Can We Improve Technological Innovation by Combining Internal and External Factors?—Based on Linkage Effect Analysis

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Abstract. Information technology is the key to enterprise development. How to realize the multi-factor linkage of technological innovation still needs to be studied deeply. Based on the configuration perspective, taking the Science innovation board companies as the research object, this paper uses the NCA and fsQCA to explore how enterprises' internal and external environments affect technological innovation and promote the development of information technology. The research shows that the development of technological innovation needs the synergy of internal and external factors, and internal innovation resources play a universal role in driving innovation performance. The high-performance innovation combination is the innovation mode assisted by research institutions and the government. The government-assisted innovation mode is more critical in improving innovation performance. Four configurations produce non-high innovation performance, which is not symmetry to the high innovation performance configuration. The conclusion of this study guides for enterprises to improve the development of information technology effectively.

Keywords: Technological innovation · Multiple concurrent factors · Information technology

1 Introduction

Information technology is the strategic support for national development. Promoting technological progress and innovation of enterprises has become a major practical problem facing the country and enterprises. Researchers have studied the factors affecting enterprise technological innovation from internal and external perspectives. From an internal perspective, scholars have found that due to the differences in innovation strategies of different firms, the degree of investment in innovation elements within organizations varies, leading to a gap between innovation vitality and effectiveness. With the further development of the concept of sustainability, scholars have found a logical relationship between the fulfillment of corporate social responsibility and corporate technological innovation. From the external perspective, scholars find that external factors such as government, universities, scientific research institutions, and regional innovation environment all impact technological innovation. This paper studies the synergistic

S. H. B. D. M. Zailani et al. (Eds.): ICMSEM 2023, 259, pp. 269–276, 2024.
https://doi.org/10.2991/978-94-6463-256-9_28

effect of the internal and external environments on technological innovation from the configuration perspective. Taking the listed companies in the first year of the Science and Technology Innovation Board as an example, NCA and fsQCA are used to discuss the influence of different linkage combinations of antecedent conditions on technological innovation at different levels.

2 Analysis Framework

Internal resources, including R&D investment [1, 8] and R&D personnel [2], provide a solid guarantee for the technological innovation of enterprises. Stakeholder theory holds that enterprises and stakeholders are interdependent and mutually restricted and advocates enterprises to fulfill their social responsibilities [3]. The triple helix theory of innovation field points out that government, enterprise, and university are the three elements of the social innovation system environment. This paper argues that government, scientific research institutions, and regional innovation environment are crucial in enterprise innovation. Government subsidy [4] is the fiscal policy that the government supports enterprise innovation. Regional innovation ability affects innovation performance through innovation policy and innovation environment [5]. Industry-university-research cooperation promotes the organic integration of various production factors needed for innovation [6, 7, 10].Many factors restrict the realization of enterprise technology innovation. We can achieve a high level of technological innovation by attaching importance to the linkage and matching between elements. Therefore, this paper introduces fsQCA and NCA to discuss the interaction of internal and external environments on enterprise technological innovation [9].

3 Research Design

This paper abandons the traditional measurement method and chooses to use NCA and fsQCA to study the internal and external factors that promote enterprise innovation.

Information technology is the core of the Science and Technology Innovation Board enterprises. This paper takes the listed companies in the first year of the Science and Technology Innovation Board as the research object, selects the technological innovation data in 2021, processes the condition variables one stage behind, and selects the data in 2020. 69 enterprises were analyzed empirically.

The result variable was innovation performance, measured by the number of patent applications derived from the company's annual report and the National Tai 'database. Condition variables are divided into internal factors and external factors. Internal factors include R&D investment, R&D personnel, corporate social responsibility, the company's annual report data, and Hexun.com's corporate social responsibility score. External factors are government subsidy, regional innovation ability, and industry-university-research cooperation. Government subsidy measures the government subsidy funds obtained by enterprises; Regional innovation capability is measured by the total utility value of regional innovation in the province where the enterprise is located. The

Table 1. Anchor points of each variable

Variable		Full subordination	Crossing point	Completely unaffiliated
Technological innovation	High	112	49	26
	No-high	26	49	112
R&D investment		15071.92	7296.33	4541.47
R&D personnel		377	198	102
CSR		25.55	22.85	20.14
Government subsidy		8293.11	3252.51	1211.10
Regional innovation ability		55.50	44.59	40.32

value of production-university-research cooperation is assigned to whether the enterprise cooperates with the double first-class universities and institutes. If there is a cooperative relationship, the value is assigned to 1; otherwise, the value is assigned to 0. The data were selected from China's regional innovation capability evaluation report and enterprise annual report.

