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Are Inventors Better CEOs? Evidence from China

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ABSTRACT

This study investigates the impact of inventor CEOs on firm performance using a manually collected database of firms' inventors. Our findings reveal that, on average, firms with inventor CEOs experience a one- and two-percentage-point increase in ROA and ROE, respectively, compared to firms with noninventor CEOs. To address potential endogeneity issues, we employ turnover analysis, an instrumental variable approach, and propensity score matching. The estimation results suggest that inventor CEOs significantly enhance firm performance by fostering innovation and total factor productivity. This research contributes novel evidence on the relationship between inventor CEOs and firm performance.

KEYWORDS

Inventor CEOs; Firm performance; Patents; Innovation efficiency; Total factor productivity

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1. Introduction

CEOs play a critical role in corporate strategic decision-making (Bennedsen et al., 2020). CEOs with diverse backgrounds exhibit various management styles, which can impact firm performance (Islam and Zein, 2020). Previous studies have primarily focused on the effects of CEOs' personal characteristics on firm performance and technological innovation (Malmendier and Tate, 2005; Kaplan et al., 2012; Kaplan et al., 2022). However, little research has examined the influence of CEOs' inventor backgrounds on firm performance and technological innovation. This study aims to empirically investigate whether inventor CEOs enhance firm performance by fostering innovation.

Accurately identifying CEOs with an inventor background poses a significant challenge for this study. We first collected a database of personal characteristics of corporate CEOs from the CSMAR database and the internet. Next, we identified inventors of Chinese public firms from the IncoPat database. Finally, we matched the CEOs with firm inventors to initially identify those with an inventor background. To minimize the impact of name overlap, we meticulously reviewed the resumes of each inventor CEO, examining their educational and professional backgrounds to eliminate possible mismatches with the same name. Through this process, we ultimately identified corporate CEOs who are also inventors.

We use return on total assets (ROA) and return on net assets (ROE) as proxies for firm performance to empirically examine the impact of inventor CEOs on firm performance. The results indicate that inventor CEOs have a significant positive impact on firm performance. On average, firms with inventor CEOs have ROA and ROE one and two percentage points higher, respectively, compared to other firms. To address possible endogeneity issues, three methods are employed in this study, namely, CEO turnover analysis, panel instrumental approaches, and propensity score matching. The CEO turnover analysis shows that the appointment of inventor CEOs significantly improves firm performance, while the resignation of inventor CEOs leads to a short-term decline in ROA and ROE. An instrumental variable approach is used by selecting the arable land area per capita of the CEOs' hometown and the number of inventor CEOs in the same region and industry as instrumental variables for inventor CEOs. The results show that inventor CEOs do promote firm performance. Using an instrumental variable approach, the study finds that inventor CEOs have a significantly positive influence on corporate technological innovation, regardless of whether it is R&D intensity or patent output.

This study provides further evidence that inventor CEOs can improve firm performance by promoting technological innovation and total factor productivity and significantly enhancing the ability to transform innovation capability into future financial performance. To address the potential explanation that inventor CEOs increase corporate innovation and financial performance due to overconfidence, a proxy variable is constructed to control for CEO overconfidence. After controlling for CEO overconfidence, the significant influence of inventor CEOs on firm performance remains, which eliminates the potential interference of CEO overconfidence as a competitive explanation.

Compared to the exist literature, this study presents several potential innovations. First, to the best of our knowledge, this article among the early studies that examined the impact and mechanism of CEO's inventor background on corporate performance, especially in emerging market like China. By addressing the research gap in related fields, this study contributes to the understanding of the relationship between CEOs, firm performance, and innovation. Second, this paper employs a variety of identification strategies to effectively address endogeneity issues. Through CEO turnover analysis, a panel instrumental variable approach, and the propensity score matching method, this study identifies the causal effect of inventor CEOs on firm performance. Moreover, the potential competitive explanation of CEO overconfidence is controlled for, enhancing the credibility and reliability of the conclusion. Third, this research analyzes the role of technological innovation as an influencing mechanism, empirically testing whether inventor CEOs promote technological innovation and increase firm total factor productivity, thereby improving future financial performance. Last, this article employs individual inventor data. The inventor database used in this study is hand-collected, which represents an innovative approach to research data collection.

The article is structured as follows: Chapter 2 provides a comprehensive literature review of the research topic. Chapter 3 describes the data processing steps and variable definitions and presents the descriptive statistics used in the study. Chapter 4 presents the estimation results of the benchmark model and analysis under different identification strategies. Chapter 5 focuses on robustness checks and heterogeneity analysis. Chapter 6 is dedicated to the mechanism analysis, examining the role of technological innovation in the relationship between inventor CEOs and firm performance. Finally, the last chapter provides a summary and conclusion of the study, highlighting the key findings and implications for future research.

2. Relation to the literature

2.1. CEO characteristics and firm innovation

As an essential factor in investment decision-making, corporate innovation can be influenced by the CEO's background and experience (Bennedsen et al., 2020). Specifically, companies with younger CEOs and a higher percentage of CEO holdings tend to invest more in R&D. Additionally, if the CEO has a science-related degree, the firm's R&D investment tends to be higher. Heavey et al. (2022) used the execution of CEO stock options to construct indicator variables for measuring CEO overconfidence and discovered that overconfident CEOs are more inclined to engage in technological innovation and more likely to lead their companies in new technological directions. This finding was also observed by Hirshleifer et al. (2012). The duration of CEO compensation incentives also affects corporate innovation. Specifically, the longer the duration of CEO compensation incentives, the more corporate patents and citations the company obtains (Lerner and Wulf, 2007; Xue, 2007). Bereskin and Hsu (2014) analyzed the impact of CEO turnover on corporate innovation and found that the new CEO taking office can increase the quantity and quality of innovation output. Moreover, the new CEO within the company promotes innovation more than an external CEO. If the CEO is a generalist, mastering a variety of management skills can motivate the firm to carry out innovation because, in the event of an innovation project failure, the CEO's skills can be applied to other aspects, thereby increasing the firm's tolerance for failure (Custodio et al., 2019).

Several scholars have examined the relationship between CEO work experience and corporate innovation and performance, specifically with regard to experience in engineering and technology. Jiang and Liu(2020) found that CEOs with experience in R&D, engineering, marketing, or sales tend to be more supportive of innovation strategies, as these experiences emphasize the development of new products and markets. As a result, CEOs with such professional backgrounds often prefer higher R&D investment. In contrast, CEOs with experience in finance, production, administration, or law tend to prioritize organizational efficiency and view R&D as a discretionary cost rather than an efficiency issue. If the CEO has significant experience in these functions, the company's R&D expenditure may be reduced.

Menz (2012) investigated the computer industry and found that companies that pursue market and product innovation strategies are more likely to have CEOs with experience in marketing, sales, or R&D departments. In contrast, efficiency-oriented companies tend to have CEOs with professional experience primarily concentrated in finance, production, or administration units.

Several scholars have examined the impact of a CEO's educational background in engineering and technology on corporate performance and innovation. Wiersema and Bantel (1992) found that as science and engineering fields prioritize processes, innovation, and continuous improvement, senior managers with a background in science or engineering tend to exhibit a stronger innovation spirit and are more willing to accept strategic changes and technological innovations. In contrast, Daellenbach et al. (1999) found that companies tend to have higher R&D expenditures when both the company team and CEO have technical work experience.

2.2. Technological innovation, productivity and financial performance

A CEO's professional experience and educational background only indirectly affect their behavior. This paper distinguishes itself from prior research by examining whether the CEO is an inventor, as inventor CEOs can have a more direct influence on technological innovation and firm performance. The earliest research on innovation and performance can be traced back to Schumpeter (1934), who demonstrated that when innovative products enter the market for the first time, firms can obtain relatively high profits due to limited competition. However, over time, these profits may be eroded by imitation and competition, but firms that continue to introduce innovative products may achieve sustained profitability within a period of time (Sharma and Lacey, 2004). Geroski et al. (1993) found that firms achieving innovative results have a positive impact on profits, and innovative firms are generally more profitable than those without innovation. Roberts (1999) studied the impact of product innovation on the sustainable profitability of American pharmaceutical companies and found that those with a higher tendency toward product innovation exhibit stronger sustained profitability. Calantone et al. (2002) developed a research framework on the relationship between research learning direction, innovation, and growth based on data from American manufacturing and service companies. Their research showed that corporate innovation positively correlates with financial performance.

