2009) suggested that having female directors on boards improves corporate innovation by bringing new and well-managed expertise to the board (Hillman *et al.*, 2002) and by enhancing board deliberation on challenging and complex issues (Huse and Solberg, 2006). Female leadership also increases decision-making efficiency by offering more innovative and effective choices (Galia and Zenou, 2012; Manolova *et al.*, 2007; Na and Shin, 2019; Torchia *et al.*, 2011). As a result, fundamental and incremental organizational innovation is enhanced by female directors (Dezso and Ross, 2012; Diaz-Garcia *et al.*, 2013), and women-led firms are more devoted to R&D (Terjesen *et al.*, 2016). Furthermore, Ostergaard *et al.* (2011) found that female leadership has a major impact on board operations, innovation, experience and expertise regarding the implementation of innovative products and services. Finally, Diaz-Garcia *et al.* (2013) proposed that female leadership within R&D teams generates specific dynamics that foster novel solutions, leading to radical innovation. The results of the studies, as mentioned above, indicate that, by enhancing governance processes and making certain decisions that improve firm value, women in organizational leadership, especially female CEOs, influence corporate decisions. Based on these deliberations, female CEOs can monitor managers better than male CEOs, and because of the economic benefits of females, their decision-making, their instructing capability, their strategic orientation, their better investment choices and their tendency to support the interest of shareholders by solving agency problems, they promote firm innovation by offering effective monitoring. Departing from this literature, which focuses on different aspects of female director's role on boards, we investigate how the gender of CEOs of publicly listed companies affects these firms' innovation.

There are several reasons why female CEOs promote innovation. First, female CEOs likely perform better than male CEOs since they must overcome discrimination to become CEOs (Lam *et al.*, 2013; Prabowo and Setiawan, 2021). As consequence, companies headed by female CEOs likely innovate more than those led by male CEOs, as female CEOs anticipate their firms benefiting from innovation. Second, female CEOs actively promote innovation because the existing evaluation systems are not favorable to women's contributions. Female CEOs enhance company value via innovation, thereby realizing their own value (Han *et al.*, 2019). The primary purpose that drives female entrepreneurs is to prove their own value and realize meaning in life (Eagly, 2007). Thus, to be recognized and valued in life, women must work more than males and provide greater outcomes for the company. Positive innovative behaviors may increase value and improve female CEOs recognition. Third, female CEOs actively encourage innovation as a result of the specific human capital advantages that they possess. The advantages that come with being a female top executive may also help to enhance corporate innovation. Women tend to have more unique qualities and characteristics than males as a result of their varied life experiences, such as emotional sensitivity, acute and powerful intuition, risk-taking and creative spirit, excellent communication and social skills and a strong sense of responsibility (Eagly, 2007). When it comes to deliberating and dealing with issues, these gender differences are beneficial. Similarly, to improve decision-making and corporate management, female senior executives may draw on their professional experiences, ways of thinking, emotional preferences and other characteristics developed from prior work to offer innovative views and novel problem-solving techniques. In fact, it is exactly these new ideas and perspectives provided by women that are required for innovation (Zeng and Wu, 2012). Due to these characteristics, top female executives may help improve

companies' market growth, enhance the potential consumers and improve market and customer knowledge (Carter *et al.*, 2003, 2010) as well as promote firm innovation. Thus, we offer the following hypothesis:

H1. Female CEOs have a positive impact on firm innovation.

2.2 Female CEOs, ownership structure and corporate innovation

SOEs are an important part of the global corporate environment. Since several countries have a significant number of SOEs, which play an important socioeconomic role, the importance of SOEs has been recognized globally: SOEs account for 5% of OECD GDP and 10% of global GDP (Peng *et al.*, 2016). China's business environment, with many SOEs, provides a valuable opportunity to research SOEs. SOEs and non-SOEs differ greatly (Ain *et al.*, 2021d) in objectives and goals, risks, performance, financial accountability and corporate governance practices (Allen *et al.*, 2012).

According to Allen *et al.* (2005), the Chinese economy is considered a transitional economy, and its key source of funding is the banking sector, not the stock market. These authors also asserted that banks provide large amounts of funds to SOEs. Studies have shown that SOEs have more advantages than non-SOEs because the state serves as an insurer, providing assistance when SOEs are in financial difficulties (Faccio, 2006). Shailer and Wang (2015) documented that, in addition to prioritizing access to financing opportunities, SOEs also benefit from reduced debt capital costs.

On the one hand, compared with non-SOEs, SOEs are usually well positioned for government assistance, such as favorable policy support and opportunities for external funding. Owing to their competitive roles in the national economy and their strong association with the government, they can invest more in innovation. Even if SOEs have incentives to innovate, lack of efficiency may hinder the process. As a result of the lack of pressure from the capital market for good governance, SOEs can make ineffective decisions concerning investments in different projects. On the other hand, SOEs might have less ability to participate in innovation practices than non-SOEs for several reasons. For instance, SOEs are most likely to be located in strategic industries with more complex entry barriers and reduced competitiveness. For certain SOEs, achieving a strategic advantage through innovation might not be a top priority. Further, non-SOEs usually have only the aim of shareholder wealth maximization, whereas SOEs prefer to stabilize their different objectives, that is, economic, social and political (Chen *et al.*, 2006). Another reason is that agency problems are potentially more severe in SOEs (Fan *et al.*, 2007) because the separation between ownership and control is higher. SOEs' actual owners (i.e. the whole populace of China) have little decision-making authority.

