# Technical Innovation and Innovation Performance: The Mediating Role of Green Innovation Strategy and the Moderating Effect of Organizational Learning Culture

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**Abstract**

This study investigates the mediating role of green innovation strategy in the relationship between technical innovation and innovation performance, with the moderating role of organizational learning culture. While previous research has examined green innovation and technical innovation independently, limited empirical evidence exists on the mechanisms through which green innovation strategy transforms technical inputs into performance outcomes. A mixed-method approach, combining quantitative survey data and qualitative interviews, was employed to validate a structural equation model encompassing technical innovation, green innovation strategy, innovation performance, and organizational learning culture. The study found that green innovation strategy significantly mediates the impact of technical innovation on innovation performance. Furthermore, organizational learning culture strengthens the effects of both technical and green innovation strategies on innovation outcomes. The research provides theoretical insights for SMEs seeking sustainable innovation performance and strategic guidance for enhancing internal innovation culture.
Keywords: Green innovation strategy; Technical innovation; Innovation performance; Organizational Learning Culture

## 1. Introduction

In the era of accelerated technological advancement and increasing environmental challenges, innovation performance has emerged as a critical determinant of organizational competitiveness, sustainability, and long-term value creation. It is broadly understood as the extent to which an organization successfully translates innovative capabilities, behaviors, and strategies into tangible outcomes (Amabile, 1983; Gruber & Wallace, 1999). However, innovation performance is a complex and multidimensional construct, often categorized into outcome-based, capability-based, and behavior-based perspectives. These frameworks reflect not only what organizations produce, but also how they think, behave, and strategize in the face of change.

Among the primary drivers of innovation performance is technical innovation, defined as the development, application, and commercialization of new products, processes, or services (Schumpeter, 1934; Freeman, 1973). It reflects an organization's capacity to transform technological ideas into market value. However, technical innovation alone may not guarantee superior innovation outcomes, especially in a business environment increasingly influenced by ecological and sustainability considerations.

To address these emerging demands, firms are adopting green innovation strategies, which incorporate environmental sustainability into innovation efforts. Green innovation includes eco-friendly products, cleaner production processes, and environmental management practices that reduce ecological impact while enhancing business performance (Chen et al., 2006; Aboelmaged, 2018). It serves as both a strategic response to regulatory and market pressures and a mechanism for sustainable value creation. As such, green innovation strategy is recognized as a mediating force that connects technical innovation inputs with desirable innovation outputs in contemporary business models.

Nonetheless, the efficacy of both technical and green innovation strategies often hinges on the organization’s internal culture and learning capacity. Organizational learning culture—a system of shared values, practices, and norms that support continuous knowledge acquisition and application—plays a critical role in enabling firms to adapt, innovate, and sustain competitive advantage (Senge, 1990; Jerez-Gómez et al., 2005). Firms with strong learning cultures tend to integrate knowledge more effectively,

promote creativity, and align innovation efforts with long-term strategic goals. This study thus proposes a comprehensive research model that explores:

- the direct effect of technical innovation on innovation performance,
- the mediating role of green innovation strategy, and
- the moderating effect of organizational learning culture.

By incorporating these constructs, the research aims to contribute to a deeper understanding of how internal capabilities and environmental strategies collectively shape innovation outcomes, particularly in the context of small and medium-sized enterprises (SMEs).

**Objective**

To assess the conditional indirect (moderated mediation) effect of technical innovation on innovation performance through green innovation strategy at different levels of organizational learning culture.

## 2. Literature review and hypothesis development

### Green Innovation Strategy (GIS)

SDGs are a company agenda in exploring renewable energy opportunities, through a green innovation strategy companies can balance sustainability performance, becoming a challenge in solving environmental problems so that sustainability competitive advantage (SCA) can be achieved through company options in adopting a green innovation strategy. GIS has been proven to achieve sustainable development (De Resende Ribeiro & Neto, 2021) . The following is a definition of green innovation strategy that is universally accepted. With the international and domestic society's advocacy of green and sustainable development for enterprises, domestic and foreign scholars. More and more attention has been paid to the green innovation strategy that brings competitive advantage and performance improvement to the industry, but the academic circle has not yet formed a broad consensus on the connotation of green innovation strategy. According to existing research, scholars also refer to green innovation strategy as environmental innovation strategy, sustainable innovation strategy and ecological innovation strategy.

