Routledge
Taylor & Francis Group

Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

Right person for the right job: the impact of top management's occupational background on Chinese enterprises' R&D efficiency

Xinfeng Jiang, Jianxing Guo, Ahsan Akbar & Petra Poulova

To cite this article: Xinfeng Jiang, Jianxing Guo, Ahsan Akbar & Petra Poulova (2023) Right person for the right job: the impact of top management's occupational background on Chinese enterprises' R&D efficiency, Economic Research-Ekonomska Istraživanja, 36:2, 2123022, DOI: 10.1080/1331677X.2022.2123022

To link to this article: https://doi.org/10.1080/1331677X.2022.2123022

Published online: 03 Oct 2022.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 2, 2123022
https://doi.org/10.1080/1331677X.2022.2123022

Right person for the right job: the impact of top management's occupational background on Chinese enterprises' R&D efficiency

Xinfeng Jiang[a], Jianxing Guo[b], Ahsan Akbar[c] and Petra Poulova[d]

[a]College of Economics and Management, Huazhong Agricultural University, Hubei, Wuhan, China; [b]Faculty of Science, University of Auckland, Auckland, New Zealand; [c]International Business School, Guangzhou City University of Technology, Guangdong, Guangzhou, China; [d]Department of Informatics and Quantitative Methods, Faculty of Informatics and Management, University of Hradec Kralove, Hradec Kralove, Czech Republic

ABSTRACT

The research on the influence of personal attributes of top management on a firm's innovative behavior has recently gained much traction in the corporate finance literature. However little is known about the role of professional background of top management in influencing corporate R&D efficiency. The present research employs data of China's A-share listed firms during the period of 2008–2016 to explore this association. Empirical outcomes reveal that top management with an R&D background significantly enhance Chinese firms' R&D efficiency. Moreover, equity incentives for the core R&D team, lesser pay disparity between senior management and employees, and the appointment of directors with R&D background play a mediating role between R&D-savvy top management and firm's innovation capacity. The study findings establish a link between top management's human capital and an enterprise's technological capability and show that adopting appropriate innovation strategies and R&D management practices is conducive to achieving the R&D efficiency in Chinese enterprises. Our results are robust to alternate econometric specifications and alternate variable specifications.

ARTICLE HISTORY
Received 31 July 2021
Accepted 25 August 2022

KEYWORDS
Top management's R&D background; R&D efficiency; mediating factors; equity incentives; pay gap; director's appointment; Chinese enterprises

JEL CLASSIFICATION
O32; J24; M52

1. Introduction

The rapidly changing technological landscape challenges firms to innovate in order to remain competitive (Zhu & Yin, 2016). Firms' R&D activities enable them to innovate new products, technologies, and processes to build competitive advantage and sustain growth in the future (Ettlie, 1998). Although China has witnessed remarkable economic growth in the past few decades, it must optimize the quality of this growth and transform it into a knowledge economy driven by the independent innovation of Chinese

CONTACT Ahsan Akbar akbar@gcu.edu.cn

enterprises (Jin et al., 2016). In this pursuit, the Chinese government has rolled out policies to promote innovation for the development of emerging technological industries.

Statistics from the World Bank show that the R&D investment's proportion of GDP in China, the United States, Japan, and South Korea in 2015 was 2.06 percent, 2.73 percent, 3.28 percent, and 4.22 percent, respectively, growing to 2.11 percent, 2.77 percent, 3.14 percent, and 4.23 percent, respectively in 2016, and 2.13 percent, 2.80 percent, 3.20 percent, and 4.55 percent, respectively, in 2017.[1] Therefore, even though China's overall R&D investment is increasing, it still lags behind that of the developed world. Enterprise, as a key micro-economic entity, has been considered the centerpiece of strategic policies to cultivate an innovation culture in the Chinese economy (Wu, 2017). In this macro-economic context, improving firms' R&D efficiency and transforming their limited R&D investments into optimal gains can help Chinese firms become competitive on the international stage.

Most research on firms' R&D activities is based on firms' fundamental characteristics, such as production scale (Kim et al., 2009), profitability (Ciftci & Cready, 2011), cash holdings (Brown & Petersen, 2011, He & Wintoki, 2016), tax incentives (Czarnitzki et al., 2011), government subsidies (Hu & Deng, 2019) and spillover impact on the stock prices (Fung, 2006). Likewise, Wu and Liao (2021) contend that R&D subsidies can considerably increase the R&D efficiency of Chinese companies. Since Hambrick and Mason (1984) proposed the upper echelons theory, the focus has shifted to decisions about corporate R&D based on corporate manager's personal characteristics like shareholdings (Jensen & Murphy, 1990), age (Chen et al., 2010), and tenure (Chen et al., 2013). Some studies have also examined manager's education (Ahn et al., 2017), personal hobbies (Sunder et al., 2017), and gender (Yin et al., 2019). Likewise, Xie et al. (2020) reveal that demographic factors like gender diversity significantly enhance innovation efficiency in Chinese enterprises.

The managers of the company offer requisite leadership, legitimacy and social capital hence they exert significant on corporate performance fundamentals (Shen, 2021). R&D activities are risky, creative endeavors that require top management's expertise and support, though the extant literature has ignored the role played by manager's occupational background. Statistics show that, in China's A-share listed companies, as many as 37 percent of the board chairs and CEOs worked with an R&D department at some point in their career. This occupational experience may reflect in the enterprise's R&D decisions. Considering that Chinese enterprises' R&D investment still lags behind that of their developed counterparts, therefore how to improve R&D efficiency and translate R&D investments into superior economic gains is a significant concern for these firms.

This paper discusses the influence of manager's R&D occupational background on the efficiency of their enterprises' R&D activities. It also examines the underlying mechanism behind this relationship. The results show that manager with R&D backgrounds can significantly enhance their enterprises' R&D efficiency because firms that have managers with such backgrounds tend to grant more equity incentives to their core technology teams, because the pay gap between senior management and employees is smaller, and because such managers tend to hire more directors with R&D backgrounds to reinforce their R&D undertakings' efficiency.

The contributions of this paper lie in three primary areas. First, the extant literature on manager's characteristics focuses on their age, gender, tenure, salary, and similar factors, but few studies address manager's occupational background. As a starting point, this paper explores manager's R&D-related occupational background, which helps to expand the literature on the effects of manager's professional characteristics on strategic decision-making based on the upper echelons theory and reveals the logic behind this association through systematic empirical investigation. Second, the existing studies on the effects of manager's characteristics on corporate R&D activities focus primarily on the link between manager's characteristics and R&D investment or output but have not provided empirical evidence on how manager's R&D background influences R&D efficiency. R&D efficiency is an effective measure with which to gauge an enterprise's innovation efficiency (Song et al., 2015). Our study fills this void by exploring the effects of manager's R&D-based professional backgrounds on corporate R&D efficiency, so it enriches research on corporate R&D activities based on efficiency perspectives. Third, this paper shows empirically that how equity incentives for core technical teams, the pay gap between senior management and employees, and the appointment of directors with R&D backgrounds play a mediating role between R&D-savvy senior management and R&D efficiency, thus opening the black box of how senior managers' R&D backgrounds optimize their enterprises' R&D efficiency.

2. Literature review and hypotheses

2.1. Manager's occupational background and R&D efficiency

The upper echelons theory applies manager's demographic characteristics to their influence on organizational decisions. The theory holds that demographic attributes are the external manifestation of manager's cognitive style and ability, as in the face of a complex and volatile market environment, managers tend to choose a corporate strategy and make strategic decisions based on their own experience, personality preferences, and career experiences (Hambrick, 2007; Hambrick & Mason, 1984). They also contend that observable managerial traits of top management team (such as age, functional area, other career experiences, education, and group characteristics) substantially influence strategic decision making and corporate performance rather than Psychological attributes. Therefore, manager's professional backgrounds and demographic characteristics are the embodiment of their cognition, which helps them make optimal choices in diverse situations and ultimately affects their enterprises' strategic decision-making and performance. Leaders with innovative orientation to work can encourage their teams to be more innovative and creative in their approach to solve complex R&D problems (Keller, 2017). Hence, the cognitive preference and occupational experience of manager with R&D backgrounds can influence their enterprises' R&D activities.