The study of Ullah *et al.* (2020) provides evidence that the role of female CEOs in non-SOEs is more pronounced for making efficient investment decisions than SOEs. Extending on earlier research on the relationship between government ownership and innovation, we investigate for the first time whether the gender of CEOs shows a more pronounced effect on innovation for non-SOEs. Consequently, we argue that female CEOs in SOEs are less likely to promote innovation than those in non-SOEs for two reasons. First, SOEs have different objectives than non-SOEs since they must fulfill sociopolitical goals (i.e. employment), which may result in their lower priority toward innovative projects. Second, SOEs are protected by the government and are entitled to implicit or explicit loan guarantees, which allow them to borrow money at advantageous rates (Dewenter and Malatesta, 2001). Because of this, they lack incentives to compete with private companies in the market, and regulatory interventions may seem to give a more convenient pathway to reap excess profits than innovating new products and services from scratch. Thus, we propose the following hypothesis:

H2. Female CEOs in SOEs are less likely to promote innovation than those in non-SOEs.

3. Data and measures

3.1 Sample data

The study sample comprises Chinese companies listed between 2008 and 2017 on the Shanghai and Shenzhen Stock Exchanges. All information on patents and other corporate governance and financial variables is primarily derived from the China Stock Market and Accounting Research (CSMAR) database. Our sample starts from this 2008 as this the first year for which the CSMAR database provides information on patents. To eliminate outliers that could affect our outcomes, we removed financial-sector firms from our sample. We also winsorized all continuous variables at the 1st and 99th percentiles. Depending on the available evidence for the variables used, our sample size varies for various investigations.

3.2 Empirical specification

Our baseline empirical model to measure the impact of female CEOs on innovation activities of the firm is estimated as:

$$\begin{aligned}\ln(1+\text{Innovation}_{i,t+k}) = {} & \alpha_0 + \beta_1 \text{F\_CEOs}_{it} + \beta_2 \text{B\_INDP}_{it} + \beta_3 \text{B\_SIZE}_{it} + \beta_4 \text{ROA}_{it} \\ & + \beta_5 \text{LEV}_{it} + \beta_6 \text{C\_EXP}_{it} + \beta_7 \text{SOE}_{it} + \beta_8 \text{TOBIN\_Q}_{it} \\ & + \beta_9 \text{F\_AGE}_{it} + \beta_9 \text{F\_AGE}_{it} + \beta_{10} \text{F\_SIZE}_{it} + \beta_{11} \text{L\_SAL}_{it} \\ & + \beta_{12} \ln(1+\text{R\&D})_{it} + \sum \text{Industry} + \sum \text{Year} + \varepsilon i_t \end{aligned} \quad (1)$$

where i and t denote the firm and year, respectively. Our dependent variable, $\text{Innovation}_{i,t+k}$, indicates one of the four innovation output indicators for firm i in the leading years ($k = 0, 1, 2$). We first estimate female CEOs' impact of on firms' innovation activities one year ahead ($k = 0$). Since it requires two to three years to grow the firm's intellectual property, we also investigate the long-term impact of female CEOs at one year ($k = 1$) and two years ($k = 2$) lead innovation.

Our key variable of interest is F_CEOs, which is calculated based on whether the firm has a female CEOs (a dummy variable equal to 1; 0 otherwise). We also use the industry-fixed effect to capture time-invariant intrinsic variations in innovation within industries. Similarly, macroeconomic shocks and time trends are captured by year-fixed effects.

3.3 Variable measurement

3.3.1 Measurement of innovation. To measure corporate innovation, our study uses patent-related metrics (Ain *et al.*, 2021a; Bernstein, 2015; Boasson and Boasson, 2015; Bradley *et al.*, 2017; Chang *et al.*, 2015; Fu, 2019; Tian and Wang, 2014). In China, patents may be divided into three categories according to Chinese patent law: invention patent applications; utility model patent applications; and design patent applications. To assess the effect of female CEOs on firm innovation output, we developed four proxies. The first measure is calculated as the total number of all three types of patent applications applied for by firms, which includes invention patent applications, utility model patent applications and design patent applications. The second and third measures use the total number of invention patent applications and the total number of utility models and design patent applications, respectively. The last measure uses the total number of invention patent applications and utility model patent applications. The amount of firm innovation is represented by these

variables. Finally, to minimize skewness in the patents data, we use the natural log (plus one) for all measures of innovation.

