Comparing the Impact of CEOs Holding an S&E Degree and Engineer Title on Firm Technological Innovation: Evidence Based on Chinese A-Share Listed Computer Companies

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Abstract. In an era where technological innovation is a key driver of firm performance, the role of a CEO's educational background and professional title in shaping this innovation becomes crucial. This study fills a gap in the literature by examining the differential impacts of a CEO's Science and Engineering (S&E) degree and the title of 'engineer' on firm technological innovation, particularly in the context of state-owned enterprises (SOEs). Using patent data from 388 Chinese listed companies in the computer industry between 2016 and 2021, we investigate how CEOs with technological expertise influence their firms' innovation. Our findings reveal that CEOs with an S&E degree exert a more positive impact on technological innovation than those with an 'engineer' title. This difference in impact is more pronounced in SOEs. Our study underscores the greater influence of educational background over work experience in innovation decision-making for CEOs. It also highlights potential shortcomings in the professional title system of 'engineer', especially within SOEs. These findings have significant implications for firm innovation strategies and talent management, particularly in the context of SOEs.

Keywords: CEO Characteristics, Imprinting, SOE, Technological Innovation, Upper Echelons.

1 Introduction

Technological innovation is vital for firms, especially in high-tech industries, with CEO technical expertise playing a pivotal role. While Upper Echelons Theory highlights CEO characteristics' influence on innovation [1], it struggles to explain why similar traits yield divergent outcomes [2]. Imprinting Theory, emphasizing early-career experiences, offers complementary insights but remains underexplored in innovation con-

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texts. Integrating both theories, this study compares two CEO technical expertise proxies—Science & Engineering (S&E) degrees (early education) and Engineer titles (later career certification)—to assess their differential impacts on firm innovation in China.

Prior research links CEO traits to innovation [3,4], yet neglects how expertise acquired at distinct career stages shapes outcomes. S&E degrees reflect foundational technical training, while Engineer titles signify professional validation within China's unique title system. We argue that early educational imprints (S&E degrees) more profoundly influence CEOs' R&D decisions than later certifications, particularly in state-owned enterprises (SOEs), where bureaucratic constraints may dilute the effect of post-education credentials.

Using data from 388 Chinese computer industry firms (2016–2021), hierarchical regression analyses reveal that CEOs with S&E degrees drive stronger R&D investment, output, and strategic focus than those with Engineer titles. This effect is amplified in SOEs, where Engineer titles exhibit weaker innovation impacts compared to non-SOEs. Findings suggest early educational experiences shape cognitive frameworks more enduringly than later professional certifications, aligning with Imprinting Theory.

The study advances theory by integrating Upper Echelons and Imprinting perspectives, demonstrating how expertise timing interacts with ownership structures to shape innovation. Practically, it highlights limitations in China's professional title system for executive evaluation, urging investors and firms to prioritize educational backgrounds in leadership selection. This underscores the need for context-sensitive approaches in managerial labor markets, particularly in transitioning economies like China.

2 Literature Review and Hypothesis Development

2.1 CEO's Technical Expertise and Firm's Technological Innovation

CEOs' technical expertise, shaped by education and career experiences, critically influences innovation. Upper Echelons Theory posits that executives' backgrounds affect strategic decisions [5], while Imprinting Theory emphasizes how early-life experiences create lasting cognitive frameworks [6,7]. A CEO's Science & Engineering (S&E) degree, acquired during formative education, instills foundational technical knowledge and problem-solving mindsets [8,9]. This contrasts with an Engineer title, typically earned later through workplace certification in China's hierarchical professional system.

S&E education fosters long-term cognitive imprints, enhancing CEOs' awareness of R&D's strategic value [10] and ability to allocate resources efficiently [11,12]. Studies show S&E-trained CEOs drive higher R&D investment and innovation output [4,13]. Conversely, Engineer titles reflect post-education industrial knowledge but lack the formative imprinting of academic training, leading to weaker innovation impacts [14,15]. Further, S&E backgrounds enable CEOs to better communicate with R&D teams and pursue technological diversity (TD) by leveraging cross-disciplinary insights [16,17], whereas Engineer titles may signal narrower specialization.

Hypothesis1: CEOs with S&E degrees exert stronger positive effects on technological innovation (R&D input, output, and TD) than those with Engineer titles.