Besides, manager's experiences have a profound influence on their cognition and emotions (Sunder et al., 2017). Top managers who have backgrounds in the field of R&D have a more comprehensive understanding of the company's research and development activities than those without such backgrounds do and attach more

importance to technological innovation (Finkelstein, 1992). Barker III and Mueller (2002) contended that, compared to managers with backgrounds in the areas of financial management, product promotion, and legal advisory, those with backgrounds in R&D, technology, and innovation are better at penetrating the market through the continuous introduction of products that transform technology, so as to realize rapid growth in sales and profits. Moreover, management with such work experience more frequently adopt an R&D innovation strategy (Zhang et al., 2021). An enterprise's decision-making is accompanied by rigorous evaluation and effective execution. We argue that senior managers with R&D backgrounds can carry out more purposeful management of firms' R&D activities than those without such backgrounds can and take corresponding incentive measures to enhance the efficiency of the enterprises' R&D undertakings.

In a dynamic corporate environment investing in R&D activities can enable firms to hold more opportunities in the future (Daellenbach et al., 1999). The professional knowledge of managers with R&D background tend to be receptive to innovative and technology-driven projects and support innovative endeavors, as such activities spur growth through the development of new products and markets (Lin et al., 2011). Moreover, top managers with R&D expertise are willing to take risks and are systematic in their decision-making (Buyl et al., 2011). On the other hand, top managers with backgrounds in throughput functional areas (administration, finance, legal) tend to emphasize more on improving their firms' internal efficiency (Finkelstein, 1992). Likewise, Custodio and Metzger (2014) show that CEOs with a finance background manage financial affairs proactively yet invest less in R&D endeavors and produce less innovation. Manager's education, attitude, patience, and entrepreneurial aspirations substantially influence open innovation in enterprises (Ahn et al., 2017). Top managers with R&D backgrounds have a deeper understanding of technology, a much deeper view of the latest theoretical and technical developments in R&D, and their human capital in terms of knowledge and skills significantly supports enterprises' overall technological advancement. Hence, they are in a better position to tackle the obstacles the R&D team encounters by providing the effective guidance and support it needs to ameliorate R&D efficiency (Nonaka & Konno, 1998).

In short, the cognitive and emotional preferences of senior managers with R&D backgrounds and the level of expertise behind their human capital have a positive effect on enterprises' R&D innovation activities and help to boost enterprises' R&D efficiency. Therefore, we propose the following hypothesis:

Hypothesis 1: *R&D background of top management significantly influences the R&D efficiency of Chinese enterprises*

2.2. Manager's occupational background and R&D efficiency: Mediation Analysis

It is equally essential to identify the underlying mechanism through which managers with R&D backgrounds promote R&D efficiency.

Equity incentives for the R&D team can encourage them to pay more attention to their enterprises' long-term development and result in capital gains through rising

stock prices brought about by R&D success and to optimize the efficiency of their undertakings (Ederer & Manso, 2013; Liu et al., 2019). Innovation is a long-term and multi-stage activity that is antithetical to short-sighted behavior. Since innovation activities need to bear many unpredictable risks, the R&D team must be able to tolerate early failure, so standard incentive mechanism is inefficient in promoting enterprise innovation (Holmstrom, 1989). Since R&D activities require team cooperation, equity incentives can enhance the core technical personnel's motivation to cooperate to achieve common goals, strengthen information-sharing, and increase interactive learning among teams, which leads to enhanced efficiency in R&D (Ederer & Manso, 2013). Xia and Tang (2008) found that equity incentives are positively linked with Chinese hi-tech enterprises' R&D performance. Equity incentives can significantly boost corporate innovation and R&D investment over the ability of non-equity-based incentives to do so Liu et al. (2019), Chen et al. (2012), Chang et al. (2015) examined the impact of equity incentives on core technical personnel's innovation output and found that these equity incentives can significantly improve firms' innovation output. As the participants in and executors of enterprise's R&D projects, the core R&D team directly affects the efficiency (Bradley et al., 2017), and success of R&D undertakings so equity incentives for the core R&D team can improve R&D efficiency.

The pay gap between senior management and employees can also have important effects on R&D efficiency. Adams (1963) contended that, when employees feel that their salary is lower than what is fair (determined by the weighted average salary in the organization), they will make the choice to reduce their work-related effort. Akerlof and Yellen (1990) argued that employees' effort is related to their input-output ratio based on their self-perceived value and that reducing the gap between management's and employees' pay will improve labor relations and promote employees' productivity. A perception of injustice caused by substantial pay differences may lead to lack of cooperation and reduced motivation among employees (Bloom & Michel, 2002, Firth et al., 2015). Choi and Chen (2007) found that the perceived deprivation caused by differences in pay has a significant negative impact on the operation of multinational companies in mainland China.

Enterprise's management team's human and social capital helps make the right R&D spending decision (Dalziel et al., 2011). The composition of the board and top management has additive effects on R&D activities (Kor, 2006). Using their own human and social capital, combined with their professional knowledge and R&D experience, directors with R&D backgrounds are well positioned to maximize the efficiency of R&D projects (Golden & Zajac, 2001; Hillman & Dalziel, 2003). The active involvement of boards significantly promote product innovation in Chinese enterprises (Wu & Wu, 2014). Directors with R&D backgrounds can also take advantage of their social capital to explore information on the R&D frontier, provide professional advice for the company's decision-making (Baysinger & Hoskisson, 1990), and make appropriate R&D decisions (Dalziel et al., 2011) that promote the efficiency of their firms' R&D projects.

As discussed above, the professional knowledge of manager's with R&D backgrounds can increase their receptivity to innovative and technology-driven projects,

the attention they pay to innovation, and their application of appropriate management methods to improve the R&D efficiency. We argue that top management with R&D backgrounds are more willing than those with other backgrounds to use appropriate management means such as reward the R&D core team, reduce the pay gap between senior management and employees, and encourage the inclusion of more R&D-savvy directors on the board to spur innovation. Therefore, we put forward the following sub-hypotheses.

Hypothesis 2a: *Equity incentives for the core R&D team play a mediating role in the association between top management's R&D background and R&D efficiency*

Hypothesis 2b: *Lowering the pay gap between senior management and employees mediates the association between top management's R&D background and R&D efficiency*

Hypothesis 2c: *The appointment of R&D-savvy directors mediates the relationship between top management's R&D background and R&D efficiency*

3. Research design

3.1. Sample selection and data sources

This paper's research sample is Shanghai and Shenzhen stock exchange A-share listed companies from 2008 to 2016. The data is extracted from the CSMAR database, which provides accurate economic, financial and securities information, and is a high-precision research database covering the main fields of China's economy and finance. The database focuses on the depth and breadth of the data, and emphasizes the deep professional processing, collation and analysis of the original data, which is convenient for researchers to build research models. We filter the sample data excluding special treatment samples, firms in the financial industry, firms with no information on the company's chairperson and the CEO's occupational background, firms whose R&D investment amount or patent data are undisclosed, and firms that lack other data essential for our analysis. We also winsorize the data at 1 percent upper and lower quartiles to eliminate the effects of extreme values. These exclusions lead to a final sample of 10,837 valid observations.

