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An Empirical Study on the Impact of CEO Education on Corporate Total Factor Productivity in the Context of Digital Economy

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Abstract. In this paper, 11,913 Chinese firms from 2012 to 2020 are selected as sample data for empirical tests. The results show a positive correlation between the CEO's education level and the firm's total factor productivity. CEO education can enhance firms' total factor productivity by improving corporate governance, increasing firms' investment efficiency, and promoting firms' innovation. In addition, CEO education has a more positive effect on firms' total factor productivity in the group of firms with low firm competition. There is a more positive impact on firm total factor productivity in the group of firms with transactional institutional investors. Therefore, enterprises should pay more attention to the investment in top management education, increase the training of managers, and smooth the channel of academic upgrade, so as to improve the level of corporate governance, enhance the efficiency of corporate investment, promote corporate innovation, and ensure the competitiveness of enterprises in the market.

Keywords: CEO education level，TFP，Corporate Governance，Enterprise Innovation，Influence Mechanism

1.Introduction

In the context of the world economic slowdown and weak global consumer demand, the rapid growth of the digital economy has attracted global attention and become a new hope, direction and engine for global economic development. With the accelerated development of China's communication infrastructure after 2000, the global smart phone technology progressed in 2006 (Chen et al., 2020), as a cutting-edge trend in China's economic development at this stage, the digital economy is characterized by high speed, high efficiency, high quality, high value-added and high innovation (Hungerland et al., 2015). With the rise of digital technology, many new business models, modes, and technologies have emerged, and the pace of enterprise innovation is accelerating. China has made significant progress and development in the areas of digital technology, the Internet and ICT, driving structural change and transformation of the economy (Zhang & Chen, 2019; Zhong et al., 2022). The rapid development of China's digital economy means that companies need to better adapt to technological change, digital transformation and innovation. All of the above cannot be done without the support of talents. China's economic and educational development requires high-quality growth, which has become a core task. Over the past 40 years of reform and opening up, the rapid growth of China's economy has mainly relied on factor inputs and is still factor-driven (Wu & Yu 2022); if we want to maintain high-speed and sustained economic growth, we need to change from factor-driven to endogenously driven (mainly the educational level of human resources and technological innovation). As a key economic driver, the high-quality development of the economy is closely linked to the high-quality development of enterprises. However, the high-quality development of enterprises depends on the long-term vision of enterprise decision-makers, the correct strategy, and accurate opportunities. The CEO, as an essential decision-maker, plays a pivotal role in the organization (Xia et al., 2023). Education is a significant investment in human capital that equips decision-makers with specialized knowledge and excellent character, enabling them to better adapt to the needs of economic development and contribute to economic growth (Walshok 1997). These traits are a central manifestation of a CEO's decision-making ability, and a well-educated decision-maker can positively impact total factor productivity by formulating rational enterprise development plans, grasping the dynamics of enterprise development, and promoting technological innovation. Therefore, the education level of CEOs is a central issue worthy of study for promoting the high-quality development of enterprises. The purpose of this paper is to study the impact of CEO education on firms' total factor productivity in the context of the digital economy and find the relationship between CEO education and firms' total factor productivity.

2. Literature Review and Research Hypotheses

2.1. Literature review

Total Factor Productivity (TFP) refers to that portion of economic value added that cannot be explained by physical and labor capital inputs. An important measure of the quality of economic growth is total factor productivity. It has been applied to different countries and regions to measure the level of economic development, as well as to manufacturing, agriculture, business, higher education and other sectors to measure their level of development. A study by Aiyar & Feyrer (2002) states that both education and total factor productivity (TFP) play an important role in economic growth and also education is a key determinant of the dynamic path of TFP. Education as a major component of human capital, plays a dominant role beyond physical capital in promoting total factor productivity growth through its potential spillover effects on technological change and efficiency gains (Qutb,2017). Human capital theory suggests that through education people can acquire knowledge, ability, and better adapt to economic needs to contribute to economic development, as an important input of human capital, education, both in terms of quantity and quality, has a positive impact on total factor productivity (Liu & Bi,2019).Czarniewski (2014) The quality of human capital is one of the main factors influencing business decisions. Education as an important input of human capital, more and better education brings

