CEO Education and Total Factor Productivity——Based on Empirical Evidence of Chinese A-share Listed Companies

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Abstract: Improving the total factor productivity of enterprises is of great significance to promoting the high-quality development of China's economy. This paper takes the Chinese A-share listed companies from 2008 to 2020 as a sample, and studies the relationship between CEO education and total factor productivity. The study found that CEO education is positively correlated with total factor productivity of enterprises, highly educated CEOs can help companies improve total factor productivity, and management ability weakens the positive correlation between the two. Further research finds that the level of innovation plays a complete mediating role, and the promotion effect of CEO education on the total factor productivity of enterprises is more significant in non-high-tech enterprises and mature enterprises. The research conclusions corroborate the conclusion that CEO personal characteristics have an important influence on enterprise operation in "High-level Echelon Theory" and "Branding Theory", and at the same time provide a new reference and basis for future enterprise managers' appointment decisions and improving enterprise total factor productivity.

1. Introduction

The report of the 19th National Congress of the Communist Party of China pointed out that the supply-side structural reform should be the main line to promote the reform of economic development quality, efficiency and power, and improve total factor productivity, so as to continuously enhance Chinese economic innovation and competitiveness, and achieve "two A hundred years" goal to build a solid foundation. The work report of the two sessions in 2021 also pointed out that it is necessary to adhere to innovation-driven development and accelerate the development of a modern industrial system. In this context, how to effectively improve the total factor productivity of enterprises and promote the long-term and effective development of enterprises is an important problem faced by modern enterprises. Total factor productivity refers to the additional production efficiency achieved under the given conditions of input levels of various production factors. There are usually two ways to improve total factor productivity. One is to improve production efficiency through technological progress, and the other is to improve allocation efficiency through efficient combination of production factors. In addition, with the deepening of research, scholars have found that not only the external economic policy environment has an important impact on enterprise productivity, but also various internal resources of enterprises, especially human resources, also play an important role in the level of enterprise productivity (HUGO et al., 2009) [1].

The high-level team theory believes that managers' traits affect their strategic choices, which in turn affect the decision-making and development of enterprises (Hambrick & Mason, 1984) [2]. As one of the most important human resources of an enterprise, the CEO is the core of the enterprise management team, and often plays a decisive role in the strategic decision-making of the enterprise, thereby affecting the productivity level of the enterprise. Based on this, many scholars have conducted research on the personal characteristics of CEOs and found that CEOs' age and personality (BLACK, 2019) [3], CEO's financial background (Chen Qian et al., 2020) [4], CEO's overseas experience (Chang Xuechen, 2021) [5], CEO communication (Zhao Jianchun et al., 2015) [6]and other aspects have an important impact on the total factor productivity of enterprises. Judging from the existing literature, researchers have carried out relatively rich research on the relationship between CEO personal characteristics and enterprise total factor productivity, but few literatures focus on the impact of CEO education on enterprise total factor productivity, and lack of its mechanism. in-depth analysis

and inspection. Since the reform and opening up, the number of college entrance examination students in China has gradually increased, and the number of postgraduate students has also risen rapidly. In 2020, the number of postgraduate students has exceeded the 3 million mark. People with higher education tend to have more knowledge reserves and have more accurate judgments on the market. Therefore, companies are more and more inclined to recruit highly educated people to become corporate executives. According to the data provided by the CSMAR database, from 2008 to 2020, the average educational level of CEOs of A-share listed companies is a master's degree, indicating that the overall level of CEO education is relatively high. In this context, it is of great practical significance to study the impact of CEO education on the total factor productivity of enterprises.

Based on this, this paper takes Chinese A-share listed companies from 2008 to 2020 as a research sample, and empirically analyzes the relationship between CEO education and total factor productivity. The study found that: CEO education is positively correlated with the total factor productivity of enterprises, highly educated CEOs can help companies improve total factor productivity, and management ability weakens the positive correlation between the two. Further research finds that the level of innovation plays a complete mediating role, and the promotion effect of CEO education on the total factor productivity of enterprises is more significant in non-high-tech enterprises and mature enterprises. Compared with the existing research, the contributions of this research are: (1) It enriches the research perspective of the total factor productivity of enterprises, and provides new thinking on how to improve the total factor productivity of enterprises in the new era. Most of the existing literature examines the total factor productivity of enterprises from external factors, and a small number of literatures use various internal factors or business strategies as the breakthrough point to explore its impact on the total factor productivity of enterprises. However, few literatures have paid attention to the relationship between specific human resources such as CEO personal characteristics and total factor productivity of enterprises. This paper analyzes the relationship between the personal characteristics of management and the total factor productivity of enterprises from the perspective of CEO education. further expansion. (2) Taking the mediating effect of innovation level as the starting point, explore the influence mechanism of CEO education on the total factor productivity of enterprises, and carry out heterogeneity test from the two aspects of enterprise type and life cycle, so as to provide suitable information for different types of enterprises through employment. CEO to improve total factor productivity provides a theoretical basis. (3) It has certain implications for the appointment of CEOs and the optimization of talent introduction policies in various regions. In the 2021 Two Sessions, it was pointed out that "R&D depends on talents, and talent innovation is vitality", and local governments have also successively introduced policies for the introduction of highly educated talents. This study provides an empirical basis for companies to introduce highly educated CEOs, provides specific guidance for companies to improve production efficiency, and provides policy inspiration for China's economy to develop high-quality.