3.2. Econometric model

Following Lu et al. (2021) and Xie and Wang (2020), the following empirical model is used to test H1:

$$\begin{aligned} Eff = {} & \alpha_0 + \alpha_1 Exp + \alpha_2 Size + \alpha_3 Lev + \alpha_4 Prof + \alpha_5 Tbdt + \alpha_6 Liq_{ratio} + \\ & \alpha_7 Lnv_{ratio} + \alpha_8 Pro_{pp} + \alpha_9 Fa_{pp} + \alpha_{10} Ca_{ratio} + \alpha_{11} Bdindt + \\ & \alpha_{12} Share_{per} + \alpha_{13} Shrz + \sum Ins + \sum Year + \varepsilon_1 \end{aligned} \quad (1)$$

Then model (2) and model (3) are constructed to account for the mediating analysis following the method used in Wen et al. (2004).

$$Mediation = \beta_0 + \beta_1 Exp + \beta_2 Size + \beta_3 Lev + \beta_4 Prof + \beta_5 Tbdt + \beta_6 Liq_{ratio} + \beta_7 Lnv_{ratio} + \beta_8 Pro_{pp} + \beta_9 Fa_{pp} + \beta_{10} Ca_{ratio} + \beta_{11} Bdindt + \beta_{12} Share_{per} + \beta_{13} Shrz + \sum Ins + \sum Year + \varepsilon_2 \quad (2)$$

$$Eff = \gamma_0 + \gamma_1 Exp + \gamma_2 Mediation + \gamma_3 Size + \gamma_4 Lev + \gamma_5 Prof + \gamma_6 Tbdt + \gamma_7 Liq_{ratio} + \gamma_8 Lnv_{ratio} + \gamma_9 Pro_{pp} + \gamma_{10} Fa_{pp} + \gamma_{11} Ca_{ratio} + \gamma_{12} Bdindt + \gamma_{13} Share_{per} + \gamma_{14} Shrz + \sum Ins + \sum Year + \varepsilon_3 \quad (3)$$

3.3. Variable definition

3.3.1. R&D efficiency

R&D efficiency is an indicator of the efficiency of the firm's research and development activities, from the beginning of R&D activities (enterprise resource input) to the final output of R&D undertakings (Hashimoto & Haneda, 2008). R&D efficiency refers to the amount of R&D output from a certain level of R&D input. Theoretically, the difference in the efficiency of R&D depends to some extent on the level to which managers promote the firm's R&D activities. During the course of R&D decisions and execution, top managers choose among various strategies, which can have heterogeneous impacts on R&D efficiency. Considering that it takes some time for R&D input to be converted into R&D output, R&D input indicators are selected from the preceding period. In line with the current practice (Cheng et al., 2017; Thomas et al., 2011), the R&D output of an enterprise is measured in terms of the number of patents applications the company files in a year and the number of patent applications granted to the company in that year. Therefore, we use the natural logarithm of R&D expenditures to measure R&D investment. Thus, this paper constructs two indicators to measure R&D efficiency: Eff_1 represents the number of applications for patents, divided by natural logarithm of one-year lagged R&D expenditures, and Eff_2 is the number of invention patents granted divided by the natural logarithm of the one-year lagged R&D expenditures.

3.3.2. Manager's occupational background

Managers' occupational background (*Exp*) refers to other career experiences that a manager had prior to his or her current position. The top management team is the primary force behind enterprise development and sets the firm's strategic direction. Among these managers, in China, the chairperson plays a central role in the top management team by largely determining the company's strategic objectives, positioning, and major decisions, which affect the firm's performance and shareholders' interest. Therefore, referring to Song et al. (2015), we select the chairperson as the main variable of interest, and when his or her occupational background includes R&D experience, *Exp* is defined as 1 and 0 otherwise. In a robustness test, we also examine the CEO's influence.

3.3.3. Mediating factors

Mediating factors (*Mediation*) include: (1) core technical personnel (*Esop*), which is measured by equity granted to core technical personnel as a proportion of the total

Table 1. Variable description.

Variable	Definition
Eff_1	The number of invention patents applied divided by the logarithm of one year lag of R&D investment
Eff_2	The number of invention patents authorized divided by the logarithm of one year lag of R&D investment
Exp	When the chairman's occupational background includes R&D experience, it is defined as 1 and 0 otherwise.
Size	Logarithm of the number of employees at the end of the year
Lev	Rate of change in earnings per share of common stock/rate of change of profit before interest and tax
Prof	(Operating Income − Operating Cost)/Operating Income
Tbdt	Total liabilities divided by total assets
Liq_ratio	Total current assets/total current liabilities
Inv_ratio	Main Business Cost/Average Inventory
Pro_pp	Increase in profits for the current year/total profits for the previous year
Fa_pp	Fixed assets increased/original fixed assets
Ca_ratio	Cash assets/current assets
Bdindt	Number of directors
Share_per	Proportion of the company's shares held by the largest shareholder
Shrz	Top 10 Major Shareholders/First Major Shareholder

Source: created by the authors.

shares of the company; (2) pay gap between managers and employee (*Gap*). Referring to Faleye et al. (2013), Banker et al. (2016), and Kong et al. (2018), *Gap* is expressed by the logarithm of the average manager salary divided by the logarithm of the average employee salary. The average manager compensation is defined as the average annual salary of the top three managers with the highest salary, while the average employee salary is equal to compensation paid to all employees divided by the number of employees. (3) Directors with R&D backgrounds (*Exp_d*), which is measured by two means: the number of directors with R&D backgrounds in the firm (Exp_d_1) and a dummy variable (Exp_d_2) that measures whether the company has a director with an R&D background, which takes the value of 1 if it does, and 0 otherwise.

3.3.4. Control variables

Referring to the work of Barker III and Mueller (2002), Song et al. (2015), De Cleyn and Braet (2012), Jin et al. (2016), and Corsi and Prencipe (2019), we choose firm size (*Size*), financial leverage (*Lev*), growth ability (*Prof*), the asset-liability ratio (*Tbdt*), the current ratio (*Liq_ratio*), inventory turnover (*Inv_ratio*), total profit growth rate (*Pro_pp*), fixed asset growth rate (*Fa_pp*), the cash-asset ratio (*Ca_ratio*), the number of directors (*Bdindt*), the ratio of the largest shareholder (*Share_per*), and the equity restriction ratio (*Shrz*) as control variables to account for their impact on R&D efficiency. Additional control variables include industry (*Ins*) and Year (*Year*) dummy variables. The variables' definitions are shown in Table 1.

4. Empirical analysis

4.1. Descriptive statistics

Table 2 reports descriptive statistics for the variables in the model. The average value of the R&D efficiency variable Eff_1, calculated based on the number of invention patents applied, is 0.4, which is significantly higher than the average of the R&D

Table 2. Descriptive statistics.

Variable	Observation	Mean	S.D.	Minimum	Median	Maximum
Eff_1	10837	0.400	0.956	0.000	0.062	6.715
Eff_2	10837	0.142	0.378	0.000	0.000	2.573
Exp	10837	0.256	0.436	0.000	0.000	1.000
Size	10837	7.667	1.167	5.338	7.556	11.088
Lev	10837	1.349	1.236	−1.163	1.045	9.242
Prof	10837	0.284	0.166	0.010	0.252	0.802
Tbdt	10837	0.387	0.204	0.037	0.371	0.863
Liq_ratio	10837	2.988	3.502	0.385	1.830	23.154
Inv_ratio	10837	6.161	11.531	0.373	3.414	95.213
Pro_pp	10837	0.236	6.208	−30.871	−0.009	34.083
Fa_pp	10837	0.284	0.704	−0.422	0.075	4.792
Ca_ratio	10837	0.187	0.145	0.014	0.143	0.679
Bdindt	10837	0.374	0.053	0.333	0.333	0.571
Share_per	10837	35.406	14.620	8.918	33.770	74.044
Shrz	10837	1.910	0.781	1.044	1.706	4.996

Source: created by the authors.

efficiency variable Eff_2, calculated based on the number of invention patents granted. This result indicates that the quality of invention patents in Chinese enterprises is still not high, as the number of patents granted is much lower than the number of patent applications. The minimum value of *Eff* in both measures is 0, reflecting that some firms do not have patent output. The median of Eff_1 is 0.062, which is well below the average of 0.4. The median of Eff_2 is 0, indicating that half of the sample companies have had no patents granted and signaling that the overall level of Chinese enterprises' R&D activities needs improvement. In addition, R&D efficiency varies widely among the sample firms, so whether senior managers with backgrounds in R&D can improve the enterprise's R&D efficiency will be investigated in follow-up research. The average value of the senior managers' occupational background variable (*Exp*) is 0.256, indicating that 25.6 percent of the sample firms have chairpersons with R&D backgrounds. Therefore, it is not uncommon for the chairperson of a Chinese company to have a professional background in R&D.