Cho and Pucik (2005) used structural equation modeling to analyze the relationships among corporate innovation, quality, growth, profitability, and value in the US financial industry. Their research demonstrated positive correlations among innovation, profitability, and corporate value. Artz et al. (2010) investigated the effects of patents and product innovations on firm performance across various industries in the United States and Canada, revealing significant positive impacts of product innovation on firm performance. Therrien et al. (2011) explored the impact of innovation on firm financial performance in a specific industry and concluded that firms aiming to increase sales from innovation must either enter the market early or introduce high-level new products to succeed.

3. Data, variables, and summary statistics

3.1. Firm performance

Previous research has commonly employed return on total assets (ROA) and return on net assets (ROE) as indicators to measure firm performance, which are also utilized in this study as proxy variables for future company performance. Specifically, ROA represents the ratio of a company's net profit to average total assets, while ROE is the ratio of a company's net profit to average shareholder equity. The data for ROA and ROE are sourced from the CSMAR database, excluding ST and *ST firms from the sample. Other studies have employed operating profit and Tobin's Q value to assess firm performance. To ensure the robustness and reliability of the findings, this study conducts a robustness check by replacing the dependent variables with operating profit and Tobin's Q value, which yield consistent results.

3.2. Measuring innovation

Firm innovation can be assessed from two dimensions: innovation input and output. Innovation input is primarily measured using R&D intensity, while innovation output refers to the patents granted by the firm (Hall et al., 2010). To remain consistent with prior research, this study uses the number of patent applications and grants as proxies for corporate innovation output (Acharya and Subramanian, 2009; Hirshleifer et al., 2012; He and Tian, 2013; Chang et al., 2015; Balsmeier et al., 2017). Design patents are combined with utility model patents, and R&D intensity is used to measure corporate innovation. The proxy variables of firm innovation in this model are R&D intensity (Rdassets_ratio), representing the proportion of R&D expenditure to total assets at the end of the previous year; the total number of patent applications filed by the firm in a specific year (Patall_apply); the firm's invention patent applications (Patinv_apply); the firm's utility model and design patent applications (Patade_apply); the total number of patents the company applied for and was granted (Patall_grant); the number of invention patents granted (Patinv_grant); and the number of utility model and design patents granted (Patade_grant). Patent data undergo logarithmic processing to calculate Ln_patall_apply = Ln(1 + Patall_apply), and similar processing is performed on other patent output variables to obtain Ln_patinv_apply, Ln_patade_apply, Ln_patall_grant, Ln_patinv_grant, and Ln_patade_grant. Additionally, this study considers the impact of inventor CEOs on innovation efficiency. Patent data are sourced from the CSMAR database and internet, while R&D data are obtained from the Wind database.

3.3. Measuring inventor CEOs

This article defines an inventor CEO as a general manager of a firm who has an inventor background. An inventor background is characterized by having obtained at least one patent, which is represented by a value of 1. If the general manager does not have an inventor background, the value is 0. The challenge of this study is to accurately identify CEOs with inventor backgrounds. First, we collected personal characteristics data of CEOs of listed Chinese manufacturing firms for each year from the CSMAR database, Wind database, and internet sources. Second, we manually collected data on inventors in public manufacturing companies in China from the IncoPat database. Finally, we matched corporate CEOs with inventors and identified CEOs with inventor backgrounds.

3.4. Control variables

This article includes a range of control variables that could potentially impact firm performance in the empirical model. These variables comprise firm size measured by the natural logarithm of the firm's total assets at the end of the previous year (Ln_assets); the natural logarithm of the company's age (Ln_firmage); the firm's leverage ratio (Leverage); the firm's cash assets ratio (Cash_ratio); and CEO duality, i.e., whether the corporate chairman and CEO are the same person (CEO_duality). Moreover, this study accounts for year, industry, and province fixed effects. Given that this research aims to analyze the influence of inventor CEOs on future firm performance, all control variables are lagged by one year. Furthermore, to remove any effect of sample outliers, all variables are winsorized at the 1% level at both tails of their distributions.

3.5. Descriptive statistics

Table 1 presents the descriptive statistics of the main variables, including the number of observations, mean value, median value, and standard deviation. The average ROA and ROE for all sample firms are approximately 8% and 6%, respectively. The mean difference test results between inventor CEO firms and noninventor CEO firms indicate that inventor CEO firms have significantly higher values for ROA, ROE, R&D intensity, and patents. This suggests that inventor CEOs may have a positive impact on firm performance and technological innovation. Notably, other control variables display a high degree of dispersion in their distribution.

4. Main results

This article investigates the specific impact of inventor CEOs on firm performance and the mechanisms underlying this relationship. To accurately establish the causal effects of inventor CEOs on firm performance, we

Table 1. Summary statistics.

Variables	Whole sample				Inventor CEOs	Noninventor CEOs
	Observations	Mean	Median	SD	Mean	Mean
	(1)	(2)	(3)	(4)	(5)	(6)
ROA	11,335	0.08	0.06	0.05	0.07	0.09***
ROE	11,335	0.06	0.07	0.11	0.06	0.09***
Patall_apply	11,335	17.63	3.00	47.10	11.49	35.72***
Patinv_apply	11,335	6.52	1.00	18.72	4.22	13.28***
Patade_apply	11,335	11.02	1.00	31.72	7.14	22.44***
Rdassets_ratio	11,335	1.89	1.64	1.51	1.71	2.30***
CEO_inventor	11,335	0.21	0.00	0.40	N/A	N/A
Ln_assets	11,335	12.32	12.18	1.10	12.25	12.53***
Ln_firmage	11,335	2.57	2.64	0.41	2.57	2.59**
Leverage	11,335	0.43	0.43	0.20	0.44	0.39***
Cash_ratio	11,335	0.19	0.14	0.15	0.18	0.21***
CEO_duality	11,335	0.24	0.00	0.42	0.22	0.26***
SOEfirm	11,335	0.39	0.00	0.49	0.40	0.35***
Hightecfirm	11,335	0.44	0.00	0.50	0.42	0.51***
Maturefirm	11,335	0.74	1.00	0.44	0.73	0.77***
Largefirm	11,335	0.29	0.00	0.45	0.27	0.34***
Eastfirm	11,335	0.63	1.00	0.48	0.60	0.69***

*Notes: This table reports the summary statistics for variables constructed based on the sample of Chinese public firms from 2001 to 2015. T tests are conducted to test for differences in mean values between the firms with inventor CEOs and firms with non-inventor CEOs. The symbols ***, **, and * indicate that subsample means are significantly different from each other at the 1%, 5%, and 10% levels, respectively.*

utilize the following identification strategies. First, we estimate the baseline model. Second, to address endogeneity concerns, we employ CEO turnover analysis, a panel instrumental approach, and propensity score matching methods.

4.1. The baseline model

First, perform benchmark model estimation. Referring to the research design of Chang et al. (2015), the benchmark model is set as follows:

$$Y_{i,t} = \alpha + \beta CEO_{inventor_{i,t-1}} + \sum \gamma_k Controls_{k,i,t-1} + \theta_i Industry + \varphi_i Year + \delta_i Province + \varepsilon_{i,t} \tag{1}$$

The model considers firm financial performance as the dependent variable, which is represented by ROA and ROE. The independent variable is the indicator variable of inventor CEO, represented by CEO_inventor. A value of 1 is assigned if the CEO has an inventor background, and 0 otherwise. The model also incorporates a series of control variables, including firm size (Ln_assets), firm age (Ln_firmage), firm leverage ratio (Leverage), cash ratio (Cash_ratio), and CEO duality (CEO_duality). All control variables are lagged by one period. Additionally, the model includes fixed effects for industry, year, and province, which are controlled in the regression analysis. The research design follows the approach taken by Chang et al. (2015), and the benchmark model is estimated in the first step.

Table 2 displays the estimation results of the baseline model. The coefficients of inventor CEOs for ROA and ROE are significantly positive and statistically significant at the 1% level. These effects hold even after controlling for a series of control variables and fixed effects of year, industry, and province in models (3) and (6). The coefficient of inventor CEOs on ROA is approximately 0.009, indicating that the ROA of inventor CEO firms is roughly one percentage point higher than that of noninventor CEO firms. The coefficient of inventor CEOs on ROE is approximately 0.018, indicating that the ROE of inventor CEO firms is approximately 2% higher than that of noninventor CEO firms on average. Thus, the impact of inventor CEOs on firm financial performance is significant both statistically and economically.