4 Empirical Analysis

4.1 Variable Calibration

This paper takes the upper quartile, median quartile, and lower quartile as the five conditional variables and different anchors of high Technological innovation, among which the industry-academic-research cooperation is a 0–1 variable, so no calibration is done. The anchor of non-high Technological innovation is the opposite of high Technological innovation. The anchor points of each variable are shown in Table 1.

4.2 Necessity Analysis

Table 2 reports the results of the NCA necessity analysis. The six condition variables studied in this paper do not meet the requirements and are not necessary conditions for technological innovation. The bottleneck analysis results are further reported, as shown in Table 3.

Table 4 shows the test results of necessity conditions for high and non-high Technological innovation obtained using fsQCA analysis. It can be seen from Table 4 that the consistency of all conditional variables is less than 0.9.

4.3 Adequacy Analysis of Conditional Configuration

In this paper, 0.75 was selected as the consistency threshold, the frequency threshold was set as 1, and the PRI value was set as 0.6. The parsimonious solution is selected for the conditional configuration report, and the results are shown in Table 5.

Table 2. Analysis results of NCA method necessary conditions

Variable	Method	Accuracy	Scope	Effect size	P
R&D investment	CR	97.1%	1	0.015	0.000
	CE	100%	1	0.021	0.000
R&D personnel	CR	92.8%	0.99	0.085	0.000
	CE	100%	0.99	0.040	0.000
CSR	CR	100%	1	0.000	1.000
	CE	100%	1	0.000	1.000
Government subsidy	CR	97.1%	0.99	0.023	0.002
	CE	100%	0.99	0.029	0.000
Regional innovation ability	CR	100%	0.99	0.000	1.000
	CE	100%	0.99	0.000	1.000
IUR cooperation	CR	100%	1	0.000	1.000
	CE	100%	1	0.000	1.000

Table 3. Analysis results of NCA method bottleneck level (%)

Technological innovation	R&D investment	R&D personnel	CSR	Government subsidy	Regional innovation ability	IUR cooperation
0	NN	NN	NN	NN	NN	NN
60	0.3	NN	NN	NN	NN	NN
70	2.0	NN	NN	NN	NN	NN
80	3.8	12.1	NN	2.6	NN	NN
90	5.6	41.3	NN	11.3	NN	NN
100	7.3	70.4	NN	20.1	NN	NN

High Technological innovation configuration

(1) Assisted innovation mode of scientific research institutions

H1 Researcher-oriented * industry-university-research cooperation. R&d personnel is the source driving force for enterprise growth and sustainable development. Enterprises should increase the reserve of R&D personnel, give full play to the advantages of agglomeration, and form more feasible technological innovation schemes. Mutual learning and communication between R&D personnel are conducive to improving innovation enthusiasm, inspiring personal innovation inspiration, and promoting enterprise innovation exploration. At the same time, we actively carry out joint research and development so enterprises can thoroughly learn and exchange cutting-edge theories with experts and

Table 4. Necessity test

	High-Tech innovation	Non-high-Tech innovation
R&D investment	0.77	0.36
~R&D investment	0.36	0.78
R&D personnel	0.72	0.41
~R&D personnel	0.38	0.68
CSR	0.56	0.53
~CSR	0.54	0.57
Government subsidy	0.64	0.42
~Government subsidy	0.45	0.67
Regional innovation ability	0.56	0.61
~Regional innovation ability	0.54	0.49
IUR cooperation	0.52	0.30
~IUR cooperation	0.48	0.70