3.3.2 Control variables. Following the literature on innovation, we use various control variables, such as board size, board independence, ROA, Tobin's q, leverage, capital expenditure, R&D spending, sales, firm age and firm size (Ain *et al.*, 2021a; Fu, 2019; Li *et al.*, 2019; Tian and Wang, 2014). We control the size of board (B_SIZE) because it impacts firms' agency costs. Yermack (1996) demonstrated that larger boards negatively impact directors' incentives to monitor management. Board independence (B_INDP) is also used as a control variable, measured by board independence over board size. Next, following Tian and Wang (2014) and He and Tian (2013), we also use other innovation determinants, such as profitability (ROA), leverage (LEV) and opportunities of growth (TOBIN_Q). Other firm characteristics that may affect innovation are also used as control variables: capital expenditures (C_EXP); state ownership (SOE); natural log of firm age (F_AGE); firm size (F_SIZE); and total sales (L_SAL) (Fu, 2019; He and Tian, 2013; Li *et al.*, 2019). Finally, we also control for R&D expenditures (R&D). Descriptions for each variable are provided in Table 1.

3.4 Summary statistics and correlation matrix

The summary statistics for all the variables used in the analysis are provided in Table 2. We split our sample into firms led by male CEOs (female = 0) and those led by female CEOs (female = 1). A total of 4.99% of firms in our sample have female CEOs, consistent with the (Vähämaa, 2017; Wu *et al.*, 2018; Ullah *et al.*, 2020; Usman *et al.*, 2018). In unreported results, we found that the percentage of firms led by female CEOs was 4.18% in 2008, while this percentage increased to 5.012% in 2017. In our sample, the average value of board independence is 37.2%, the average value of firm age is 1.942, ROA is 4.3%, capital expenditure is 5.4% and Tobin's q is 2.827.

Table 3 provides details of the correlation between the variables. The results demonstrate that all the measures for innovation and female CEOs are positively correlated, showing that female-led firms are linked with high innovation activities, thereby encouraging innovation efficiency in Chinese listed firms. There is no multicollinearity problem in our data, as shown by the correlation between the variables, which is not high.

Dependent variables	
PATENTS	Ln(1 + the total no. of patent applications for all categories applied by firms)
PATENTS1	Ln(1 + the no. of invention patent applications applied by firms)
PATENTS2	Ln(1 + the no. of utility model patent applications and design patent applications applied by firms)
PATENTS3	Ln(1 + the no. of invention patent applications and utility model patent applications applied by firms)
Independent variables	
F_CEOs	If the firm has a FCEO, this dummy variable equals 1; otherwise, it equals 0
B_INDP	Percentage of independent directors on the board
B_SIZE	Ln(board size)
ROA	Net income divided by total assets
LEV	Long-term debt divided by total assets
C_EXP	Capital expenditure divided by total assets
SOE	A dummy variable: Equals 1 if the state or central government owns the firm, 0 otherwise
TOBIN_Q	The market value of equity divided by total assets
F_AGE	Ln(the no. of a firm's listing years)
F_SIZE	Ln(total assets)
L_SAL	Ln(total sales)
R&D	The research and development expenses

Table 1.
Definitions of variables

Table 2.
Descriptive statistics

	Full sample		Sub-sample of female CEOs		Sub-sample of male CEOs	
	Mean	SD	Mean	SD	Mean	SD
PATENTS	0.979	1.66	1.03	1.565	0.854	1.701
PATENTS1	0.493	1.133	0.373	1.04	0.534	1.172
PATENTS2	0.605	1.312	0.651	1.223	0.503	1.355
PATENTS3	0.272	0.553	0.228	0.512	0.292	0.569
F_CEOs	0.049	0.235	–	–	–	–
B_INDP	0.372	0.055	0.382	0.056	0.371	0.054
B_SIZE	2.148	0.198	2.089	0.193	2.152	0.197
ROA	0.043	0.055	0.047	0.053	0.043	0.054
LEV	0.426	0.218	0.406	0.213	0.426	0.218
C_EXP	0.054	0.05	0.054	0.052	0.054	0.05
SOE	0.568	0.484	0.382	0.425	0.578	0.485
TOBIN_Q	2.827	2.038	3.055	2.134	2.811	2.025
F_AGE	1.942	0.896	1.941	0.964	1.842	0.893
F_SIZE	21.909	1.346	21.716	1.232	21.922	1.35
L_SAL	7.238	1.532	6.987	1.427	7.256	1.532
Ln(1 + R&D)	3.99	7.077	4.058	6.219	3.002	7.128

Note(s): All variables are as defined in Table 1

4. Empirical findings

The key findings are discussed in this section by using the dependent variable of current year innovation. We then provide results for the long-term influence of F_CEOs on firms' innovation output at one and two years ahead as dependent variables.

