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Research on the Impact of Corporate Innovation Capacity on Total Factor Productivity—Moderating Effect Test Based on R&D Intensity

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Abstract: *Enhancing the innovation ability of enterprises is the key to promote the high-quality development of the economy, and total factor productivity, as a key indicator of enterprise production efficiency, has an important impact on economic development. Based on the data of China's A-share listed companies in 2019-2023, this paper empirically examines the impact of corporate innovation capacity on total factor productivity and the moderating effect of R&D intensity. It is found that there is an "inverted U-shaped" relationship between corporate innovation capacity and total factor productivity, i.e., the improvement of innovation capacity can significantly promote the growth of total factor productivity at the initial stage, but when the innovation capacity exceeds a certain threshold, its promotion effect on total factor productivity gradually weakened or even turned to be suppressed. Further analysis shows that an increase in R&D intensity can prolong the duration of the positive effect of firms' innovative capacity on total factor productivity and mitigate its negative effect. Heterogeneity analysis finds that the enhancement of innovation capacity on total factor productivity is more significant in non-state-owned enterprises, while it is relatively weaker in state-owned enterprises. Through the above analysis, this paper further suggests the limitations of the study and future research directions, provides theoretical support for understanding the role of enterprise innovation capability in enhancing total factor productivity, and provides a reference for enterprises and the government to make decisions on the enhancement of innovation capability and R&D management.*

Keywords: *Firms' Innovative Capacity; Total Factor Productivity; R&D Intensity*

1. Introduction

In the context of the new era, total factor productivity, as a core indicator for measuring the efficiency of resource allocation and technological progress of enterprises, is of great significance in promoting high-quality economic development. The 19th CPC National Congress put forward the requirement of improving total factor productivity, making it one of the important work priorities of governments at all levels. The report of the 20th CPC National Congress once again listed "accelerating the construction of a modernized economic system and striving to improve total factor productivity" as an important element, further strengthening the strategic role of total factor productivity as an indicator for Chinese-style modernization. Enhancing total factor productivity has been elevated to an important national strategy, and it is urgent to improve the role of total factor productivity in supporting high-quality development[1]. The report of the 20th CPC National Congress emphasized that it adheres to the theme of promoting high-quality development, focuses on improving total factor productivity, focuses on improving the resilience and security level of the industrial chain supply chain, and focuses on promoting urban-rural integration and coordinated regional development. A significant increase in total factor productivity is the core symbol of the development of new quality productivity, the two main cores of which are scientific and technological innovation and institutional mechanism innovation. Under the constraints of global value chain restructuring and the "dual carbon" goal, the improvement of total factor productivity of enterprises is directly related to the reshaping of national competitive advantages and the realization of sustainable development path. Traditional factor inputs are subject to the law of diminishing marginal returns, while the improvement of total factor productivity can effectively avoid this problem and provide sustainable power for economic growth[2]. In this context, the role of enterprise innovation capacity as a key factor in promoting total factor productivity has become more and more prominent.

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In today's era, enterprise innovation ability has become an important embodiment of the core competitiveness of enterprises and plays a crucial role in the survival and development of enterprises. Enterprise innovation ability is not only embodied in the research and development of new products and new technologies, but also includes the innovation of management mode and business model. With the continuous progress of science and technology and the increasingly fierce competition in the market, the enhancement of enterprise innovation ability is particularly urgent. There is a close relationship between enterprise innovation ability and total factor productivity. On the one hand, the improvement of innovation ability can directly promote the improvement of total factor productivity by optimizing the production process, improving the production efficiency and reducing the production cost[3]. On the other hand, the improvement of innovation ability can also indirectly promote the growth of total factor productivity through enhancing the market competitiveness of enterprises, expanding market share, and improving the added value of products. Therefore, the enhancement of enterprise innovation ability is of great significance to the improvement of total factor productivity.