4.2. Baseline regression analysis

Model (1) examines the impact of senior managers with R&D backgrounds on enterprise R&D activities' efficiency. The regression results are shown in Table 3. The coefficient of *Exp* in column (1) is 0.088, and the coefficient of *Exp* in column (2) is 0.024, both of which are significant at the 1% level. Therefore, there is a significant positive relationship between manager's R&D backgrounds and enterprises' R&D efficiency, which supports H1. The efficiency of such firms' R&D activities may be enhanced through top managers with R&D backgrounds' rigorous evaluation and implementation of R&D strategies, purposeful management, and incentive measures.

As for the control variables, the size of the enterprise (*Size*), growth ability (*Prof*), the ratio of cash assets (*Ca_ratio*), and the ratio of the largest shareholder (*Share_per*) are all significantly positively associated with R&D efficiency, reflecting the impact of a firm's fundamental characteristics on the efficiency of its R&D activities.

Table 3. Manager's occupational background and corporate R&D efficiency.

	(1) Eff_1	(2) Eff_2
Exp	0.088***	0.024***
	(4.21)	(2.85)
Size	0.224***	0.062***
	(24.81)	(17.29)
Lev	−0.010	−0.003
	(−1.38)	(−0.99)
Prof	0.160**	0.080***
	(2.48)	(3.16)
Tbdt	0.174***	0.032
	(2.61)	(1.23)
Liq_ratio	0.010***	−0.000
	(2.67)	(−0.02)
Inv_ratio	−0.000	−0.000
	(−0.57)	(−0.06)
Pro_pp	0.001	0.000
	(0.51)	(0.40)
Fa_pp	0.016	0.002
	(1.24)	(0.31)
Ca_ratio	0.304***	0.085***
	(3.71)	(2.63)
Bdindt	−0.027	−0.031
	(−0.16)	(−0.47)
Share_per	0.002**	0.001***
	(2.06)	(3.06)
Shrz	0.019	0.005
	(1.18)	(0.79)
Year	Control	Control
Ins	Control	Control
Cons	−2.124***	−0.544***
	(−4.50)	(−2.92)
N	10837	10837
Adj. R^2	0.090	0.093
F	27.265	28.198

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.

4.3. Robustness check

4.3.1. Alternate measures for manager's occupational background

The baseline regressions employ the chairperson's occupational background as an independent variable. To check robustness, we replaced the measure of manager's occupational background with the CEO's occupational background (*Exp-CEO*) as an independent variable such that, if the CEO has R&D experience, *Exp-CEO* is defined as 1 and 0 otherwise. Then, we take the occupational background of both the CEO and the chairperson to represent senior managers such that, if the CEO or chairperson's occupational background encompasses R&D experience, the *Exp-TWO* variable takes the value of 1, and 0 otherwise.

The regression results are reported in Appendix A. The regression coefficients of the CEO's career background (*Exp-CEO*) are positive and significant at the 5% level. Likewise, the coefficients of the CEO and chairperson's occupational background (*Exp_TWO*) are positive and significant at the 1% and 5% levels, respectively. This result shows that there is a significant positive link between a CEO with an R&D background with an enterprise's R&D efficiency and between a CEO or chairperson

with an R&D background and an enterprise's R&D efficiency. These findings reinforce the baseline results, indicating that top management with an R&D background can significantly improve the efficiency of R&D activities of Chinese enterprises.

4.3.2. Heckman two-stage inspection

Firms with diverse fundamental characteristics may have diverse preferences in the choice of managers. Companies with high levels of R&D efficiency may prefer to select managers with R&D backgrounds, so the endogenous nature of this reverse causation can lead to biased estimates.

Therefore, we employ the Heckman two-stage model (Heckman, 1979) to alleviate endogeneity issues that may be present in the analysis. Considering that the company's selection of managers with R&D backgrounds may be influenced by the regional R&D environment, the total patent applications received by a firm's location provincial patent administration department ten years prior to the start of this sample (*Patent*) is included in the Heckman test first-stage regression model as the influence factor that reflects the company's choice of R&D-savvy managers. Subsequently, this regression result is used to construct the reverse Mills ratio (IMR) to carry out the second-stage regression.

Appendix B shows that *Patent* variable in column (1) has a significant positive influence on the selection of managers with R&D backgrounds (*Exp*). And after including the IMR variable into model (1), the coefficient of *Exp* remains significantly positive. Therefore, the principle conclusions remain unchanged.

4.3.3. Match sample test

The proportion of managers with R&D backgrounds in our research sample is relatively small, which may lead to small-sample bias. To ensure empirical rigor, the propensity-score-matching method is used to match the firms who hire a R&D background manager. Hence, by controlling for firms' fundamental characteristics, the nearest-collar matching technique is used to match the pairs according to the standard of 1:1. The results of regression model (1) using a paired sample are shown in Appendix C.

The regression coefficient of manager's career background (*Exp*) in Appendix C is significantly positive. This result is in line with the main regression outcomes, which shows that our empirical findings are consistent and robust.

These findings suggest that managers with R&D backgrounds can help improve an enterprise's R&D efficiency, although it is still unclear how this mechanism works. Next, we discuss managers with R&D backgrounds' management style.

4.4. Managerial preferences of managers with R&D backgrounds

Here we examine the management preferences of managers with R&D backgrounds which enable them to enhance R&D efficiency of Chinese enterprises. These preferences are reflected in the presence or absence of equity incentives for the core technical

team, the pay gap between managers and employees, and the appointment of directors with R&D backgrounds.

First, we test whether the regression coefficient of manager's professional background (*Exp*) is significant for R&D efficiency (*Eff*). If it is significant, subsequently, we observed whether the regression coefficient of manager's occupational background (*Exp*) is significant with the mediating variables. Then, if that is significant, we regress R&D efficiency (*Eff*) with both *Exp* and the mediating variables. If we find that *Mediation* is significant and *Exp* is significant, then there is a partial mediation effect, and if *Mediation* is significant but *Exp* is insignificant, then there is a complete mediation effect. The first step of the test was conducted in the baseline regression.

4.4.1. Equity incentives for core technology personnel

As the direct participants in and executors of R&D projects, core technology personnel substantially influence enterprises' innovation outcomes, so they must be properly motivated through the internal incentive system to improve their risk-taking and performance-sharing capabilities. Such incentives can help to intensify their efforts, stimulate creativity, and alleviate the agency problem between senior managers and employees, thus promoting the firm's R&D efficiency.

Managers with R&D backgrounds tend to have a deep understanding of the importance of R&D outcomes for their firms' continued operation. Moreover, based on the knowledge they gained from their R&D experience, they are aware of the value of their firms' core R&D personnel. As a result, they are likely to know how to improve their firms' R&D efficiency by effectively motivating their firms' core technical team to use their expertise. The regression results are shown in Table 4.