4.1 Female CEOs and corporate innovation

The pooled ordinary least squares (OLS) outcomes are provided in Table 4 using current year innovation ($Innovation_t$) as the dependent variable. All the coefficient values for the relationship between F_CEOs and innovation show a significant positive relationship, regardless of how innovation is calculated. For instance, in column 4, we used invention patent applications and utility model patent applications as the dependent variable. By using this measure, the coefficient value is 0.010 (1% significance level). These results show that female CEOs positively influence corporate innovation, supporting *H1*.

Furthermore, the control variable coefficients are compatible with previous research. Board size (B_SIZE) is significantly negative when using $PATENTS_t$ and $PATENTS2_t$ as dependent variables, suggesting that smaller boards are more likely to enhance innovation (Ain *et al.*, 2021a; Fu, 2019; Yermack, 1996). Board independence (B_INDP) shows a significant positive relationship, in line with Fu (2019). Firm size (F_SIZE), measured by the natural log of total assets, demonstrates a positive relationship with innovation and implies that larger firms are more inclined to increase firms' innovation activities (Brockman *et al.*, 2018). Leverage (LEV) has a significant negative impact using $PATENTS3_t$ as the dependent variable, implying that high-leveraged corporations are less inclined to invest in high-risk innovative projects (Ain *et al.*, 2021a; Lu and Wang, 2018). Similarly, ROA is positively associated with innovation, meaning that profitable companies are more inclined to innovate. Finally, R&D is positively correlated with all the innovation measures, consistent with Li *et al.* (2019).

4.2 Female CEOs, corporate innovation and state ownership

Our study argues that female CEOs have no effect on innovation at SOEs. To analyze the impact of SOEs by following Yuan and Wen (2018) and Du *et al.* (2017), we also use an

Table 3.
Correlation matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1) PATENTS	1.000															
(2) PATENTS1	0.540***	1.000														
(3) PATENTS2	0.455***	0.459***	1.000													
(4) PATENTS3	0.528***	0.434***	0.382***	1.000												
(5) F_CEOs	0.024***	0.032***	0.026**	0.027***	1.000											
(6) B_INDP	0.005	0.023***	0.022***	0.013**	0.047***	1.000										
(7) B_SIZE	0.014**	−0.004	−0.021***	−0.029***	−0.076***	−0.483***	1.000									
(8) ROA	0.071***	0.068***	0.067***	0.069***	0.019***	−0.019***	−0.007	1.000								
(9) LEV	−0.052**	−0.068***	−0.087**	−0.117***	−0.022***	−0.014**	0.158***	−0.396***	1.000							
(10) C_EXP	0.056*	0.037**	0.038*	0.043	−0.003	−0.020***	0.058***	0.118***	−0.075***	1.000						
(11) SOE	−0.020***	−0.038***	−0.063***	−0.083**	−0.070**	−0.051***	0.243**	−0.155***	0.297***	−0.070***	1.000					
(12) TOBIN_Q	0.002	0.035***	0.039***	0.052***	0.028***	0.060***	−0.190***	0.240**	−0.336***	−0.012*	−0.251***	1.000				
(13) F_AGE	−0.111***	−0.106***	−0.132***	−0.156***	−0.026***	−0.042***	0.110**	−0.184***	0.391***	−0.268**	0.388***	−0.152**	1.000			
(14) F_SIZE	0.104***	0.045**	0.013**	−0.026***	−0.036***	0.030***	0.259***	−0.036**	0.420***	−0.031***	0.326**	−0.488***	0.289***	1.000		
(15) L_SAL	0.129***	0.063***	0.035***	−0.003	−0.041***	0.009	0.250***	0.046***	0.421***	−0.009	0.310***	−0.451**	0.247**	0.184***	1.000	
(16) Ln(1 + R&D)	0.184**	0.133***	0.105***	0.094***	−0.035***	0.055***	−0.014**	0.020**	−0.056***	−0.013*	−0.019**	0.054***	0.014**	0.138***	0.093***	1.000

Note(s): All variables are as defined in Table 1

Variable	(1) Ln(1+PATENTS$_t$)	(2) Ln(1+PATENTS1$_t$)	(3) Ln(1+PATENTS2$_t$)	(4) Ln(1+PATENTS3$_t$)
F_CEOs	0.016*** (2.800)	0.021*** (5.459)	0.023*** (5.059)	0.010*** (5.427)
B_INDP	0.078*** (2.941)	0.365* (1.916)	0.257 (1.169)	0.012 (0.134)
B_SIZE	−0.018** (−2.311)	−0.026 (−0.457)	−0.011* (−1.714)	−0.044 (−1.634)
ROA	0.615*** (5.316)	0.300*** (6.015)	0.421*** (5.703)	0.542*** (5.225)
LEV	−0.066 (−0.763)	−0.018 (−0.289)	−0.062 (−0.875)	−0.059** (−1.999)
C_EXP	0.210 (0.771)	0.183 (0.940)	0.040 (0.179)	0.055 (0.593)
SOE	−0.122*** (−3.997)	−0.099*** (−4.552)	−0.077*** (−3.087)	−0.026** (−2.501)
TOBIN_Q	0.022** (2.468)	0.020*** (3.173)	0.009 (1.200)	0.001 (0.313)
F_AGE	−0.205*** (−11.387)	−0.159*** (−12.404)	−0.205*** (−13.856)	−0.091*** (−14.704)
F_SIZE	0.160*** (6.095)	0.061*** (3.277)	0.034 (1.597)	0.002 (0.228)
L_SAL	0.056** (2.541)	0.033** (2.087)	0.041** (2.287)	0.015** (2.029)
Ln(1 + R&D)	0.035*** (16.812)	0.016*** (10.726)	0.014*** (8.498)	0.006*** (7.878)
Constant	−3.604*** (−9.957)	−2.003*** (−7.782)	−1.246*** (−4.198)	−0.053 (−0.425)
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	16,051	16,051	16,051	16,051
R-squared	0.139	0.098	0.100	0.105