R&D intensity plays an important role as a moderating variable in the relationship between firms' innovation capacity and total factor productivity. R&D intensity reflects the extent of enterprises' investment in R&D activities, and is a key indicator of enterprises' innovation potential and innovation efficiency. In the relationship between enterprise innovation capacity and total factor productivity, R&D intensity can significantly affect the relationship between the two, which is manifested in the positive moderating effect on innovation capacity. Enterprises with high R&D intensity are able to more effectively transform innovation inputs into actual productivity improvement, thus enhancing the promotion effect of innovation capacity on total factor productivity[4]. In addition, R&D intensity can mitigate the potential negative impact of innovation capacity on total factor productivity. When innovation capacity is low, the increase in R&D intensity can help firms accumulate innovation resources and experience more quickly, thus accelerating the improvement of innovation capacity and thus promoting the growth of total factor productivity.

As a core indicator of the quality of economic development, the drivers of total factor productivity have been the focus of academic attention. With the promotion of innovation-driven development strategy, the impact of enterprise innovation capacity on total factor productivity has gradually become a research hotspot. Existing literature has revealed the impact mechanism of enterprise innovation capacity on total factor productivity from various angles, but there are still the following limitations: first, most studies focus on the mediating effect of innovation capacity, but do not explore the moderating role of R&D intensity in the "innovation-productivity" chain; second, studies on financial support and digital transformation mostly focus on the direct effect, and lack of research on R&D intensity; second, studies on financial support and digital transformation mostly focus on the direct effect, and lack of research on R&D intensity. Second, studies on financial support and digital transformation mostly focus on the direct effect, but lack the analysis of the interaction between R&D intensity and the external policy environment. For example, financial support can become an important driving force for the improvement of enterprises' innovation capacity by optimizing resource allocation and reducing financing constraints. According to Guo[5], digital finance significantly enhances the total factor productivity of science and innovation firms by reducing the cost of equity and debt financing and promoting the transformation of innovation results. Similarly, financial openness improves the innovation environment of enterprises through the dual mechanisms of "capital supply" and "efficiency enhancement", which in turn improves total factor productivity, and this effect is more significant in enterprises with stronger absorptive capacity[6]. Based on the background of "double-loop", the pilot S&T financial policy promotes the growth of total factor productivity by alleviating financing constraints and incentivizing innovation, and this phenomenon is more obvious in SOEs and enterprises in the growth period[7]. However, the effects of financial policies are moderated by firm heterogeneity and the external institutional environment.

Based on the above analysis, the possible marginal contribution of this paper's research lies in, firstly, the inclusion of R&D intensity as a moderating variable into consideration, R&D intensity is an important embodiment of enterprises' sustained innovation and R&D, and exploring its moderating effect on the relationship between enterprises' innovation capacity and total factor productivity provides new perspectives and analytical frameworks for the theoretical study of total factor productivity, which embodies this paper's innovation point. In today's context of accelerating economic transformation and the rapid development of artificial intelligence, analyzing the effect of R&D intensity on enterprise innovation capability helps to deepen the understanding of enterprise innovation process and innovation management theory. Secondly, it concretizes the relationship between R&D capability and enterprise performance, and provides empirical support for the study of the effect of R&D intensity on enterprise performance through the key indicator of total factor productivity. Through the data regression results, this study proposes and verifies the existence of an "inverted U-shape" relationship between enterprise

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innovation capability and total factor productivity, which further enriches the theory of the relationship between enterprise innovation and productivity.

2. Theoretical analysis and research hypotheses

2.1 Enterprise innovation capacity and total factor productivity

Combined with resource allocation theory, the role of R&D behaviors conducted by firms in influencing total factor productivity may not be a simple linear relationship[8].