Regarding the remaining control variables, the analysis shows that firm size has a positive impact on firm performance. Specifically, the larger the firm's scale is, the better its performance. On the other hand, the level of corporate leverage is significantly and negatively correlated with firm performance, indicating that an increase in leverage is not beneficial for performance improvement. Moreover, the corporate cash ratio has a significant positive impact on firm financial performance. Finally, the results suggest that neither firm age nor CEO duality has a significant effect on firm performance.

Table 2. Baseline regressions of firm performance on inventor CEOs.

Variables	ROA (1)	ROA (2)	ROA (3)	ROE (4)	ROE (5)	ROE (6)
CEO_inventor	0.013*** (0.001)	0.009*** (0.001)	0.009*** (0.001)	0.035*** (0.002)	0.021*** (0.002)	0.018*** (0.002)
Ln_assets		0.003*** (0.001)	0.005*** (0.001)		0.010*** (0.001)	0.015*** (0.001)
Ln_firmage		-0.006*** (0.002)	-0.001 (0.002)		-0.010*** (0.003)	-0.004 (0.003)
Leverage		-0.049*** (0.004)	-0.049*** (0.004)		-0.037*** (0.009)	-0.047*** (0.009)
Cash_ratio		0.021*** (0.005)	0.019*** (0.005)		0.085*** (0.008)	0.068*** (0.008)
CEO_duality		0.001 (0.001)	0.002 (0.001)		0.003 (0.002)	0.003 (0.002)
Year fixed effects	No	No	Yes	No	No	Yes
Industry fixed effects	No	No	Yes	No	No	Yes
Province fixed effects	No	No	Yes	No	No	Yes
Observations	12836	7327	7327	12836	7327	7327
Adjustment R2	0.012	0.053	0.178	0.019	0.053	0.158

*Notes: This table reports regressions of firm performance variables(ROA and ROE) on inventor CEOs and other control variables. Robust standard errors clustered by industry are listed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

4.2. CEO turnover analysis

This study has provided initial empirical evidence that inventor CEOs have a positive impact on firm performance in the baseline model regressions. However, the estimation results of the baseline model may be subject to two types of endogenous issues. The first type of endogeneity issue is missing variable bias. Although this article controls for a series of important variables that may affect firm performance based on existing research, there may still be other unobserved variables that could lead to endogenous bias. The second potentially endogenous issue arises from reverse causality. Since firms are heterogeneous in choosing CEOs, they may have different preferences for CEO capabilities, leading to potential reverse causality issues. Such endogeneity may lead to biased results, and therefore, future research should consider addressing these potential issues.

The turnover of CEOs provides a quasinatural experiment. As the timing of CEO turnover varies across firms, we use the turnover of inventor CEOs as our research sample and consider the year of their turnover as the base period. We analyze the changes in firm performance during the three years before and after inventor CEOs assumed and left their positions.

Figure 1 illustrates the trend of the average firm performance in the three years before and after inventor CEOs assumed their positions. As shown, there was a clear upward trend in the average ROA and ROE of the firms after inventor CEOs took office, particularly in the case of ROE. These findings suggest that the appointment of inventor CEOs leads to a significant improvement in firm performance (ROA and ROE).

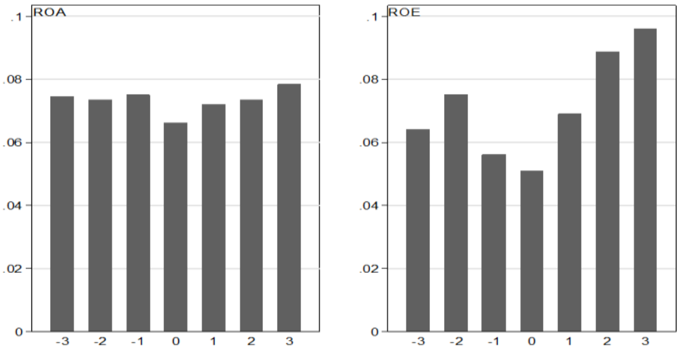

Figure 1. Trends of ROA and ROE before and after the inventor CEO takes office.

Notes: Period 0 represents the year when the inventor CEO took office. Periods -3, -2, -1 represent the third, second and first year before the CEO of the inventor took office. Similarly, periods 1, 2, and 3, respectively represent the CEO of the inventor. The first, second and third years after taking office.

As a point of comparison, we also present changes in firm performance in the three years before and after the resignation of inventor CEOs. Figure 2 illustrates that ROA changed relatively smoothly and showed no significant downward trend when the inventor CEO stepped down. In the case of ROE, there was a marked decline in the first year after the inventor CEO resigned, but this trend was short-lived and returned to the preresignation level in the second year. In summary, Figures 1 and 2 demonstrate that inventor CEOs can significantly enhance firm performance.

This study illustrates the trend of firm performance before and after the appointment and departure of inventor CEOs in Figures 1 and 2, respectively. Thereafter, empirical analysis was performed by collecting cross-sectional data on firm performance changes before and after the inventor CEOs assumed and left their positions. The OLS method was employed for cross-sectional regression analysis, and Panel An in Table 3 presents the impact of inventor CEO appointments on firm ROA and ROE. The regression analysis includes the change values of ROA and ROE in the first, second, and third years after the inventor CEO's appointment as dependent variables and all first-order difference terms as explanatory variables.

Panel An in Table 3 indicates that the coefficients of the inventor CEO are positive, signifying that they have improved the financial performance of the firm. However, the impact is only statistically significant in the first two years after assuming their position. Additionally, this study estimates the effect of inventor CEO resignation on the change in firm performance, as demonstrated in Panel B in Table 3. The estimated coefficient of inventor resignation is negative, suggesting that there will be a decline in corporate performance after the inventor CEO resigns.

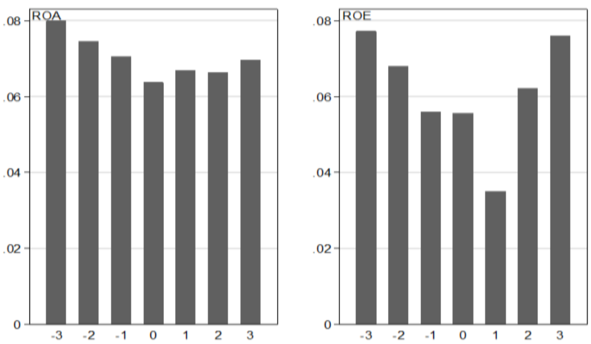

Figure 2. Trends of ROA and ROE before and after the departure of the inventor CEO.

Notes: Period 0 represents the year when the inventor CEO took office. Periods -3, -2, -1 represent the third, second and first year before the CEO of the inventor took office. Similarly, periods 1, 2, and 3, respectively represent the CEO of the inventor. The first, second and third years after taking office.

Table 3. CEO turnover analysis.