more human capital accumulation.Academic qualifications as an objective expression of the human capital of a business manager also become the key human capital of the manager (Israelsen & Yonker.,2017). Human capital positively affects TFP in both developed and developing countries (Tsamadias et al., 2019) and TFP growth can be achieved by increasing the level of human capital and improving governance (Kariuki & Kabaru, 2022). Liu & Bi, (2019) argued that education as an important input of human capital and tertiary education of Chinese residents can affect the growth of total factor productivity (TFP) and thus the sustainability of the economy. The top echelon theory suggests that:Top management's education, expertise, etc. can have a significant impact on organizational performance (Carpenter, 2002). The CEO, as the top executive of the organization, controls the direction of the company. Numerous studies have shown that the higher the average level of education of CEOs, as well as the diversity of their educational backgrounds, the higher the likelihood of strategic organizational change, the higher the organizational performance, and the higher the degree of organizational innovation (Wiersema & Bantel,1992). Feng et al (2022) A college education for CEOs significantly increases firms' total factor productivity and significantly increases the probability of innovation and the likelihood that firms will receive government policy support, so the increase in CEO human capital is an important driver of productivity growth in China.Xu (2021) study used the CEO's previous experience and the composition of the top management team's (TMT) board of directors (BOD) to enrich its measure of human capital, and found that the CEO's managerial dynamism, incentives to innovate, career experience in various functions, and some special experiences promote TFP. There is a positive correlation between the level of CEO education in the manufacturing industry, with a higher positive correlation between firms' total factor productivity and CEO education for R&D-intensive industries, and a lower positive correlation between firms' total factor productivity and CEO education for industries with a high dependence on external finan (Correia et al.,2021). CEO educational attainment, as a non-factor input to the firm, enhances organizational performance and advances firm innovation, thus contributing to total factor productivity.

2.2. Theoretical Analysis and Research Hypothesis

In the study of education and economic growth theory, education is recognized as a significant factor influencing total factor productivity (TFP). Education, as an input of individual human capital, plays a crucial role in enhancing individual productivity, fostering individual technological and knowledge innovation, and improving individuals' ability to understand and process information. This enables individuals to acquire and implement new technologies and disseminate new knowledge, thereby contributing to overall economic growth (Hanushek & Woessmann, 2010). The growth of TFP is essential for promoting sustained and stable economic growth without increasing resource inputs. It serves as an indicator to measure the efficiency of production factor output (Liu & Bi, 2019). Human capital, as a fundamental component of knowledge-based economic growth, has become a core element of TFP. According to human capital theory, education and training lead to the development of knowledge, competencies, and integrative qualities that contribute to personal and economic well-being (Marimuthu et al., 2009). The education level of CEOs and the diversity of their educational backgrounds have a positive relationship with organizational strategic change, organizational performance, and the degree of organizational innovation. Higher education levels and cognitive abilities of CEOs enable them to make rational decisions regarding investments and production, fostering corporate innovation and enhancing total factor productivity. This aligns with the top echelon theory, which suggests that the education level and expertise of top managers significantly impact organizational performance (Carpenter, 2002). Therefore, this paper proposes that education plays a crucial role in driving total factor productivity, and emphasizes the importance of investing in human capital to achieve sustained economic growth.

Hypothesis **H1**: CEO education is positively related to firm total factor productivity.

Hypothesis **H2**: CEO education affects firms' total factor productivity by improving the level of corporate governance, corporate investment efficiency and corporate innovation.

3. Index Selection and Data Acquisition

3.1. Research design

In order to better examine the impact of CEO's education on firms' total factor productivity, this paper will test the research hypotheses in the previous paper by using a two-way fixed effects model, which is designed as follows:

$$TFP_{it} = \beta_0 + \beta_1 EDU_{it} + \sum Controls_{it} + \sum Firm_i + \sum year_t + \varepsilon_{it} \quad (1)$$