At the early stage of innovation activities of enterprises, this stage of enterprise innovation capability is at a low level, and the improvement of innovation capability has a significant contribution to the total factor productivity of enterprises. At this time, the enterprise is in the stage of active exploration and accumulation, and each innovation achievement represents a substantial breakthrough in key areas such as technology, management or business model. These innovations can effectively optimize the enterprise's production process, significantly improve production efficiency and significantly reduce production costs, thus directly promoting the total factor productivity. The learning effect generated by R&D activities further reduces the cost of technology application, enabling innovations to be quickly transformed into real productivity[9]. For example, through the development of new technologies, enterprises have improved their production equipment or processes, resulting in a significant increase in product output per unit of time or a great improvement in product quality, which in turn enhances the overall productivity of the enterprise. At the same time, the improvement of innovation ability also helps enterprises to develop new markets, increase the added value of products, improve the economic efficiency of enterprises, and further promote the growth of total factor productivity. In addition, the improvement of enterprise innovation ability can also enhance the market competitiveness of enterprises, attract more talents and resources, and provide strong support for the sustainable development of enterprises. At this stage, the improvement of enterprise innovation capacity provides a strong impetus for the improvement of total factor productivity, and the two show an obvious positive relationship.

However, when the innovation capacity of an enterprise is enhanced to a certain degree, its promotional effect on the total factor productivity of the enterprise is gradually weakened, and even the inhibitory effect may occur, resulting in the second half of the inverted U-shaped relationship between the innovation capacity of the enterprise and the total factor productivity. It is manifested in the fact that when the innovation ability crosses a specific threshold, its law of diminishing marginal returns and the rigid constraint of organizational management ability will trigger the productivity inhibition effect. At this stage, the further improvement of enterprise innovation capability may face many challenges and bottlenecks. On the one hand, excessive pursuit of innovation may lead to excessive dispersion and waste of enterprise resources. In order to maintain a high innovation capacity, enterprises need to invest a large amount of resources such as capital, manpower and time, and the investment of these resources does not necessarily result in matching innovation output. On the other hand, too rapid an increase in innovation capacity may lead to difficulties in adapting and matching the technology, management and other systems within the enterprise in a timely manner, thus leading to a series of coordination and integration problems. For example, new innovations may conflict with existing production processes, organizational structures or corporate cultures, requiring large-scale adjustments and changes, which may bring certain risks and uncertainties, affecting the normal production and operation activities of the enterprise and thus negatively affecting total factor productivity.

Based on the above analysis, this paper proposes the following hypothesis:

H1: There is an "inverted U-shaped" relationship between firms' innovative capacity and total factor productivity.

2.2 The moderating role of R&D intensity

R&D intensity is often used in academia to reflect the strength and importance of an enterprise's investment in R&D activities. This indicator not only reflects the resources invested by enterprises in innovation activities, but also indirectly reflects the innovation capability and market competitiveness of enterprises. An increase in R&D intensity can bring more innovation opportunities to enterprises, thus enhancing their innovation capability and total factor productivity. In traditional studies, R&D intensity is usually regarded as an antecedent variable, which directly affects the enterprise's innovation ability or total factor productivity[10]. Using R&D intensity as a moderating variable can provide a new perspective

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on innovation management theory. On the one hand, this approach emphasizes the moderating role of R&D intensity in the process of enterprise innovation, which helps enterprises better understand and manage their innovation activities, and improve their innovation efficiency and results conversion rate. On the other hand, this change of perspective helps to reveal the impact of R&D intensity on the transformation efficiency of innovation results in different contexts, thus deepening the understanding of the intrinsic law of enterprise innovation activities.

An increase in R&D intensity means that firms invest more in R&D activities, which can bring more innovation opportunities and resources to firms. At the early stage of innovation capacity enhancement, enterprises can utilize these resources to carry out innovation activities more effectively, thus significantly contributing to the improvement of total factor productivity. For example, firms can acquire advanced R&D equipment, attract high-quality innovative talents, and carry out more R&D projects, all of which can help improve the efficiency and quality of innovation activities, and thus contribute more significantly to the growth of total factor productivity. In addition, higher R&D intensity can also enhance the innovation capacity and technological level of enterprises, giving them a greater advantage in market competition and further promoting total factor productivity.