Panel A: Inventor CEOs take office.								
Variables	△ ROA	△ ROE	△ ROA	△ ROE	△ ROA	△ ROE	△ ROA	△ ROE
	Year -1 to Year 1		Year -1 to Year 2		Year -1 to Year 3		Year -1 to Year 1~3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
△ CEO_inventor	0.007	0.141***	0.009	0.184**	0.013	0.085	0.027	0.034
	(0.021)	(0.048)	(0.039)	(0.070)	(0.042)	(0.122)	(0.038)	(0.061)
△ Ln_assets	0.032	-0.073	0.045	-0.194	-0.026	-0.290	-0.001	-0.007
	(0.028)	(0.065)	(0.080)	(0.144)	(0.067)	(0.194)	(0.060)	(0.097)
△ Ln_firmage	-0.266	-1.564***	-0.223	-1.784**	-0.301	-0.804	-0.429	-0.578
	(0.242)	(0.562)	(0.444)	(0.796)	(0.467)	(1.349)	(0.408)	(0.653)
△ Leverage	-0.062	0.350	-0.025	0.564	0.069	0.518	0.004	0.143
	(0.118)	(0.273)	(0.199)	(0.357)	(0.175)	(0.504)	(0.151)	(0.241)
△ Cash_ratio	-0.076	0.052	0.099	0.016	-0.105	-0.052	-0.024	-0.056
	(0.095)	(0.222)	(0.160)	(0.288)	(0.136)	(0.391)	(0.114)	(0.182)
Observations	147	147	140	140	132	132	130	130
Panel B: Inventor CEOs departure.								
Variables	△ ROA	△ ROE	△ ROA	△ ROE	△ ROA	△ ROE	△ ROA	△ ROE
	Year -1 to Year 1		Year -1 to Year 2		Year -1 to Year 3		Year -1 to Year 1~3	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
△ CEO_inventor	-0.026	-0.052	-0.060	-0.208**	-0.055	-0.132	-0.054	-0.161**
	(0.031)	(0.102)	(0.041)	(0.083)	(0.069)	(0.087)	(0.052)	(0.073)
△ Ln_assets	0.034	-0.087	0.071*	0.138*	0.050	0.110	0.064	0.072
	(0.023)	(0.076)	(0.035)	(0.071)	(0.066)	(0.082)	(0.050)	(0.070)
△ Ln_firmage	0.209	0.458	0.479	2.549**	0.453	1.643	0.451	1.901*
	(0.429)	(1.407)	(0.543)	(1.095)	(0.892)	(1.118)	(0.676)	(0.944)
△ Leverage	-0.093	-0.723*	-0.023	0.200	-0.089	-0.010	-0.059	-0.248
	(0.112)	(0.367)	(0.136)	(0.274)	(0.231)	(0.290)	(0.175)	(0.245)
△ Cash_ratio	0.064	-0.693*	-0.168	0.089	-0.303	-0.499	-0.113	-0.287
	(0.121)	(0.398)	(0.169)	(0.342)	(0.278)	(0.349)	(0.211)	(0.295)
Observations	144	144	131	131	126	126	126	126

*Notes: This table presents the results of the change of ROA and ROE on inventor CEOs take office or departure after controlling for the change of control variables, with changes computed in four different periods, namely, from year -1 to year 1 through year 3 and the mean value of year 1, year 2, and year 3. Year 0 is the inventor CEOs take office year. Robust standard errors clustered by industry are listed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

4.3. Instrumental variable approach

To address endogeneity issues, this study employs the panel instrumental variable approach. An appropriate instrumental variable should meet two conditions. First, it should be correlated with the endogenous explanatory variables. Second, it should be uncorrelated with the model disturbances, indicating that the only way instrumental variables affect the explained variable is through the endogenous explanatory variables, and all other potential influence channels are excluded.

Based on the aforementioned criteria, this study has chosen two instrumental variables. The first instrumental variable, CEO_homelandpp, is the arable land area per capita of the CEO's homeland. As the arable land area per capita varies insignificantly across regions, this study has used the data from 2008 on the arable land area per capita for each region as an instrumental variable for the inventor CEO. A clear negative correlation exists between natural resource endowments and innovation spirit. On the one hand, regions with a lower per capita arable land area have more scientific and technological researchers per 10,000 people, and a stronger innovation spirit leads to a higher likelihood of becoming an inventor. Therefore, the instrumental variable satisfies the relevance criterion. On the other hand, the CEO's homeland is usually distinct from the firm's location. Thus, the land resource endowment of the CEO's homeland has no bearing on the firm's management and financial performance. Thus, this instrumental variable satisfies the exogeneity criterion.

The second instrumental variable, CEOinvent_othernum, represents the number of firms in the same industry and region as the firm under investigation that have inventor CEOs. A greater number of inventor CEO firms in the same industry and region increases the likelihood that the firm being studied also has an inventor CEO, thereby fulfilling the relevance and exogeneity criteria. To summarize, both the arable land area per capita of the CEO's homeland and the number of inventor CEO firms in the same region and industry satisfy the necessary conditions. The former exhibits a negative correlation with the independent variable of inventor CEO, while the latter shows a positive correlation.

Before proceeding with the empirical analysis, it is necessary to conduct an endogeneity test. In this study, the Hausman-Wu endogeneity test is utilized to determine the presence of endogeneity issues. The results of all tests indicate the existence of endogeneity issues, which necessitates the use of an instrumental variable approach. The panel instrumental variable estimation results are presented in Table 4. For comparison purposes, the OLS estimation results of the baseline model are also reported in columns 1 and 2. The third column presents the estimation results of the first stage. The coefficient of the instrumental variable CEO_homelandpp is -0.11, which is statistically significant at the 5% level. This implies that a smaller arable land per capita in the CEO's birthplace is associated with a higher likelihood of the CEO having an inventor background, which is consistent with our theoretical expectations. Furthermore, the estimated coefficient of the instrumental variable CEOinventor_othernum is significantly positive, indicating that when there are more inventor CEOs in other firms in the same region and industry, the probability of the firm under study having an inventor CEO increases. This finding is also consistent with our previous theoretical expectations.

In addition, the Anderson LM test significantly rejects the null hypothesis, indicating that the model is not underidentified, i.e., the selected instrumental variables are related to the endogenous explanatory variables. The Cragg-Donald Wald F statistic is significantly larger than the critical value of the Stock-Yogo weak instrumental variable test, and the null hypothesis of weak instrumental variables is significantly rejected, indicating that the model does not suffer from the problem of weak instrumental variables (Wooldridge, 2010). The Sargan overidentification test also confirms the suitability of the two instrumental variables selected in this study. The fourth and fifth columns of Table 4 present the regression estimation results of the second stage. The coefficients of the inventor CEO for ROA and ROE are 0.198 and 0.543, respectively. Both are statistically significant at the 10% and 5% levels, respectively. These panel instrumental variable estimation results suggest that having an inventor CEO promotes firm performance.

4.4. Propensity score matching estimation

Next, this paper utilizes the propensity score matching method (PSM) to estimate the treatment effect of having an inventor CEO on firm performance. PSM has gained increasing attention for causal identification in recent years. The process involves defining treatment variables (inventor CEOs), outcome variables (ROA and ROE), and a set of covariates (other relevant influencing factors that need to be controlled). In selecting covariates, it is crucial to include all relevant variables that affect the outcome and treatment variables to ensure satisfaction of the negligibility assumption. Therefore, this paper includes all control variables from the baseline model as covariates. The conditional probability (propensity score) of the research object being randomly assigned to the treatment or control group is then calculated. Propensity scores of the treatment and control groups are matched, and the

Table 4. Instrumental variable approach.

Variables	Baseline OLS regression		First-stage regression	Second-stage regressions	
	ROA	ROE	CEO_inventor	ROA	ROE
	(1)	(2)	(3)	(4)	(5)
CEO_inventor	0.009***	0.018***		0.198*	0.543**
	(0.001)	(0.002)		(0.117)	(0.277)
CEO_homelandpp			-0.110**		
			(0.050)		
CEO_othernum			0.004**		
			(0.002)		
Ln_assets	0.005***	0.015***	-0.007	-0.022***	-0.044***
	(0.001)	(0.001)	(0.016)	(0.006)	(0.014)
Ln_firmage	-0.001	-0.004	0.045	-0.022	-0.022
	(0.002)	(0.003)	(0.046)	(0.018)	(0.043)
Leverage	-0.049***	-0.047***	0.042	0.052**	0.215***
	(0.004)	(0.009)	(0.058)	(0.022)	(0.051)
Cash_ratio	0.019***	0.068***	-0.035	0.021	0.133***
	(0.005)	(0.008)	(0.054)	(0.020)	(0.047)
CEO_duality	0.002	0.003	-0.042***	0.013*	0.027
	(0.001)	(0.002)	(0.015)	(0.007)	(0.017)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	7327	7327	1317	1317	1317
Joint F test(p value)	20.35	17.63			
	(0.000)	(0.000)			
Joint test of excluded instruments(p value)			4.75		
			(0.008)		
Anderson Canon. Corr. LM test(p value)				9.467	9.467
				(0.008)	(0.008)
Cragg-Donald Wald F test				14.746	14.746
Stock-Yogo Weak ID Test Critical Values: 15% Maximal IV Size				11.59	11.59
Stock-Yogo Weak ID Test Critical Values: 20% Maximal IV Size				8.75	8.75
Stock-Yogo Weak ID Test Critical Values: 25% Maximal IV Size				7.25	7.25
Sargan test (p value)				1.334	0.018
				(0.248)	(0.893)

*Notes: This table reports the 2SLS regressions of the firm performance (ROA and ROE) on inventor CEOs. Each regression includes year, industry, and province fixed effects. Robust standard errors clustered by industry are listed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

average treatment effect of the two groups is computed. Matching for covariates enables control of the covariates. If the mean value of the outcome variable of the two groups differs significantly, it indicates that the treatment variable has a significant effect on firm performance.