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Table 4. Relationship between female CEOs and innovations

Variable	(1) Ln(1+PATENTS$_t$)	(2) Ln(1+PATENTS1$_t$)	(3) Ln(1+PATENTS2$_t$)	(4) Ln(1+PATENTS3$_t$)
F_CEOs	0.012* (1.898)	0.013*** (2.814)	0.026*** (4.922)	0.013*** (5.436)
F_CEOs*SOE	−0.110 (−0.892)	−0.063 (−0.770)	−0.121 (−1.199)	−0.066 (−1.577)
SOE	−0.013** (−2.092)	−0.093*** (−4.540)	−0.072*** (−2.817)	−0.023** (−2.173)
B_INDP	0.792*** (2.953)	0.293* (1.656)	0.260 (1.185)	0.014 (0.155)
B_SIZE	−0.182** (−2.316)	−0.029 (−0.553)	−0.110* (−1.706)	−0.044 (−1.624)
ROA	0.515*** (5.313)	0.293*** (6.444)	0.422*** (5.707)	0.543*** (5.230)
LEV	−0.067 (−0.768)	−0.029 (−0.506)	−0.062 (−0.868)	−0.059** (−1.990)
C_EXP	0.213 (0.780)	0.086 (0.476)	0.037 (0.167)	0.054 (0.577)
TOBIN_Q	0.022** (2.459)	0.002 (0.288)	0.009** (2.212)	0.001 (0.329)
F_AGE	−0.205*** (−11.375)	−0.157*** (−13.202)	−0.205*** (−13.870)	−0.091*** (−14.722)
F_SIZE	0.160*** (6.088)	0.049*** (2.805)	0.035 (1.607)	0.002 (0.215)
L_SAL	0.056** (2.547)	0.031** (2.175)	0.041** (2.279)	0.015** (2.018)
Ln(1 + R&D)	0.035*** (16.808)	0.020*** (14.535)	0.014*** (8.503)	0.006*** (7.885)
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	16,051	16,051	16,051	16,051
R-squared	0.239	0.220	0.200	0.206

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Table 5. Female CEOs, innovation and state ownership

interaction term of F_CEOs with SOEs (F_CEOs*SOEs) in all the regression and examine its effect on innovation [1]. The results in Table 5 show that female CEOs have no impact on innovation output in SOEs as the findings are insignificant, supporting *H2*. These results

suggest that SOEs differ from non-SOEs because SOEs have more serious agency problems and diversified operational goals. Due to the differences in goals, default risks, financing channels and sociopolitical goals, SOEs' investment decisions are not influenced by the same factors as in non-SOEs. Therefore, the role of female CEOs in enhancing innovation is more pronounced in non-SOEs than in SOEs (Kato and Long, 2006; Li *et al.*, 2019).

4.3 Long-term effect of female CEOs and corporate innovation

We estimated equation (1) again to study the long-term effect of F_CEOs using alternative measures of innovation. Table 6 displays the results, which are aligned with our key conclusions. In Panel A, we used one-year lead innovation ($Innovation_{t+1}$) as an alternative dependent variable; in Panel B, we used two-year lead innovation ($Innovation_{t+2}$). Table 6 shows that F_CEOs can enhance firms' future innovation by showing a significant positive relationship in all the measures [2].

5. Additional test

5.1 Female CEOs, innovation and financial constraints

Financial constraints, according to agency theory, may help to reduce agency costs related to free cash flows (Kumar and Langberg, 2009) while still improving the efficacy of innovation and performance. The explanation is that financially constrained firms will focus their scarce capital on the most valuable programs, avoiding any wasteful or empire-building activity (Hoegl *et al.*, 2008). Therefore, the impact of F_CEOs on innovation output could be more significant in firms with financial constraints. On the other hand, Brown *et al.* (2009) reported that financial constraints may cause companies to slash their innovation-related costs as these expenditures are expensive in the short term and risky in the long term. Female CEOs of financially unconstrained companies have greater choice to try out risky yet valuable innovation-related projects. For example, Schroth and Szalay (2009) indicated that more cash in hand helps companies to obtain more patents.