In model (1), subscripts i and t denote firm i and year t, respectively, while the explanatory variable is the total factor productivity of the firm（TFP_{it}）, and the core explanatory variable is the education level of the CEO（EDU_{it}）. According to the research hypothesis of this paper, we focus on the estimated coefficients of the core explanatory variable（EDU_{it}） in the empirical analysis. If this estimated coefficient is significantly greater than 0, it proves that the higher education level of the CEO is more conducive to promoting the total factor productivity of the firm, i.e., it supports that the research hypothesis H1 is valid. $Controls_{it}$ is the firm-level control variable, $Firm_{it}$ is the individual firm fixed effect, $year_{it}$ is the Time-fixed effect, and ε_{it} is the random disturbance term. In order to be able to effectively control for the endogeneity problem due to time and sample individual differences between CEO education and total factor productivity, individual fixed effects and time fixed effects are controlled for in model (1), respectively and regression analysis was performed on the model.

Meanwhile, considering that the mediation effect model may introduce new endogeneity problems, we adopt the moderating effect model to test the mechanism of the impact of the CEO's education level on firms' total factor productivity, and the specific model is set as follows:

$$TFP_{it} = \emptyset_0 + \emptyset_1 EDU_{it} + \emptyset_2 EDU_{it} \times Moderator_{it} + \sum Controls_{it} + \sum Firm_i + \sum year_t + \varepsilon_{it} \quad (2)$$

Among them, in model (2), the influence mechanism variables $Moderator_{it}$ are corporate governance level (Report), investment efficiency (Inv) and enterprise innovation (Patent), respectively. It should be noted that to mitigate the endogeneity problem in model (2), we re-assign the level of corporate governance, investment efficiency, and firm innovation to the annual industry median, respectively. If the variable is greater than its annual industry median, it is assigned a value of 1. Conversely, it is assigned a value of 0 and the reassigned dummy variables are reset to ReportH, InvH & PatentH. In model (2), we will focus on the estimated coefficients of the cross-multiplication term of the core explanatory variable (EDU_{it}) and the influence mechanism variable $Moderator_{it}$

3.2. Data descriptions and variable definitions

3.2.1. Data description

We have selected Chinese A-share-listed non-financial companies from the period 2012 to 2020 as our research sample. The relevant data for our analysis have been obtained from the CSMAR and Wind databases. They are highly accurate research-based data on major areas of China's economy and finance. Based on the large sample size and data availability principles and ensuring the integrity and reliability of our data, we have followed the general principles of previous studies and processed the data as follows: (1) Exclusion of listed companies in the financial industry. (2) Exclusion of ST (Special Treatment) companies during the window period and companies with negative undistributed profits. (3) Firms with missing relevant financial data and samples with missing data on CEO education are excluded. (4) Exclusion of companies with net fixed assets exceeding total assets. After applying these data processing steps, we have collected a final sample of 11,913 data points from 2,119 companies.

Additionally, a Winsorize shrinkage technique has been applied to the main continuous variables, limiting extreme values by truncating the top and bottom 1% of the data distribution. This helps to mitigate the influence of outliers in our analysis.

3.2.2. Variable Definition

(1) Explained Variables

The explanatory variable Total Factor Productivity (TFP_{it}) we use the method proposed by Levinsohn & Petrin (2003) to estimate the total factor productivity of firms. At the same time, we also re-run the robustness test using the estimation method of Olley & Pakes (1996).

(2) Core explanatory variables

The core explanatory variable CEO education (EDU_{it}) is defined according to the CSMAR database. Secondary school or below, the value is 1; college, the value is 2; bachelor's degree, the value is 3; master's degree (including MBA/EMBA), the value is 4; doctoral degree, the value is 5.

(3) Influencing Mechanism Variables

①The level of corporate governance is assessed using two measures: the number of analysts tracked (Analyst) and the number of analyst reports (Report). These measures serve as indicators of the extent of corporate governance oversight. Research has shown that companies tracked by analysts tend to have higher value in the UK (Lehmann, 2019). When firms are tracked by a larger number of analysts or have more analyst reports, it suggests that they face stricter external regulatory constraints. Consequently, these firms are motivated to enhance their corporate governance practices.

