

Innovation Efficiency of Chinese Manufacturing Listed Companies Towards the Development of An Improved Policy Guidelines

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Abstract: This dissertation examines the factors influencing innovation efficiency among Chinese listed manufacturing companies, aiming to develop improved policy guidelines. The study focuses on the impact of enterprise digitalization level and government subsidy intensity on innovation efficiency. The findings indicate that digitalization significantly boosts innovation efficiency, while government subsidies also positively contribute with pronounced effect. Furthermore, the study reveals enterprise ownership and region variations, with enterprise digitalization having a significant impact on innovation efficiency in state-own enterprise but not in non state-owned enterprise, while government subsidies having a significant impact on innovation efficiency in developed provinces but not in non-developed provinces. The results highlight the heterogeneity of these factors across different ownership types and regional development levels. Based on these findings, the thesis recommends that enterprises should enhance their digital transformation efforts and that governments should refine subsidy policies, increase resource investment, and improve the policy environment to jointly promote a comprehensive leap in the industrial value chain and high-quality economic development.

Keywords: Innovation Efficiency, Enterprise Digitalization, Level of Intellectual Property Protection, Internet Availability Rate.

1. Introduction

1.1. Background of the Study

A fresh wave of economic upheaval and scientific technological revolution has emerged, innovation has gradually surpassed traditional production resources, become an important engine leading the development of human society (Liu Lingbo & Liu Jun, 2023). The past growth model, which mainly relied on factors and efficiency, is no longer sufficient to support the current requirements of social and economic development (Lin Miaoxin et al., 2022), and it is necessary to achieve a new leap forward driven by innovation (Wu Fei et al., 2019), in order to win the development opportunity in economic globalization and fierce international competition, and become a real big country.

Under the new economic background, the research gap gradually appears. Previous studies have focused only at the social context of that time. But as science and technology advance at an accelerated rate, innovation efficiency has a new connotation in the new background, and it is imperative to update the old research. In recent years, digitalization has become a new economic engine, but there is insufficient correlation between enterprise innovation efficiency and digitalization. In the current situation of increasingly fierce market competition, whether market competition can improve innovation efficiency, the research results are different. Therefore, the current research gap is that the analysis of influencing factors of innovation efficiency has not kept up with the current technological development and social background.

According to the above research gaps, this study will fill in. And in the future research, the expansion goal is extended, in order to explore meaningful suggestion guidelines for future economic development.

This study's primary goal is to offer recommendations for

enhancing businesses' innovation efficiency, which will focus on the theme of "influencing factors of enterprise innovation efficiency".

As a result, this study has several goals: assessing how innovative businesses are, identifying the variables that influence how innovative businesses are, and to make recommendations for enhancing businesses' innovation efficiency based on empirical study findings.

1.2. Hypotheses

Accordingly, the following null hypotheses will be established based on SOP above:

H₀₁: For state-owned enterprises, enterprise digitalization does not impact enterprise innovation efficiency.

H₀₂: For non-state-owned enterprises, enterprise digitalization does not impact the innovation efficiency of enterprises.

H₀₃: For developed provinces, the intensity of government subsidies does not impact the innovation efficiency of enterprises.

H₀₄: For non-developed provinces, the intensity of government subsidies does not impact the innovation efficiency of enterprises.

1.3. Related Literature

By comparing the above related literature, it can be figured out some similarities, differences and commonalities to the study.

The similarities of the above related literature are that Alan Guoming Huang & Kevin Jialin Sun (2019), Bai Junhong et al. (2022), Fang Mingyue et al. (2022) proposed great importance to the research on innovation efficiency. This is consistent with the current era's trend. In today's social context, innovation has long overcome traditional production indicators such as capital and labor, and become a key factor