2.2 Effect of Enterprise Ownership

In China, state-owned enterprises (SOEs) exhibit institutional dynamics amplifying the distinction between S&E degrees and Engineer titles. SOEs prioritize bureaucratic credentials, often linking Engineer titles to career advancement unrelated to technical competence [18,19]. Executives in SOEs are frequently promoted from government roles [20], and non-technical leaders may acquire Engineer titles ceremonially to meet administrative criteria [21]. This politicized title system dilutes the Engineer title's validity as a proxy for genuine technical expertise.

In contrast, S&E degrees represent rigorous academic training less susceptible to institutional distortion. SOEs' innovation strategies are also shaped by political objectives [22], further marginalizing the influence of post-hoc certifications like Engineer titles. Non-SOEs, driven by market competition, prioritize actual technical competence, making both S&E degrees and Engineer titles more reflective of genuine expertise. Thus, the gap in innovation impact between S&E-educated CEOs and title-holding CEOs widens in SOEs.

Hypothesis2: The differential impact of CEO's S&E degrees versus Engineer titles on innovation is more pronounced in SOEs than in non-SOEs.

3 Data, Methodology, and Empirical Results

Table 1. Descriptive statistics of variables.

Variable	N	Mean	SD	Min	Median	Max
CEO Education	1552	17.31	2.43	9	18	22
CEO S&E Degree	1552	0.32	0.47	0	0	1
CEO Engineer	1552	0.34	0.48	0	0	1
CEO Duality	1552	0.44	0.50	0	0	1
CEO Gender	1552	0.90	0.30	0	1	1
CEO Age	1552	49.79	6.88	27	50	71
CEO Tenure	1552	6.72	4.87	1	6	29
Ln_Firm Size	1552	22.02	1.19	19.43	21.79	26.77
Leverage	1552	0.36	0.20	0.03	0.35	3.22
ROA	1552	0.05	0.08	-1.00	0.05	0.35
R&D Staff Ratio (%)	1552	24.40	16.81	2.07	18.37	92.06
R&D Intensity (%)	1552	9.22	18.45	0.16	5.99	454.45
HCIE	1552	2.11	71.85	0.00	8.11	979.33
Ln_MCIE	1552	14.21	17.19	0.00	14.78	19.14
Total $Patent_{t+1}$	1552	104.52	452.80	1	31	6395
Main Category $Patent_{t+1}$	1552	36.54	132.62	1	10	1822
Patent $Category_{t+1}$	1552	12.64	11.05	1	9	50
TD_{t+1}	1552	0.30	0.23	0.04	0.24	1.00
SOE	1552	0.15	0.463	0	0	1

The study analyzes 388 Chinese A-share listed high-tech firms (industry code C39) from 2016 to 2021, excluding delisted, financially distressed (ST/ST*), non-innovative

(no patents in 2019–2021), and incomplete-data firms. Patent data (IPC classifications, application dates) were sourced from China's State Intellectual Property Office. Financial and CEO data (R&D investment, tenure, education) were obtained from CSMAR, supplemented by manual extraction from annual reports and financial portals. The final sample comprises 1,552 firm-year-CEO observations.

The variables in this study are introduced in three categories. For independent variables, we used *CEO S&E Degree*, 1 if the CEO holds a science/engineering degree (per China's 2011 discipline catalog), else 0; and *CEO Engineer*, 1 if the CEO holds an engineer title or engineering-related role, else 0. For dependent variables, we used *R&D Input*, represented by R&D staff ratio (%) and R&D intensity (R&D/revenue); *R&D Output*, represented by Total patents, main-category patents (IPC 4-digit), and patent categories; *R&D Efficiency*, represented by Human (HCIE: patents/R&D staff) and monetary (MCIE: patents/R&D expenditure) efficiency; and *Technological Diversity* (TD), represented by Herfindahl-Hirschman Index (lower values = higher diversity). For control variables, we used *Firm size* (ln(assets)), *leverage, ROA, SOE, CEO age, gender, tenure, education, duality*, and year/province dummies. Descriptive statistics of the main variables used in the regression analysis can be found in Table 1.

In Table 2 we present the coefficient estimates for our fixed-effect OLS models on R&D Input and Output. From Model 3 and 6, the coefficients of CEO S&E Degree is positive (b=.086, p=.007; b=.083, p=.010), while the coefficients of CEO Engineer is not significant, providing support for Hypothesis 1. Results show that CEO S&E Degree indeed increased the R&D input on both staff ratio and intensity, but CEO Engineer has no significant impact on them.