②Investment efficiency: We use the method of Richardson (2006) to carry out the estimation, and the specific model setting is as follows:

$$Inv_{i,t} = \delta_0 + \delta_1 TQ_{i,t-1} + \delta_2 LEV_{i,t-1} + \delta_3 CASH_{i,t-1} + \delta_4 AGE_{i,t-1} + \delta_5 SMB_{i,t-1} + \delta_6 RETURN_{i,t-1} + \delta_7 Inv_{i,t-1} + \sum INDU + \sum YEAR + \varepsilon \quad (3)$$

In model (3), $Inv_{i,t}$ is cash paid by other business units of the enterprise + cash paid for investment - net cash recovered from the disposal of fixed assets, intangible assets and other long-term assets - net cash received from the disposal of subsidiaries and other business units - cash received from recovery of investment)/total assets at the beginning of the period; $TQ_{i,t-1}$ is the TBQ value of the firms in the previous period; $LEV_{i,t-1}$ is the gearing ratio of the firms in the previous period; $CASH_{i,t-1}$ is the ratio of the firms' year-end cash assets to the total assets in the previous period; $AGE_{i,t-1}$ is the logarithm of the assets of the firms with listed maturity at the end of the previous period; $RETURN_{i,t-1}$ is the annualized return on the individual shares of the firms that consider reinvestment of the cash dividends in the previous period; $INDU$ and $YEAR$ are the dummy variables for the industry and year. Through the regression of model (3), the absolute value of its residuals is taken to measure the enterprise's investment efficiency (Inv), and the larger the value, the more inefficient investment in the enterprise, the lower the investment efficiency, and vice versa, the higher, so the enterprise's investment efficiency (Inv) is the reverse indicator.

③Enterprise innovation:We draw on existing methods (Salike et al., 2022) and use the natural logarithm of the total number of inventions, utility models, and design applications filed by firms plus one.

④Other control variables: Regarding the selection of control variables, we draw on existing studies (Bae et al., 2012) and select firm size (SIZE), firm age (AGE), profitability (ROA), firm growth (Growth), leverage (LEV), board size (Board), percentage of independent directors (Indep), and investment opportunities (TBQ) as the control variables.

4. Descriptive Statistical Analysis and Empirical Results

4.1. Descriptive statistical analysis

From the data presented, the mean value of the total factor productivity (TFP) of the enterprises in the

sample is 9.299, the standard deviation is 1.102, the minimum value is 6.893, and the maximum value is 12.141, which is in a reasonable range of values, while the standard deviation is large, indicating that there are large differences in total factor productivity among different enterprises. The mean value of CEO education level (EDU) is 3.478, the standard deviation is 0.848, the minimum value is 1, and the maximum value is 5, indicating that more than half of the firms in the sample have CEOs with only a bachelor's degree of education.

4.2. Results of empirical analysis

To examine the impact of CEO education on total factor productivity (TFP), this paper uses Model (1) for empirical analysis. Table 1 presents the regression results. Column (1) shows the regression result coefficient of 0.0586 when no control variables are added to model (1) and there are no controls for individual and time-fixed effects, and the results show that the estimated coefficient on CEO education (EDU) is significantly positive at the 1% significance level. Column (2) shows the resulting coefficient of the regression of model (1) with the inclusion of control variables is 0.0169, and the estimated coefficient remains significantly positive at the 1% level of significance. The regression result in (3) after controlling for individual fixed effects and time fixed effects has a coefficient of 0.0150, which is significantly positive at the 5 per cent significance level, addressing potential endogeneity issues. The results support Hypothesis **H1**, indicating a positive correlation between CEO education level and TFP, and suggesting that higher CEO education levels may promote TFP.

Table 1: Benchmark regression results

	(1)	**(2)**	**(3)**
	TFP	**TFP**	**TFP**
EDU	0.0586***	0.0169***	0.0150**
	(6.3360)	(2.5805)	(2.3312)
lnsize		0.3204***	0.3186***
		(22.6482)	(22.5744)
Age		0.9665***	0.2953***
		(46.5726)	(5.6416)
ROA		1.9321***	1.8715***
		(16.9245)	(16.6394)
Growth		0.1958***	0.2034***
		(16.3790)	(16.9677)
Lev		0.6982***	0.7202***
		(13.3872)	(13.6970)
Board		0.1547***	0.1293***
		(3.5951)	(3.0293)
Indep		0.3219***	0.2207*
		(2.6130)	(1.8216)
TBQ		-0.0385***	-0.0156***
		(-8.2779)	(-2.9097)
_cons	9.0688***	3.1188***	4.9147***
	(281.1165)	(19.1532)	(24.2225)
Individual fixed effect	Clogged	Clogged	Containment
Time fixed effect	Clogged	Clogged	Containment
Sample size	11931	11931	11931
AdR-squared	0.0051	0.4759	0.4947

Emarks: *, **, *** denote 10%, 5%, 1% significance levels, respectively, and The t-statistic for the regression coefficients within ().