in economic victory. Bai Junhong (2022), Fang Mingyue (2022), Pan Xingchen (2020), Qian Binhua (2023), Nastiti Pambayun Kinasih Yekti (2019), Ren Guangqian et al. (2022) and (Mounir Amdaoud et al. 2020) also believed that innovation efficiency is the key indicator of enterprise value, and expected to find out the determining factors of innovation efficiency to improve. This is similar to the point in this article. Based on this starting point, this study explores the elements that impact businesses' ability to innovate efficiently and puts forward the improvement plan. Bimo Irenius Dwinanto et al. (2022), Tang Min et al. (2019), Xiaoyang Jia & Sheng Lin (2021) and Chao Wang (2019), Yang Xuehui (2022) and Chircop J (2020) have used the input-output ratio as a measure of enterprise innovation efficiency similarly. After comprehensive weighing, this study will also adopt this measurement method. Ruonan Zhang & Hong Yin (2019), Sun, H et al. (2021) directly used R&D efficiency for innovation efficiency. This paper disagrees with this view.

The differences of the above related literature are that, by far the scholars are unable to draw an absolute conclusion about the impact of a certain factor on the innovation efficiency. Liu Bin & Wang Qingtao (2022), Dong Hyun Kim & Younho Lee (2020), Kliestik T (2021) and Mangiaracina R et al. (2019) observed that the degree of enterprise financing had an impact on innovation efficiency. Ghasemaghaei M & Calic G (2020), While Safitri V. A. D. & Anggara, B (2019), Zakari A et al. (2022), Dauda L et al. (2021), Cao S et al. (2021), Lopez, F. J. D. et al. (2019), Safitri V. A et al. (2019) and Bai Y et al. (2019) believed that the level of enterprise digitalization had a greater impact, especially in today's social context. This study also took into account the rapid progress of digitalization in recent years, so the level of digitalization of enterprises was adopted as the main internal influencing factor. And their conclusions might even be contradictory each other. For example, Jiang Qingquan (2020), Yuan Chun (2021), Dong Shugong (2022), Ghasemaghaei (2020), Sun H (2021) Tang Min (2019), Xiaoyang Jia & Sheng Lin (2021) proposed that as the same enterprise age, it was positive in one study and negative or even insignificant in another study (Yang Xuehui, 2022). This had been shown in a lot of studies, and Qian Binhua (2023), Fang Mingyue et al. (2022), Isidro

Helena & Marques Ana, (2021), Forson Joseph Ato (2022), Sun H (2021) and Ebrahim Endris (2023) all thought it's a manifestation of different situations.

Abang'a (2024), Fei Ding (2024), Siwen Song (2024), Ziyi Chen (2023) distinguished state-owned enterprises and non-state-owned enterprises. It is discovered that the significance of the same factor for the same dependent variable is different because of different grouping. For example, for state-owned enterprises, corporate financing constraints had different effects on corporate innovation efficiency. When grouping for regional development levels still showed differences between the two groups. Tutuba Nicholas Bhikolimana (2022), Xu Jinghong et al. (2022), Rixing Liu. (2020) and Li Min (2019) found that developed regions and non-developed regions had different degrees of influence on independent variables and even opposite directions on dependent variables.

The above researches can not reach a consensus yet, and it is only limited to a specific background, and may not be consistent with the manufacturing industry (Zakari, A et al., 2022). Furthermore, given how quickly digitization has advanced, research on the effects of digitization on business innovation has received very little attention from academics, therefore this field is still blank. As a result, the current research gap is that the analysis of influencing factors of innovation efficiency has not kept up with the current technological development and social background (Dauda L. et al., 2021).

1.4. Conceptual Framework

The conceptual framework visually represents the relationships between the variables described above. It shows the hypothesized direct or indirect effects of enterprise digitalization and government subsidy intensity on innovation efficiency. The framework provides a theoretical basis for understanding how these influencing factors affect and promote the innovation ability of Chinese listed companies. Studying these relationships empirically, the aim of the thesis is to find out the key elements that affect the effectiveness of innovation and to develop policies to support the innovation activities of the manufacturing sector. See Figure 1 for details.