We measure financial constraints by using a constraint index (WW-index; Whited and Wu, 2006), which comprises a linear function of six firm characteristics: cash flow; dividend dummy; long-term debt; firm size; firm's sales growth; and industry sales growth [3]. Using these coefficients, we calculate the WW-index as follows:

$$\mathrm{WW-index(WWI)} = -0.091 * \mathrm{CF} - 0.062 * \mathrm{DIVPOS} + 0.021 * \mathrm{TLTD} - 0.044 * \mathrm{LNTA} - 0.035 * SG + 0.102 * ISG$$

We include an interaction term for the WW-index (WWI) and female CEOs (F_CEOs*WWI) in all the regressions of innovation measures, aiming to find out whether female CEOs' effect on innovation varies with the firm's financial constraints. The findings are reported in Table 7, which shows that when WWI = 0, F_CEOs are negatively associated with $PATENTS_t$ and $PATENTS1_t$. The WWI mean value is −0.915 in our sample. Companies with a zero WWI value, that is, more than three standard deviations away from the average WWI value, are more financially constrained firms. The value of the F_CEOs*WWI coefficient shows significant negative relationships using all the dependent variables for patents. These findings support the notion that F_CEOs have more flexibility to engage in more risky/rewarding projects, resulting in more patent applications.

6. Robustness tests

6.1 Female CEOs and firm innovation: alternative measures of innovation

We employ R&D% as an alternative measure of innovation proxied by R&D expenses over sales (Li *et al.*, 2019). We also use the number of patent grants for all the dependent variables,

Table 6.
Relationship between female CEOs and innovation long-term effect (alternative measures)

Panel A: One-year lead ahead innovation and F_CEOs

Variables	(1) Ln(1+PATENTS$_{t+1}$)	(2) Ln(1+PATENTS1$_{t+1}$)	(3) Ln(1+PATENTS2$_{t+1}$)	(4) Ln(1+PATENTS3$_{t+1}$)
F_CEOs	0.0125** (2.201)	0.018*** (4.633)	0.019*** (4.272)	0.080*** (4.313)
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	15,353	15,353	15,353	15,353
R-squared	0.119	0.178	0.179	0.182

Panel B: Two-year ahead innovation and F_CEOs

Variables	(1) Ln(1+PATENTS$_{t+2}$)	(2) Ln(1+PATENTS1$_{t+2}$)	(3) Ln(1+PATENTS2$_{t+2}$)	(4) Ln(1+PATENTS3$_{t+2}$)
F_CEOs	0.012** (1.984)	0.014*** (3.414)	0.016*** (3.456)	0.065*** (3.418)
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	14,518	14,518	14,518	14,518
R-squared	0.110	0.173	0.176	0.179

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Variable	(1) Ln(1+PATENTS$_t$)	(2) Ln(1+PATENTS1$_t$)	(3) Ln(1+PATENTS2$_t$)	(4) Ln(1+PATENTS3$_t$)
F_CEOs	−1.016* (−1.898)	−1.026*** (−3.558)	−0.090 (−0.347)	−0.012 (−0.436)
F_CEOs*WWI	−1.110*** (−2.892)	−1.154*** (−3.756)	−1.025** (−2.351)	−1.066*** (−3.577)
Control variables	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	16,051	16,051	16,051	16,051
R-squared	0.139	0.198	0.167	0.106

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Table 7. Female CEOs, innovation and financial constraints

using patent applications as dependent variables in regressions (Fu, 2019). Table 8 summarizes the findings using alternative dependent variables. In column 1, we used the ratio of R&D, and in columns 2–5, we used invention-related measures. The findings in Panel A are consistent with our main findings that F_CEOs have a positive impact on firm innovation. Moreover, the findings in Panel B also show that female CEOs have no significant impact of corporate innovation in SOEs.

6.2 Additional testing: female CEOs and firm innovation (negative binomial regression)

As a robustness test, we employed negative binomial regression analysis, which is consistent with earlier studies of innovation based on patent data (Almeida *et al.*, 2002; Chang *et al.*, 2006; Choi *et al.*, 2011). In our sample, firm's patent activities are widely distributed, indicating that most firms generate few innovations, whereas a very small number of firms generate a significant number of innovations. The number of patent applications is an overdispersed count variable, whose variance is significantly greater than its mean. Therefore, we also used negative binomial regression to check the robustness of our results. The findings are presented in Table 9 and show that our main results are robust.

6.3 Endogeneity concerns

We have explored the positive relationship between female CEOs and firm innovation in previous sections. However, this relationship may be affected by endogeneity concerns. To mitigate this problem, we used various approaches. First, we used the fixed-effect method because the OLS method may represent a critical issue regarding endogeneity. Unobservable firm-level characteristics may influence the relationship between F_CEOs and firm innovation. The findings are reported in Table 10 (Panel A) and are consistent with those in Tables 4 and 5 Second, we employed the lag of the explanatory variable (L.F_CEOs). In corporate governance research, using this approach is an appropriate method to address endogeneity problems (Ain *et al.*, 2021b; Bennouri *et al.*, 2018; Wintoki *et al.*, 2012). The results are reported in Table 10 (Panel B), which confirms that F_CEOs have a positive association with innovation output and that there is insignificant relationship between female CEOs and innovation in SOEs.