4.3. Robustness check

To test the reliability of the above empirical results, we continue to conduct robustness tests in the following ways:

4.3.1. Substitution of explanatory variables

Following the methodology of Olley & Pakes (1996), we re-estimate Total Factor Productivity (TFP) and replace the explanatory variables in Model (1) before re-running the regression. Table 4.3 (1) presents the regression results, showing that the estimated coefficients of the core explanatory variable CEO educational attainment (EDU) remain significantly positive at the 10% level of significance, even after replacing the estimation method of the explanatory variables. These results support Hypothesis H1, indicating that the positive correlation between CEO education and TFP is still valid after making these changes.

4.3.2. Controls for industry and year cross-multiplier terms

To account for changes in firms' industries over time, which may have unobservable influences, we include a cross-multiplier term of industry and year in Model (1) to examine its effect on the empirical results. The regression results in Table 4.3 (2) show that after controlling for this term, the estimated coefficient of the core explanatory variable CEO education (EDU) remains significantly positive at the 5% level of significance. This supports Hypothesis H1, indicating that CEO education has a positive correlation with total factor productivity, even after accounting for changes in industries over time.

4.3.3. Controlling for the effects of time trends

Considering that the time trends of firms' total factor productivity influences may also interfere with the empirical results of model (1), we further control the time trends of these influences in the model. Specifically, referring to Moser & Voena (2012), the control variables and time trend trinomials were controlled separately in the model, which was designed as follows:

$$TFP_{it} = \theta_0 + \theta_1 EDU_{it} + Controls_{it} + D_i(Controls_{it} \times f(T)) + Firm_i + Year_i + \varepsilon_{it} \quad (4)$$

Where $f(T)$ in the model (4) is denoted as a trinomial polynomial of the time trend T. In the specific regression process, this paper constructs the cross-multiplication terms of the first-order form, the second-order form, and the third-order form of the time trend T with the control variables. Following this, the paper further examines the robustness of model (4) by controlling for the factors affecting firms' total factor productivity and their time trends. Column (3) of Table 2 shows the regression results of model (4), which shows that the estimated coefficient of the core explanatory variable CEO's educational attainment (EDU) remains significantly positive at the 5% significance level, proving that the research hypothesis H1 is robust.

Table 2: Robustness Tests

	(1)	(2)	(3)
	TFP_OP	**TFP**	**TFP**
EDU	0.0115*	0.0129**	0.0128**
	(1.7126)	(2.0905)	(2.0912)
Other control variables×T			Containment
Other control variables×T2			Containment
Other control variables×T3			Containment
Sector×Particular year		Containment	
Individual fixed effect	Containment		Containment
Time fixed effect	Containment		Containment
Sample size	12445	11931	11931
AdR-squared	0.3620	0.5322	0.5163

Remarks: *, **, *** denote 10%, 5%, 1% level of significance, respectively. () within is the t-statistic of the regression coefficient.

4.3.4. Endogeneity test

While we control for as many influences on CEO education as possible in the design of model (1), it is difficult to exhaust all influences. Therefore, in order to eliminate as much as possible the