It can be concluded that research on green innovation strategies has only begun to flourish in recent years. Different scholars define the connotation of green innovation strategy differently, but they generally believe that green innovation strategy is based on the consideration of environmental protection and sustainable development of enterprises, and managers try to reduce the impact of enterprise production practices on the environment through green production and operation behaviors. The negative impact of strategic choices. Although scholars have defined the connotation of green innovation strategy from different perspectives, at present, green innovation strategy has not yet formed a definition widely recognized by the academic community. Through sorting out and summarizing the existing research content, this study believes that the green innovation strategy emphasizes that enterprises can reduce the negative impact of production practices on the environment through innovative means and methods, and try to integrate new knowledge, new technology or new management. In terms of methods and other aspects, it creates new profit points and differentiated competitive advantages for enterprises. Therefore, this paper integrates the related research on environmental strategy, forward-looking environmental strategy, green innovation, and green innovation strategy, and draws lessons from scholars such as Eiadat et al. (2008), Tomomi (2010), Zhang Gang and Zhang Xiaojun (2014) [32], Chen et al. (2006). From the point of view, the green innovation strategy is defined as a kind of green innovation in products and processes to weaken the adverse impact of enterprise production and operation practices on the environment, bring unique competitive advantages and profitability to enterprises, and realize sustainable development of enterprises active environmental strategy.

### Technical innovation (TI)

#### Definition of technical innovation

Schumpeter (1912) pioneered the concept of innovation in his book "The Theory of Economic Development." He classified innovation into five cases: the introduction of a new product, the adoption of a new production method, the opening of a new market, the acquisition of new sources of supply for raw materials or intermediate goods, and the establishment of a new industrial organization. He believed that the essence of technical innovation lies in the recombination of production factors. Subsequently, different scholars have further enriched the connotation of technical innovation. Enos (1962) first explicitly defined Technical innovation, stating that it is "the result of a combination of several different activities, generally including the manufacture and certification of new inventions, obtaining funding,

establishing factories, employing managers and workers, market development, and production and distribution." Freeman (1973) defined Technical innovation in his article "Success and Failure in Industrial Innovation" as "the whole process of technology, process, and commercialization, which leads to the realization of new products in the market and the commercial application of new technological processes and equipment."

Although Technical innovation has received extensive attention and research by scholars, there is still no unified view on the concept of technical innovation. Based on an analysis of over 300 literature sources on Technical innovation, Mueser (1985), an American scholar, proposed his own understanding of Technical innovation, highlighting two aspects: novelty of the concept and successful implementation. He believed that technical innovation is a series of meaningful discontinuous events. Liu (1993) defined Technical innovation as activities related to the first commercial application of new products, new process techniques, or equipment, including product innovation, process innovation, and diffusion. Process innovation, also known as process technology innovation, refers to the transformation of production technology. Product innovation refers to the commercialization of products with technological changes. Fu (2000) provided a new definition of Technical innovation in his article, stating that it refers to the means by which companies explore and utilize potential business opportunities in the market through Technical innovation. It involves the recombination of old production methods, resulting in a new system that is more efficient and profitable. However, its essence is for commercial profit, achieved by reducing production costs, improving work efficiency, opening new markets, and supplying new materials to new companies, which is the embodiment of the commercialization process of technical innovation. Ren (2018) believes that technical innovation is a complete process from innovation input to the commercialization of new products. This "process perspective" suggests that the content of technical innovation should include the research and formation process of new inventions and creations, as well as the application and implementation process. The process of commercializing new technological achievements should also be included. Qiao (2021) argues that Technical innovation should encompass a series of creative activities, including basic scientific research, technological experimentation and application, and business practices. It is not just a technical means but also an application oriented towards the market, and it should be viewed from an "economic perspective" and an "industrial perspective." Chege et al. (2020) suggest that Technical innovation includes various creative aspects such as the introduction of new processes, new products, or new services; research and development investments; and technological progress. Bu (2021), from the perspective of tourism products, defines Technical innovation as the identification and development of new products to meet market demands. It refers to a new item or service that is perceived by the market. Innovation forms are not limited to tangible objects but also include intangible services. Du (2021) views Technical innovation from a product perspective, stating that it is the subjective judgment of consumers that a particular product is distinguished.