Table 5 displays the balancing test results of the propensity score matching. The standardized deviations of all covariates are less than 10%, and the t tests fail to reject the null hypothesis that there is no systematic difference between the treatment and control groups. Moreover, the standard deviations of all variables have been substantially reduced, indicating that all covariates have passed the balancing test. After applying propensity score matching, the differences in characteristics between inventor CEO firms and noninventor CEO firms have been significantly reduced. The method leads to only a small loss of samples.

Table 5. The balancing test of the propensity score matching.

variable		Mean		%bias	t test	
		Treated	Control		t	P>|t|
Ln_assets	Unmatched	12.600	12.416	16.700	7.510	0.000
	Matched	12.592	12.599	-0.700	-0.260	0.794
Ln_firmage	Unmatched	2.660	2.683	-7.100	-3.160	0.002
	Matched	2.661	2.649	3.800	1.420	0.154
Leverage	Unmatched	0.386	0.395	-4.500	-1.990	0.047
	Matched	0.386	0.392	-3.000	-1.180	0.237
Cash_ratio	Unmatched	0.207	0.191	10.600	4.760	0.000
	Matched	0.207	0.204	2.000	0.770	0.441
CEO_duality	Unmatched	0.281	0.247	7.900	3.560	0.000
	Matched	0.280	0.279	0.200	0.090	0.932

Notes: This table reports the results of balance test of the propensity score matching.

Panel An in Table 6 displays the results of Models (1) to (8), which examine the impact of inventor CEOs on ROA using various matching methods: one-to-one, neighbor, caliper, radius, kernel, local linear regression, spline, and mahalanobis matching. The ATE reflects the matching results of the entire sample, while the ATU reflects only the matching results of noninventor CEO firms, and the ATT reflects only the average treatment effect of inventor CEO firms, which is of particular interest in this study. The matching results are all statistically significant at the 1% level and indicate a positive relationship between having an inventor CEO and a firm's ROA, with an average increase of approximately one percentage point.

Panel B in Table 6 reports the matching estimation results of the inventor CEO on ROE. The inventor CEO increases ROE by 2% on average. The results of propensity score matching are closer to the baseline model, further verifying the conclusion of this article. Inventor CEOs can significantly improve firm performance.

5. Robustness checks and heterogeneity analysis

5.1. Robustness checks

The evaluation of firm performance commonly relies on indicators such as return on assets (ROA) and return on equity (ROE). However, some scholars use operating profits and Tobin's q as proxies for firm performance. In this study, we adopt operating profits and Tobin's q as proxies for firm performance to ensure stability and explore the impact of inventors' CEOs on firm performance. We present the specific impact of inventor CEOs on the firm's operating profits and Tobin's q in Model (1) and Model (2) of Table 7 while maintaining consistency with the baseline model by including control variables. We also control for fixed effects of year, industry, and province. Given the length limitations of this article, we report only the coefficients of the core explanatory variable.

The estimated results of Model (1) and Model (2) reveal that the coefficients for inventor CEOs are significantly positive for both operating profits and Tobin's q, and both are significant at the 1% level. In summary, our estimation results indicate that the conclusion is robust.

There exists a time lag between a CEO's strategic decision and its effect on firm performance. To maintain consistency with the literature, explanatory variables are typically lagged by one period. This study employs the same method but includes independent variables with two and three lags to ensure robustness and reliability. The specific estimation results are presented in Models (3) and (4) of Table 7. The positive impact of inventor CEOs on ROA and ROE remains significant, regardless of whether it is two or three lags.

The four first-tier cities in China, Beijing, Shanghai, Shenzhen, and Guangzhou, are concentrated areas of China's innovative high-tech enterprises, particularly Beijing and Shenzhen, which are commonly known as China's "Silicon Valley." In Model (5), we exclude the samples of enterprises in these cities and reanalyze the effect of

Table 6. Propensity score matching regressions.

Panel A: Propensity score matching regression of ROA on inventor CEOs.								
Variables	ROA One to one matching (1)	ROA Neighbor matching (2)	ROA Caliper matching (3)	ROA Radius matching (4)	ROA Kernel matching (5)	ROA Local linear regression matching (6)	ROA Spline matching (7)	ROA Mahal matching (8)
Unmatched	0.011*** (0.001)	0.011*** (0.001)	0.011*** (0.001)	0.011*** (0.001)	0.011*** (0.001)	0.011*** (0.001)	0.011*** (0.001)	0.011*** (0.001)
ATT	0.008*** (0.002)	0.009*** (0.002)	0.009*** (0.002)	0.009*** (0.001)	0.009*** (0.001)	0.008*** (0.001)	0.009*** (0.001)	0.008*** (0.001)
ATU	0.009*** (0.002)	0.009*** (0.002)	0.009*** (0.001)	0.008*** (0.001)	0.007*** (0.001)	0.008*** (0.001)	0.008*** (0.001)	0.005*** (0.001)
ATE	0.009*** (0.001)	0.009*** (0.002)	0.009*** (0.001)	0.008*** (0.001)	0.008*** (0.001)	0.008*** (0.001)	0.008*** (0.001)	0.006*** (0.001)
Observations	8745	8745	8745	8745	8745	8745	8745	8745
Panel B: Propensity score matching regression of ROE on inventor CEOs.								
Variables	ROE One to one matching (1)	ROE Neighbor matching (2)	ROE Caliper matching (3)	ROE Radius matching (4)	ROE Kernel matching (5)	ROE Local linear regression matching (6)	ROE Spline matching (7)	ROE Mahal matching (8)
Unmatched	0.022*** (0.002)	0.022*** (0.002)	0.022*** (0.002)	0.022*** (0.002)	0.022*** (0.002)	0.022*** (0.002)	0.022*** (0.002)	0.022*** (0.002)
ATT	0.018*** (0.003)	0.018*** (0.003)	0.018*** (0.003)	0.017*** (0.002)	0.018*** (0.002)	0.019*** (0.002)	0.018*** (0.002)	0.017*** (0.002)
ATU	0.021*** (0.003)	0.020*** (0.003)	0.020*** (0.003)	0.019*** (0.002)	0.018*** (0.002)	0.019*** (0.003)	0.018*** (0.002)	0.014*** (0.002)
ATE	0.020*** (0.002)	0.019*** (0.002)	0.019*** (0.002)	0.019*** (0.002)	0.018*** (0.002)	0.019*** (0.002)	0.018*** (0.002)	0.016*** (0.002)
Observations	8745	8745	8745	8745	8745	8745	8745	8745

*Notes: This table reports the propensity score matching regressions of ROA and ROE on inventor CEOs. Robust standard errors clustered by industry are listed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

inventor CEOs on firm performance. The results in Model (7) of Table 7 demonstrate that after excluding the samples from the four first-tier cities, the coefficients of inventor CEOs remain significantly positive at the 1% level. This further confirms the robustness and reliability of the paper's conclusions.

To exclude the impact of the international financial crisis, this paper excludes the samples after 2008 from the model. The study reveals that the positive influence of inventor CEOs on firm performance still exists. Additionally, considering samples with positive and negative ROE, the test results do not affect the primary conclusions, indicating the robustness and reliability of this research.

In conclusion, a series of robustness checks attests to the robustness and reliability of the article's findings.

5.2. Heterogeneity analysis

5.2.1. Quantile regression estimation

We have obtained empirical evidence that inventor CEOs can significantly improve firm performance. However, the impact of inventor CEOs on firm performance we have obtained is limited to the mean level. Quantile regression, on the other hand, can provide insights into the effects of inventor CEOs at different quantile points of the dependent variable, thus offering a more accurate description of the range of changes that inventor CEOs can bring to firm performance.

Table 7. Robustness checks.