2. Literature Review and Research Hypotheses

2.1 CEO Education and Total Factor Productivity

Chinese economy has shifted from a high-speed growth stage to a high-quality development stage. During this period, it is of great significance to promote the high-quality development of China's economy by improving the total factor productivity of enterprises. In the early days, most scholars started from external factors of enterprises. The research found that transportation infrastructure has a significant positive impact on total factor productivity (Liu Bingyao et al., 2010) [7]; “Inverted N” relationship (Wang Jie and Liu Bin, 2014) [8]; government subsidies completely offset the negative effect of financing constraints on productivity (Ren Shuming and Lv Bang, 2014) [9]; the scale of public expenditures has an impact on social total factor productivity There is a significant negative effect (Xue Gang et al., 2015) [10]. In recent years, some scholars have gradually turned to discuss the influence of various internal factors or business strategies on the total factor productivity of enterprises. Existing studies have found that investment in technological development and technological transformation has a significant positive correlation with the total factor productivity

of enterprises (Cheng Huifang and Lu Jiajun, 2014) [11]; state-owned enterprise mergers and acquisitions are conducive to improving the total factor productivity of enterprises (Wei Jingjing, 2017) [12]; the relationship between the enterprise pension insurance contribution rate and its total factor productivity is an inverted "U" shape (Yu Xinliang et al., 2019) [13]; the executive compensation gap has a significant positive effect on the improvement of enterprise total factor productivity Towards the role (Sheng Mingquan et al., 2019) [14]. However, few studies have focused on specific human resources within a firm, such as the impact of CEO personal characteristics on firm total factor productivity.

Combined with the theory of high-level echelon and imprinting theory, the operation and strategy of the enterprise are affected by the characteristics of the managers themselves. According to different environmental changes, managers will gradually form a relatively stable imprint feature that adapts to environmental changes, and the impact of this imprint on the subsequent behavior of the subject will persist (Hambrick & Mason, 1984; Finkelstein et al., 1990) [2][15]. Based on this, this paper argues that various background characteristics of CEOs will have an important impact on corporate governance. Li Xiaorong and Liu Xing (2012) [16] found that the CEO is the most important decision maker in the company's daily operations, and even influenced by traditional culture, the "top leaders" of some Chinese companies play a decisive role in the company's decision-making. Zeng Sanyun et al. (2015) [17] found that CEO, as the top executive of enterprise management affairs, plays a crucial role in the survival and development of the enterprise.

As a unique characteristic, CEO education level often has a significant impact on the performance of corporate innovation and investment. Zeng Sanyun et al. (2015) [17] believe that CEOs with higher education are more flexible in thinking, prefer changes and challenges, and can identify more investment opportunities. WALLY & BAUM (1994) [18] found that CEOs with a high level of education have stronger information processing capabilities than CEOs without a high level of education, are more sensitive to market factors that lead to corporate innovation, and enhance the tendency of companies to carry out technological innovation. In addition, schools are the icing on the cake for expanding network resources. CEOs with highly educated backgrounds often accumulate a large number of network connections, accumulating more intangible resources for enterprise development. Shen Yu et al. (2015) [19] found that the depth and breadth of executive alumni relationship networks are significantly positively correlated with corporate innovation performance. Shen Yu et al. (2017) [20] believe that the breadth and depth of alumni relationships can bring positive improvements to the fund’s performance. The higher the CEO's education level, the more highly educated classmates and alumni he can have, and the more high-level contacts he can make.

Through the above analysis, it is found that highly educated CEOs are more likely to use their solid professional foundation and extensive personal connections to grasp market information in a timely manner, improve the investment efficiency and resource allocation level of the enterprise, and then improve the total factor productivity of the enterprise. Therefore, this paper proposes the following assumptions:

H1: There is a positive correlation between CEO education and total factor productivity.

2.2 The Moderating Role of Management Ability

According to management theory, capable managers have higher cognitive levels and the ability to handle complex affairs, and can establish a more effective internal control environment to optimize resource allocation (He Weifeng et al., 2015) [21]. However, the principal-agent theory holds that under the condition of information asymmetry, the management of the enterprise pursues the maximization of its own interests, and the first consideration is its own interests when making project investment. Zhou Pin and Peng Kaijun (2019) [22] believe that management with higher ability is more likely to choose relatively high-yield or relatively low-risk investment activities, thus reducing corporate innovation investment. He Weifeng et al. (2016) [23] found a negative correlation between managerial ability and enterprise risk taking, and verified the risk avoidance hypothesis.

Generally speaking, enterprises increase total factor productivity by increasing investment, pursuing enterprise scale efficiency, or increasing R&D and improving the level of innovation. When

the enterprise is capital-intensive or labor-intensive, the R&D expenditure of the enterprise is often relatively low, and the management can exert personal influence in a low-risk state to improve the total factor productivity of the enterprise. Most technology-intensive companies tend to have high R&D investment, and management will make some decisions out of risk aversion. Therefore, the marginal effect on enterprise efficiency improvement is small. In addition, in a real enterprise, management's ability may not be consistent with its power. Zhang Weiying (2000) [24] believes that people with high ability are easily defeated by those with low ability because they are not keen on power struggle, which leads to the possibility that management with high ability may be defeated by those with low ability. Without absolute influence and great decision-making power (Zhang Tiezhu and Shaman, 2014) [25], even if the ability is very strong, it may have to acquiesce to some plans that are not conducive to the development of enterprises.