However, the increasing R&D intensity of firms may also accelerate the phase of diminishing returns. As innovation capabilities are further enhanced, firms may face uncertainties and risks in their innovation activities, such as technological bottlenecks and market changes. While higher R&D intensity can help firms better cope with these challenges, it may also lead to wastage of innovation inputs, thus accelerating the arrival of the stage of diminishing returns. Specifically, when an enterprise's innovation capacity has been raised to a certain level, further increases in R&D investment may not lead to a corresponding increase in total factor productivity, but may instead lead to a waste of resources and a decline in efficiency. In economics, this phenomenon is known as the law of diminishing marginal returns, i.e., all other things being equal, as an input factor increases, the marginal returns it brings will gradually decrease.

Based on the above analysis, this paper proposes the following hypothesis.

H2: Increased R&D intensity of firms can moderate the "inverted U-shaped" relationship between firms' innovative capacity and total factor productivity.

H2a: The increase in R&D intensity of enterprises enhances the marginal effect of enterprise innovation capacity on total factor productivity, but accelerates the arrival of the stage of diminishing returns, which is manifested in the leftward shift of the inflection point of the "inverted U-shape" relationship between enterprise innovation capacity and total factor productivity.

3. Research design

3.1 Data sources and processing

In this paper, the enterprises listed in China's A-share companies from 2019-2023 are selected as the research sample, and the data are obtained from the Cathay Pacific database (CSMAR) and annual reports of listed companies. The selected samples are processed as follows: enterprises with consecutive missing values and anomalies in the main variables such as total factor productivity, enterprise innovation capacity, R&D intensity, etc. are excluded; ST category and delisted samples are excluded. In the end, a total of 750 sets of observations from 150 sample enterprises are obtained. Given that the latest year's data is not yet fully published, this time period is chosen to better fulfill the research needs. In addition, 2019 to 2023 is an important period for China's economic development, a period in which the pace of China's economic restructuring and transformation and upgrading is accelerated and the innovation-driven development strategy is deeply implemented.

3.2 Modeling

In order to verify the impact of enterprise innovation capacity on total factor productivity and also to test the hypotheses proposed in the article, this paper constructs the following model, TFP_GMM is the total factor productivity of the enterprise measured by GMM method, IC is the number of invention patents of the enterprise after logarithmic treatment, α is the coefficient of the variable, t is the year, Control is the control variable, RD is the research and development intensity, and logarithmization of the RD is the R&D intensity, the logarithmized amount of R&D investment is used as a measure, ε is a

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random disturbance term, in model (1), the positive and negative of α2 determines the direction of the opening of the U-shape curve, if α(2)>0, then it is a "positive U", and vice versa, then it is an "inverted U".

The moderator variable, firm R&D intensity RD, is introduced in model (2) and focuses mainly on the positive and negative coefficients of the squared term of IC and the interaction term coefficient of RD, α5, thus illustrating the role that the moderator variable plays in this process.

$$TFP\_GMM_t=\alpha_0+\alpha_1 IC_t+\alpha_2 IC_t^2+ \alpha_3 Control_t+\varepsilon_t \quad (1)$$

$$TFP\_GMM_t=\alpha_0+\alpha_1 IC_t+\alpha_2 IC_t^2 +\alpha_3 RD_t+\alpha_4 IC_t*RD_t+\alpha_5 IC_t^2 *RD_t+\alpha_6 Control_t+\varepsilon_t \quad (2)$$

3.3 Definition and measurement of variables

3.3.1 Core explanatory variables

In this study, enterprise innovation capacity [ln (IC+1)] is the core explanatory variable, which is measured by the natural logarithm of the number of invention patents of enterprises after adding one. Based on the Innovation Output Theory (IOT), invention patents can objectively reflect the substantive innovation achievements of enterprises due to their high technological content and strict examination standards, which is an important manifestation of the innovation strength of enterprises. The operation of plus one is mainly to avoid calculation problems in the process of taking logarithm when the number of invention patents is zero, and to ensure the rationality of data processing. Taking the natural logarithm helps to alleviate the skewed distribution of the data, makes the data more in line with the requirements of statistical analysis, and facilitates the subsequent comparison and analysis with other variables, so as to more accurately reveal the relationship between the innovation capacity of enterprises and total factor productivity.