(1): Using the variable of return on sales (Profit_ratio) as dependent variable		
	Profit_ratio	
CEO_inventor	0.008*** (0.003)	
(2): Using the variable of tobin's q (Tobin_Q) as dependent variable		
	Tobin_Q	
CEO_inventor	0.129*** (0.032)	
(3): Replacing CEO_inventort-1 by CEO_inventort-2		
	ROA	ROE
CEO_inventor	0.009*** (0.001)	0.018*** (0.002)
(4): Replacing CEO_inventort-1 by CEO_inventort-3		
	ROA	ROE
CEO_inventor	0.009*** (0.001)	0.017*** (0.003)
(5): Excluding firms located in Beijing, Shanghai, Guangzhou, Shenzhen		
	ROA	ROE
CEO_inventor	0.008*** (0.001)	0.019*** (0.002)
(6): Excluding the period after 2008 international financial crisis		
	ROA	ROE
CEO_inventor	0.014*** (0.004)	0.036*** (0.007)
(7): Excluding firm-years with negative ROE		
		ROE
CEO_inventor		0.012*** (0.002)
(8): Excluding firm-years with positive ROE		
		ROE
CEO_inventor		0.028*** (0.015)

*Notes: This table reports robustness checks on alternative model specifications and variable definitions. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

To further explore the relationship between inventor CEOs and firm performance, we estimate the results of quantile regression in Table 8. QR_10, QR_25, QR_50, QR_75, and QR_90 represent standardized levels of 10%, 25%, 50%, 75%, and 90%, respectively. As shown in Table 8, both ROA and ROE demonstrate significantly positive coefficients on inventor CEOs at the 1% level, and these coefficients increase as the quantile level rises. These findings suggest that the impact of inventor CEOs on firm performance is more pronounced in firms with better financial performance.

5.2.2. High-tech firms and nonhigh-tech firms

Adhering to the classification standards of the National Bureau of Statistics of China, we divided the sample firms into high-tech and nonhigh-tech firms according to their respective industries, thus enabling us to examine the specific impact of inventor CEOs on firm performance for both types of firms. The corresponding estimation results are presented in Panel An in Table 9. Our findings indicate that inventor CEOs have a significantly positive impact on both ROA and ROE for high-tech and nonhigh-tech enterprises alike. Additionally, the effects of inventor CEOs are significant at the 1% level for both types of firms.

Table 8. Quantile regression approach.

Panel A: the quantile regressions of ROA on inventor CEOs.					
Variables	ROA QR_10 (1)	ROA QR_25 (2)	ROA QR_50 (3)	ROA QR_75 (4)	ROA QR_90 (5)
CEO_inventor	0.003*** (0.001)	0.004*** (0.001)	0.008*** (0.001)	0.009*** (0.002)	0.012*** (0.003)
Control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	7327	7327	7327	7327	7327
Panel B: the quantile regressions of ROE on inventor CEOs.					
Variables	ROE QR_10 (1)	ROE QR_25 (2)	ROE QR_50 (3)	ROE QR_75 (4)	ROE QR_90 (5)
CEO_inventor	0.009* (0.005)	0.010*** (0.001)	0.014*** (0.002)	0.020*** (0.002)	0.020*** (0.004)
Control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	7327	7327	7327	7327	7327

*Notes: This table reports the quantile regressions of ROA and ROE on inventor CEOs. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

5.2.3. SOEs and non-SOEs

As the world's largest developing country, China's economy is significantly influenced by state-owned enterprises (SOEs). However, there are notable differences in terms of internal management and incentive designs between SOEs and non-SOEs. Therefore, we divided our sample into SOEs and non-SOEs to investigate the impact of inventor CEOs on the performance of these two types of enterprises. The results presented in Panel B demonstrate that inventor CEOs have a significantly positive impact on company performance, regardless of whether the enterprise is an SOE or non-SOE.

5.2.4. Mature firms and growing firms

This study further subdivided the sample of firms based on their age of operation, distinguishing between mature firms (operating for ten years or more) and growing firms. We aimed to examine the differences in the impact of inventor CEOs on firm performance between these two types of firms. Panel C presents the specific estimation results. The findings suggest that inventor CEOs have a significant positive influence on firm performance, as measured by both ROA and ROE, for both mature and growing enterprises. Furthermore, the effects of inventor CEOs are significant at the 1% level for both types of firms.

5.2.5. Large firms and med-small firms

Firm size is a crucial factor influencing firm performance and technological innovation. To investigate the impact of inventor CEOs on firm performance for different sizes of firms, we divided our research sample into large and medium-small firms based on whether their sales exceeded the average sales in the same industry and year. Panel D presents the specific estimation results, showing that the coefficients on inventor CEOs are significantly positive at the 1% level for both large and medium-small firms.

5.2.6. Eastern and midwestern firms

Significant economic, social, and cultural differences exist between various regions in China. To investigate the influence of inventor CEOs on firm performance in different regions, we classified the sample companies into two groups based on existing regional division standards: eastern and mid-western firms. We conducted an empirical analysis of the impact of inventor CEOs on the performance of both groups of firms. Panel E presents the estimation results, which demonstrate that inventor CEOs have a significantly positive influence on firm financial performance, regardless of whether the firms are located in the eastern or mid-western regions. Furthermore, the positive impact of inventor CEOs is more pronounced in midwestern firms.

6. Possible mechanisms

6.1. Inventor CEOs and technological innovation

We empirically analyze the effect of inventor CEOs on corporate technological innovation. The model is set as follows:

$$Rdassets_{ratio_{i,t}} = \alpha + \beta CEO_{inventor_{i,t-1}} + \sum \gamma_k Controls_{k,i,t-1} + Industry + Year + Province + \varepsilon_{i,t} \quad (2)$$

$$Ln_{patall_{apply_{i,t}}}\left(Ln_{patinv_{apply_{i,t}}}; Ln_{patade_{apply_{i,t}}}\right) = \alpha + \beta CEO_{inventor_{i,t-1}} + \sum \gamma_k Controls_{k,i,t-1} + Industry + Year + Province + \varepsilon_{i,t} \quad (3)$$

$$Ln_{patall_{grant_{i,t}}}\left(Ln_{patinv_{grant_{i,t}}}; Ln_{patade_{grant_{i,t}}}\right) = \alpha + \beta CEO_{inventor_{i,t-1}} + \sum \gamma_k Controls_{k,i,t-1} + Industry + Year + Province + \varepsilon_{i,t} \quad (4)$$

In this study, we examine several dependent variables, including R&D intensity (Rdassets_ratio), the total number of all three types of applied patents (Ln_patall_apply), the number of applied invention patents (Ln_patinv_apply), the number of applied utility model and design patents (Ln_patade_apply), the total number of all three types of granted patents (Ln_patall_grant), the number of granted invention patents (Ln_patinv_grant), and the number of granted utility model and design patents (Ln_patade_grant).

To control for other relevant factors, we include several control variables in the analysis. Specifically, we use the natural logarithm of the firm's total assets (Ln_assets) as a proxy for firm size and include the number of years since the firm's inception (Ln_firmage). We also use the natural logarithm of net fixed assets per capita (Ln_fixedpp) as a proxy for the firm's capital density and the natural logarithm of sales per capita (Ln_salespp) as a proxy for labor productivity. We measure the firm's growth opportunities using the sales growth rate (Salesgrowth) and the book-to-market ratio (MB_ratio). Finally, we introduce the asset-liability ratio (Leverage) as a control variable to account for the impact of capital structure on innovation.

This article investigates the impact of corporate cash holdings on technological innovation. The cash asset ratio (Cashassets_ratio) is used as a proxy for corporate cash holdings (Lyandres and Palazzo, 2016). The firm's stock market performance is considered an important factor influencing innovation (Fang et al., 2014), and this article uses the annual holding period stock return rate (Stock_return) to measure stock market performance. Corporate stock volatility is measured using the standard deviation of the firm's daily stock returns (stock_volatility). Control variables include the Herfindahl index (Herfindahl) and its squared term (Herfindahl_sq). The relationship between innovation and product market competition follows an "inverted U-shaped" curve (Aghion et al., 2005).

To examine the specific impact of inventor CEOs on corporate innovation input, the variable of R&D intensity is used as a proxy for innovation input. In addition, the Poisson counting model is employed to estimate the specific effects of inventors' CEOs on corporate innovation output.

Table 9. Cross-sectional differences in the effects of inventor CEOs on firm performance.