Through the above analysis, it can be considered that based on the maximization of self-interest, managers with strong ability will have stronger self-protection awareness and self-interest motivation, and they will adopt conservative strategies based on self-interest, which is not conducive to the improvement of enterprise productivity. Based on this, the following assumptions are made:

H2a: When other conditions remain unchanged, management ability negatively moderates the relationship between CEO education and total factor productivity.

Although the management ability may have a negative adjustment effect on the total factor productivity of the enterprise, the management with high ability is generally more efficient in the use of enterprise assets, and the management with higher ability is better able to control risks, obtain resources, and Seize opportunities and keep learning (Zhou Pin and Peng Kaijun, 2019) [22]. Li Hong and Wang Juan (2019) [26] found that companies with higher management capabilities have lower information asymmetry, because in such companies, asset utilization efficiency and resource allocation efficiency are higher. Based on this, the following assumptions are made:

H2b: When other conditions remain unchanged, management ability positively moderates the relationship between CEO education and total factor productivity.

3. Model setting and variable measurement

3.1 Sample Selection and Data Sources

In this study, A-share listed companies from 2008 to 2020 were selected as the research samples. Referring to the method of Sheng Mingquan et al. (2019) [14], the initial data of A-share listed companies from 2008 to 2020 were processed as follows: (1) excluding ST (2) Exclude financial companies; (3) Exclude company samples with severely missing data; (4) In order to eliminate the influence of extreme values, this paper performs 1% abbreviated treatment for all continuous variables. The data in this article are mainly from the CSMAR database. Some vacancies of CEO education are manually sorted through Sina.com, Baidu and the company's annual report, and Stata16.0 is used for statistical analysis of the data.

3.2 Variable Selection and Measurement

1) Explained variable

Firm total factor productivity (TFP). There are roughly LP method, OP method, OLS method and ACF method for measuring total factor productivity in the existing literature. Lu Xiaodong and Lian Yujun (2018) [27] found that semi-parametric methods such as LP and OP can solve the sample selection problem in traditional OLS estimation. Therefore, this paper chooses to use the calculation results of the LP method as the benchmark for analysis, and uses the calculation results of the OP method to test the robustness.

2) Explanatory variables

CEO education ($Degree$). On the basis of Wen Fang (2008) [28], the CEO's educational background is divided into 7 categories: 1 = technical secondary school and below; 2 = junior college; 3 = undergraduate; 4 = master's degree; 5 = doctoral degree; 6 = Others (degrees announced in other forms, such as honorary doctorate, correspondence, etc.); 7=MBA/EMBA.

3) Adjustment variables

Management Capability (MA). Yao Lijie et al. (2020) [29] first used data envelopment analysis (DEA) to measure the production efficiency (θ) of the enterprise when measuring the management ability. The influence of factors on the production efficiency of enterprises, that is, the influence of factors such as management ability. That is to say, the residual obtained from the model regression with production efficiency (θ) as the dependent variable is a measure of the management ability (MA).

4) Control variables

Referring to Ren Shuming and Lv Bian (2014) [9] and Zou Yi et al. (2009) [30] and other related studies, introduce the size of the enterprise (Size), the financial leverage (Lev), the cash position (Cash), and the age of the enterprise (Age), ownership concentration (Own), independent directors (Indep), profitability (ROA) as basic control variables. Please refer to Table 1 for the description of the specific variables.

Table.1. Definition and meaning of variables

variable type	variable name	variable symbol	Variable definitions
Explained variable	Firm total factor productivity	*TFP*	LP method to measure the total factor productivity of enterprises
Explanatory variables	CEO education	*D*egree	The CEO education is divided into 7 categories: 1 = technical secondary school and below; 2 = junior college; 3 = undergraduate; 4 = master's degree; 5 = doctoral degree; Correspondence, etc.); 7=MBA/EMBA.
Moderator	management ability	*MA*	Enterprise productivity regression residuals
Control variable	Enterprise size	*S*ize	The logarithm of the total number of employees in the company
	Financial leverage	*L*ev	Total Liabilities/Total Assets
	Cash situation	*C*ash	Monetary funds at the end of the period/total assets at the end of the period
	Business age	*A*ge	The logarithm of the number of days between the establishment date of the business and the reporting period
	Ownership concentration	*O*wn	Total shareholding ratio of the top ten shareholders
	Independent director	*I*ndep	Number of Independent Directors/Number of Board of Directors
	Profitability	*ROA*	Net profit/Total assets
	Year	*Year*	Dummy variable
	Industry	*Ind*	Dummy variable

3.3 Construction of the Model

1) In order to examine the relationship between CEO education and total factor productivity (H1), the following model is established with reference to existing research methods:

$$TFP_{it} = \alpha_0 + \alpha_1 Degree_{it} + \alpha_i Controls + \mu_i + \varphi_t + \varepsilon_{it} \quad (1)$$