3.3.2 Explained variables

Total Factor Productivity (TFP) is a key indicator for measuring the productivity of an enterprise, which integrates the efficiency of all factors of production in the operation of the enterprise[11]. These factors include not only traditional labor and capital, but also knowledge, technology, and management skills. Total factor productivity reflects the effective utilization of resources and technological progress, and plays a very important role in the economic growth of enterprises.

The calculation of total factor productivity is not directly derived from total production and needs to be estimated by indirect methods. The commonly used formula is: economic growth rate = total factor productivity growth rate + labor share × labor increase rate + capital share × capital growth rate. This formula reveals the relationship between total factor productivity and labor and capital inputs as well as technological progress. In neoclassical production theory, total factor productivity was initially regarded as synonymous with the level of technology. With the depth of research, scholars have found that total factor productivity is a more complex concept, which includes not only technical progress, but also pure technical efficiency and scale efficiency. Measurement methods of total factor productivity at the enterprise level mainly include ordinary least squares (OLS), ordinary product (OP), and least product (LP). Among them, the OP method solves the problem of linkage bias in OLS estimation, and the LP method further uses intermediate inputs as unobserved productivity proxy variables. It is generally believed that the OLS and FE methods have major drawbacks in calculating the total factor productivity of enterprises. Later scholars have used generalized moment estimation (GMM) and control function (CF) methods to estimate total factor productivity at the firm level more accurately[12]. In this paper, the GMM method is firstly applied to calculate the total factor productivity of enterprises, and the OP method is used to check the robustness of total factor productivity.

3.3.3 Moderating variables

In this paper, R&D intensity (ln RD) is selected as a moderator variable, which is measured by the natural logarithm of the amount of enterprise R&D investment. The amount of enterprise R&D investment can clearly show the scale of enterprise's resource investment in R&D activities, which is a key indicator to measure the degree of enterprise's attention to innovation activities. Taking the natural logarithm of the amount of R&D investment can reduce the skewness of the data and the impact of outliers on the analysis results, which can help to explore more accurately the moderating effect of R&D intensity on the relationship between enterprise innovation capacity and total factor productivity, and

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provide a more comprehensive perspective for the in-depth study of enterprise innovation activities.

3.3.4 Control variables

In order to avoid the omission of variables on the regression results caused by large errors, this paper from the corporate governance characteristics as well as financial characteristics of the two aspects of the selection of control variables, the selected control variables are the number of employees (Number), management shareholding ratio (Mshare), corporate profitability (PR), the percentage of independent directors (Indep) and the percentage of fixed assets (Fixed). The variable definitions and measures are shown in Table 1.

Table 1: Definitions of key variables

Variable type	Variable Definition	notation	way of measuring
outcome variable	Total factor productivity	TFP_GMM	Measurement of total factor productivity using the GMM methodology
antecedent variable	Enterprise innovation capacity	IC	Logarization of the number of patents for inventions in enterprises after adding one
moderator variable	R&D intensity	RD	Logarithmic treatment of the amount of firms' R&D inputs, i.e., ln(R&D inputs)
control variable	Number of employees	Number	Measured in tens of thousands of people
	Management shareholding	Mshare	Ratio of corporate management shareholding to total shareholding
	profitability	PR	Ratio of net profit of the enterprise to total income for the year
	Percentage of independent directors	Indep	Ratio of the number of corporate independent directors to the size of the board of directors
	Fixed assets as a percentage	Fixed	Ratio of net fixed assets to total assets of the enterprise

4. Empirical results and analysis

4.1 Descriptive statistics of variables

Table 2: Descriptive statistics

variable symbol	Total sample size	minimum value	maximum values	average value	(statistics) standard deviation
IC	750	0	7.241	2.391	1.203
TFP_GMM	750	3.833	7.570	5.626	0.567
Mshare	750	0	69.226	15.011	17.652
Indep	750	27.270	66.670	37.908	5.482
PR	750	-1.721	0.605	0.069	0.182
RD	750	16.070	22.372	18.825	1.032
Number	750	0.024	9.578	0.441	0.812
Fixed	750	0.004	0.699	0.193	0.131

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The descriptive statistics in Table 2 show that this paper retains three decimal places for the values of the indicators except for the sample total and the indicator with the minimum value of 0, which visualizes the difference in size comparison between the data. The above table shows that the proportion of management shareholding ranges from 0 to 69.226, indicating that there are differences in equity allocation among different enterprises. In addition, the standard deviation of the indicators of enterprise innovation ability, total factor productivity and number of employees is small, indicating that the changes of the above variables are small in this time interval.