Panel A: High-tech firms v.s. non high-tech firms.				
Variables	High-tech firms ROA (1)	Non high-tech firms ROA (2)	High-tech firms ROE (3)	Non high-tech firms ROE (4)
CEO_inventor	0.011*** (0.002)	0.007*** (0.002)	0.018*** (0.003)	0.017*** (0.003)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	3521	3806	3521	3806
Panel B: SOEs v.s. non SOEs.				
Variables	SOEs ROA (1)	Non SOEs ROA (2)	SOEs ROE (3)	Non SOEs ROE (4)
CEO_inventor	0.008*** (0.002)	0.009*** (0.002)	0.017*** (0.004)	0.017*** (0.002)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	2405	4922	2405	4922
Panel C: Mature firms v.s. growing firms.				
Variables	Mature firms ROA (1)	Growing firms ROA (2)	Mature firms ROE (3)	Growing firms ROE (4)
CEO_inventor	0.009*** (0.001)	0.010*** (0.004)	0.019*** (0.002)	0.015*** (0.006)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	6568	759	6568	759
Panel D: Large firms v.s. Med-small firms.				
Variables	Large firms ROA (1)	Med-small firms ROA (2)	Large firms ROE (3)	Med-small firms ROE (4)
CEO_inventor	0.009*** (0.002)	0.004*** (0.002)	0.018*** (0.003)	0.010*** (0.003)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	4787	2540	4787	2540
Panel E: Eastern firms v.s. Med-west firms.				
Variables	Eastern firms ROA (1)	Med-west firms ROA (2)	Eastern firms ROE (3)	Med-west firms ROE (4)
CEO_inventor	0.007*** (0.001)	0.012*** (0.002)	0.014*** (0.002)	0.025*** (0.005)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	5060	2267	5060	2267

*Notes: This table reports the OLS regressions of cross-section differences. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

Table 10 reports the specific effects of inventor CEOs on technological innovation. Models (1) examine the influence of inventor CEOs on R&D intensity, and the coefficients of inventor CEOs are significantly positive at the

1% level. Compared with firms with noninventor CEOs, firms with inventor CEOs have higher R&D intensity. Models (2) to (9) examine the effects of inventor CEOs on the firm's patent output. The regression results indicate that inventor CEOs have a significantly positive influence on the firm's applied and granted patents.

Furthermore, Poisson counting regressions were conducted to re-examine the influence of inventor CEOs on firm innovation, and the specific estimation results are shown in models (8) and (9), which confirm the previous findings. In summary, inventor CEOs have a significant positive effect on promoting technological innovation.

Inventor CEOs not only affect innovation patent output but also affect the firm's innovation efficiency. Referencing Hirshleifer et al. (2013), innovation efficiency is defined as follows:

$$IE = \frac{Patent_{i,t+1}}{R\&D_{i,t} + 0.8 \times R\&D_{i,t-1} + 0.6 \times R\&D_{i,t-2} + 0.4 \times R\&D_{i,t-3} + 0.2 \times R\&D_{i,t-4}} \quad (5)$$

This study then tests the impact of inventor CEOs on innovation efficiency. Table 11 reports the regression results of inventor CEOs on innovation efficiency. All the coefficients on inventor CEOs are significantly positive and significant at the 1% level. This indicates that inventor CEOs can not only promote technological innovation but also improve innovation efficiency.

Table 10. Regression effects of firm technological innovation on inventor CEOs.

Variables	Rdassets_ratio OLS (1)	Ln_patall_apply OLS (2)	Ln_patinv_apply OLS (3)	Ln_patad_apply OLS (4)	Ln_patall_grant OLS (5)	Ln_patinv_grant OLS (6)	Ln_patad_grant OLS (7)	Patall_apply Poisson (8)	Patall_grant Poisson (9)
CEO_inventor	0.467***	1.180***	0.892***	0.916***	1.037***	0.460***	0.896***	0.705***	0.708***
	(0.035)	(0.031)	(0.028)	(0.031)	(0.030)	(0.021)	(0.031)	(0.041)	(0.044)
Ln_assets	0.061***	0.419***	0.377***	0.370***	0.394***	0.213***	0.371***	0.702***	0.682***
	(0.023)	(0.020)	(0.017)	(0.019)	(0.019)	(0.013)	(0.019)	(0.020)	(0.022)
Ln_firmage	-0.106*	-0.349***	-0.233***	-0.238***	-0.291***	-0.123***	-0.227***	-0.133*	-0.155**
	(0.054)	(0.050)	(0.042)	(0.046)	(0.047)	(0.031)	(0.046)	(0.069)	(0.073)
Ln_fixedpp	-0.386***	-0.149***	-0.102***	-0.142***	-0.148***	-0.054***	-0.144***	-0.250***	-0.239***
	(0.026)	(0.022)	(0.019)	(0.020)	(0.021)	(0.013)	(0.020)	(0.030)	(0.032)
Ln_salespp	0.342***	-0.018	-0.003	-0.039*	-0.018	0.029**	-0.038*	0.052	0.032
	(0.031)	(0.024)	(0.020)	(0.023)	(0.023)	(0.014)	(0.023)	(0.035)	(0.038)
Leverage	-0.412***	-0.412***	-0.116	-0.304***	-0.355***	-0.131**	-0.278***	-0.233	-0.213
	(0.119)	(0.096)	(0.080)	(0.089)	(0.090)	(0.056)	(0.088)	(0.143)	(0.154)
Cash_ratio	-0.070	0.231**	0.172*	0.253**	0.242**	-0.031	0.302***	0.080	0.095
	(0.132)	(0.112)	(0.096)	(0.104)	(0.105)	(0.070)	(0.103)	(0.156)	(0.165)
MB_ratio	-0.229***	-0.080**	-0.119***	-0.019	-0.058*	-0.086***	-0.019	-0.187***	-0.173***
	(0.034)	(0.037)	(0.032)	(0.034)	(0.034)	(0.022)	(0.034)	(0.040)	(0.041)
Salesgrowth	0.044	0.047	-0.010	0.110*	0.072	-0.002	0.106*	0.011	0.026
	(0.072)	(0.060)	(0.049)	(0.057)	(0.058)	(0.037)	(0.057)	(0.088)	(0.092)
Stock_return	-0.012	0.003	0.003	0.033	0.016	-0.017	0.036	0.030	0.043
	(0.037)	(0.029)	(0.025)	(0.027)	(0.028)	(0.019)	(0.027)	(0.047)	(0.049)
Stock_voatility	-0.577***	-0.651***	-0.503***	-0.635***	-0.752***	-0.498***	-0.660***	-1.074***	-1.201***
	(0.183)	(0.158)	(0.133)	(0.149)	(0.148)	(0.092)	(0.148)	(0.258)	(0.279)
Herfindahl	1.923	3.752*	4.154**	4.466**	5.445***	6.453***	4.802**	6.059*	7.815**
	(2.416)	(2.139)	(1.736)	(1.997)	(2.053)	(1.354)	(1.993)	(3.577)	(3.594)
Herfindahl_sq	1.082	-9.875*	-7.013*	-12.992***	-14.049***	-14.362***	-14.028***	-14.324	-17.175*
	(5.518)	(5.231)	(4.202)	(4.858)	(5.030)	(3.318)	(4.858)	(9.696)	(9.689)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,586	8,959	8,959	8,959	8,959	8,959	8,959	8,959	8,959

*Notes: This table reports regressions of the firm technological innovation on inventor CEOs and other control variables. Robust standard errors clustered by industry are listed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

Table 11. Regression results of innovation efficiency (IE) on inventor CEOs.