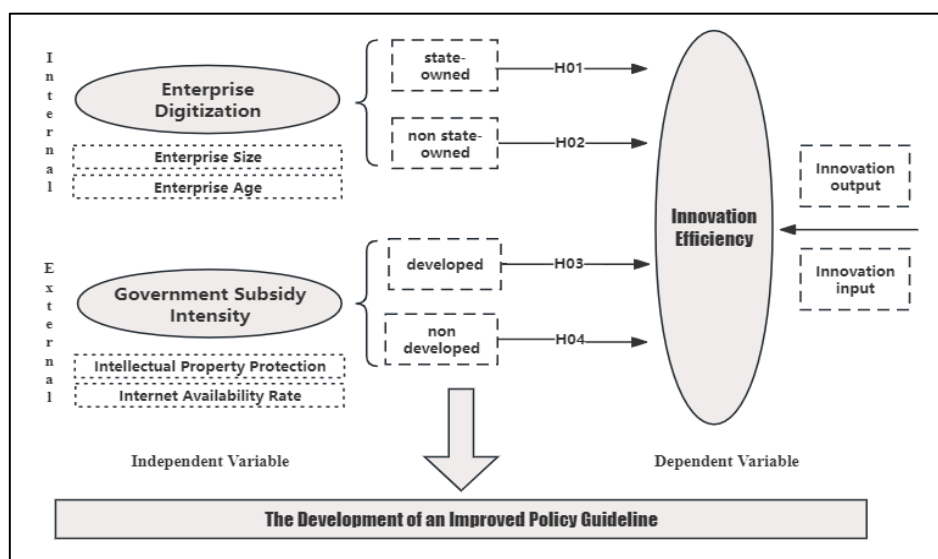


Figure 1. Author's Conceptual Framework

2. Methods

This chapter explains the overall methodology used in collecting data and addressing the research issues. It starts with the selection and justification of the research design used in the study, followed by information about the data management and statistical treatment.

2.1. Research Design

This paper mainly adopts the empirical analysis method in the research. Firstly, the paper quantitatively describes the innovation efficiency of micro-business, then puts forward the internal influencing elements: degree of digitalization, external influencing factors: the intensity of government subsidies, and finally adopts regression analysis to analyze the direction and significance of the internal and external factors that affect the effectiveness of listed firms' innovation, as well as the heterogeneity analysis. Finally, it puts forward suggestions on how to increase businesses' efficiency in innovation.

How to measure innovation efficiency is an important and difficult point in the whole research. This study synthesizes the previous literature experience. It is consistently emphasized that the role of R&D in innovation, and some believed that the output of innovation should be based on interests. To sum up, innovation efficiency measurement in this study is as follows.

The measurement of enterprise innovation efficiency is separated into two halves: input and output. Innovation input uses the R&D investment to business income ratio as a measure of the innovation input intensity. Innovation output takes the ratio between the number of innovation patent output and business income as the intensity of innovation output. Finally, the ratio of innovation output intensity divided by innovation input intensity is taken as the overall effectiveness of businesses' innovation.

How to measure the digitalization degree of enterprises is the difficulty of this research. Following the practice of general scholars, this study adopts the PWC enterprise digital Maturity assessment framework, and directly obtains the digitalization degree index value of specific enterprises from its report.

The characteristics of property rights of enterprises is heterogeneity analysis factor to this research topic. This study divides the property rights of enterprises into two categories: state-owned enterprises and non-state-owned enterprises. In order to reflect the characteristics of enterprise property rights, the index measures the degree of nationalization of enterprises by proportion of state-owned enterprises holding.

According to the act of most scholars, the ratio of financial subsidies to business income of firms is a measure of the extent of government subsidies. Government subsidies can help ease financial pressure of enterprise innovation, encourage enterprise innovation, and help obtain more research and development funds through the "government endorsement" effect, and government subsidies are expected to help enterprise innovation.

The province category of the firm is used as the heterogeneity analysis factor for this research topic. In this study, the provinces where enterprises are located are divided into developed provinces and non-developed provinces. In order to reflect the differences in location, the indicator distinguishes developed provinces and non-developed provinces by the province in which the business is situated

and its per capita GDP.

2.2. Statistical Treatment

There are three main variables: the digitalization of enterprises, the intensity of public subsidies and the efficiency of enterprise innovation.