probability that the endogeneity problem causes the empirical results of model (1) to be a biased estimator, the empirical analysis is re-run using two-stage least squares estimation (2SLS) using an instrumental variables approach. For the selection of instrumental variables, we draw on existing research (Fisman & Svensson 2007) and use the mean of other firms in the industry as an instrumental variable, the reason being that the characteristics of the overall sample do not directly receive the influence of the behavior of individual firms but are directly related to the explanatory variables. Table 4.4 shows the results of the two-stage regression using the mean value of CEO education (EDU_AV) of other firms in the industry as an instrumental variable. In particular, column (1) of Table 4.4 shows the results of the regression test on whether it is reasonable to use the mean value of CEO education level of other firms in the industry (EDU_AV), and the results show that model (1) is still significantly positive at the 5% significance level in terms of CEO education level (EDU) when the mean value of CEO education level of other firms in the industry (EDU_AV) is included, whereas the mean value of CEO education level of other The mean value of CEO education (EDU_AV) of other firms in the industry is insignificant at the 10% level of significance, which justifies the use of the mean value of CEO education (EDU_AV) of other firms in the industry as an instrumental variable for CEO education (EDU).

Column (2) of Table 3, on the other hand, shows the results of the first-stage regressions, which show that the estimated coefficient on the instrumental variable (EDU_AV) is significantly positive, suggesting that CEOs in the industry are characterized by convergence in their educational attainment. Column (3) of Table 3 further shows the results of the second-stage regression, which shows that the estimated coefficients of the instrumental variables are still significantly positive at the 5% level of significance, indicating that the results of model (1) are robust and proving that the research hypothesis H1 holds true, after eliminating the problem of endogeneity.

Table 3: Endogeneity test

	(1)	**(2)**	**(3)**
	TFP	**EDU**	**TFP**
EDU	0.0144**		
	(2.2493)		
EDU_AV	-0.2482	0.0135**	
	(-0.8074)	(2.1374)	
EDU（Instrumented）			0.6576**
			(2.2362)
lnsize	0.3197***	0.0243*	0.3040***
	(22.6388)	(1.6932)	(21.6011)
Age	0.2819***	0.0445	0.2533***
	(5.4460)	(0.5026)	(3.1995)
ROA	1.8624***	1.2476***	1.9179***
	(16.5660)	(3.5645)	(17.3220)
Growth	0.2024***	0.0001	0.2021***
	(16.8702)	(0.0490)	(18.1820)
Lev	0.7167***	-0.0387	0.7416***
	(13.5992)	(-0.6472)	(13.8605)
Board	0.1264***	0.088**	0.0696
	(2.9698)	(2.0527)	(1.0377)
Indep	0.2226*	-0.1490	0.3185*
	(1.8380)	(-0.7930)	(1.8902)
TBQ	-0.0159***	0.0004	-0.0162***
	(-2.9785)	(0.0719)	(-2.8932)
_cons	5.4226***	0.0338	0.0298
	(20.3310)	(1.3762)	(1.2237)
Individual fixed effect	Containment	Containment	Containment
Time fixed effect	Containment	Containment	Containment
Sample size	12445	11722	11722
AdR-squared	0.3620	0.3213	0.3465

Remarks: *, **, *** denote 10%, 5%, 1% level of significance respectively，() within is the t-statistic of the regression coefficient.

5. An Examination of the Mechanisms by Which CEO Education Affects Firm Total Factor Productivity

First of all, corporate governance is a mechanism for improving total factor productivity. A higher level of education in CEOs leads to increased specialization and cognitive ability, enabling more rational decision-making in investment and production. This improves corporate governance and subsequently enhances total factor productivity. Increasing diversity in educational backgrounds improves corporate governance, while educated CEOs protect shareholder value (He & Ho, 2011). Their specialized knowledge and skills enable scientific management and improved corporate governance, contributing to enhanced total factor productivity. Regression results in Table 5.1 columns (1) and (2) show that the CEO's education level has a significant positive effect on total factor productivity when corporate governance is low. This demonstrates that improving corporate governance through increased CEO education level promotes total factor productivity.

Secondly, a more educated CEO improves business investment efficiency, leading to greater benefits. Higher CEO education levels facilitate long-term vision, promoting the realization of long-term enterprise value over short-sighted behavior. This reduces opportunistic and inefficient investment, improves corporate governance, and enhances investment efficiency, ultimately boosting total factor productivity. Regression results in Table 4 column (3) with investment efficiency as the variable show a significantly positive coefficient for the cross-multiplier term (EDU x InvH). This indicates that the positive effect of CEO education on total factor productivity is stronger when investment efficiency is lower. Thus, increasing CEO's education level enhances total factor productivity by improving investment efficiency.

