

Research on the Driving Path of Enterprises' Green Technology Innovation under the Group Perspective

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Abstract: With the start of the new journey of the "14th Five-Year Plan", green technology innovation has become the main theme of the new development stage. This paper takes the petrochemical industry as a sample, based on the TOE framework, and adopts the group perspective to explore the intrinsic driving path of green technological innovation in enterprises. It is found that green technology innovation needs to be matched by the linkage of technology-organization-environmental factors, and the driving paths are mainly technology-based and supportive, in which government subsidies play a central role in stimulating the willingness of green technology innovation in the petrochemical industry.

Keywords: Green Technology Innovation; Petrochemical Companies; TOE Framework; Configuration Perspective

1. Introduction

In recent years, the long-standing rough development has brought serious challenges to the high-quality development of China's economy, and how to drive enterprises to actively carry out green technological innovation has become particularly important. Based on the research of scholars at home and abroad, it can be found that most of the existing studies explore the impact of a single factor, and less explore the common impact of multiple factors, which is difficult to reveal the complex causality of green technological innovation, and the histogram perspective can better analyze the causal complexity of multi-factor concurrency. Based on this, this paper will explore the driving path of green technology innovation from the group perspective, which is of great significance to improve the awareness of green development of enterprises.

2. Theoretical foundation and framework construction

2.1 Green Technology Innovation (GTI)

GTI is a new paradigm of technological innovation centered on ecological conservation^{[2][3]}. Compared with traditional technological innovation, GTI is characterized by double externalities and requires higher capital investment and technological reserves. On the one hand, "free-riding" by latecomers will jeopardize the incentives of "first-movers" to innovate; on the other hand, insufficient regulation of polluters will lead to the fact that polluting is more profitable than greening, and the endogenous motivation of enterprises to protect the environment will be further diminished.

2.2 GTI in the framework of the TOE theory

GTI is a kind of technology adoption behavior based on the concept of ecological protection, and the technological base, organizational resources and environmental changes of enterprises all play an important role in it, so this paper tries to extend and apply the TOE framework to GTI, and constructs an integrative analytical framework containing six secondary indicators, as shown in Figure 1.

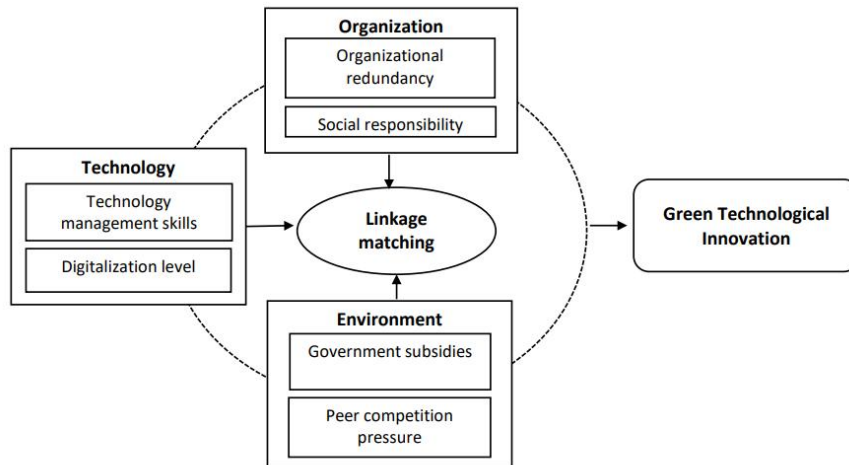


Fig 1 Green technology innovation driving model based on TOE framework

Technology management capability. In the practice of GTI, it is necessary to cultivate technology management capabilities that are compatible with green and effectively transform green technology capabilities into green technology capabilities^[4], to promote the smooth implementation of GTI through cost reduction and efficiency enhancement.

Digitization level. Enterprises with high digitization levels can provide low-cost information sources for GTI, which can effectively increase the motivation of enterprises' GTI by improving green knowledge reserves and alleviating financing constraints.