The regression coefficients of *Exp* in column (1) is positive and significant at the 1% level. In column (2), the regression coefficient of *Esop* is positive and significant at the 5% level, and the coefficient of *Exp* is positive at the 1% level. We find similar results in column (3) after replacing the dependent variable with Eff_2.

These results explicate that managers with R&D backgrounds tend to improve the level of equity incentives for core technical personnel, which is conducive to improving their firms' R&D efficiency. The results also reveal that equity incentives for core technical personnel (*Esop*) mediates the relationship between managers with R&D backgrounds and corporate R&D efficiency. Enterprise R&D activities face a high probability of failure, which means that R&D personnel must undertake risks to pursue such endeavors. Through an equity incentive plan, firms associate their wealth creation with the benefits of R&D employees. As a result, R&D personnel have a monetary incentive to optimize their R&D output. Therefore, giving equity incentives to core technology personnel is one of the mechanisms used by managers with R&D background to improve the efficiency of R&D.

4.4.2. Manager-employee pay gap

Managers and employees drive corporate value-creation activities, although they play different roles and assume different responsibilities in the R&D process. However, the sense of injustice caused by an excessive pay gap between top managers and

Table 4. Mediating effect of equity incentive for core technology personnel.

	(1) *Esop*	(2) *Eff*$_1$	(3) *Eff*$_2$
Exp	0.000***	0.087***	0.023***
	(2.97)	(4.15)	(2.78)
Esop		3.695**	1.720**
		(2.06)	(2.43)
Size	0.000	0.224***	0.062***
	(0.96)	(24.80)	(17.27)
Lev	−0.000**	−0.010	−0.003
	(−2.29)	(−1.33)	(−0.94)
Prof	0.002***	0.151**	0.077***
	(6.42)	(2.35)	(3.01)
Tbdt	−0.000	0.176***	0.033
	(−1.27)	(2.64)	(1.26)
Liq_ratio	−0.000***	0.010***	0.000
	(−5.33)	(2.78)	(0.10)
Inv_ratio	0.000*	−0.001	−0.000
	(1.80)	(−0.61)	(−0.10)
Pro_pp	0.000	0.001	0.000
	(1.52)	(0.48)	(0.36)
Fa_pp	0.000*	0.015	0.001
	(1.87)	(1.20)	(0.26)
Ca_ratio	0.002***	0.299***	0.083**
	(3.47)	(3.64)	(2.55)
Bdindt	0.001	−0.029	−0.032
	(0.56)	(−0.17)	(−0.48)
Share_per	−0.000	0.002**	0.001***
	(−0.12)	(2.07)	(3.07)
Shrz	0.000**	0.019	0.005
	(2.27)	(1.14)	(0.74)
Year	Control	Control	Control
Ins	Control	Control	Control
Cons	−0.003	−2.115***	−0.540***
	(−1.03)	(−4.48)	(−2.90)
N	10837	10837	10837
Adj. R^2	0.031	0.091	0.094
F	9.441	26.725	27.679

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.

employees may lead to discontent among employees and a reduction in team cooperation (Bloom & Michel, 2002, Firth et al., 2015), enthusiasm for work, and eventually the enterprise's R&D efficiency. We assume the R&D background managers will avoid this situation by decreasing the pay gap to improve the R&D efficiency.

Regression results for models (2) and (3) are shown in Table 5. The regression coefficient of *Exp* is negative in column (1), which shows that managers with R&D backgrounds significantly reduce the pay gap. Similarly, *Gap* has a negative coefficient in both column (2) and column (3), and it is significant at the 1% level, indicating that a high pay gap negatively affects firms' R&D efficiency. Consistent with the previous results, *Exp* has a significant positive coefficient with both proxies for R&D efficiency.

These results show that managers with R&D backgrounds tend to reduce the pay gap between managers and employees, which is conducive to increasing R&D efficiency. Hence, the pay gap decreasing plays a mediating role between managers with R&D backgrounds and R&D efficiency and is one of the underlying mechanisms through which senior managers with R&D backgrounds improve R&D efficiency.

Table 5. Mediating effect of the manager-employee pay gap.

	(1) *Gap*	(2) *Eff*$_1$	(3) *Eff*$_2$
Exp	−0.007***	0.087***	0.020**
	(−4.70)	(3.96)	(2.29)
Gap		−0.403***	−0.152***
		(−2.82)	(−2.67)
Size	0.024***	0.240***	0.067***
	(37.10)	(24.06)	(16.85)
Lev	−0.001*	−0.010	−0.002
	(−1.67)	(−1.26)	(−0.74)
Prof	0.045***	0.171**	0.092***
	(9.76)	(2.55)	(3.46)
Tbdt	−0.059***	0.157**	0.021
	(−12.23)	(2.25)	(0.76)
Liq_ratio	−0.001**	0.009**	−0.001
	(−2.45)	(2.24)	(−0.43)
Inv_ratio	−0.000	−0.000	0.000
	(−1.34)	(−0.54)	(0.07)
Pro_pp	−0.000	0.001	0.000
	(−0.06)	(0.68)	(0.35)
Fa_pp	0.006***	0.015	0.002
	(6.85)	(1.10)	(0.31)
Ca_ratio	−0.017***	0.319***	0.103***
	(−2.76)	(3.64)	(2.95)
Bdindt	−0.070***	−0.057	−0.040
	(−5.81)	(−0.33)	(−0.58)
Share_per	−0.000***	0.002**	0.001***
	(−7.12)	(2.00)	(2.99)
Shrz	0.004***	0.022	0.007
	(3.52)	(1.28)	(1.09)
Year	Control	Control	Control
Ins	Control	Control	Control
Cons	0.946***	−1.821***	−0.482**
	(28.63)	(−3.67)	(−2.44)
N	10217	10217	10217
Adj. R^2	0.180	0.094	0.094
F	55.724	26.274	26.131

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.

4.4.3. Appointment of directors with R&D background

In addition to modest incentives for company employees and lowering the pay gap, managers with R&D backgrounds may be more inclined to appoint directors with R&D expertise to form a more effective decision-making team and boost the efficiency of their firms' R&D endeavors.

The regression results are shown in Table 6. The coefficients of manager's R&D backgrounds (*Exp*) are positive and significant at the 1% level in column (1) and column (2). The coefficient of the number of directors with R&D background (*Exp_d*$_1$) is positive, and the coefficient of manager's professional background (*Exp*) is also positive in column (3), and all are significant at the 1% level. The coefficient of the dummy variable for directors with R&D backgrounds (*Exp_d*$_2$) is positive and significant at the 5% level, and the coefficient of manager's occupational background (*Exp*) is positive and significant at the 1% level in column (4). We find similar results once the dependent variable is replaced with *Eff*$_2$.

Table 6. Mediating effects of the appointment of directors with R&D background.