2.2.1. Enterprise Digitalization

Enterprise digitalization refers to the extent to which a listed Chinese manufacturing

company has adopted digital technology and integrated it into its operations, processes and products. This variable acts as one of the independent variables in the framework, that is, it is considered to influence the dependent variable, which is the efficiency of innovation. Examples of factors related to the digitalization of the company can be the introduction of Industry 4.0 technologies, the introduction of digital production systems, the use of data analysis. in decision-making and the integration of Internet of Things (IoT) devices in the production processes.

2.2.2. The Intensity of Government Subsidies

The degree of financial assistance that the government offers to Chinese listed firms in order to foster innovation is indicated by the intensity of government subsidies. This variable also serves as an independent variable, indicating that it is expected to have an impact on the dependent variable, which is innovation performance. Government subsidies can take many forms, such as grants, tax credits, R&D funding and technology deployment grants. The intensity of these subsidies may vary between different companies and industries.

2.2.3. Innovation Efficiency

Innovation efficiency represents the efficiency and success of innovation activities of listed companies in China. It serves as a dependent variable i.e. it is influenced or determined by the independent variables of the digitalization of companies and the intensity of state subsidies.

The effectiveness of innovation can be evaluated based on several indicators, including the degree of development of new products, the speed of introduction, innovations, the return on investment of innovative projects and general influence of innovation on outcomes and competitiveness of the company.

2.2.4. Enterprise Age

Enterprise age refers to length of time from inception of a business to the present. This indicator is often used to describe and analyze an enterprise's life cycle, development stage, and its ability to adapt to changes in the market environment. Enterprise age has a significant effect on business operation and strategic decision.

2.2.5. Enterprise Size

The size of the business in accordance with applicable rules and laws is referred to as enterprise size, which can usually be determined by the quantity of workers, total assets, turnover and market value. The size of an enterprise usually affects its management mode, development strategy and market competitiveness, as well as its relationship and interaction with the government, society and other aspects.

2.2.6. Level of Intellectual Property Protection

The degree and impact of intellectual property rights protection are referred to as the level of protection. This covers a thorough analysis of the extent of intellectual property laws and enforcement, the resolution of intellectual property conflicts, and the detection and retribution of

violations. Increasing the protection of intellectual property promotes creativity, promote scientific and technological progress and economic development.

2.2.7. Internet Availability Rate

Internet availability rate is the percentage of the population in a country or region that uses the Internet. It is a crucial metric for assessing a nation's or region's degree of information development and the ability of people to obtain information. This metric is calculated in a relatively straightforward way by dividing the number of users of internet usage by the local population as a whole, usually expressed as a percentage. It reflects the popularity and reach of the Internet in the region.

3. Results

In this section, the SOP proposed in chapter 1 of this study

$$Efficiency_{i,t} = \alpha_0 + \beta_1 digitalize_{i,t} + \beta_2 age_{i,t} + \beta_3 size_{i,t} + \varepsilon_{i,t}$$

In this section, a baseline regression analysis is first conducted, followed by a further heterogeneity analysis to address Hypothesis 1 and Hypothesis 2:

H01: For state-owned enterprises, enterprise digitalization does not impact enterprise innovation efficiency.

H02: For non-state-owned enterprises, enterprise digitalization does not impact the innovation efficiency of

Model A. Internal Influencing Factors

$$Efficiency_{i,t} = \alpha_0 + \beta_1 digitalize_{i,t} + \beta_2 age_{i,t} + \beta_3 size_{i,t} + \varepsilon_{i,t}$$

Table 1. Baseline regression results for model A

VARIABLES	Model A Efficiency	Interpretation & Remark
Digitalize	0.070*** (0.026)	SIG & Reject
Age	-0.102*** (0.016)	SIG & Reject
Size	0.079*** (0.015)	SIG & Reject
Constant	1.198*** (0.324)	
Observations	27,836	
R-squared	0.210	
F	51.17***	
Mean Vif	1.316	
CODE	control	
YEAR	control	
Number of code	3,776	

Notes:

1. t statistics in parentheses
2. *** p<0.01, ** p<0.05, * p<0.1

As indicated in Table 1, in Model A, the regression model explains almost 21% of the variation in enterprise innovation efficiency, according to the R-squared value of 0.210. In Model A, the F value is 51.17, reaching a significance level of p<0.01, indicating that every independent variable in the model has a statistically significant impact on the dependent variable (Yifan Wu, 2023). In other words, the overall regression model has a significant explanatory power for enterprise innovation efficiency. The Mean VIF (Variance Inflation Factor) value is 1.316, which is less than 10, suggesting that there is no multicollinearity present. Although the R-squared value is relatively low, the combined influence

is thoroughly discussed. However, the suggested policy guidelines will be addressed in the Conclusions and Recommendations section.

3.1. Enterprise Digitalization Affecting Innovation Efficiency

Based on the aforementioned, the factors affecting enterprise innovation efficiency can be divided into internal and external factors. Therefore, two multiple linear regression models, Model A and Model B, have been correspondingly constructed. In this section, the empirical results related to Model A and Model B of this study will be comprehensively and systematically presented. Based on SOP2, this study constructs multiple linear regression Model A:

enterprises.

3.1.1. Baseline Regression Analysis

Using the previously established regression model, Model A, regression analysis was conducted by substituting all sample data into the model. Table 1 displays the precise findings of this regression study.

of independent variables in model on dependent variable remains significant.

Regression coefficient for enterprise digitalization (Digitalize) is 0.070 (p<0.01), indicating a favorable and statistically substantial influence of digitalization about enterprise innovation efficiency. For every 1 unit increase in digitalization, the enterprise innovation efficiency increases by an average of 0.070 units. This suggests that investments in digital transformation by enterprises can significantly enhance their innovation efficiency. (Yiming He & Heyuan Huang, 2020)

The regression coefficient for enterprise age (Age) is -

0.102 ($p < 0.01$), demonstrating the detrimental and statistically significant influence of enterprise age about innovation efficiency. For every 1 unit increase in enterprise age, the enterprise innovation efficiency decreases by an average of 0.102 units. As enterprises grow and age, their innovation efficiency tends to decline, as mature enterprises exhibit reduced flexibility in innovation. (Yiming He & Heyuan Huang, 2020)

The regression coefficient for enterprise size (Size) is 0.079 ($p < 0.01$), indicating a favorable and statistically noteworthy effect of enterprise size on innovation efficiency. For every 1 unit increase in enterprise size, the enterprise innovation

efficiency increases by an average of 0.079 units. This suggests that larger enterprises typically have higher innovation efficiencies due to their more abundant resources and funds, which better support innovation activities. (Yuan Chun et al., 2021)

3.1.2. Descriptive Analysis

After data processing is completed, a descriptive analysis should be conducted on all variables of the model to understand the overall picture of the data, as detailed in Table 2.

Table 2. Descriptive statistics for model A

Name	Min	Max	Mean	Std.Dev.
Efficiency	0.000	9.358	2.021	1.623
Digitalize	0.000	1.350	0.486	0.398
Age	0.000	3.526	1.897	0.956
Size	17.641	27.638	22.005	1.191

The effectiveness of businesses' innovation is mainly determined by output of innovation divided by input of innovation. Innovation efficiency has been discussed in SOP1, and showed a high degree of dispersion across all samples.

The enterprise digitalization degree has a minimum value of 0, which means that some enterprises have not yet started their digital transformation journey. The maximum value is 1.350, indicating that some enterprises have reached a fairly high level of digitalization. The standard deviation is 0.398 and the average is 0.486. These figures suggest that there is some variance in the degree of digitalization across businesses, but the variation is not particularly large. These numbers show that the performance of most enterprises in terms of digital transformation is relatively concentrated. (Wang Lihui, Liu Zhihong & Shi Huailong, 2022)

3.1.3. Heterogeneity Analysis

SOP2 proposed in the chapter 1 of this study: Does enterprise digitalization significantly affect enterprise innovation efficiency in following groups: State owned enterprises and Non state owned enterprises? Based on SOP2, two hypotheses have been established:

H01: For state-owned enterprises, enterprise digitalization does not impact enterprise innovation efficiency.