Based on the above analysis, the concept of technical innovation can be traced back to the early 20th century. Through a review of previous literature, it is evident that the formation of the concept of technical innovation has undergone a lengthy process. Despite extensive research by scholars from various perspectives, there is still no unified view on the concept of technical innovation. Based on the research conducted in this article, technical innovation is defined as the process of identifying and developing new products to meet market demands. It involves the reorganization of production conditions and factors in practical production activities, as well as the creative application of knowledge, experience, and skills accumulated through scientific experimentation and production processes. This process encompasses product innovation, process innovation.

**Dimensions of technical innovation**

According to different criteria and dimensions, technical innovation can be classified into different types. Based on the intensity of innovation, Freeman & Soete(1997) creatively divided technical innovation into incremental and radical innovation. Building upon this, Christensen & Rosenbloom (1995) elaborated on the differences between these two types and traditional innovation in terms of "value system change." Li Aimei (2019), in her study on the impact of different types of product innovation on consumers' willingness to share content and engage in cooperative innovation, also categorized technical innovation into incremental and radical innovation. Tushman & Nadler(1986) approached technical innovation from the perspective of enterprise products and proposed that it includes both product innovation and process innovation. Since then, more and more scholars have divided technical innovation into product innovation and process innovation (Yang, 2021; Han, 2017; Zhang, 2021). Fu (1993) classified technical innovation into three types: independent innovation, collaborative innovation, and imitative innovation, based on the different subjects of technical innovation within enterprises. Zhang et al. (2010) argued from the perspective of the connotation and extension of technical innovation that, in addition to the development of new products or processes, Technical innovation

should also encompass changes in organization and market. Fang (2021), in his exploration of the impact of Technical innovation on the quality of export products in Guangdong Province's manufacturing industry, divided Technical innovation into the dimensions of product innovation, process (technological) innovation, market innovation, organizational innovation, and institutional innovation. Chege et al. (2020), in their discussion of the influence of technical innovation on the performance of small and medium-sized enterprises in the context of sustainable environmental practices in Kenya, included three aspects: product innovation, process innovation, and market innovation. This article has compiled various scholars' classifications of the dimensions and types of technical innovation.

In summary, numerous scholars from various fields and perspectives have discussed the connotations and dimensions of technical innovation, affirming the "process view" of Technical innovation. This "process innovation" specifically involves significant changes in technology, equipment, or software. The intensifying market competition drives equipment manufacturing companies to continuously update their products. How to achieve product innovation has attracted increasing attention, and Technical innovation is closely related to product innovation, process innovation, and market innovation.Narrowly defined Technical innovation refers to Technical innovation that includes product and process innovation. However, the broader perspective suggests that it should also include management innovations such as market, policy, and institutional changes. Considering the focus of this study in the field of marketing, the main references would be Chege & Wang (2020), Zhang et al. (2010), and Fang (2021), who argue that technical innovation encompasses product innovation, process innovation, and market innovation.

**Innovation Performance (IP)**

In the era of the knowledge explosion, innovation means staying competitive, and innovation performance becomes a representation of the outcome of innovation and is increasingly valued by knowledge-intensive team organizations. Amabile, Nystrom (1993), and others have argued that individual innovation performance is the basis for embodying the ability to generate innovation and actual innovation. Existing research has been conducted on the individual innovation characteristics of individuals, as well as the contextual factors that enhance innovation, and the interaction between the two.

**Definition of Innovation Performance Measurement**

Existing studies have concluded that innovation performance focuses on two core characteristics, uniqueness and usefulness, and therefore, there are various measurement theories developed around these two characteristics. Min-Yang Han (2014) identified knowledge traits, thinking traits, personality traits, and behavioral traits as the four sub-dimensions of innovation capability. Jihong Xu (2016) argued that innovation capability includes a common element of innovative personality, knowledge structure, innovative thinking, and innovative practice.

This study agrees with the implicit and explicit theories about Amabile innovation, and innovation performance measurement should be divided into two major parts: explicit performance (i.e., innovation outcomes) and implicit performance (innovation motivation, innovation personality, and innovation thinking).

