Research on the Impact of Artificial Intelligence Penetration Rate on the Innovation Performance of State-owned Enterprises

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Abstract. Using data on China's state-owned A-share listed firms from 2013 to 2023, this study examines how AI penetration affects innovation performance. A two-way fixed-effects model is employed, with invention patent applications as the dependent variable and AI word frequency (via Python text recognition) as the core independent variable, alongside controls such as asset size and leverage. Results show that AI penetration in SOEs has risen steadily, with notable industry-level performance. Correlation and regression analyses reveal a significant positive relationship between AI adoption and technological innovation, which remains robust after controlling for other factors. These findings enrich innovation theory and offer practical guidance for SOEs in formulating AI strategies and for policymakers promoting high-quality economic development.

Keywords: Artificial Intelligence Penetration Rate; Innovation Performance; State-Owned Enterprise

1 Introduction

Artificial intelligence (AI) is transforming industries and driving innovation. As pillars of China's economy, state-owned enterprises (SOEs) must leverage AI to enhance competitiveness, yet empirical evidence on this link remains limited. Using Python-based text analysis of annual reports from Chinese A-share listed SOEs (2013–2023), we construct a firm-level AI penetration index and apply a two-way fixed-effects model to examine its impact on innovation performance, measured by invention patent applications. Results show a significant positive relationship, robust to controls. This study fills a gap in SOE-specific AI research and offers practical implications for strategy and policy.

2 Research Background and Significance

In 2023, state-owned enterprises achieved a total operating revenue of 85,730.61 billion yuan, and the total profit of state-owned and state-controlled enterprises nationwide reached 4,633.28 billion yuan. State-owned enterprises are the backbone of national

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economic development and the pillar of socialism with Chinese characteristics. As a form of production and operation organization, state-owned enterprises possess characteristics of both commercial and public welfare entities. Their commercial nature is reflected in the pursuit of maintaining and increasing the value of state-owned assets, while their public welfare nature is manifested in the fact that they are often established to achieve the goal of national economic regulation, playing a role in harmonizing the development of various aspects of the national economy.

In the report delivered at the 20th National Congress of the Communist Party of China, it was proposed to promote the integrated cluster development of strategic emerging industries and build a new generation of growth engines in areas such as information technology, artificial intelligence, biotechnology, new energy, new materials, high-end equipment, and green environmental protection. As an emerging general-purpose technology, the deep integration of artificial intelligence (AI) and the real economy brings about continuous technological restructuring and complementary innovation. This not only facilitates the transformation and upgrading of traditional industries but also spurs disruptive and cutting-edge technological innovations, cultivating and incubating strategic emerging industries and future industries, thereby achieving industrial structure transformation and the development of new productive forces. Studying the relationship between AI penetration and innovation performance can help enterprises address the challenges and opportunities that state-owned enterprises (SOEs) may encounter during their development process. It analyzes how AI applications affect the innovation performance of SOEs and provides new theoretical basis and practical guidance for the development of China's SOEs. The aim is to provide practical and feasible suggestions for SOEs to better adapt to market changes in the digital economy era, enhance their competitiveness, and further make continuous progress and innovative breakthroughs in digital transformation, thereby promoting the high-quality development and transformation and upgrading of China's economy.

Technology serves as one of the fundamental and strategic pillars for comprehensively building a socialist modernized country. We must uphold innovation as the primary driving force, pursue an innovation-driven development strategy, explore new domains and tracks for development, continuously forge new developmental drivers and advantages, and maximize the role of innovation. Therefore, studying the impact of artificial intelligence on the innovation performance of state-owned enterprises holds significant practical and theoretical implications.

3 Current Research Status and Research Hypotheses at Home and Abroad

Research achievements in AI-related fields have been widely applied in various areas such as national life, industrial production, and national defense construction. In the modern business environment, enterprises regard AI as an empowering partner to achieve a leap in productivity [1]. Studying the penetration rate of AI helps to understand its popularity and application depth in different industries and fields. This plays an im-

portant guiding role for enterprises in formulating strategies, for governments in planning industrial development, and for the academic community in conducting in-depth research on its impact [2][3].