Third, we used the two-step Heckman procedure (Heckman, 1979) to control for self-selection bias. This is a significant problem for our rationale for a causal relationship between female executives and innovation performance. In other words, the choice of having female

Table 8.
Female CEOs and firm innovation (using alternative measures of innovation)

Variable	(1) R&D%	(2) Ln(1+PATENTSG$_t$)	(3) Ln(1+PATENTSG1$_t$)	(4) Ln(1+PATENTSG2$_t$)	(5) Ln(1+PATENTSG3$_t$)
Panel A: Relationship between F_CEOs and innovation					
F_CEOs	0.003** (2.442)	0.013** (2.393)	0.011*** (2.839)	0.027*** (3.736)	0.092** (2.070)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observations	16,051	16,051	16,051	16,051	16,051
R-squared	0.166	0.139	0.120	0.185	0.131
Panel B: Relationship between F_CEOs and innovation in SOEs					
F_CEOs	0.013** (2.018)	0.062*** (4.972)	0.023*** (2.814)	0.025*** (3.584)	0.010** (2.089)
F_CEOs*SOE	0.000 (0.075)	−0.037 (−0.386)	−0.063 (−0.770)	−0.006 (−0.074)	−0.062 (−0.632)
SOE	−0.005** (−2.547)	−0.093*** (−6.434)	−0.073*** (−4.540)	−0.056*** (−2.759)	0.047*** (2.921)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observations	16,051	16,051	16,051	16,051	16,051
R-squared	0.126	0.119	0.120	0.175	0.141

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Variable	(1) ($PATENTS_t$)	(2) ($PATENTS1_t$)	(3) ($PATENTS2_t$)	(4) ($PATENTS3_t$)
Panel A: relationship between F_CEOs and innovation				
F_CEOs	0.024*** (3.317)	0.347*** (3.531)	0.330*** (4.623)	0.060** (2.208)
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.075	0.091	0.027	0.037s
Panel B: relationship between F_CEOs and innovation in SOEs				
F_CEOs	0.053*** (3.635)	0.031*** (5.176)	0.132** (2.563)	0.159*** (2.931)
F_CEOs*SOE	−0.175 (−0.882)	0.828 (0.295)	−0.052 (−0.196)	0.355 (1.030)
SOE	−0.077** (−1.992)	0.203*** (4.485)	−0.019 (−0.153)	−0.205** (−2.519)
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.075	0.091	0.057	0.087

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Table 9. Female CEOs and firm innovation (using negative binomial regression)

CEOs may not be randomly assigned, but rather determined endogenously between companies. Therefore, we used a two-stage Heckman procedure to run regressions to address this issue. We ran a probit regression by regressing female CEOs considering all control variables and obtained the inverse Mills ratio in the first stage. Finally, we estimated our main regression using the inverse Mills ratio as the independent variable. The results of the two-stage Heckman procedure are presented in Table 11. These findings are similar to those in Table 4, showing that our findings remain consistent after controlling for endogeneity in choosing F_CEOs.

7. Conclusion

Although the literature has demonstrated that females can significantly influence corporate performance, they are still underrepresented in various fields, especially in top positions. This study investigates whether female CEOs impact firms' innovation output as measured by patent applications. Our study thus employed a large sample of Chinese A-share listed firms from 2008 to 2017. The results show that female CEOs are positively connected with innovation output, that is, promoting firms' innovation activities. We also investigated the relationship between female CEOs and innovation in SOEs and found an insignificant relationship. Our study also demonstrates that positive results are stronger in less financially constrained firms. Our findings hold with robustness checks.

Our results provide numerous implications for enterprises and policymakers. Firms in China and other developing economies can improve their innovation performance by appointing capable women to top executive roles. This study shows that female CEOs contribute to corporate innovation. Promoting innovation requires a human-resource-driven strategy. Women should be acknowledged in corporate management practices. Women and men should be treated equally in the selection of top executives so that a greater number of outstanding and capable women may participate in corporate management. This encompasses affirming and valuing women in management practice, actively recruiting more women into senior management, capitalizing on female CEOs' innovation advantages and fostering environments for women to help companies build competitive advantages.