2) The moderating effect of management ability. In order to test the moderating effect of management competence on CEO education and firm total factor productivity (H2), the following

model is established:

$$TFP_{it} = \beta_0 + \beta_1 Degree_{it} + \beta_2 MA_{it} + \beta_3 Degree\_MA_{it} + \beta_i \text{Controls} + \mu_i + \varphi_t + \varepsilon_{it} \quad (2)$$

In the above model, TFP_{it} is the result measured by the LP method, $Degree_{it}$ is the CEO education, and Controls is the control variable, ε_{it} represents the random disturbance term, i represents the industry, and t represents the year. Model 2 introduces an interaction term $Degree_{it}\_MA_{it}$ based on model 1 to examine the impact of management ability on the relationship between CEO education and total factor productivity. If the coefficient of the interaction term is significant, it indicates that the moderating effect is significant.

4. Empirical Analysis

4.1 Descriptive Statistics

In order to conduct a preliminary analysis of the research problem, this paper makes a descriptive analysis of the main variables, and the results are shown in Table 2. It can be seen from Table 2 that in the sample studied, the average total factor productivity of enterprises measured by the LP method is 6.859, and the calculation results are similar to the results of existing research (Chen Qian et al., 2020) [4]. The mean of CEO education (Degree) is 3.651. It can be seen that the overall level of CEO education of A-share listed companies is master's degree. The statistical results of other variables are similar to those of the existing studies, and will not be repeated here.

Table.2. Descriptive statistics of variables

Variable	Number of samples	Mean	Standard deviation	Median	Minimum	Maximum value
TFP	22561	6.859	2.128	6.152	3.753	10.431
*D*egree	22561	3.651	1.276	4.000	1.000	7.000
*S*ize	22561	7.597	1.290	7.533	4.263	11.116
*L*ev	22561	0.427	0.211	0.418	0.050	0.935
*C*ash	22561	0.191	0.141	0.151	0.014	0.694
*A*ge	22561	9.010	0.240	9.030	8.390	9.478
*O*wn	22561	0.595	0.156	0.606	0.233	0.942
*I*ndep	22561	0.374	0.053	0.333	0.333	0.571
ROA	22561	0.040	0.062	0.039	-0.261	0.207

Table.3. Correlation analysis results

Variable	*TFP*	*D*egree	*S*ize	*L*ev	*C*ash	*Age*	*O*wn	*I*ndep	*ROA*
TFP	1								
*D*egree	0.058***	1							
*S*ize	0.516***	0.077***	1						
*L*ev	0.132***	0.025***	0.360***	1					
*C*ash	-0.056***	0.024***	-0.213***	-0.422***	1				
*A*ge	0.039***	-0.037***	0.050***	0.225***	-0.127***	1			
*O*wn	0.182***	0.021***	0.066***	-0.158***	0.178***	-0.241***	1		
*I*ndep	-0.006	0.028***	-0.010	-0.009	-0.007	-0.065***	0.051***	1	
ROA	0.465***	-0.004	0.010	-0.378***	0.269***	-0.085***	0.269***	-0.026***	1

Note: ***, **, * denote significant at the 1%, 5% and 10% levels, respectively.

4.2 Correlation Analysis

Table 3 shows the correlation analysis results of the main variables in the model. The correlation coefficient between firm total factor productivity (TFP) and CEO education ($Degree$) is 0.058 and is significantly positive at the 1% level, which preliminarily proves the hypothesis H1. However, the above results still require further regression testing. In addition, according to Table 3, the correlation coefficients between the variables are basically less than 0.5, so it can be preliminarily judged that there is no serious collinearity among the variables.

4.3 Regression Analysis

Table.4. Regression results of the basic model

Explanatory variables	Explained variable TFP				
	model (1)	model (2)	model (3)	model (4)	model (5)
$Degree$	0.095*** (9.157)	0.038*** (5.234)	0.018*** (2.598)	0.050*** (3.179)	0.043*** (2.881)
$Size$		0.733*** (77.176)	0.806*** (81.056)	0.897*** (76.397)	0.915*** (73.446)
Lev		1.509*** (22.265)	0.772*** (11.252)	0.765*** (8.961)	0.430*** (5.043)
$Cash$		-0.609*** (-8.557)	-0.105 (-1.413)	-0.657*** (-7.478)	-0.160* (-1.764)
Age		0.313*** (7.489)	0.102** (2.519)	0.071 (1.449)	0.053 (1.127)
Own		0.007*** (9.627)	0.003*** (4.768)	0.003*** (3.613)	0.002** (2.179)
$Indep$		0.450** (2.516)	0.184 (1.094)	0.213 (1.056)	-0.002 (-0.010)
ROA		18.310*** (67.307)	17.683*** (66.684)	18.767*** (54.186)	18.527*** (54.762)
MA_{it}				0.000*** (6.370)	0.000*** (5.446)
$Degree_{it} \_ MA_{it}$				-0.000*** (-1.563)	-0.000*** (-2.461)
$Cons$	6.447*** (163.186)	-3.595*** (-9.017)	-2.248*** (-5.355)	-2.422*** (-5.268)	-2.725*** (-5.425)
$Year$	No	No	Yes	No	Yes
Ind	No	No	Yes	No	Yes
N	22561	22561	22561	22561	22561

Note: ***, **, * denote significant at the 1%, 5% and 10% levels, respectively, with t values in parentheses (same below).