In recent years, the attention of scholars both domestically and internationally to the penetration rate of artificial intelligence has been increasing year by year[5]. Chen Qiang (2020) investigated the impact of artificial intelligence applications on output (such as production volume and sales revenue) or performance indicators (such as cost reduction and efficiency improvement), and calculated the penetration rate based on this[6]. Zhao Ting (2018) analyzed the proportion of investment in artificial intelligence in terms of research and development, manpower, and funds to the total investment, indirectly reflecting the penetration rate [7].

Innovation performance is a crucial indicator for assessing the success of corporate innovation activities[8]. It reflects the efficiency and effectiveness of transforming innovation inputs (such as R&D expenditure and R&D manpower) into innovation outcomes (such as patents, new products, and new technologies)[9]. Corporate innovation serves as a significant driver for economic growth and industrial upgrading. By evaluating corporate innovation performance, we can gain a deeper understanding of the contribution of corporate innovation to economic development, thereby providing valuable insights for the government to formulate industrial policies and innovation support policies [10].

Scholars both domestically and internationally employ various methods to evaluate innovation performance. Firstly, there is the evaluation method based on financial indicators. Traditional financial indicators such as revenue growth rate, net profit growth rate, and return on assets are commonly used to evaluate corporate innovation performance[11]. These indicators can intuitively reflect the economic benefits brought by corporate innovation activities, but they also have certain limitations, such as not fully reflecting the innovation capability and potential of enterprises, and being susceptible to short-term financial fluctuations. Secondly, there is the evaluation method based on non-financial indicators. Non-financial indicators include the number of patents, R&D investment intensity, proportion of R&D personnel, and speed of new product launches[12]. These indicators can more comprehensively reflect the innovation capability and potential of enterprises, but there are certain difficulties in data collection and quantification.

In the context of rapid technological development, artificial intelligence (AI) has become a significant force driving corporate innovation. With the continuous advancement and application of AI technology, its role in corporate innovation performance is gradually gaining attention. Most researchers believe that information technology can promote the improvement of corporate innovation performance. For example, Gomez et al. (2017) [13]and Wu et al. (2021)[14] argue from the perspective of absorptive capacity that information technology can enhance corporate absorptive capacity, thereby reducing the cost of knowledge identification, absorption, and utilization, and improving corporate innovation performance. Fang Haochao (2024) found through research on Chinese A-share listed companies that AI significantly promotes corporate innovation, especially in non-high-tech enterprises, enterprises with high media attention, and enterprises with high R&D investment [15]. In addition, the research of Li Meng and Li

Han (2024) also supports this conclusion, finding that AI affects the quality of technological innovation through scale effects and structural effects, and pointing out that this impact is particularly prominent in non-state-owned enterprises, non-high-tech enterprises, and large and medium-sized enterprises[16].

Different measurement methods have their own advantages and disadvantages[17]. Choosing the appropriate measurement method and indicators is crucial for accurately evaluating innovation performance and the level of artificial intelligence (AI) application. Based on the above research summary, this paper intends to use the number of annual patent applications of enterprises as a measurement. For AI penetration, this paper adopts the frequency of AI-related keywords in enterprise annual reports for measurement, based on the support of existing literature and data availability. The specific selection of AI-related keywords refers to the approach adopted by Yao Jiaquan[4].

Based on these studies, it can be concluded that the application of artificial intelligence can significantly enhance corporate innovation performance. Therefore, the following hypothesis is proposed:

Hypothesis: The application of artificial intelligence effectively promotes the innovation capability of state-owned enterprises.