4.2 Correlation analysis

Table 3: Correlation analysis of main variables

	IC	TFP_GMM	Mshare	Indep	PR	Number	Fixed	RD
IC	1							
TFP_GMM	0.347**	1						
Mshare	-0.120**	-0.135**	1					
Indep	0.023	-0.102**	0.085*	1				
PR	-0.028	0.265**	0.070	-0.078*	1			
Number	0.507**	0.287**	-0.149**	-0.009	0.004	1		
Fixed	-0.065	-0.213**	-0.091*	-0.018	-0.069	0.211**	1	
RD	0.625**	0.583**	-0.251**	-0.031	0.099**	0.576**	-0.010	1

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% level of significance, respectively.

According to the result of the correlation analysis in Table 3, it is clear that the magnitude of the correlation coefficients between the variables does not differ significantly. R&D capability positively affects total factor productivity and is significant at 1% level. Each variable is basically significantly correlated with each other, and the correlation analysis results can lay a good foundation for the main effect as well as the moderating effect regression analysis of this paper.

4.3 Baseline regression analysis

In order to verify the relationship between firms' innovation capacity and total factor productivity, model (1) is first empirically tested. Column (1) of Table 4 shows the regression analysis conducted by adding control variables. The results show that the coefficient of the primary term of innovation capacity is significantly positive at the 1% level, and the coefficient of the secondary term is significantly negative at the 5% level, indicating that there is an "inverted U-shaped" relationship between the two, which is in line with hypothesis H1. The value at the inflection point of the curve is calculated as 4.932=-[0.217/(2 ×-0.022)], based on which, the moderating effect of R&D intensity in the relationship between enterprise innovation capacity and total factor productivity is further investigated, and the results are shown in column (2) of Table 4.

In the model of column (2), the coefficient of the interaction term consisting of the quadratic term of the variable of enterprise innovation capacity and R&D intensity is significantly positive at the 10% level, and hypothesis H2 is verified. After calculation, the value of enterprise innovation capacity at the inflection point of the curve is 2.364, which is shifted to the left by 2.568 units compared with the original inflection point, and this phenomenon suggests that the increase in R&D intensity makes the promotion effect of enterprise innovation capacity on total factor productivity reach the peak at a lower level of innovation capacity, i.e., the promotion effect of the initial stage of the improvement of enterprise innovation capacity is more significant on total factor productivity, but at the same time it also accelerates the arrival of the stage of diminishing returns, leading to the early emergence of the inflection point, hypothesis H2a is tested.

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Table 4: Results of empirical tests

variant	TFP_GMM (1)	TFP_GMM (2)
IC	0.217***	1.026
	(4.376)	(1.466)
IC^2	-0.022**	-0.217*
	(-2.396)	(-1.871)
RD		0.369***
		(5.789)
IC*RD		-0.053
		(-1.400)
IC^2*RD		0.011*
		(1.834)
Control	Yes	Yes
Constant	5.698***	-0.889
	(39.765)	(-0.769)
observed value	750	750
R2	0.276	0.421

Note: *, **, *** indicate significant at 10%, 5%, and 1% level of significance, respectively, with t-values in parentheses, below.

4.4 Robustness tests

4.4.1 Substitution of explanatory variables

In conducting the robustness analysis, referring to the research practice of scholar Ren[13], the total factor productivity of enterprises is re-measured using the ordinary product method (TFP_OP) and substituted into model (1) for the robustness test to ensure the robustness of the empirical results. The results show that the coefficient of the primary term of its R&D capacity is significantly positive at the 1% level and the coefficient of the secondary term is significantly negative at the 5% level. It is consistent with the results of the benchmark regression analysis, which proves the robustness of the findings of this paper.