Firstly, it analyzes the influence of CEO education on the total factor productivity of enterprises, and then analyzes the moderating effect of management ability on the two. Model (1) in Table 4 only includes CEO education ($Degree$), and the results show that the coefficient between CEO education ($Degree$) and firm total factor productivity (TFP) is significantly positive at the 1% level; model (2) is in model (1) On the basis of the regression results after incorporating more control variables, the coefficient is positively significant at the 1% level; model (3) is the regression results after controlling the annual and industry fixed effects, CEO education ($Degree$) and enterprise total factor productivity (TFP) is still significantly positive at the 1% level (the regression coefficient is 0.018), which supports the hypothesis H1 of this study. Model (4) is based on model (2) by adding management capability (MA) and the interaction term between CEO education and management capability, and the coefficient of the interaction term is negative and significant at the 1% level. Model (5) is the regression result after controlling the annual and industry fixed effects on the basis of model (4), the interaction term

and enterprise total factor productivity (TFP) are still negatively significant at the level of 1%, that is, the management ability is negative. Adjusting the relationship between CEO education and firm total factor productivity, hypothesis H2a is verified.

Regarding the control variables, it is found that the cash situation of the enterprise negatively affects the total factor productivity, and the enterprise will give up some projects that are beneficial to the enterprise for higher capital reserves, thus inhibiting the growth of the total factor productivity. Enterprise size, age, equity concentration, and profitability all positively affect the total factor productivity of the enterprise, indicating that the larger the enterprise scale, the longer the listing time, the more concentrated the equity, the better the profitability, and the higher the total factor productivity.

4.4 Robustness Test

1) Change the calculation method of total factor productivity

In order to ensure the robustness of the research results, this paper uses the OP method to recalculate the total factor productivity (TFP), and the re-regression results are shown in Table 5. Model (1) in Table 5 controls CEO education, control variables, year, and industry, and CEO education ($Degree$) is significant at the 1% level. After the model (2) in Table 5 continues to introduce the interaction terms of management capability (MA) and CEO education and management capability, the interaction term is significantly negative at the 1% level, which verifies the hypotheses H1 and H2a again.

Table.5. Robustness test regression

Explanatory variables	Explained variable TFP					
	model (1)	model (2)	model (3)	model (4)	model (5)	model (6)
$Degree$	0.018*** (2.598)	0.041***(2.718)	0.021*** (2.709)	0.042*** (2.638)	0.018*** (2.598)	0.043*** (2.881)
MA_{it}		0.000*** (5.241)		0.000*** (4.631)		0.000*** (5.446)
$Degree_{it} \_ MA_{it}$		-0.000** (- 2.315)		-0.000** (-2.158)		-0.000** (-2.461)
$Size$	0.806*** (81.056)	0.912*** (73.273)	0.901*** (68.490)	0.974*** (65.675)	0.806*** (81.056)	0.915*** (73.446)
Lev	0.772*** (11.252)	0.460*** (5.376)	0.572*** (6.806)	0.334*** (3.418)	0.772*** (11.252)	0.430*** (5.043)
$Cash$	-0.105 (-1.413)	-0.140 (-1.526)	0.422*** (4.820)	0.229** (2.248)	-0.105 (-1.413)	-0.160* (-1.764)
Age	0.102** (2.519)	0.062 (1.305)	0.072 (1.518)	-0.070 (-1.301)	0.102** (2.519)	0.053 (1.127)
Own	0.003*** (4.768)	0.002** (2.195)	0.001 (0.685)	0.001 (1.365)	0.003*** (4.768)	0.002** (2.179)
$Indep$	0.184 (1.094)	0.006 (0.029)	0.148 (0.746)	0.085 (0.382)	0.184 (1.094)	-0.002 (-0.010)
ROA	17.683*** (66.684)	18.535*** (54.536)	17.338*** (55.051)	18.923*** (48.692)	17.683*** (66.684)	18.527*** (54.762)
$Cons$	-2.289*** (-5.470)	-2.796*** (-5.561)	-2.625*** (-5.736)	-2.377*** (-4.546)	-2.248*** (-5.355)	-2.725*** (-5.425)
$Year$	Yes	Yes	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes	Yes	Yes
N	22561	22561	15130	15130	23195	23195

2) Replace the sample

Drawing on the practice of Chang Xuechen (2021) [5], a representative manufacturing sample was selected for regression. Model (3) in Table 5 controls CEO education, control variables, year and industry, and the coefficient of CEO education ($Degree$) is still positively significant at the 1% level,

which verifies hypothesis H1 again. Model (4) continues to introduce the interaction term of management capability (*MA*) and CEO education and management capability, and the interaction term is significantly negative at the 5% level. In addition, considering the impact of the new crown epidemic in 2020, this paper excludes the data in 2020 for regression, and the regression results are model (5) and model (6) in Table 5. The regression results are consistent with the previous ones, which again verifies the conclusions of this paper.