4 Research Design

4.1 Model Construction

To examine the relationship between the application of artificial intelligence technology and technological innovation, the following model is constructed:

$$Innov_{i,t} = \alpha_0 + \alpha_1 Ai_{i,t} + \alpha_2 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t}$$

Among them, $i$represents the enterprise, $t$and represents the year;$Innov$ represents technological innovation of the enterprise;Ai represents the degree of artificial intelligence application in the enterprise;X is the control variable;α_0 , α_1, $\alpha_2$and represent the intercept term, digital transformation, and regression coefficients of each control variable, respectively; $\mu_i$and $\lambda_t$represent individual fixed effects and time fixed effects, respectively;ε and represents the random disturbance term.

4.2 Variable Definition

4.2.1 Explained Variable.

Enterprise technological innovation (Innov) serves as the explained variable in this paper. Drawing on the research of Li Yuhua et al. (2024), it is represented by the number of invention patent applications filed by enterprises in the current year. To eliminate the impact of heteroscedasticity, the logarithm of the number of applications after adding one is used[18].

4.2.2 Core Explanatory Variables.

The application of artificial intelligence technology (AI) serves as the core explanatory variable. Following the approach of Yao Jiaquan et al. (2024), text recognition of annual reports of listed companies was conducted using Python. The word frequencies related to artificial intelligence technology, such as artificial intelligence, AI products, and AI chips, were summed up to ultimately obtain data on the degree of digital transformation. Considering the "right-skewed" characteristic of the data, it was logarithmically processed after adding one [4].

4.2.3 Control Variables.

This article controls factors that may affect corporate technological innovation, specifically including: enterprise asset size (Size), represented by the logarithm of the total assets at the end of the period; asset-liability ratio (Lev), represented by the ratio of total liabilities to total assets; enterprise age (Age), represented by the logarithm of the time span from the establishment of the enterprise to the year of study; return on assets (Roa), represented by the ratio of net profit to total assets; and enterprise growth (Growth), represented by the ratio of year-end operating income to the previous period's operating income.

5 Empirical Analysis

5.1 Data Sources and Descriptive Statistics

This paper selects Chinese state-owned A-share listed companies from 2013 to 2023 as the research subjects. Data such as total assets and asset-liability ratio are sourced from databases like CSMAR and Wind, while artificial intelligence word frequency statistics are obtained from the annual reports of each company. Following the common practice in existing articles, the raw data undergoes the following processing steps: (1) exclusion of financial enterprises; (2) exclusion of ST, PT, and data-missing enterprises; (3) exclusion of abnormal enterprises with asset-liability ratios outside the range of 0 and 1; (4) winsorization of all continuous variables at the 1% and 99% quantiles. Descriptive statistics for the variables in this paper are presented in Table 1.

Table 1. Descriptive Statistics

	N	Mean	SD	Min	p25	Median	p75	Max
Innov	15797	1.94	1.8	0	0	1.792	3.178	7.604
Ai	15797	0.573	0.982	0	0	0	0.693	4.89
Size	15797	22.66	1.427	19.688	21.653	22.507	23.534	27.299
Lev	15797	0.489	0.204	0.054	0.334	0.496	0.645	0.972
Roa	15797	0.031	0.055	-0.361	0.01	0.03	0.057	0.213
Age	15797	2.978	0.345	10.386	2.773	3.045	3.219	3.761
Growth	15797	0.145	0.422	-0.693	-0.041	0.084	0.23	4.095

5.2 Correlation Analysis

The results of the correlation analysis are presented in Table 2. Table 2 reveals that the correlation coefficient between the application of artificial intelligence technology and corporate technological innovation is 0.326 and is significant at the 1% level, which preliminarily verifies that the application of artificial intelligence technology can drive corporate technological innovation. The study further plotted a scatter plot and linear regression graph of artificial intelligence and corporate technological innovation, also verifying a positive correlation between the two. Additionally, this paper conducted a multicollinearity test, and the results are presented in Table 3. Table 3 indicates that the variance inflation factor (VIF) among all variables is less than 2, which means there is no severe multicollinearity among the main variables.