H02: For non-state-owned enterprises, enterprise digitalization does not impact enterprise innovation efficiency.

Therefore, to address SOP2 and test these hypotheses, a heterogeneity analysis was conducted by splitting the sample into two groups: state-owned enterprises and non-state-owned enterprises, followed by regression analysis. Table 3 displays the findings.

It is clear from Table 3 that the degree of digitalization (Digitalize) for state-owned firms has a regression coefficient of 0.277 ($p < 0.01$), suggesting that digitalization significantly improves the innovation efficiency of state-owned enterprises. This means that for each unit increase in the degree of digitalization, innovation efficiency will increase by 0.277 units. However, the regression coefficient for digitalization in non-state-owned businesses is 0.132 ($p > 0.1$), suggesting that digitalization does not significantly affect the effectiveness of innovation. These results support the view of Amir Rahmani

that degree of digitalization positively affects corporate innovation efficiency (Amir Rahmani et al., 2024).

Table 3. Heterogeneity analysis for model A

VARIABLES	State-owned		Non-state-owned	
	Efficiency		Efficiency	
Digitalize	0.277*** (0.033)	SIG & Reject	0.132 (0.012)	NOT SIG & Accept
Age	-0.170*** (0.040)	SIG & Reject	-0.189*** (0.014)	SIG & Reject
Size	0.156*** (0.025)	SIG & Reject	0.206*** (0.015)	SIG & Reject
Constant	-1.089** (0.537)		-1.525*** (0.310)	
Observations	6,654		21,182	
R-squared	0.230		0.220	
Number of code1	819		2,957	
CODE	control		control	
YEAR	control		control	

Notes:

- t statistics in parentheses
- *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Age's effect on the effectiveness of innovation is negative on both types of enterprises, with a coefficient of -0.170 ($p < 0.01$) for businesses owned by the state and -0.189 ($p < 0.01$) for businesses not controlled by the state. This indicates that an increase in enterprise age will decrease innovation efficiency, with a slightly stronger effect in businesses that are not state-owned. Findings confirm the views of Su Weihua (Su Weihua et al., 2023).

The innovation efficiency of both kinds of businesses is positively impacted by the enterprise's size (Size). The regression coefficient is 0.156 ($p < 0.01$) for state-owned businesses and 0.206 ($p < 0.01$) for non-state-owned businesses, with the size effect being higher in the latter. These findings support Ma Lan's theory that an organization's size positively affects innovation efficiency (Ma Lan, Wang Qi & Wang Dalei, 2023).

In summary, overall, among the state-owned business group, P-value for corporate digitalization is $p < 0.01$, indicating three-star significance, suggesting that the null hypothesis H01 is not valid, overturning the initial theory, accepting the alternative hypothesis, that is, the level of digitalization of state-owned businesses significantly improves their capacity for innovation.

However, in group of non-state-owned enterprises, P-value

for corporate digitalization is $p > 0.1$, indicating no significance, suggesting that the null hypothesis H02 is valid, accepting the original hypothesis, that is, the level of innovation efficiency of non-state-owned businesses is not

significantly impacted by their level of digitization.

Empirical results of model A can be summarized in Table 4.

Table 4. Heterogeneity analysis result in state-owned enterprises

Group	Coefficient	t	p	Interpretation	Remark
State-owned	0.277	0.033	<0.01	Significant	Reject H01
Non-state-owned	0.132	0.012	>0.1	Not Significant	Accept H02

*H01: For state-owned enterprises, enterprise digitalization does not impact enterprise innovation efficiency.

*H02: For non-state-owned enterprises, enterprise digitalization does not impact the innovation efficiency of enterprises.

3.2. Government Subsidies Affecting Innovation Efficiency

According to SOP3, this study constructed a multiple linear

$$Efficiency_{i,t} = \alpha_0 + \beta_1 subsidy_{i,t} + \beta_2 protection_{i,t} + \beta_3 internet_{i,t} + \varepsilon_{i,t}$$

In this section, first perform a baseline regression analysis, and then proceed to heterogeneity analysis to address Hypotheses 3 and Hypotheses 4.