Organizational redundancy. When companies engage in GTI when organizational redundancy is more adequate, they can improve risk resilience and resource utilization.

Level of social responsibility. Signaling theory suggests that active corporate social responsibility creates a reputational effect through earnings signaling, which indirectly finances GTI.

Government subsidies. Government subsidies can directly provide firms with a partial source of funding to reduce the cost of trial and error, and thus stimulate firms' willingness to GTI.

Peer competition pressure. Under the compulsion of the peer competition effect, the incentive for firms to strengthen their own competitive advantage through GTI becomes greater, and other firms will be reluctant to imitate the same group of firms in GTI.

3. Research design

3.1 Research methodology

This paper focuses on whether there are differentiated driving paths in GTI and whether there is a substitution effect between the driving paths, which is a significant advantage of the fs/QCA approach over traditional regression analysis as it is able to show the correlation between multiple factors.

3.2 Sample selection and data processing

The petrochemical industry, as a technology-intensive industry with high requirements for environmental protection and safety, is one of the important areas in China to promote green intelligent manufacturing, so this paper selects it as a research sample.

In order to enhance the reliability of the research conclusions, this paper lags the resultant variables by one period, and analyzes the GTI of 2019-2021 based on the data of 2018-2020, and excludes the samples of enterprises with ST, PT, listed after 2018, the number of green technology patent applications in three years are all 0, and the data are missing in turn, and finally obtains 97 valid samples, involving six industries. The variable measurement and calibration methods are shown in

Table 1.

Name	Measurement method	Gauge	Calibration method
Technical Management Capability (TMC)	【R&D /Sales+High-level Talents/Total Number of Enterprises+Return on Assets】 /3	Su Rujie and Chang Yuhao ^[5]	
Digitization (DIG)	Frequency of words reported annually		
Social Responsibility (CSR)	Hexun.com rating number	Liang Yunji and Liu Bingbing ^[1]	Quartile
Organizational redundancy (OS)	[Current ratio + Administrative expenses/sales+ Owners' equity/liabilities]/3	Sharfman et al. ^[6]	
Government grants (GIV)	Government grants/total assets	Zhang Bingfa et al. ^[7]	
Market Competition (MC)	Top 5 Sales / Total Industry Sales		Assigning values 0 and 1 to the median industry concentration as a cut-off point
Green Technology Innovation (GTI)	Number of green patent applications	Liang Yunji and Liu Bingbing ^[3]	50, 10 and 1 times the value of 0.7 green patents per 10,000 people

3.3 Necessity analysis

When the consistency threshold of a particular antecedent condition is higher than 0.9, then it can be judged as being necessary for the outcome variable. As shown in Table 2, the consistency level of each antecedent condition is less than the threshold of 0.9, and no antecedent condition can constitute a necessary condition for GTI alone. This also indicates that GTI is difficult to explain adequately by a single antecedent variable, and that combining multiple antecedent conditions in a group perspective is necessary.

Table 2 Necessity analysis of single conditional variables

Conditional variable	GTI		~GTI	
	Consistency	Coverage	Consistency	Coverage
TMC	0.604458	0.282938	0.560173	0.849427
~TMC	0.678322	0.322527	0.527118	0.811928
DIG	0.544581	0.2498	0.585132	0.869487
~DIG	0.715472	0.347411	0.495143	0.778863
CSR	0.648601	0.305601	0.539126	0.8229
~CSR	0.624126	0.294798	0.539126	0.834021
OS	0.435315	0.21424	0.57218	0.912239
~OS	0.821678	0.372204	0.507151	0.744209
GIV	0.64292	0.319922	0.515246	0.830579
~GIV	0.659528	0.295766	0.578117	0.839867
MC	0.73208	0.223333	0.785888	0.776667
~MC	0.26792	0.278636	0.214112	0.721364

Note: "~" denotes a nonset of antecedent conditions

3.4 Adequacy analysis

The grouping analysis is mainly evaluated by the truth table, and three solutions with different complexity levels are obtained, and a combination of intermediate and simple solutions is adopted for the conformation. As shown in Table 3, two antecedent grouping paths are derived in this paper, and the consistency of their individual grouping paths and the overall solution is higher than the consistency threshold of fs/QCA of 0.75. Based on this, analyzing the antecedent grouping of GTI based on the TOE framework can adequately explain the results generated.