Table 5. Configurations that produce high and non-high Technological innovation

				High-Tech innovation	Non-high-Tech innovation			
	H1	H2	H3	H4	NH1	NH2	NH3	NH4
R&D investment		•		•	⊗	⊗	⊗	⊗
R&D personnel	•		•	•	•	⊗	⊗	
CSR			•			⊗		•
Government subsidy		⊗	•	•		⊗		
Regional innovation ability				⊗			⊗	•
IUR cooperation	•	•			⊗		•	⊗
consistency	0.89	0.96	0.88	0.93	0.82	0.89	0.86	0.88
coverage	0.39	0.12	0.34	0.29	0.17	0.25	0.16	0.24
Global consistency			0.86				0.87	
Overall coverage			0.60				0.61	

Note •Indicates that a condition variable exists, ⊗said condition variable does not exist, presence or absence of a condition variable blank areas said not to affect the outcome variables

scholars. Configuration H2 Research and development investment * ~ government subsidy * industry-university-research cooperation oriented. Adequate capital investment is the core guarantee for R&D and innovation. Meanwhile, enterprises actively cooperate with industry-university-research to improve their innovation capacity and quality. High R&D investment and industry-university-research cooperation play a linkage effect in

the making up for the shortage of external financial support, promoting technological innovation and information technology development.

(2) Government-assisted innovation model

The H3 configuration is dominated by R&D personnel * corporate social responsibility * and government subsidy. High costs and high risks characterize R&D and innovation activities. Given the financing difficulties of technology-innovation-oriented enterprises, government subsidy policies actively signal and send out the good news to help enterprise financing. At the same time, enterprises actively fulfill their social responsibilities and win the trust and support of shareholders, investors, employees, and consumers. Configuration H4 R&D input * R&D personnel * government subsidies * ~ regional innovation capability oriented. Enterprises should increase the proportion of R&D personnel and form synergy by accumulating high-quality talents to complement each other's advantages. Meanwhile, they should increase R&D investment and obtain large government subsidies to provide a robust financial guarantee for the Technological innovation of enterprises.

It can be seen that enterprises need "internal" and "external" factors to play a driving role in achieving high innovation performance. Among them, internal innovation resource factors of enterprises appear in the four configurations, play a universal role in driving high-level Technological innovation. In addition, according to the coverage index, it is found that most enterprises achieve high Technological innovation through the government-assisted innovation mode.

In order to ensure the robustness of the configuration of high Technological innovation, the consistency threshold was raised to 0.8, and the result did not change compared with that before the adjustment, indicating that the analyzed configuration results of high Technological innovation were generally reliable.

Non-high Technological innovation configuration

There are four configurations of non-high Technological innovation, the consistency of the overall solution is 0.87, and the coverage is 0.60. In addition, by comparing the above eight configurations, it is found that the factors affecting enterprise Technological innovation are asymmetrical.

5 Conclusions and Suggestions

Based on the case study of technology innovation in Chinese science and technology board companies, this paper conducts conditional configuration analysis, explores the linkage effect of R&D input, R&D personnel, corporate social responsibility, government subsidy, regional innovation capability, and industry-university-research cooperation on technological innovation, reveals the core factors affecting enterprise technological development and their complex linkage nature, and provides guidance for enterprises to promote the development of information technology. The results show that enterprise technological innovation needs the synergistic effect of internal and external factors. Innovation resources are universal in driving enterprises to achieve high-level technological innovation. In this paper, the configuration of high-tech innovation is summarized

into two innovation modes: research institution-assisted type and government-assisted type, and the government-assisted type is more likely to promote technological innovation. There are four configurations of non-high-tech innovation, There is an asymmetric relationship between the configuration of non-high-tech innovation and the configuration of high-tech innovation.

This paper puts forward the following suggestions: technological innovation is systematic engineering, and the reasons influencing technological innovation have a configuration effect. Enterprises should consider the internal links between different influencing factors rather than blindly regard one factor as the key to developing high-level technology. Enterprises should attach importance to the driving role of innovation resources to promote the development of enterprise informatization. At the same time, they are combined with the support of external forces to achieve high-quality technological breakthroughs. The government should create a fair and transparent environment for innovation, reform the system and mechanism, create a favorable external environment for technological innovation, and comprehensively promote the development of information technology. Universities, research institutes, and enterprises should give full play to their initiative in the fields they are good at and promote the development of scientific and technological innovation with the help of the IUR cooperation platform established by the government.

Acknowledgment. Project of Liaoning Education Department; Education Project of Social Science Planning Fund of Liaoning Province.

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