**Motivation for innovation**

The most indispensable factor for achieving the quality of an individual's innovative performance is a strong motivation to innovate, which is the source of motivation and the basis for the implicit part of innovative performance. According to Amabile's (1997) theory, innovation motivation is measured in two categories: internal motivation and external motivation; Amabile suggests that internal motivation should reflect the degree to which an individual focuses on the original challenge of the job and derives self-drive from it, while external motivation should reflect the fact that an individual engages in a job mainly to achieve some purpose other than the job, such as reward, gaining external satisfaction, etc., which is more The focus on external motivation, praise, is oriented to the outside of the job. Thus, internal motivation to innovate has been considered as a personality trait that contributes to the development of innovation, while external motivation is an incentive to innovate, which indirectly enhances internal motivation to innovate and thus drives up the level of performance. Internationally, the measurement of innovation motivation commonly utilizes the Job Preference Scale developed by Amabile et al. This scale facilitates the identification of intrinsic and extrinsic motivation characteristics, including intrinsic motivation such as curiosity, self-determination, commitment to the task, competence, pleasure, and interest, and extrinsic motivation such as evaluation, concern for competence, expectation of specific inducements, expectation of recognition, and external constraints. This study agrees with Amabile's theory on the categorical measurement of innovation motivation, and measures innovation motivation into two aspects: internal innovation motivation and external innovation motivation. Since

the research subjects are college students, their identities are different from those of the Amabile Job Preference Scale, and different from those of full-time workers, combining the identity characteristics of school students and the Chinese university context, the internal motivation and external rational matching should be The question items of the Job Preference Scale were modified by deletion.

**Innovative personality**

Innovative personality, also known as innovative personality, is an important personal attribute of an individual for high innovative performance to function successfully, including self-efficacy. It corresponds to Creativity-Relevant Processes in Amabile's Componential Theory of Creativity. Existing research on the theory of innovative personality is divided into two main branches: one branch is under the presence theory, which considers innovative behavior as a product of the interaction between personality and environment, to divide innovative personality into two parts: personality and environment; the other is based on the affective domain, which argues that innovation requires a great deal of total commitment, great cost and effort, and responsibility (Pervin & John, 1999). In research measurements, innovative personality is measured in four areas: thinking flexibility, drive, ambition, achievement motivation, and social traits such as assertiveness, arrogance, hostility, self-confidence, autonomy, introversion, and independence (Bland et al., 2006). In China, it has been suggested that for students, innovative individuals should consist of five elements such as curiosity, challenging, exploratory, willpower, and self-belief (Shen, 2005).

To gain a comprehensive understanding of the factors that contribute to innovation, it's important to go beyond an individual's psychological perceptions of their social environment and consider their personal characteristics. Each person may have a different approach to the same social environment or event, which can affect their creativity and training outcomes. These differences can be attributed to unique creative traits and expressions among individuals. Therefore, it's reasonable to assume that the same social environment or event may yield significantly different outcomes depending on the orientation of the individuals involved (Hennessey & Amabile, 1988). Individual orientation is also strongly linked to the outcomes or products of creative performance and training (Besemer & O'Quin, 1987). To establish a relationship between creative performance and college students, it's essential to consider not only their creative personality but also traits such as teamwork and determination.

**Innovative thinking**

Innovative thinking is the reflection of innovation in the development of thinking, which is the core element of the implicit part of the innovative performance of college students, reflecting the process of advanced integrated activities of thinking in which college students break the constraints of thinking and seek new solutions to problems on the basis of existing knowledge. The GuilFord theory, which has a great influence in the field of thinking, believes that the measurement of innovative thinking can be divided into two dimensions: divergent thinking and convergent thinking, divergent thinking generally consists of imaginative thinking and intuitive thinking, which reflects the intuitive perception of individuals without relying on definite logical reasoning, and intuitive thinking mainly reflects personal insight and understanding of things; convergent thinking is based on logical thinking and focuses on the relationship between things. Convergent thinking is based on logical thinking, focusing on the disconnectedness of things, focusing on problem solving, and is a kind of convergent thinking with organization and scope. In contrast, Chinese scholars (Guiqing Qian, 2008) and others believe that innovative thinking should be composed of logical thinking, non-logical thinking and inspiration. Logical thinking, also known as abstract thinking, reflects the use of traditional formal logic rules, the information obtained from perceptual cognition into abstract concepts, reasoning in accordance with certain logical relationships to form a new cognitive thinking ability; non-logical thinking, also known as image thinking, mainly reflects the individual's inner mental activity, from information processing, representation, intuition, imagination and other thinking ability to grasp and understand the essence of the object from the image; inspiration also called epiphany, reflects the individual's brain in a sudden whim, suddenly find a new way to solve the problem thinking ability.