Table 10. Endogeneity concerns: fixed-effect method and lagged measures of F_CEOs

Variable	F_CEOs and corporate innovation				F_CEOs, corporate innovation and SOEs			
	(1) Ln(1+PATENTS$_t$)	(2) Ln(1+PATENTS1$_t$)	(3) Ln(1+PATENTS2$_t$)	(4) Ln(1+PATENTS3$_t$)	(1) Ln(1+PATENTS$_t$)	(2) Ln(1+PATENTS1$_t$)	(3) Ln(1+PATENTS2$_t$)	(4) Ln(1+PATENTS3$_t$)
Panel A: fixed-effect method								
F_CEOs	0.137** (2.140)	0.038*** (2.802)	0.068*** (3.698)	0.042* (1.827)	0.018** (1.987)	0.086** (2.352)	0.067* (1.747)	0.078*** (2.739)
F_CEOs*SOE					−0.208 (−0.264)	0.130 (1.060)	−0.049 (−0.640)	0.095 (0.138)
SOE					−0.002*** (−3.041)	−0.021*** (−4.408)	−0.059* (−1.812)	−0.007** (−2.570)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	16,051	16,051	16,051	16,051	16,051	16,051	16,051	16,051
R-squared	0.121	0.113	0.124	0.122	0.121	0.114	0.125	0.120
Panel B: lagged measure of F_CEOs								
L.F_CEOs	0.013** (2.201)	0.021*** (5.068)	0.022*** (4.560)	0.094*** (4.736)	0.083*** (3.216)	0.053*** (5.215)	0.048*** (4.439)	0.010*** (4.730)
L.F_CEOs*SOE					−0.168 (−1.291)	0.157 (1.697)	0.111 (1.037)	0.058 (1.308)
SOE					−0.047*** (−4.550)	−0.003** (−2.451)	−0.086*** (−3.238)	−0.029** (−2.506)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	15,155	15,155	15,155	15,155	15,155	15,155	15,155	15,155
R-squared	0.138	0.196	0.199	0.103	0.135	0.192	0.190	0.105

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Variable	(1) Ln(1+PATENTS$_t$)	(2) Ln(1+PATENTS1$_t$)	(3) Ln(1+PATENTS2$_t$)	(4) Ln(1+PATENTS3$_t$)
F_CEOs	0.084*** (4.349)	0.014** (2.118)	0.020** (2.151)	0.069* (1.693)
Inverse Mills ratio	−0.481 (−1.406)	−0.173 (−0.813)	−0.217 (−0.883)	−0.083 (−0.810)
Control variables	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	16,001	16,001	16,001	16,001
R-squared	0.139	0.198	0.100	0.105

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Table 11. Endogeneity concerns: Heckman two-step model

Furthermore, firms should train female staff by setting up innovation-related training programs and also increase their job possibilities. Innovation begins by looking for exploratory or exploitative solutions from routines. In emerging countries, women's position is frequently lower than men's, requiring them to remain passive. Because innovation requires a proactive and progressive attitude, companies should work to overcome this cultural barrier in order to enhance their innovation performance. Our conclusions also have implications for corporate and government decision-makers in other emerging countries with similar institutional frameworks, including those where intellectual property rights are weak.

Finally, we acknowledge that our research has certain shortcomings that need further investigation. The first limitation is that, because of a lack of patent citation data in China, we were unable to determine whether female CEOs contribute solely to incremental patents or both to incremental and innovative patents. If this data were made available, this would be a valuable topic for further research. Second, future research can examine female CEOs' governance role in promoting innovation by incorporating within-country institutional contingencies, such as ownership concentration, family ownership and regional development, and by distinguishing between public and private listed companies. The third limitation concerns the endogeneity issue. Although we have used various methods to overcome this issue, endogeneity still may arise from time-invariant unobservable confounders.

Notes

1. We also split the data into two subsets, SOEs and non-SOEs, and perform model (1) regressions on each subset separately. These results are reported in Appendix, which indicates that the positive effect of female CEOs and innovation is less pronounced for SOEs sample than for non-SOEs sample, supporting *H2*.
2. The complete regression results for this and subsequent parts are available upon request.
3. CF is measured as net income plus depreciation over the beginning of the year's assets book value. DIVPOS is a dummy for dividends, TLTD is calculated as long-term debt over current assets, and LNTA is defined as natural log of book value of assets. Finally, SG is calculated as firm's real sales growth, and ISG is the sales growth rate of the industry in which the firm operates.

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Appendix

Variable	(1) Ln(1+PATENTSG$_t$)	(2) Ln(1+PATENTSG1$_t$)	(3) Ln(1+PATENTSG2$_t$)	(4) Ln(1+PATENTSG3$_t$)
Panel A: relationship between F_CEOs and innovation (SOEs sample)				
F_CEOs	−0.022 (−0.131)	0.010 (1.376)	−0.015 (−0.793)	0.061 (0.799)
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	9,418	9,418	9,418	9,418
R-squared	0.189	0.121	0.114	0.104
Panel B: relationship between F_CEOs and innovation (non-SOEs sample)				
F_CEOs	0.013** (2.206)	0.026*** (5.668)	0.027*** (4.864)	0.061* (1.799)
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Industry-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Number of observations	6,633	6,633	6,633	6,633
R-squared	0.110	0.187	0.192	0.109

Note(s): All variables are as defined in Table 1. ***, ** and * represent significance at the 0.01, 0.05 and 0.10 level, respectively

Table A1. Female CEOs and firm innovation (using subsample of ownership).

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