	(1) Exp_d_1	(2) Exp_d_2	(3) Eff_1	(4) Eff_1	(5) Eff_2	(6) Eff_2
Exp	0.773***	0.850***	0.075***	0.082***	0.018**	0.021**
	(24.81)	(12.44)	(3.47)	(3.89)	(2.09)	(2.50)
Exp_d_1			0.017***		0.007***	
			(2.66)		(2.91)	
Exp_d_2				0.053**		0.024***
				(2.42)		(2.83)
Size	−0.008	−0.040*	0.224***	0.224***	0.062***	0.062***
	(−0.63)	(−1.66)	(24.84)	(24.85)	(17.32)	(17.34)
Lev	0.011	0.042**	−0.011	−0.011	−0.003	−0.003
	(0.99)	(2.05)	(−1.40)	(−1.43)	(−1.02)	(−1.05)
Prof	0.198**	0.338*	0.156**	0.157**	0.079***	0.079***
	(2.08)	(1.92)	(2.43)	(2.44)	(3.11)	(3.11)
Tbdt	0.006	−0.347*	0.174***	0.178***	0.032	0.034
	(0.06)	(−1.95)	(2.61)	(2.66)	(1.23)	(1.29)
Liq_ratio	0.001	0.008	0.010***	0.010***	−0.000	−0.000
	(0.17)	(0.70)	(2.67)	(2.67)	(−0.03)	(−0.03)
Inv_ratio	−0.007***	−0.009***	−0.000	−0.000	0.000	0.000
	(−5.22)	(−3.89)	(−0.44)	(−0.49)	(0.09)	(0.05)
Pro_pp	0.001	−0.003	0.001	0.001	0.000	0.000
	(0.37)	(−0.66)	(0.50)	(0.53)	(0.39)	(0.42)
Fa_pp	0.077***	0.132***	0.014	0.015	0.001	0.001
	(4.06)	(3.25)	(1.13)	(1.17)	(0.19)	(0.22)
Ca_ratio	0.497***	0.263	0.296***	0.302***	0.082**	0.084***
	(4.08)	(1.12)	(3.60)	(3.68)	(2.52)	(2.60)
Bdindt	−3.782***	−4.235***	0.038	0.012	−0.003	−0.013
	(−15.28)	(−9.78)	(0.23)	(0.07)	(−0.04)	(−0.20)
Share_per	0.003**	0.005**	0.002**	0.002**	0.001***	0.001***
	(2.15)	(2.20)	(2.01)	(2.01)	(3.00)	(3.00)
Shrz	0.143***	0.220***	0.017	0.018	0.004	0.004
	(5.92)	(4.64)	(1.03)	(1.08)	(0.63)	(0.67)
Year	Control	Control	Control	Control	Control	Control
Ins	Control	Control	Control	Control	Control	Control
Cons	0.588	1.595***	−2.135***	−2.133***	−0.549***	−0.548***
	(0.84)	(4.30)	(−4.53)	(−4.52)	(−2.95)	(−2.94)
N	10837.000	10831.000	10837.000	10837.000	10837.000	10837.000
Adj. R^2	0.156	0.081	0.091	0.091	0.094	0.094
F	49.828	946.723	26.800	26.768	27.748	27.735

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.

These results show that managers with R&D backgrounds are more likely to choose directors with R&D backgrounds and that increasing the number of directors with R&D backgrounds is conducive to improving R&D efficiency. Thus, the appointment of directors with R&D backgrounds by these top managers is the mediating channel through which they improve the efficiency of R&D projects.

5. Conclusion and managerial implications

This paper explores the relationship between top management's R&D background and enterprise R&D efficiency. Besides we also examine the mechanism through which management with an R&D background promote R&D efficiency. The empirical findings of this research establish that top management with R&D background enhance their firms' R&D efficiency more than their counterparts do and that they do so by emphasizing equity

incentives for the core technology team, narrowing the pay gap between senior managers and employees, and appointing more directors with R&D backgrounds.

The vision and strategic decision of top management directly influences the efficiency of R&D activities. Based on their career backgrounds, these managers will make unique strategic decisions to boost the innovation capacity of the firm and their specific management approaches and preferences vary considerably based on their past knowledge and experiences. These findings assert that top management with an R&D background optimize their firms' R&D efficiency through an effective management style and by the efficient use of their human and social capital.

The conclusions from this research can particularly encourage technology firms to choose top management with an R&D background to enhance the innovation capability of their firms. Besides, firms whose business model is highly reliant on R&D should also prefer chairperson or CEO with an R&D background to align their corporate objectives with the management's human and social capital. This research also provides inspiration for the top management who do not have an R&D background to pay due consideration to optimize firm's R&D capabilities and appoint R&D-savvy directors to advance their firms' innovation endeavors. Nevertheless, top management shall devise policies to motivate the core R&D team by linking their equity incentives with the R&D efficiency of their enterprise. Lastly, our results confirm that narrowing the pay gap between senior managers and these employees can also help increase the morale of employees hence they will actively contribute towards the R&D endeavors of their firm.

Notwithstanding, the empirical investigation of this study is limited to the influence of top management with an R&D background on the R&D efficiency of Chinese firms. Future line of research can explore and contrast various professional backgrounds of top management on their innovative behavior. Furthermore, it will be interesting to draw a comparison between professional attributes of top management in Chinese companies and other advanced economies and its ultimate impact on the innovation capability of firms.

Note

1. Data Source: Website of World Bank, https://data.worldbank.org.cn/indicator/GB.XPD.RSDV.GD.ZS

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research is supported by the National Natural Science Foundation of China (71802088), the Humanities and Social Sciences Youth Fund project of the Ministry of Education (18YJC630058), the Fundamental Research Funds for the Central Universities (2662021JGPYG01, 2662020JGPY009).

ORCID

Ahsan Akbar http://orcid.org/0000-0001-7506-6416

References

Adams, J. S. (1963). Towards an understanding of inequity. *Journal of Abnormal Psychology*, *67*, 422–436. https://doi.org/10.1037/h0040968

Ahn, J. M., Minshall, T., & Mortara, L. (2017). Understanding the human side of openness: The fit between open innovation modes and CEO characteristics. *R&D Management*, *47*, 727–740.

Akerlof, G. A., & Yellen, J. L. (1990). The fair wage-effort hypothesis and unemployment. *The Quarterly Journal of Economics*, *105*(2), 255–283. https://doi.org/10.2307/2937787

Banker, R. D., Bu, D., & Mehta, M. N. (2016). Pay gap and performance in China. *Abacus*, *52*(3), 501–531. https://doi.org/10.1111/abac.12082

Barker, V. L., III, & Mueller, G. C. (2002). CEO characteristics and firm R&D spending. *Management Science*, *48*(6), 782–801. https://doi.org/10.1287/mnsc.48.6.782.187

Baysinger, B., & Hoskisson, R. E. (1990). The composition of boards of directors and strategic control: Effects on corporate strategy. *The Academy of Management Review*, *15*(1), 72–87. https://doi.org/10.2307/258106

Bloom, M., & Michel, J. G. (2002). The relationships among organizational context, pay dispersion, and among managerial turnover. *Academy of Management Journal*, *45*, 33–42.

Bradley, D., Kim, I., & Tian, X. (2017). Do unions affect innovation? *Management Science*, *63*(7), 2251–2271. https://doi.org/10.1287/mnsc.2015.2414

Brown, J. R., & Petersen, B. C. (2011). Cash holdings and R&D smoothing. *Journal of Corporate Finance*, *17*(3), 694–709. https://doi.org/10.1016/j.jcorpfin.2010.01.003

Buyl, T., Boone, C., Hendriks, W., & Matthyssens, P. (2011). Top management team functional diversity and firm performance: The moderating role of CEO characteristics. *Journal of Management Studies*, *48*(1), 151–177. https://doi.org/10.1111/j.1467-6486.2010.00932.x

Chang, X., Fu, K., Low, A., & Zhang, W. (2015). Non-executive employee stock options and corporate innovation. *Journal of Financial Economics*, *115*(1), 168–188. https://doi.org/10.1016/j.jfineco.2014.09.002

Chen, H. L., Hsu, W. T., & Huang, Y. S. (2010). Top management team characteristics, R&D investment and capital structure in the IT industry. *Small Business Economics*, *35*(3), 319–333. https://doi.org/10.1007/s11187-008-9166-2

Chen, H. L., Ho, M. H. C., & Hsu, W. T. (2013). Does board social capital influence chief executive officers' investment decisions in research and development? *R&D Management*, *43*, 381–393.

Chen, S., Jing, R.-T., & Liao, K.-R. (2012). How do social capital, corporate governance effect on private enterprise's R&D investment intensity. *Studies in Science of Science*, *30*, 916–922.