Table 2. The impact of CEO S&E Degree and CEO Engineer on R&D Input and R&D Output (patent).

			(1) DV:Ln_R&D Staff Ratio		(2) DV:Ln_R&D Intensity			(3) DV:Ln_Total Patent		(4) DV:Ln_Patent Category		
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CEO S&E Degree	.093*** (.044)		.086*** (.045)	.087** (.036)		.083** (.036)	.030* (.085)		.035* (.086)	.012 (.054)		.021 (.055)
CEO Engineer		.058* (.043)	.044 (.043)		.036 (.035)	.022 (.035)		-.024 (.082)	-.030 (.083)		-.047 (.052)	-.050 (.053)
Observations	1552	1552	1552	1552	1552	1552	1552	1552	1552	1552	1552	1552
Adjusted R^2	20.9%	20.4%	20.9%	19.0%	18.5%	19.0%	28.9%	28.8%	28.9%	21.7%	21.8%	21.8%
F value	15.845***	15.438***	15.081***	14.214***	13.763***	13.441***	23.853***	23.822***	22.580***	16.565***	16.723***	15.808***

Standardized coefficients are presented with two-tailed p-values. Standard errors are reported in parentheses. All models display OLS estimates. Year and firm fixed effects included in all models. *p < 0.05; **p < 0.01; ***p < 0.001

In Model 9, results show that CEO S&E Degree is positively related to *Total Patent* (b=.035, p=.052), while CEO engineer is not significantly impacting *Total Patent*, providing support for Hypothesis 1. As for *Main Category Patent*, if the dependent variable in Model 9 is replaced by Ln_Main Patent, the R^2 of the model is 27.4%, the coefficient of CEO Engineer is still not significant and the coefficient of CEO S&E

Degree is positive (b=.035, p=.079). To make the table more concise, only the regression results of *Total Patent* are included.

In Table 3, we further explored the impact of CEO Engineer and CEO S&E Degree on the technological diversity of enterprises. They significantly moderated the three variables affecting technological diversity, which are *Total Patent* (TP), *Main Category Patent* (MCP), and *Patent Category* (PC). We found a positive interaction between CEO S&E Degree and *Total Patent* on TD (b=-.203, p=.035). Therefore, the moderation effect of CEO S&E Degree on technological diversity is mainly reflected in moderating the relationship between the *Total Patent* and TD.

Table 3. Comparing the moderating effect of CEO S&E Degree and CEO Engineer between patent and technological diversity.

	(5) DV: Technological Diversity$_{t+1}$								
Variables	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total Patent(TP)		-.525***	-.516***	-.515***	-.519***	-.523***	-.524***	-.524***	-.523***
		(.016)	(.016)	(.016)	(.016)	(.016)	(.016)	(.016)	(.016)
Main Category Patent(MCP)		.662***	.656***	.652***	.660***	.660***	.660***	.662***	.660***
		(.011)	(.011)	(.011)	(.011)	(.011)	(.011)	(.011)	(.011)
Patent Category(PC)		-.336***	-.340***	-.339***	-.340***	-.336***	-.336***	-.336***	-.336***
		(.013)	(.013)	(.013)	(.013)	(.013)	(.013)	(.013)	(.013)
CEO S&E Degree		-.001	.008	.006	.007				.003
		(.008)	(.008)	(.008)	(.008)				(.008)
CEO Engineer		.013				.016	.016	.015	.013
		(.008)				(.007)	(.007)	(.007)	(.008)
CEO S&E Degree×TP			-.050***						-.203**
			(.005)						(.035)
CEO S&E Degree×MCP				-.045***					.092
				(.006)					(.026)
CEO S&E Degree×PC					-.035**				.084*
					(.009)				(.029)
CEO Engineer×TP						-.033**			-.069
						(.005)			(.034)
CEO Engineer×MCP							-.030**		.031
							(.006)		(.024)
CEO Engineer×PC								-.023*	.028
								(.008)	(.028)
Observations	1552	1552	1552	1552	1552	1552	1552	1552	1552
Adjusted R^2	3.8%	79.1%	79.3%	79.3%	79.2%	79.2%	79.2%	79.2%	79.4%
F value	5.290**	278.745***	282.557***	281.833***	280.516***	280.566***	280.234***	279.642***	202.295***