Table 3 Antecedent grouping patterns that shape high levels of green technology innovation

Conditional variable	High-level green technology innovation-driven pathway configuration	
	G1	G2
Technical Management Capability (TMC)	●	×
Level of digitization (DIG)	×	●
Social Responsibility (CSR)	×	●
Organizational redundancy (OS)		×
Government grants (GIV)	●	●
Market Competition (MC)	×	●
consistency	0.88	0.81
original coverage	0.07	0.15
Unique coverage	0.07	0.15
Overall solution coverage		0.22
Overall solution consistency		0.83

Note: ● indicates that the core condition exists; × indicates that the core condition is missing; ● indicates that the edge condition exists; × indicates that the edge condition is missing; blank indicates that the condition is optional.

Technology-based: The combination of high technology management capability as the core condition and high government subsidies as the antecedent variable can lead to a high level of GTI, which shows that despite the lack of digitization and competitive forces, enterprises will also make use of such resources as high technology management capability to promote green technological innovation and realize the leading role of green manufacturing in the interest of cost reduction and efficiency enhancement as well as consolidating their competitive position. Typical examples include Meijin Energy and Jinneng Technology. Taking Jinneng Technology as an example, it leverages its good technology management capabilities to improve resource utilization as a starting point, and develops a differentiated competitive advantage of "high-efficiency and low-carbon" through GTI, which consolidates its competitive position in the industry. The competitive position of the enterprise in the industry has been consolidated.

Supportive: It means that with the support of government subsidies and high awareness of social responsibility, the enterprise can still generate a high level of GTI with the assistance of competitive pressure and digitalization, despite the core conditions of organizational redundancy and the lack of technological management capability. As a large state-owned enterprise, Huayi Group strictly adheres to the concept of green development and integrates social responsibility into its corporate management and daily operation, which provides a reputation effect for its GTI, and at the same time, digitization and intelligent management provide the basis for GTI, which has led to fruitful results for the Group's GTI.

In summary, comparing the two paths, it can be seen that government subsidies play an important supporting role, while organizational redundancy does not have a significant facilitating effect on corporate GTI. Among them, high technology management capability has a slight offsetting effect on government subsidies, but the combination of high level of social responsibility, market competition and digitization can offset the promotion effect of high technology management capability on GTI, and the two paths are in the same direction. At the same time, both driving paths require the combined effect of "technology-organization-environment", which confirms the rationality of the application of the TOE framework and provides different options for corporate GTI.

4. Conclusions and recommendations

The conclusions of the study are as follows: ① None of the technological-organizational-environmental factors alone can constitute a necessary condition for high GTI. However, government subsidies are an important source of motivation for petrochemical companies to conduct GTI. ② The groupings that generate high levels of GTI can be categorized into 2 types, technical and enabling driving paths, confirming the diversity and complexity of GTI influencing factors. ③ The technical and enabling drive paths are both related and different. The technical drive focuses mainly on the internal technical management capability of the organization, while the enabling drive mainly comes from the combination of external influences and internal resources, which better reflects the joint matching role of the three parties.

Based on the above conclusions, the following recommendations are made: ① Technical level: Enterprises should improve their R&D resource investment and green technology management capability, especially focusing on the accumulation of R&D talents to provide guarantee for the transformation of GTI achievements. ② Organizational level: Enterprises should actively respond to the national green call, put social responsibility into practice, and bring practical benefits to enterprises through reputation capital. ③ Environmental level: the government should increase the subsidies for petrochemical enterprises' GTI and solve the practical financial problems for enterprises' GTI. For the petrochemical industry, green technology has a strong industry attributes, need to invest in higher costs, capital is often the reason why it is deterred from GTI, therefore, it is necessary to be based on the industry to develop government subsidy policy for petrochemical enterprises GTI to remove the worries.

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