Cheng, H., Song, F., & Li, D. (2017). How Middle managers' participation in decision-making influences firm innovation performance: Evidence from china employer–employee survey data. *Chinese Management Studies*, *11*(1), 72–89. https://doi.org/10.1108/CMS-12-2016-0253

Choi, J., & Chen, C. C. (2007). The relationships of distributive justice and compensation system fairness to employee attitudes in international joint ventures. *Journal of Organizational Behavior*, *28*(6), 687–703. https://doi.org/10.1002/job.438

Ciftci, M., & Cready, W. M. (2011). Scale effects of R&D as reflected in earnings and returns. *Journal of Accounting and Economics*, *52*(1), 62–80. https://doi.org/10.1016/j.jacceco.2011.02.003

Corsi, C., & Prencipe, A. (2019). Does CEO promote innovation in SMEs? A comparison between internal and external CEO. *International Journal of Innovation Management*, *23*(05), 1950042. https://doi.org/10.1142/S1363919619500427

Custodio, C., & Metzger, D. (2014). Financial expert CEOs: CEO's work experience and firm's financial policies. *Journal of Financial Economics*, *114*(1), 125–154. https://doi.org/10.1016/j.jfineco.2014.06.002

Czarnitzki, D., Hanel, P., & Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms. *Research Policy*, *40*(2), 217–229. https://doi.org/10.1016/j.respol.2010.09.017

Daellenbach, U. S., McCarthy, A. M., & Schoenecker, T. S. (1999). Commitment to innovation: The impact of top management team characteristics. *R&D Management*, *29*, 199–208.

Dalziel, T., Gentry, R. J., & Bowerman, M. (2011). An integrated agency–resource dependence view of the influence of directors' human and relational capital on firms' R&D spending. *Journal of Management Studies*, *48*(6), 1217–1242. https://doi.org/10.1111/j.1467-6486.2010.01003.x

De Cleyn, S. H., & Braet, J. (2012). Do board composition and investor type influence innovativeness in SMEs? *International Entrepreneurship and Management Journal*, *8*(3), 285–308. https://doi.org/10.1007/s11365-010-0168-6

Ederer, F., & Manso, G. (2013). Is pay for performance detrimental to innovation? *Management Science*, *59*(7), 1496–1513. https://doi.org/10.1287/mnsc.1120.1683

Ettlie, J. E. (1998). R&D and global manufacturing performance. *Management Science*, *44*(1), 1–11. https://doi.org/10.1287/mnsc.44.1.1

Faleye, O., Reis, E., & Venkateswaran, A. (2013). The determinants and effects of CEO–employee pay ratios. *Journal of Banking & Finance*, *37*(8), 3258–3272. https://doi.org/10.1016/j.jbankfin.2013.03.003

Finkelstein, S. (1992). Power in top management teams: Dimensions, measurement, and validation. *Academy of Management Journal. Academy of Management*, *35*(3), 505–538.

Firth, M., Leung, T. Y., Rui, O. M., & Na, C. (2015). Relative pay and its effects on firm efficiency in a transitional economy. *Journal of Economic Behavior & Organization*, *110*, 59–77. https://doi.org/10.1016/j.jebo.2014.12.001

Fung, M. K. (2006). R&D, knowledge spillovers and stock volatility. *Accounting and Finance*, *46*(1), 107–124. https://doi.org/10.1111/j.1467-629X.2006.00166.x

Golden, B. R., & Zajac, E. J. (2001). When will boards influence strategy? Inclination × power = strategic change. *Strategic Management Journal*, *22*(12), 1087–1111. https://doi.org/10.1002/smj.202

Hambrick, D. C. (2007). Upper echelons theory: An update. *Academy of Management Review*, *32*(2), 334–343. https://doi.org/10.5465/amr.2007.24345254

Hambrick, D. C., & Mason, P. A. (1984). Upper echelons: The organization as a reflection of its top managers. *The Academy of Management Review*, *9*(2), 193–206. https://doi.org/10.2307/258434

Hashimoto, A., & Haneda, S. (2008). Measuring the change in R&D efficiency of the Japanese pharmaceutical industry. *Research Policy*, *37*(10), 1829–1836. https://doi.org/10.1016/j.respol.2008.08.004

He, Z., & Wintoki, M. B. (2016). The cost of innovation: R&D and high cash holdings in US firms. *Journal of Corporate Finance*, *41*, 280–303. https://doi.org/10.1016/j.jcorpfin.2016.10.006

Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica*, *47*(1), 153–161. https://doi.org/10.2307/1912352

Hillman, A. J., & Dalziel, T. (2003). Boards of directors and firm performance: Integrating agency and resource dependence perspectives. *The Academy of Management Review*, *28*(3), 383–396. https://doi.org/10.2307/30040728

Holmstrom, B. (1989). Agency costs and innovation. *Journal of Economic Behavior & Organization*, *12*(3), 305–327. https://doi.org/10.1016/0167-2681(89)90025-5

Hu, A. G., & Deng, Y. (2019). Does government R&D stimulate or crowd out firm R&D spending? Evidence from Chinese manufacturing industries. *Economics of Transition and Institutional Change*, *27*(2), 497–518. https://doi.org/10.1111/ecot.12188

Jensen, M. C., & Murphy, K. J. (1990). Performance pay and top-management incentives. *Journal of Political Economy*, *98*(2), 225–264. https://doi.org/10.1086/261677

Jin, X., Lei, G., & Yu, J. (2016). Government governance, executive networks and enterprise R&D Expenditure. *China Journal of Accounting Research*, *9*(1), 59–81. https://doi.org/10.1016/j.cjar.2015.09.001

Keller, R. T. (2017). A longitudinal study of the individual characteristics of effective R&D project team leaders. *R&D Management*, *47*, 741–754.

Kim, J., Lee, S. J., & Marschke, G. (2009). Relation of firm size to R&D productivity. *International Journal of Business and Economics*, *8*, 7.

Kong, D., Kong, G., Pang, L., & Zhang, J. (2018). Who gets the wage premium from export: Top managers or employees? *International Review of Economics & Finance*, *58*, 356–370. https://doi.org/10.1016/j.iref.2018.04.006

Kor, Y. Y. (2006). Direct and interaction effects of top management team and board compositions on R&D investment strategy. *Strategic Management Journal*, *27*(11), 1081–1099. https://doi.org/10.1002/smj.554

Lin, C., Lin, P., Song, F. M., & Li, C. (2011). Managerial incentives, CEO characteristics and corporate innovation in China's private sector. *Journal of Comparative Economics*, *39*(2), 176–190. https://doi.org/10.1016/j.jce.2009.12.001

Liu, B., Huang, W., & Wang, L. (2019). Performance-based equity incentives, vesting restrictions, and corporate innovation. *Nankai Business Review International*, *10*(1), 138–164. https://doi.org/10.1108/NBRI-10-2018-0061

Lu, X., Qian, Q., Song, W., & Ge, Z. (2021). Returnee executives and corporate innovation efficiency: Help or resistance. *Science and Technology Management Research, 41*(1), 143–150.

Nonaka, I., & Konno, N. (1998). The concept of "Ba": Building a foundation for knowledge creation. *California Management Review*, *40*(3), 40–54. https://doi.org/10.2307/41165942

Shen, Y. (2021). CEO characteristics: A review of influential publications and a research agenda. *Accounting & Finance*, *61*(1), 361–385. 10.1111/acfi.12571

Song, M., Ai, H., & Li, X. (2015). Political connections, financing constraints, and the optimization of innovation efficiency among China's private enterprises. *Technological Forecasting and Social Change*, *92*, 290–299. https://doi.org/10.1016/j.techfore.2014.10.003

Sunder, J., Sunder, S. V., & Zhang, J. (2017). Pilot CEOs and corporate innovation. *Journal of Financial Economics*, *123*(1), 209–224. https://doi.org/10.1016/j.jfineco.2016.11.002

Thomas, V., Sharma, S., & Jain, S. K. (2011). Using patents and publications to assess R&D efficiency in the states of the USA. *World Patent Information*, *33*(1), 4–10. https://doi.org/10.1016/j.wpi.2010.01.005

Wen, Z., Chang, L., Hau, K. T., & Liu, H. (2004). Testing and application of the mediating effects. *Acta Psychologica Sinica*, *36*, 614–620.