3) Endogenous test

Although the regression results above provide empirical evidence for the promotion effect of CEO education (*D*egree) on firm total factor productivity (*TFP*), this effect may be caused by its endogeneity. First of all, there is a two-way choice between enterprises and employees. Firms with high total factor productivity generally have better performance and thus are more likely to attract highly educated talents. Therefore, the positive relationship between CEO education and firm total factor productivity may be due to selection factors. Second, the positive relationship between CEO education and firm total factor productivity may be caused by unobservable ability factors, rather than purely educational levels. Based on this, this paper uses two-stage least squares (2SLS) and generalized estimation of moments (GMM) to re-estimate the impact of CEO on firm total factor productivity.

Table.6. Endogeneity test

Explanatory variables	Explained variable *TFP*		
	model (1)2SLS (FIRST)	model (2)2SLS(SECOND)	model (3)GMM
*S*chool	0.043*** (8.410)		
*D*egree		1.041*** (5.873)	1.041*** (6.170)
*S*ize	0.087*** (9.442)	0.716*** (33.694)	0.716*** (32.784)
*L*ev	0.056 (0.847)	0.702*** (7.081)	0.702*** (6.555)
*C*ash	0.328*** (3.979)	-0.486*** (-3.525)	-0.486*** (-3.587)
*A*ge	-0.269*** (-5.997)	0.499*** (5.907)	0.499*** (5.953)
*O*wn	-0.001 (-1.341)	0.005*** (4.619)	0.005*** (4.541)
*I*ndep	0.244 (1.313)	-0.316 (-1.118)	-0.316 (-1.118)
ROA	0.018 (0.097)	17.793*** (63.291)	17.793*** (49.044)
Cons	5.028*** (10.850)	-8.577*** (-7.418)	-8.577*** (-7.612)
Year	Yes	Yes	Yes
Ind	Yes	Yes	Yes
N	22561	22561	22561

This paper selects the number of 985 in the city where the CEO is located as an instrumental variable, denoted as. The main reasons for selecting this instrumental variable are: First, when a region has more 985 institutions, it indicates that the region has more adequate educational resources, so the students in the region have higher opportunities for higher education. Second, "Project 985" is a project of 39 world-class schools announced on May 4, 1998, which will not directly affect the total factor productivity of enterprises. Therefore, this indicator is reasonable as an instrumental variable.

The 2SLS regression results are shown in model (2) in Table 6. After controlling for endogeneity,

the coefficient of CEO education ($Degree$) is 1.041, which is significant at the 1% level, indicating that hypothesis H1 still holds after controlling for endogeneity. . Considering that GMM estimation will be better than 2SLS when there is heteroscedasticity, this paper further conducts GMM estimation on the relationship between CEO education and total factor productivity of enterprises. The GMM regression results are shown in model (3) in Table 6. 2SLS is basically the same, and the conclusion of this paper still holds. In addition, according to the weak instrumental variable test, it is found that the F value is 70.726 and the P value is 0.000, indicating that there is no weak instrumental variable problem.

5. Further analysis

The above research found that CEO education can improve the total factor productivity of enterprises. However, how CEO education can improve the total factor productivity of enterprises requires further mechanism analysis. In addition, although the relationship between CEO education and total factor productivity can be observed through full-sample regression, differences between different samples cannot be observed. Considering that factors such as company type and company life cycle will affect the CEO's total factor productivity Therefore, according to the above factors, this paper conducts a group regression on the sample, and further examines whether there is heterogeneity in the promotion effect of CEO education on the total factor productivity of enterprises.

5.1 Further Analysis: the Mediating Effect of Innovation Level

Enterprise R&D is a high-risk, long-term and high-investment strategic decision-making behavior, which requires the CEO at the strategic decision-making level to have high capabilities. Zhang Xuan (2015) [31] believes that the influence of CEO characteristics on corporate performance is achieved through corporate R&D investment. Xue Yue and Chen Qiao (2014) [32] believe that a high level of education means stronger information acquisition, analysis, and processing capabilities, which means more receptiveness to changes, more willingness to innovate, and more R&D investment. In addition, CEOs with higher education have higher overall quality and higher tolerance for risks in corporate decision-making, which can increase corporate R&D expenditures, and increase corporate innovation levels, thereby improving corporate total factor productivity. Therefore, this paper speculates that CEO education affects the level of total factor productivity of enterprises through the impact on the level of innovation of enterprises.

Referring to Zhou Xuan et al. (2012) [33], Zhang Xueyong et al. (2017) [34], Yao Lijie and Zhou Ying (2018) [35], and Li Wenjing and Zheng Manni (2016) [36], this paper uses the number of patent applications to measure the innovation capability of enterprises. Because: First, technological innovation is the ultimate manifestation of resource input and utilization efficiency. Therefore, the number of patent applications representing the direct output of innovation activities can better reflect the innovation capability of enterprises (Zhou Xuan et al., 2012) [33]. Second, the number of patent applications more truly reflects the level of innovation than the number of grants. Patent grants have a certain lag, and are also affected by various systems and other factors (Yao Lijie and Zhou Ying, 2018) [35], and patent grants require testing and annual fees, which are more uncertain and unstable (Zhou Xuan et al., 2012) [33]. And when a patent is pending, it proves that research and development activities have yielded results. Therefore, the number of patent applications will be more reliable and timely than the number of grants. At the same time, considering the biased distribution of the number of patent applications (Yao Lijie and Zhou Ying, 2018) [35], this paper uses the logarithm of the number of patent applications plus 1 as an indicator to measure the innovation level ($Patent$).