Finally, a more educated CEO harnesses the role of technological innovation in economic development, promoting total factor productivity. Technological innovation is vital for maintaining industry status, improving market share, and realizing long-term value. Increased investment efficiency facilitates innovation and development, safeguarding shareholders' rights and interests. Regression results in Table 4 column (4) with firm innovation as the variable show a significantly negative coefficient for the cross-multiplier term (EDU x PatentH). This indicates that the impact of CEO education level on total factor productivity is more pronounced when the level of innovation is low. Thus, CEO education level enhances total factor productivity by promoting corporate innovation.

The above studies corroborate (Garrett, 2020; Bennedsen et al., 2020; Wang et al., 2019; Elaoud & Jarboui, 2017) and others while complementing each other, and providing a new path to improve the influence mechanism of total factor productivity of enterprises. However, the sample of this study is limited to China, and the next step could be to expand the scope of the study and search for international data to enhance the generalisability of the study. Furthermore, in this kind of research is difficulty to choose exogenous variables to solve the endogeneity problem, and the exogenous variables chosen in this study are the common practice in existing research, but better instrumental variables can be explored to broaden the ideas for the study. Finally, enterprises should pay more attention to the investment in CEO education, increase the training of managers, and smooth the channel of academic upgrading in order to improve the level of corporate governance, enhance the efficiency of corporate investment, promote corporate innovation, and ensure the competitiveness of enterprises in the market.

Table 4: Impact Mechanism Tests

	(1)	(2)	(3)	(4)
	TFP	**TFP**	**TFP**	**TFP**
EDU	0.0279***	0.0269***	0.0027	0.0273***
	(2.9717)	(2.7395)	(0.3221)	(3.1322)
ReportH	0.4755***			
	(4.4519)			
EDU×ReportH	-0.0245*			
	(-1.9215)			
AnalystH		0.1529**		
		(1.9957)		
EDU×AnalystH		-0.0218*		
		(-1.6757)		
InvH			-0.3398***	
			(-4.5095)	
EDU×InvH			0.0237*	
			(1.9024)	
PatentH				0.0761**
				(2.1249)
EDU×PatentH				-0.0241**
				(-2.3721)
Individual fixed effect	Containment	Containment	Containment	Containment
Time fixed effect	Containment	Containment	Containment	Containment
Sample size	11931	11931	11931	11931
AdR-squared	0.4976	0.4949	0.4968	0.4949

Remarks: *, **, *** denote 10%, 5%, 1% level of significance, respectively. () within is the t-statistic of the regression coefficient.

6. Conclusions and Policy Recommendations

Through our study, we find that there is a positive relationship between CEO education and firms' total factor productivity, and this relationship remains robust after various tests.CEO education improves corporate governance, enhances investment efficiency, fosters innovation and development, and ultimately increases firms' total factor productivity. In addition, this effect is more significant when the degree of competition in the industry to which the firm belongs is weak and in firms with traded institutional investors. The research in this paper not only enriches the role of education on enterprise total factor productivity in specific practices and corroborates the contribution of CEOs to economic growth, but also enriches the related literature on the impact of CEO education on enterprise total factor productivity and expands the related research on enterprise total factor productivity.

Therefore, the government should prioritize and increase investment in higher education in the digital economy era as an important national development strategy to promote economic development. Enterprises should increase the construction of the top management team, enhance the investment in top management education, provide more training for managers, and open up the channels for academic upgrading. In future research, the education level of CEOs can also be extended to corporate risk-taking, labour income and other research areas to provide more suggestions for the development of enterprises in the era of the digital economy.

References

Aiyar, S. S., & Feyrer, J. (2002). A contribution to the empirics of total factor productivity.

Bae, K. H., Ozoguz, A., Tan, H., & Wirjanto, T. S. (2012). Do foreigners facilitate information transmission in emerging markets?. Journal of Financial Economics, 105(1), 209-227

Carpenter, M. A. (2002). The implications of strategy and social context for the relationship between top management team heterogeneity and firm performance. Strategic Management Journal, 23(3), 275-284.

Correia, E., Santos, M. R., & Fancio, V. (2021). Manager Education and Firm Productivity in the Brazilian Industry. Available at SSRN 3870543.