Wu, A. (2017). The signal effect of Government R&D Subsidies in China: Does ownership matter? *Technological Forecasting and Social Change*, *117*, 339–345. https://doi.org/10.1016/j.techfore.2016.08.033

Wu, J., & Wu, Z. (2014). Integrated risk management and product innovation in China: The moderating role of board of directors. *Technovation*, *34*(8), 466–476. https://doi.org/10.1016/j.technovation.2013.11.006

Wu, Z., & Liao, H. (2021). Government R&D subsidies and enterprise R&D activities: Theory and evidence. *Economic Research-Ekonomska Istraživanja*, https://doi.org/10.1080/1331677X.2021.2019077

Yin, X., Hai, B. L., & Chen, J. (2019). Financial constraints and R&D investment: The moderating role of CEO characteristics. *Sustainability*, *11*(15), 4153. https://doi.org/10.3390/su11154153

Xia, Y., & Tang, Q. (2008). China's high-tech enterprises equity incentives and R&D spendings. *Securities Market Herald*, *18*(10), 29–34.

Xie, Z., & Wang, J. (2020). Influence of open innovation on enterprises' R&D efficiency: An empirical study based on the panel data from high - tech industries. *Science Research Management, 41*(9), 22–32.

Xie, L., Zhou, J., Zong, Q., & Lu, Q. (2020). Gender diversity in R&D teams and innovation efficiency: Role of the innovation context. *Research Policy*, *49*(1), 103885. https://doi.org/10.1016/j.respol.2019.103885

Zhang, X., Wang, L., & Chen, F. (2021). R&D subsidies, executive background and innovation of Chinese listed companies. *Economic Research-Ekonomska Istraživanja*, *34*(1), 484–497. https://doi.org/10.1080/1331677X.2020.1792324

Zhu, W.-Y., & Yin, Q. (2016). *The influence of TMT characteristics on technological innovation: Evidence from public listed companies in China*. Proceedings of the 6th International Asia Conference on Industrial Engineering and Management Innovation, Springer, 963–970.

Appendices

Appendix A: Alternate measures for the occupational background of managers

	(1) Eff_1	(2) Eff_2	(3) Eff_1	(4) Eff_2
Exp_CEO	0.041**	0.017**		
	(2.00)	(2.09)		
Exp_TWO			0.056***	0.015**
			(2.98)	(1.98)
Size	0.222***	0.061***	0.223***	0.061***
	(24.64)	(17.21)	(24.68)	(17.20)
Lev	−0.010	−0.003	−0.010	−0.003
	(−1.37)	(−0.98)	(−1.38)	(−0.99)
Prof	0.168***	0.082***	0.166***	0.082***
	(2.62)	(3.22)	(2.59)	(3.24)
Tbdt	0.174***	0.032	0.175***	0.033
	(2.60)	(1.22)	(2.62)	(1.24)
Liq_ratio	0.010***	0.000	0.010***	0.000
	(2.83)	(0.07)	(2.78)	(0.05)
Inv_ratio	−0.001	−0.000	−0.001	−0.000
	(−0.68)	(−0.13)	(−0.61)	(−0.08)
Pro_pp	0.001	0.000	0.001	0.000
	(0.53)	(0.41)	(0.56)	(0.43)
Fa_pp	0.016	0.002	0.016	0.002
	(1.28)	(0.32)	(1.29)	(0.34)
Ca_ratio	0.309***	0.086***	0.307***	0.086***
	(3.76)	(2.66)	(3.74)	(2.65)
Bdindt	−0.007	−0.026	−0.002	−0.024
	(−0.04)	(−0.40)	(−0.01)	(−0.36)
Share_per	0.002**	0.001***	0.002**	0.001***
	(2.12)	(3.10)	(2.10)	(3.09)
Shrz	0.021	0.006	0.020	0.005
	(1.30)	(0.86)	(1.25)	(0.84)
Year	Control	Control	Control	Control
Ins	Control	Control	Control	Control
Cons	−2.132***	−0.546***	−2.131***	−0.546***
	(−4.52)	(−2.93)	(−4.52)	(−2.93)
N	10837	10837	10837	10837
Adj. R^2	0.089	0.093	0.090	0.093
F	26.897	28.096	27.028	28.085

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.

Appendix B: Heckman two-stage inspection

	(1) *Exp*	(2) *Eff*$_1$	(3) *Eff*$_2$
Exp		0.606***	0.148**
		(3.26)	(2.02)
Size	−0.094***	0.237***	0.063***
	(−6.55)	(22.91)	(15.54)
Lev	−0.001	−0.011	−0.003
	(−0.08)	(−1.44)	(−0.82)
Prof	0.538***	0.065	0.061**
	(5.43)	(0.91)	(2.15)
Tbdt	−0.021	0.157**	0.033
	(−0.19)	(2.34)	(1.25)
Liq_ratio	0.022***	0.005	−0.001
	(4.27)	(1.24)	(−0.72)
Inv_ratio	−0.004***	−0.000	0.000
	(−2.63)	(−0.03)	(0.24)
Pro_pp	0.002	0.000	0.000
	(0.75)	(0.20)	(0.28)
Fa_pp	0.024	0.010	0.000
	(1.26)	(0.77)	(0.00)
Ca_ratio	0.282**	0.250***	0.072**
	(2.28)	(2.97)	(2.17)
Bdindt	0.824***	−0.166	−0.064
	(3.22)	(−0.95)	(−0.92)
Share_per	0.002	0.001	0.001***
	(1.63)	(1.29)	(2.97)
Shrz	0.072***	0.005	0.003
	(2.86)	(0.28)	(0.43)
Patent	0.000***		
	(8.21)		
IMR		−0.315***	−0.075*
		(−2.88)	(−1.74)
Year	Control	Control	Control
Ins	Control	Control	Control
Cons	−1.582***	−1.543**	−0.398
	(−5.82)	(−2.35)	(−1.54)
N	10681	10681	10681
Adj. R^2*/Pseudo* R^2	0.083	0.089	0.092
F/Chi^2	1002.485	26.435	27.516

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.

Appendix C: Match sample test

	(1) Eff_1	(2) Eff_2
Exp	0.061**	0.022**
	(2.19)	(2.09)
Size	0.232***	0.059***
	(15.72)	(10.44)
Lev	−0.033**	−0.010*
	(−2.32)	(−1.88)
Prof	0.179*	0.130***
	(1.85)	(3.54)
Tbdt	0.160	0.047
	(1.47)	(1.13)
Liq_ratio	0.009*	−0.003
	(1.93)	(−1.44)
Inv_ratio	−0.003**	−0.001*
	(−2.51)	(−1.79)
Pro_pp	−0.000	0.000
	(−0.13)	(0.43)
Fa_pp	0.015	−0.001
	(0.82)	(−0.22)
Ca_ratio	0.222*	0.093**
	(1.88)	(2.08)
Bdindt	−0.125	−0.070
	(−0.48)	(−0.71)
Share_per	0.002	0.000
	(1.34)	(0.20)
Shrz	−0.006	−0.006
	(−0.24)	(−0.66)
Year	Control	Control
Ins	Control	Control
Cons	−1.438	−0.164
	(−1.52)	(−0.45)
N	4695	4695
Adj. R^2	0.075	0.092
F	10.458	12.891

Note: t-values are in parentheses.
*, **, *** indicates the significance level of 10%, 5%, and 1%, respectively.
Source: created by the authors.