In this paper, the mediation effect of innovation level is tested according to the three-step method of mediation effect test of Wen Zhonglin et al. (2014) [37]. The model is constructed as follows:

$$Patent_{it} = \phi_0 + \phi_1 CEO_{it} + \phi_i Controls + \mu_i + \varphi_t + \varepsilon_{it} \quad (3)$$

$$TFP_{it} = \lambda_0 + \lambda_1 CEO_{it} + \lambda_2 Patent_{it} + \lambda_i Controls + \mu_i + \varphi_t + \varepsilon_{it} \quad (4)$$

The regression results are shown in Table 7. In Table 7, model (1) examines the influence of CEO

education (*D*egree) on enterprise innovation level (*P*atent). The results show that the coefficient of CEO education is positively significant at the level of 1% (regression coefficient is 0.014). It can be seen that CEO education will improve the innovation level of enterprises. Model (2) in Table 7 examines the effects of CEO education (*D*egree) and firm innovation level (*P*atent) on firm total factor productivity (*TFP*). At this time, the coefficient of corporate innovation level (*P*atent) is positively significant at the 1% level, but CEO education (*D*egree) and total factor productivity (*TFP*) are positively correlated but not significant. Through the above analysis and combined with the mediation effect test steps of Wen Zhonglin et al. (2014) [37], it can be found that the level of corporate innovation plays a mediating effect in the influence of CEO education and total factor productivity, and its specific manifestation is a complete mediating effect.

Table.7. Mediating effect test

Explanatory variables	Explained variable *P*atent	Explanatory variables	Explained variable *TFP*
	model (1)		model (2)
*D*egree	0.058*** (9.039)	*D*egree	0.008 (1.155)
*S*ize	0.576*** (63.073)	*S*ize	0.735*** (66.588)
*L*ev	0.039 (0.674)	*L*ev	0.816*** (11.701)
*C*ash	0.099 (1.420)	*C*ash	-0.232*** (-3.094)
*A*ge	-0.275*** (-7.079)	*A*ge	0.134*** (3.307)
*O*wn	-0.003*** (-4.686)	*O*wn	0.006*** (8.084)
*I*ndep	0.119 (0.702)	*I*ndep	0.132 (0.788)
ROA	1.567*** (9.265)	*ROA*	18.425*** (64.824)
		*P*atent	0.116*** (15.440)
Cons	-1.451*** (-3.716)	*Cons*	-2.156*** (-5.163)
Year	Yes	*Year*	Yes
Ind	Yes	*Ind*	Yes
N	22561	N	22561

5.2 Further Analysis: Heterogeneity Analysis

1) Distinguish between different business types

Compared with other enterprises, high-tech enterprises need more technological innovation and R&D investment support. Yao Xiaolin et al. (2018) [38] believe that directors with technical background can obtain tacit knowledge about corporate R&D, which can promote the continuous allocation of financial redundancy resources to high-risk R&D investment projects, and reduce the lack of R&D investment under financial redundancy. Sukun (2016) [39] believes that the CEO education level has a significant negative impact on the company's risk taking. In times of environmental uncertainty or financial crisis, highly educated CEOs will pay more attention to risk control and debt repayment pressure, and may interrupt high-risk R&D investments in order to reduce their reputational risk. Therefore, in high-tech enterprises, the impact of CEO education on total factor productivity may be weakened.

Dividing the enterprise sample into high-tech enterprises and non-high-tech enterprises, the test results of model (1) and model (2) in Table 8 show that in the non-high-tech enterprise group, CEO education is positively significant at the 1% level, but In the high-tech enterprise group, the coefficient

of CEO education is negative and not significant, indicating that the promotion effect of CEO education on the total factor productivity of enterprises is mainly reflected in non-high-tech enterprises.

2) Differentiate between different business life cycles

Generally speaking, companies in different life cycles tend to have different characteristics. Huang Hongbin et al. (2016) [40] believe that the financing constraints of enterprises in the growth period are the largest, followed by enterprises in the recession period, and the least in the mature period. Wang Yun et al. (2016) [41] showed that compared with the mature period, the corporate debt structure in the growth period and recession period is higher. In the mature stage, the CEO is more likely to exert personal influence in the face of various internal and external advantages. Therefore, CEO education has a more significant impact on total factor productivity in mature enterprises.

In order to verify the influence of the enterprise life cycle on the relationship between the CEO's educational background and the total factor productivity of the enterprise, according to the practice of Li Yunhe et al. (2011) [42], four indicators, such as sales revenue growth rate, retained yield rate, capital expenditure rate and enterprise age, are used to divide the development stage of the enterprise. According to the total score of the four indicators, the total sample is sorted by industry from large to small, and each industry sample is divided into three parts according to the total score. About 1/3 of the enterprises are in recession, and the middle part are mature enterprises.