4.4.2 Lagged core explanatory variables

In order to further verify the robustness of the model, this paper incorporates the explanatory variables into the regression model after lagging them by one period, and the regression results obtained are consistent with those described above, which can indicate that the model's estimation results have a high degree of reliability. Specifically, by lagging the explanatory variables by one period, the potential endogeneity problem can be effectively avoided, and the dynamic relationship between the variables can also be better captured. The significance and sign direction of the regression results are consistent with the previous paper, further validating the reasonableness of the model and the robustness of the conclusions. The robustness test regression results are shown in Table 5.

Table 5: Robustness test regression results

variant	OP method for measuring total factor productivity (1)	One period lagged explanatory variables (2)
IC	0.252***	0.178***
	(4.761)	(3.718)
IC^2	-0.024**	-0.022**

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	(-2.415)	(-2.612)
Number	0.222*** (6.251)	0.224*** (7.979)
Mshare	-0.005*** (-4.278)	-0.004*** (-3.415)
PR	0.900*** (8.627)	0.806*** (8.143)
Indep	-0.009** (-2.717)	-0.007** (-2.280)
Fixed	-0.193 (-1.269)	-1.137*** (-8.069)
Constant	6.598*** (43.086)	5.761*** (39.367)
observed value	750	749
R^2	0.290	0.254

4.5 Heterogeneity analysis

This study further considers the heterogeneity of the nature of firms' property rights when exploring the impact of firms' innovative capacity on total factor productivity under the moderating effect of R&D intensity. Specifically, the firms in the sample are divided according to whether they are state-owned enterprises or not. It has been shown that the nature of enterprise property rights is an important factor affecting the innovative behavior and productivity of enterprises[14]. Therefore, differentiating between state-owned and non-state-owned enterprises helps to understand more deeply the heterogeneity arising from the impact of the innovation capacity of enterprises with different ownership on total factor productivity under the moderating effect of R&D intensity. The results of the heterogeneity analysis are shown in Table 6. The regression results show that the coefficients of the primary terms of the model independent variables in SOEs are significantly positive at the 10% level, and the regression coefficients of the quadratic terms are negative but not significant. The coefficient of the primary term in non-SOEs is significantly positive at the 5% level, and the coefficient of the quadratic term is negative but not significant in line with SOEs.

The coefficient of the primary term of SOEs' innovative capacity (number of invention patents plus one taking the logarithm) on total factor productivity is significantly positive at the 10 percent level, while the coefficient of the secondary term is negative but not significant. This result may be closely related to the special attributes of SOEs. SOEs usually undertake more policy-oriented tasks and their innovation activities are often driven by administrative directives rather than purely competitive market pressures[15]. For example, the R&D intensity target in the 14th Five-Year Plan suggests that SOEs may tend to file patents in order to fulfill the innovation assessment targets set by the government, but the actual conversion efficiency of patents may be low. This leads to an initial increase in total factor productivity through scale effects, but as investment increases, the accumulation of redundant R&D or inefficient patents may lead to a waste of resources, thus eroding marginal returns. In addition, the soft budget constraint characteristic of SOEs may make them more tolerant of innovation failure, leading to the difficulty of forming a significant inflection point effect for the sustained improvement of innovation capacity, which is manifested in the non-significant quadratic term. In terms of the role of the moderating variable R&D intensity, SOEs usually have stable financial support for R&D, such as financial subsidies and a better financing environment, but the allocation efficiency of their R&D inputs is constrained by the management agency problem, which may weaken the transmission path of innovation results to productivity.