H03: For developed provinces, the intensity of government subsidies does not impact the innovation efficiency of enterprises.

H04: For non-developed provinces, the intensity of government subsidies does not impact the innovation efficiency of enterprises.

3.2.1. Baseline Regression Analysis

By applying the previously established regression Model B to all sample data, the regression analysis results were obtained, as displayed in Table 4.

Model B. External Influencing Factor

$$Efficiency_{i,t} = \alpha_0 + \beta_1 subsidy_{i,t} + \beta_2 protection_{i,t} + \beta_3 internet_{i,t} + \varepsilon_{i,t}$$

From Table 5, it can be seen that in Model B, the regression model accounts for about 27.1% of the variation in corporate innovation efficiency, according to the R-squared value of 0.271. F-value is 51.62, reaching a significant level of $p < 0.01$, indicating that every independent variable in the model has a statistically significant impact on the dependent variable, that is, the overall regression model has a significant explanatory power for enterprise innovation efficiency. The Mean Vif value is 1.279, which is less than 10, suggesting that there is no multicollinearity. Although the R-squared value is not high, in the model, the independent variables' combined impact on the dependent variable is still substantial.

The government subsidy regression coefficient intensity (Subsidies) is 0.812 ($p < 0.01$). The effect of the level of government subsidies on the effectiveness of business innovation is positive and statistically significant. For each unit increase in government subsidy intensity, enterprise innovation efficiency increases on average by 0.812 units. This indicates that government grants significantly contribute to the improvement of business innovation efficiency, and subsidy funds can effectively promote enterprise innovation activities.

The degree of intellectual property protection (Protection)

regression Model B:

Table 5. Baseline regression results for model B

VARIABLES	Model B Efficiency	Interpretation & Remark
Subsidies	0.812*** (0.257)	SIG & Reject
Protection	-1.050*** (0.082)	SIG & Reject
Internet	0.001 (0.001)	NOT SIG & Accept
Constant	0.973*** (0.323)	
Observations	27,836	
R-squared	0.271	
F	51.62***	
Mean Vif	1.279	
CODE	control	
YEAR	control	
Number of code1	3,776	

Notes:

1. t statistics in parentheses

2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

has a regression coefficient of -1.027 ($p < 0.01$), and effects of the degree of protection provided by intellectual property about enterprise innovation efficiency is negative and statistically significant. For each unit increase in the degree of protection provided by intellectual property, enterprise innovation efficiency decreases on average by 1.027 units. Although theoretically, intellectual property protection should help to promote innovation, according to this model, lesser innovation efficiency is linked to a larger degree of protection.

The regression coefficient for the rate of internet availability (Internet) is 0.001 ($p > 0.1$), indicating that effectiveness of enterprise innovation is not much impacted by internet access.

3.2.2. Descriptive Analysis

After completing data processing, a descriptive analysis of all variables in this model should be conducted to understand the overall of the data, as displayed in Table 6.

Table 6. Descriptive statistics for model B

Name	Min	Max	Mean	Std.Dev.
Efficiency	0.000	9.358	2.021	1.623
Subsidies	0.000	0.430	0.068	0.044
Protection	0.404	0.938	0.779	0.123
Internet	0.242	0.919	0.663	0.140

From Table 6, enterprise innovation efficiency ranges from 0 to 9.358, as can be observed, with an average value of 2.021 and 1.623 as the standard deviation. This demonstrates how different businesses' levels of innovation efficiency are. The performance in innovation efficiency is quite dispersed. A few companies have a high level of innovation efficiency, which indicates significant investment in research and innovation, leading to successful innovative outcomes. However, some companies have an innovation efficiency of 0. (Zakari et al., 2022)

The minimum value for government subsidy intensity is 0, 0.430 is the maximum, 0.068 is the average, and 0.044 is the standard deviation, reflecting that most companies receive a lower and more concentrated proportion of government subsidies. The low standard deviation of subsidy intensity indicates that there is not much variation in the level of subsidies, and the subsidy levels received by companies are relatively consistent. (Zhang Jing & Liu Xuxu, 2022)

3.2.3. Heterogeneity Analysis

SOP3 aims to address: Does the level of government subsidies have a substantial impact on businesses' ability to innovate? In following groups: Developed provinces and Non-developed provinces? Based on SOP3, two hypotheses have been established in the previous text:

H03: For developed provinces, the intensity of government subsidies does not impact the innovation efficiency of enterprises.