Chen, S., Liang, Y. C., Sun, S., Kang, S., Cheng, W., & Peng, M. (2020). Vision, requirements, and technology trend of 6G: How to tackle the challenges of system coverage, capacity, user data-rate and movement speed. IEEE Wireless Communications, 27(2), 218-228.

Czarniewski, S. (2014). Quality parameters of human capital in the digital economy. International Journal of Academic Research in Accounting, Finance and Management Sciences, 4(3), 193-198.

Feng, Y., Tan, X., & Wang, R. (2022). The value of higher education to entrepreneurial performance: Evidence from higher education expansion in China. China Economic Review, 73, 101789.

Fisman, R., & Svensson, J. (2007). Are corruption and taxation really harmful to growth? Firm level evidence. Journal of development economics, 83(1), 63-75.

Hanushek, E. A., & Woessmann, L. (2010). Education and economic growth. Economics of education, 60(67), 1.

Israelsen, R. D., & Yonker, S. E. (2017). Key human capital. Journal of Financial and Quantitative analysis, 52(1), 175-214.

Kariuki, C. W., & Kabaru, F. W. (2022). Human capital, governance, foreign direct investment and their relationship with TFP growth: Evidence from Sub-Saharan Africa. The Journal of International Trade & Economic Development, 31(5), 708-724.

Lehmann, N. (2019). Do corporate governance analysts matter? Evidence from the expansion of governance analyst coverage. Journal of Accounting Research, 57(3), 721-761.

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. The review of economic studies, 70(2), 317-341.

Liu, J., & Bi, C. (2019). Effects of higher education levels on total factor productivity growth. Sustainability, 11(6), 1790.

Marimuthu, M., Arokiasamy, L., & Ismail, M. (2009). Human capital development and its impact on firm performance: Evidence from developmental economics.

Moser, P., & Voena, A. (2012). Compulsory licensing: Evidence from the trading with the enemy act. American Economic Review, 102(1), 396-427.

Olley, S., & Pakes, A. (1992). The dynamics of productivity in the telecommunications equipment industry.

Qutb, R. (2017). How education does at all levels influence total factors productivity growth?. International Research Journal of Finance and Economics, (159).

Tsamadias, C., Pegkas, P., Mamatzakis, E., & Staikouras, C. (2019). Does R&D, human capital and FDI matter for TFP in OECD countries?. Economics of Innovation and New Technology, 28(4), 386-406.

Walshok, M. L. (1997). Expanding roles for research universities in regional economic development. New directions for higher education, 1997(97), 17-26.

Wiersema, M. F., & Bantel, K. A. (1992). Top management team demography and corporate strategic change. Academy of Management journal, 35(1), 91-121.

Wu, H. X., & Yu, C. (2022). The impact of the digital economy on China's economic growth and productivity performance. China Economic Journal, 15(2), 153-170.

Xia, Q., Tan, M., Cao, Q., & Li, L. (2023). The microfoundations of open innovation: CEO overconfidence and innovation choices. R&D Management, 53(1), 43-57.

Xu, J. (2021). Human capital, decision-making and performance.

Zhang, M. L., & Chen, M. S. (2019). China's digital economy: Opportunities and risks. International Monetary Fund.

Zhong, R., He, Q., & Qi, Y. (2022). Digital economy, agricultural technological progress, and agricultural carbon intensity: Evidence from China. International Journal of Environmental Research and Public Health, 19(11), 6488.

Appendices

Table Descriptive statistics

Variant	Sample size	Average value	Standard deviation	minimum value	Maximum values
TFP	11913	9.299	1.102	6.893	12.141
EDU	11913	3.478	0.848	1	5
Lnsize	11913	7.907	1.267	4.454	11.292
Age	11913	2.885	0.333	1.609	3.497
ROA	11913	0.034	0.057	-0.217	0.198
LEV	11913	0.152	0.466	-0.587	3.238
Board	11913	0.459	0.203	0.065	0.904
Indep	11913	2.259	0.175	1.792	2.773
Growth	11913	0.374	0.053	0.333	0.571
TBQ	11913	1.974	1.343	0.840	8.871