Standardized coefficients are presented with two-tailed p-values. Standard errors are reported in parentheses. All models display OLS estimates. Year and province fixed effects included in all models. *p < 0.05; **p < 0.01; ***p < 0.001

Based on the above analysis we can conclude that the impact of CEO Engineer on corporate technological innovation is similar to that of the CEO S&E Degree, but weaker. Both variables represent the CEO's engineering expertise, but CEO S&E Degree has a greater influence than CEO Engineer, supporting Hypothesis 1. To test hypothesis 2, we divide enterprises into SOE and non-SOE, and conduct an independent sample T test. The results in Table 4 show that in terms of the proportion of CEO with S&E degrees, the proportion in SOE is 35%, and that of non-SOE is 37%, and there is no significant difference. By comparison, in SOE, 64% of CEO have the title of engineer, much higher than 35% in non-SOE, and significant at the 1% level (p<0.01).

Table 4. Independent samples T test.

	CEO in SOE (N=236)		CEO not in SOE (N=1316)		Mean Differences
	Mean	Std.Deviationion	Mean	Std.Deviation	
CEO Education	17.25	2.07	17.24	2.53	.01
CEO S&E Degree	.35	.48	.37	.48	-.02
CEO Engineer	.64	.48	.35	.48	.29***
CEO Duality	.13	.33	.55	.50	-.42***
CEO Gender	.98	.13	.91	28	.07***
CEO Age	50.67	5.70	48.98	7.04	1.69***
CEO Tenure	4.86	3.96	7.76	5.52	-2.90***

***. Independent samples T test results are significant at the 0.01 level (2-tailed).

**. Independent samples T test results are significant at the 0.05 level (2-tailed).

In the subsequent pairwise comparisons, the results show that among the six variables, when the enterprise is a SOE, for the four variables, Total Patent, HCIE, MCIE, and TD, there is a significant difference, if the CEO is with or without S&E degree (p=.00; p=.00; p=.00; p=.04), but in the case of the CEO with or without the title of engineer, there is not significant differences (p=.36; p=.12; p=.92; p=.88). As for R&D Staff Ratio and R&D Intensity, the two variables measuring R&D input, there are significant differences between CEO with and without S&E degree (p=.00; p=.00), and engineer title (p=.00; p=.08) in non-SOE, but not in SOE. Due to space limitations, full tables are not presented here.

We can conclude that in the R&D input stage, the impact of CEO's S&E degree and engineer title is similar, but their impact in the R&D output stage is quite different, especially in SOE. In non-SOE, among the four variables of R&D output, only TD has a significant difference when the CEO has S&E degree or not (p=.05). By comparison, in SOE, whether the CEO has S&E degree or not has a significant difference for all four variables, but there is no significant difference for the four variables whether CEO has engineer title or not. Combined with the exceptionally high proportion of engineer CEO in SOE, it is plausible to speculate that in some SOEs, the high proportion of CEOs with an engineer title does not necessarily reflect their technical expertise or hands-on experience in the field. Our findings support Hypothesis 2, indicating that the CEO's S&E degree has a more significant impact on enterprise innovation compared to the engineer title, particularly in SOE. This underscores the importance of formal technical education in fostering innovation in state-owned enterprises.

The robustness tests were conducted in this study by expanding the time range of the samples, grouping the samples based on coastal-inland areas, and conducting endogeneity corrections. The results were all significant. Due to space limitations, specific results are not presented here.

4 Conclusions

S&E degrees outperform engineer titles in driving innovation, particularly in SOEs, where bureaucratic processes distort title significance. Formal technical education fosters enduring cognitive imprints critical for R&D success, while engineer titles often lack substantive expertise. This underscores the importance of prioritizing educational backgrounds in CEO selection, especially in SOEs. Integrating Upper Echelons and Imprinting Theories, the study advances understanding of how executive traits, shaped by early experiences and institutional contexts, influence innovation, reinforcing the need for reforms in China's professional title systems to align credentials with genuine technical competence. While our study offers valuable insights, it is not without limitations. Firstly, our research scope is confined to the computer industry and does not encompass other high-tech sectors. Secondly, our assessment of patent output focuses solely on the number of patents, overlooking the crucial aspect of patent quality.

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