Table 2. Correlation analysis

	Innov	Ai	Size	Lev	Roa	Age	Growth
Innov	1						
Ai	0.326***	1					
Size	0.463***	0.106***	1				
Lev	0.080***	-0.068***	0.402***	1			
Roa	0.084***	0.00500	0.054***	-0.371***	1		
Age	0.088***	0.195***	0.166***	0.076***	-0.088***	1	
Growth	-0.00100	-0.0100	0.025***	0.035***	0.204***	-0.058***	1

Table 3. Multicollinearity Test

variable	VIF	1/VIF
Lev	1.51	0.660756
Size	1.32	0.755105
Roa	1.32	0.759628
Age	1.08	0.929261
Ai	1.06	0.939450
Growth	1.06	0.940290

5.3 Benchmark Regression Results

Based on the bidirectional fixed-effects model constructed in the previous text, the results are presented in Table 4. Column (1) shows the regression results without any control variables and with individual and time-point double fixed effects, indicating that the application of artificial intelligence technology has a significant positive effect on the technological innovation level of state-owned enterprises. Columns (2) to (6) gradually add control variables based on the first step. As shown in the table, whether it is direct regression or gradually adding control variables, the regression coefficient of artificial intelligence technology application on technological innovation of state-owned enterprises is significantly positive. Therefore, the hypothesis of this paper is

preliminarily verified, that is, the application of artificial intelligence technology improves the technological innovation level of state-owned enterprises.

Table 4. Benchmark regression results

	(1) Innov	(2) Innov	(3) Innov	(4) Innov	(5) Innov	(6) Innov
Ai	0.179***	0.138***	0.138***	0.138***	0.141***	0.141***
	(8.547)	(6.841)	(6.861)	(6.880)	(7.073)	(7.073)
Size		0.424***	0.421***	0.417***	0.416***	0.416***
		(11.709)	(11.463)	(11.267)	(11.375)	(11.328)
Lev			0.045	0.081	0.038	0.039
			(0.359)	(0.610)	(0.294)	(0.297)
Roa				0.218	0.197	0.201
				(1.039)	(0.943)	(0.931)
Age					0.950***	0.950***
					(4.446)	(4.446)
Growth						-0.001
						(-0.088)
_cons	1.841***	-7.738***	-7.691***	-7.640***	-10.423***	-10.426***
	(154.335)	(-9.449)	(-9.357)	(-9.249)	(-10.259)	(-10.224)
individual fixed	YES	YES	YES	YES	YES	YES
The year is fixed	YES	YES	YES	YES	YES	YES
N	15,615	15,615	15,615	15,615	15,615	15,615
R^2	0.823	0.832	0.832	0.832	0.833	0.833

Note: The value of *t* is in parentheses; ** * * and * * * represent significance levels of 10%, 5%, and 1%, respectively.

6 Conclusion

Research findings indicate that there is a positive correlation between the penetration rate of artificial intelligence and the innovation performance of state-owned enterprises. The application of artificial intelligence technology has significantly enhanced the technological innovation level of state-owned enterprises, demonstrating the important role of artificial intelligence technology in promoting enterprise innovation. To strengthen the research, development, and application of artificial intelligence technology, state-owned enterprises should increase their investment in research and development in the field of artificial intelligence technology, in order to enhance their innovation capabilities and market competitiveness. At the same time, enterprises should formulate reasonable artificial intelligence development strategies based on their own characteristics and market demands, in order to fully utilize artificial intelligence technology to drive enterprise innovation and transformation. For the government, it should promote the

application of artificial intelligence technology in state-owned enterprises by formulating relevant policies and providing financial support, thereby enhancing the innovation performance of enterprises and promoting the high-quality development of the national economy. Enterprises should establish and improve an innovation performance evaluation system to continuously monitor and enhance their innovation activities and achievements. Given the positive impact of artificial intelligence technology on innovation performance, enterprises should attach importance to the cultivation and introduction of relevant talents to support technological progress and innovative development. While promoting the application of artificial intelligence technology, attention should also be paid to the ethical and social issues it may bring, ensuring the sustainable development of the technology.

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