The test results of model (3), model (4) and model (5) in Table 8 show that in the sample group in the growth period and in the decline period, the CEO education level is positive and insignificant; in the mature period sample group, the CEO education level is positive and it is significant at the level of 5%, indicating that the promotion effect of CEO education on the total factor productivity of enterprises is more reflected in mature enterprises.

Table.8. Heterogeneity analysis

Explanatory variables	Explained variable *TFP*				
	High-tech enterprises	Non-high-tech enterprises	Growth period	Maturity	Recession
	model (1)	model (2)	model (3)	model (4)	model (5)
*D*egree	-0.002 (-0.241)	0.050*** (3.918)	0.013 (0.981)	0.024** (1.986)	0.002 (0.176)
*S*ize	0.950*** (69.800)	0.682*** (46.733)	0.812*** (40.121)	0.839***(48.506)	0.781*** (50.301)
*L*ev	0.454*** (5.138)	1.001*** (9.180)	1.376*** (9.480)	0.628*** (5.026)	0.594*** (5.686)
*C*ash	0.154* (1.790)	-0.262* (-1.904)	-0.373*** (-2.714)	-0.208(-1.633)	-0.008 (-0.062)
*A*ge	-0.134*** (-2.677)	0.390*** (5.622)	-0.004 (-0.045)	0.238*** (3.167)	0.175*** (2.600)
*O*wn	0.001 (0.989)	0.010*** (8.991)	0.000 (0.321)	0.004*** (3.196)	0.007*** (6.912)
*I*ndep	-0.504** (-2.421)	1.240*** (4.504)	-0.127 (-0.400)	-0.362(-1.226)	0.678** (2.502)
ROA	17.192*** (51.532)	18.517*** (41.247)	20.932*** (37.926)	17.950*** (37.161)	17.730*** (36.406)
Cons	-0.241 (-0.473)	-5.538*** (-7.823)	-1.814** (-2.118)	-3.082*** (-4.017)	-3.261*** (-4.716)
Year	Yes	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes	Yes
N	13228	9100	5793	7131	8994

6. Conclusions and Implications

This paper uses the relevant data of Chinese A-share listed companies from 2008 to 2020 as a sample to test the relationship between CEO education and total factor productivity. The study found that: (1) CEO education is positively correlated with the total factor productivity of enterprises, and CEOs with high education can help enterprises to improve total factor productivity (2) Management ability negatively moderates the relationship between CEO education and total factor productivity. (3) The level of innovation plays a complete mediating effect in the influence of CEO education on the total factor productivity of enterprises. A CEO with a high education can promote the improvement of the innovation level of enterprises, thereby promoting the total factor productivity of enterprises. (4) The type and life cycle of the enterprise will also affect the relationship between the CEO education and the total factor productivity of the enterprise. In non-high-tech enterprises and mature enterprises, CEO education has a greater role in promoting the total factor productivity of enterprises.

The above research conclusions have important implications for listed companies to hire CEOs and improve their total factor productivity. First, when building a core leadership, an enterprise should appropriately focus on the core quality and ability of managers, and recruit highly educated personnel to become senior executives, with their professional knowledge, diversified thinking, extensive Intangible resources such as interpersonal relationships and so on to strengthen the construction of enterprise management and help enterprises improve production efficiency. Second, improve the company's internal governance system and strengthen the supervision of the management. In this way, the power of the management can be more effectively restrained, and the conservative strategy of the management based on self-interest is avoided, which is not conducive to improving the efficiency of the enterprise. Third, compared with non-high-tech enterprises, when appointing management positions, high-tech enterprises should specifically consider their majors and specialties, pay more attention to the technical background and practical experience of senior managers, and strengthen the construction of enterprise management. , in order to give full play to the key role of the human capital dividend of highly educated managers in the improvement of enterprise efficiency; for enterprises in the growth period and recession period, it is necessary to deeply understand the importance of innovation and research and development for the development of the enterprise itself, not because of the large external risks. Therefore, these enterprises can formulate relevant strategies to improve the level of innovation and thus improve the efficiency of enterprises, and when appropriate, they can hire highly educated talents to further optimize the innovation strategy of enterprises. Fourth, local governments should further increase the talent introduction strategy, establish a complete talent market supply and demand information network, provide better development space and welfare guarantee for high-level talents, and improve the service quality for enterprises and high-level talents. Recognize the important role of highly educated talents in the development of various regions, use the advantages of highly educated talents to drive the development of enterprises, and at the same time promote the development of local society, politics and economy.

Follow-up related research can be considered to be carried out and deepened from the following aspects: (1) This paper selects management ability as a moderator variable, but in fact, the impact of CEO education on the total factor productivity of enterprises is a very complex issue. The neglected factors may also play an important moderating role, and exploring how these variables affect the production efficiency of enterprises is also a direction that can be further studied in the future. (2) This paper does not distinguish between domestic and foreign schools when classifying CEO education. These can be used as the direction of follow-up research to further improve the existing conclusions. (3) Based on the data of listed companies, this paper analyzes the influence of CEO education on the total factor productivity of enterprises, but the generality of its laws and the universality of experience still need to be further explored, whether the conclusions and experience based on the analysis of listed companies are applicable to The issue of non-listed companies still needs further research.

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