The coefficient of the primary term of the innovation capacity of NSOEs on total factor productivity is significantly positive at the 5% level, and the secondary term is also negative but not significant. Compared with SOEs, the innovation behavior of non-SOEs is more market-oriented, and their patent

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layout is more inclined to applied technologies rather than strategic reserves. This makes the innovation inputs made by the firms more directly translated into process improvement or product upgrading, thus significantly increasing total factor productivity. However, NSOEs usually face stronger financing constraints, and when innovation investment exceeds a certain threshold, they may face the risk of R&D funds crowding out operating cash flow, leading to a decline in the marginal return on subsequent investment, which is manifested by a negative quadratic term coefficient. However, this negative trend has not yet reached the level of statistical significance because non-state-owned enterprises are usually able to quickly adjust the direction of R&D or terminate inefficient projects, which makes them have more flexible resource allocation capabilities. In addition, the moderating effect of R&D intensity of NSOEs may be realized through the market competition mechanism, which is manifested in the fact that higher R&D inputs tend to be accompanied by more intensive access to market information, thus optimizing the direction of innovation, but such dynamic adjustments may be difficult to capture in short-term panel data, resulting in the quadratic coefficients failing to reach the level of significance.

Table 6: Results of heterogeneity analysis

variant	TFP_GMM	
	nationalized business	non-state enterprise
IC	0.142* (1.916)	0.211** (3.293)
IC^2	-0.018 (-1.427)	-0.015 (-1.142)
Number	0.200** (2.750)	0.161*** (4.034)
Mshare	-0.018 (-1.598)	-0.002** (-1.975)
PR	0.253 (0.631)	0.805*** (7.761)
Indep	-0.009 (-1.540)	-0.005 (-1.412)
Fixed	-0.259 (-1.031)	-1.355*** (-8.097)
Constant	5.813*** (25.801)	5.586*** (31.681)
observed value	170	580
R^2	0.131	0.305

5. Conclusions and outlook

5.1 Conclusions of the study

This paper analyzes empirically the data of China's A-share listed companies from 2019-2023, and the study has the following main findings. First, there is an "inverted U-shaped" relationship between enterprise innovation capacity and total factor productivity, that is, in the initial stage, the improvement of enterprise innovation capacity can benignly promote the enhancement of total factor productivity, but with the deepening of innovation activities, total factor productivity will reach a peak, and then there will be a decline. Secondly, the improvement of R&D intensity can enhance the effect of firms' innovative capacity, which has a significant moderating effect on the "inverted U-shaped" relationship between firms' innovative capacity and total factor productivity. Specifically, the improvement of R&D intensity makes the promotion effect of enterprise innovation capacity on total factor productivity peak at a lower

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level of innovation capacity, that is, the promotion effect of enterprise innovation capacity on total factor productivity is more significant at the early stage of the improvement of enterprise innovation capacity, but at the same time it also accelerates the arrival of the stage of diminishing returns, which leads to the emergence of the inflection point in advance. In addition, there is a difference in the impact of enterprise innovation capacity on total factor productivity between state-owned enterprises and non-state-owned enterprises under the moderating effect of R&D intensity. The enhancement of total factor productivity by innovation capacity is more significant in non-state-owned enterprises, while it is relatively weaker in state-owned enterprises.

5.2 Research shortcomings and prospects

This paper provides an empirical analysis of the impact of corporate innovation investment on total factor productivity under the moderating effect of R&D intensity, but there are still some limitations and prospects for future research. In this paper, the relevant data of 150 enterprises are selected as the research sample for analysis, the sample size is small, and there may be some bias and limitations, future research can further expand the sample size to cover more enterprises of different types and sizes, in order to enhance the reliability of the research conclusions.

This study focuses on the relationship between firms' innovation capability, total factor productivity, and R&D intensity, but the process of firms' operation and innovation is also affected by numerous other factors, such as the internal organizational structure, corporate culture, and employee quality, as well as the external policy environment, the degree of market competition, and industry characteristics. These factors may have complex interactions with enterprise innovation capability, R&D intensity and total factor productivity, and this study fails to fully consider the impact of these factors. Future research can further expand the scope of variables and deeply explore the role mechanisms of these factors in the process of enterprise innovation and productivity enhancement.

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