Variables	IE OLS (1)	IE OLS (2)	IE OLS (3)	IE OLS (4)
CEO_inventort-1	0.008*** (0.001)			
CEO_inventort-1		0.007*** (0.001)		
CEO_inventort-1			0.007*** (0.001)	
CEO_inventort-1				0.007*** (0.001)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	1969	1969	1969	1969

*Notes: This table reports the regressions of innovation efficiency on inventor CEOs. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

6.2. Technological innovation, TFP and firm performance

This article aims to investigate the impact of a firm's technological innovation on its financial performance. While patents may serve as a means to this end, the ultimate objective of firms is to enhance their technological innovation and total factor productivity, leading to improved financial performance. Specifically, this study examines the effects of inventor CEOs on total factor productivity (TFP). TFP is defined at the macro level as the contribution factors, such as technological progress or cultural institutions, that cannot be fully explained by input factors. At the firm level, TFP can be estimated by specifying the firm's Cobb–Douglas production function as follows:

$$Y_{i,t} = A_{i,t} L_{i,t}^{\alpha} K_{i,t}^{\beta} \tag{6}$$

Y represents output, L and K represent labor and capital input, respectively, and A is the total factor productivity, which can simultaneously increase the marginal output of various factors. It can be transformed into linear form by taking the logarithm of (6):

$$y_{i,t} = \alpha l_{i,t} + \beta k_{i,t} + u_{i,t} \tag{7}$$

Equation (7) expresses Y, L, and K as the logarithmic form of output, labor, and capital, respectively. The residual term in the equation includes TFP. Estimating Equation (7) allows for obtaining the value of TFP. The TFP calculation method for listed firms follows Giannetti et al. (2015). This study estimates the firm's total factor productivity using both the OP method (Olley and Pakes, 1996) and the LP method (Levinsohn and Petrin, 2003), which yield consistent conclusions. Due to space constraints, we present only selected estimation results. Specifically, we empirically examine the effects of inventor CEOs on TFP, employing the following estimation model:

$$TFP_{i,t} = \alpha + \beta CEO_{inventor_{i,t-1}} + \sum \gamma_k Controls_{k,i,t-1} + \theta_i Industry + \varphi_t Year + \delta_i Province + \varepsilon_{i,t} \tag{8}$$

Table 12 shows the impact of inventor CEOs on TFP. To account for potential lag effects and ensure robustness, we lag the independent variables by one to four periods. The results demonstrate that inventor CEOs have a significant positive impact on TFP, with all coefficients significant at the 1% level. These findings suggest that inventor CEOs can substantially enhance a firm's total factor productivity.

Table 12. Regression results of total factor production (TFP) on inventor CEOs.

Variables	TFP (1)	TFP (2)	TFP (3)	TFP (4)
CEO_inventort-1	0.021*** (0.006)			
CEO_inventort-2		0.019*** (0.006)		
CEO_inventort-3			0.017*** (0.006)	
CEO_inventort-4				0.017** (0.007)
Ln_assets	-0.030*** (0.003)	-0.030*** (0.004)	-0.032*** (0.004)	-0.033*** (0.004)
Ln_firmage	0.003 (0.009)	0.000 (0.010)	-0.011 (0.011)	-0.020 (0.012)
Ln_fixedpp	-0.059*** (0.005)	-0.062*** (0.005)	-0.065*** (0.005)	-0.067*** (0.006)
Ln_salespp	0.117*** (0.005)	0.122*** (0.006)	0.124*** (0.006)	0.128*** (0.006)
Leverage	-0.028 (0.022)	-0.052** (0.022)	-0.054** (0.023)	-0.056** (0.024)
Cash_ratio	-0.127*** (0.025)	-0.121*** (0.028)	-0.129*** (0.032)	-0.143*** (0.036)
MB_ratio	-0.052*** (0.006)	-0.049*** (0.006)	-0.047*** (0.006)	-0.047*** (0.007)
Salesgrowth	-0.000 (0.014)	-0.006 (0.014)	-0.011 (0.015)	-0.012 (0.016)
Stockreturn	0.013** (0.006)	0.017** (0.007)	0.024*** (0.007)	0.026*** (0.008)
Stock_volatility	-0.165*** (0.035)	-0.222*** (0.043)	-0.250*** (0.047)	-0.257*** (0.049)
Herfindahl	-0.562 (0.380)	-0.503 (0.408)	-0.373 (0.436)	-0.220 (0.456)
Herfindahl_sq	0.282 (0.904)	0.151 (0.983)	-0.078 (1.052)	-0.300 (1.095)
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	8956	8212	7374	6580

*Notes: This table reports the regressions of total factor production (TFP) on inventor CEOs. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

This study investigates whether inventor CEOs contribute to improved corporate productivity and technological innovation. We introduce interaction terms of inventor CEOs, firm patents, and total factor productivity in the baseline model. The results estimated from models (1) to (10) in Table 13 show that all coefficients on inventor CEOs, corporate patents, and total factor productivity are significantly positive, indicating that inventor CEOs, corporate patents, and TFP can significantly enhance a firm's financial performance. Furthermore, in models (5) and (10), the coefficients on the interaction terms between inventor CEOs, patents, and TFP are significantly positive. These results suggest that inventor CEOs improve a firm's performance by promoting corporate technological innovation and total factor productivity.

Table 13. Regression results of firm performance (ROA and ROE) on technological innovation.

Variables	ROA			ROE		
	(1)	(2)	(3)	(4)	(5)	(6)
CEO_inventor	0.007***	0.012***	0.006***	0.015***	0.023***	0.013***
	(0.001)	(0.003)	(0.001)	(0.002)	(0.005)	(0.002)
TFP	0.056***		0.059***	0.094***		0.095***
	(0.003)		(0.003)	(0.006)		(0.006)
TFP × CEO_inventor	0.024***			0.017**		
	(0.005)			(0.008)		
Ln_patall_apply		0.003***	0.002***		0.004***	0.002***
		(0.001)	(0.000)		(0.001)	(0.001)
Ln_patall_apply × CEO_inventor		-0.002**			-0.003*	
		(0.001)			(0.002)	
TFP × Ln_patall_apply × CEO_inventor			0.005***			0.004*
			(0.002)			(0.003)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7327	7327	7327	7327	7327	7327

*Notes: This table reports the regressions of firm performance (ROA and ROE) on technological innovation. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

6.3. Potentially competitive explanation: CEO overconfidence

Previous research has indicated that CEO overconfidence can lead to significant increases in firm innovation and financial performance (Hirshleifer et al., 2012; Malmendier and Tate, 2005). It is possible that inventor CEOs promote firm financial performance due to their overconfidence. To address this potential confounding variable, we construct two proxy indicators, CEO_payratio and CEO_shareincrease, to measure CEO overconfidence. CEO_payratio measures the proportion of CEO compensation in the total compensation of all executives, while CEO_shareincrease is a dummy variable indicating whether there is a CEO share increase. Higher CEO compensation ratios suggest greater levels of overconfidence. We incorporate the CEO overconfidence variables into our baseline model and rerun the regressions. According to Table 14, the coefficients of ROA and ROE on CEO overconfidence are significantly positive, indicating that CEO overconfidence can indeed improve firm performance. However, even after controlling for CEO overconfidence variables, the coefficients on inventor CEOs remain significantly positive at the 1% level, indicating that the positive effects of inventor CEOs on firm performance are not altered, which eliminates the potential competitive explanation caused by CEO overconfidence.

7. Summary and conclusion

Motivating firms to innovate and transform their innovation capabilities into financial performance remains a persistent challenge. While numerous studies have examined the impact of CEO characteristics and special experiences on firm performance, few have explored the impact of CEO inventor backgrounds on firm performance, technological innovation, and total factor productivity. The rise of inventor CEOs in recent years has made understanding how they shape firm performance an important issue, particularly in the context of China's current economic structural transformation and upgrading.

Through theoretical and empirical analysis, this article explores how inventor CEOs influence firm performance. We manually collected inventor data of Chinese listed manufacturing firms from 2001 to 2015 based

Table 14. Potential competitive explanation: CEO overconfidence.

Variables	ROA			ROE		
	(1)	(2)	(3)	(4)	(5)	(6)
CEO_inventor	0.009***	0.009***	0.009***	0.018***	0.018***	0.017***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
CEO_payratio		0.012**			0.023**	
		(0.006)			(0.010)	
CEO_shareincrease			0.009***			0.014***
			(0.002)			(0.002)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7327	7250	7327	7327	7250	7327

*Notes: This table reports the regressions of baseline model after controlling CEO overconfidence. Each regression also includes firm control variables, year, industry, and province fixed effects. Robust standard errors clustered by industry are displayed in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.*

on the IncoPat database and matched it with corporate CEOs to identify Inventor CEOs. Our study found that CEOs with an inventor background can significantly improve firm financial performance. Our study represents the first to examine the influence of inventor CEOs on firm performance and the role of technological innovation and total factor productivity of Chinese public firms, providing an important supplement to research on CEOs, firm performance, and innovation. The findings suggest that firms can encourage inventors to participate in corporate governance and become executives to promote firm performance and innovation.

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Declaration of Competing Interest

The authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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