H04: For non-developed provinces, the intensity of government subsidies does not impact the innovation efficiency of enterprises.

Table 7. Heterogeneity analysis for model B

VARIABLES	Developed		Non-developed	
	Efficiency		Efficiency	
Subsidies	1.314*** (0.310)	SIG & Reject	0.017 (0.012)	NOT SIG & Accept
Protection	-1.313*** (0.112)	SIG & Reject	-0.256** (0.110)	SIG & Reject
Internet	-0.001 (0.001)	NOT SIG & Accept	0.001 (0.001)	NOT SIG & Accept
Constant	-1.374*** (0.355)		-1.831*** (0.438)	
R-squared	0.230		0.210	
Observations	16,705		11,131	
Number of code1	2,315		1,461	
CODE	control		control	
YEAR	control		control	

Notes:

- t statistics in parentheses
- *** p<0.01, ** p<0.05, * p<0.1

From Table 7, it is evident that for developed regions, government subsidies have a strong positive impact on businesses' innovation efficiency, as evidenced by the regression coefficient for subsidies, which is 1.314 (p<0.01) in developed regions. This means that for each unit increase in the government subsidies innovation efficiency will increase by 1.314 units. In contrast, for non-developed regions. The government subsidies regression coefficient (Subsidies) is 0.017 (p>0.01), indicating that government subsidies have no discernible effect on the innovation efficiency of businesses in these areas.

In developed areas, intellectual property protection has a major detrimental effect (regression coefficient of -1.313, p<0.01), while in non-developed regions, the impact is smaller but still significant (regression coefficient of -0.256, p<0.05). This indicates in developed regions, the effectiveness of innovation is more significantly impacted by the degree of intellectual property protection. Scholar Carl Benedikt Frey about the negative variation in intellectual property and corporate innovation efficiency between regions are strongly supported by these data (Carl Benedikt Frey., 2023).

The rate of internet availability (Internet) has a negative impact in developed regions, however, it fails the test of statistical significance (regression coefficient of -0.001, p>0.1). In non-developed regions, the rate of internet availability (Internet) has a weak positive impact, however, it fails the statistical significance test as well (regression coefficient of 0.001, p>0.1). The views of scholar Chong Wang on the relationship between regional internet availability rates and corporate innovation efficiency are confirmed (Chong Wang & Lei Wang., 2024).

4. Suggestions

According to SOP4, based on the findings of the aforementioned empirical investigation, to improve the innovation efficiency of Chinese manufacturing firms, several guidelines should be implemented.

Firstly, governments should establish clear and comprehensive digitalization strategies that include financial incentives, technical support, and training programs tailored to both businesses that are owned by the state and those that are not. Regarding state-owned businesses, policies should emphasize deepening their digital transformation through strategic partnerships with technology firms and fostering a culture of continuous innovation. Conversely, for non-state-owned enterprises, policies should focus on creating an enabling environment by providing easy access to capital, reducing regulatory barriers, and facilitating knowledge sharing platforms.

Secondly, governments must refine their subsidy allocation mechanisms to better target innovative projects with high potential for market success. In developed regions, subsidies should be focused on advanced research and development in key technology areas, ensuring funds are allocated based on rigorous evaluations of project feasibility and expected societal benefits. In non-developed regions, subsidies should be used to build foundational infrastructure and capacity building, such as enhancing digital literacy and access to broadband internet, to create a conducive environment for long-term innovation growth. By tailoring subsidy policies to the specific needs and capacities of different regions, governments can maximize the effect of their assistance on the effectiveness of enterprise innovation.

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