High-quality and productive thinking is commonly referred to as creative thinking, which plays a vital role in our lives (Paul & Elder, 2019). As noted by Hadar and Tirosh (2019), creative thinking involves the capacity to generate novel ideas or solutions while problem-solving. According to Munandar (2004), the traits of creative thinking comprise of (1) fluency, which encompasses the ability to generate ideas, solve problems, and provide answers to questions; (2) flexibility, which involves the capacity to produce multiple ideas, answers, and solution strategies; (3) originality, which pertains to the ability to think in unconventional ways to generate unique and innovative expressions; and (4) elaboration, which involves the ability to refine and enrich ideas, making them more fascinating and detailed.

This study starts from the localization of innovative thinking, combines the development characteristics of college students' own thinking, and agrees with Qian Guiqing et al. (2008) that the

development of innovative thinking of graduate students should be based on the comprehensive development of all thinking in the Chinese university context, about the innovative thinking measurement from two aspects of problem identification and problem solving, while adding the thinking performance of college students when they encounter academic difficulties, such as calmness, etc. .

**Organizational Learning Culture**

Organizational learning culture refers to the values, practices, and systems that encourage continuous learning, knowledge sharing, and the pursuit of improvement within organizations. Senge (1990) emphasizes that a "learning organization" is one that facilitates the learning of all its members and continuously transforms itself to adapt and respond to external changes. In the context of innovation, learning culture enhances a firm's ability to absorb new knowledge and apply it creatively to products, services, and processes (Jerez-Gómez et al., 2005).

Research shows that learning-oriented organizations are more likely to succeed in implementing technical and green innovations due to their openness to experimentation and systemic thinking (López-Muñoz et al., 2022). These cultures enable employees to question existing routines, integrate sustainability into strategic planning, and accelerate the translation of innovation inputs into outcomes. Thus, the inclusion of organizational learning culture in the innovation framework can offer insights into how internal dynamics amplify or weaken innovation performance.

**Moderating Role of Organizational Learning Culture**

The effectiveness of technical innovation and green innovation strategy often depends on how knowledge is managed and applied within the firm. Organizational learning culture moderates the relationship between green innovation strategies and performance by promoting collaboration, knowledge exchange, and strategic alignment (Nonaka & Takeuchi, 1995). For instance, firms with strong learning cultures are better positioned to overcome resistance to green technologies and to adapt their technical innovations to market and regulatory changes.

Empirical studies support this assertion. Chen et al. (2014) found that environmental innovation performance is significantly enhanced in firms where learning and knowledge flow are prioritized. Similarly, organizations that emphasize continuous learning and feedback mechanisms are more capable of exploiting technological innovations for sustainable outcomes. Therefore, integrating organizational learning culture into the conceptual model addresses the "how" behind innovation implementation and performance realization.

H4 is based on the premise that organizational learning culture enhances firms' ability to integrate and apply technical innovations (Nonaka & Takeuchi, 1995).

H5 suggests that green innovation strategies are more effective in improving performance outcomes when an organizational learning culture is present, as it facilitates knowledge flow and alignment across functional units (López-Muñoz et al., 2022).

**Development of Hypothesis**

From the review of literature and related research, the researcher also studied articles from Suwandej, N., Thongves, M., & Kleebbuabarn, N. (2024, November). THE EFFECT OF TECHNICAL INNOVATION ON INNOVATION PERFORMANCE IN SMES: THE MEDIATING OF GREEN INNOVATION STRATEGY. In International Conference" Actual economy: local solutions for global challenges" (pp. 40-51). to improve and develop a new research framework by adding variables that are important for the development of the research framework. The researcher has studied additional literature and related research, which found that there are important variables that affect the independent variables, mediating variables, and dependent variables, which are control variables. The importance of all variables can be summarized as follows:

Independent Variable: Technical Innovation (Process Innovation, Product Innovation)

Mediating Variable: Green Innovation Strategy (Green Product Innovation, Green Process Innovation, Green Management)

Moderating Variable: Organizational Learning Culture (Knowledge Sharing, Continuous Learning)

Dependent Variable: Innovation Performance (Motivation Innovation, Innovative Personality, Innovative Thinking). The hypothesis development is as follows:

Hypothesis 1: Technical innovation positively influence Innovation performance.

Hypothesis 2: Technical innovation positively influence Green innovation strategic.

Hypothesis 3: Green innovation strategic positively influences Innovation performance.

Hypothesis 4: Organizational learning culture positively moderates the relationship between technical innovation and innovation performance.

Hypothesis 5: Organizational learning culture positively moderates the relationship between green innovation strategy and innovation performance.

The overall research hypothesis framework is shown in Figure 1.

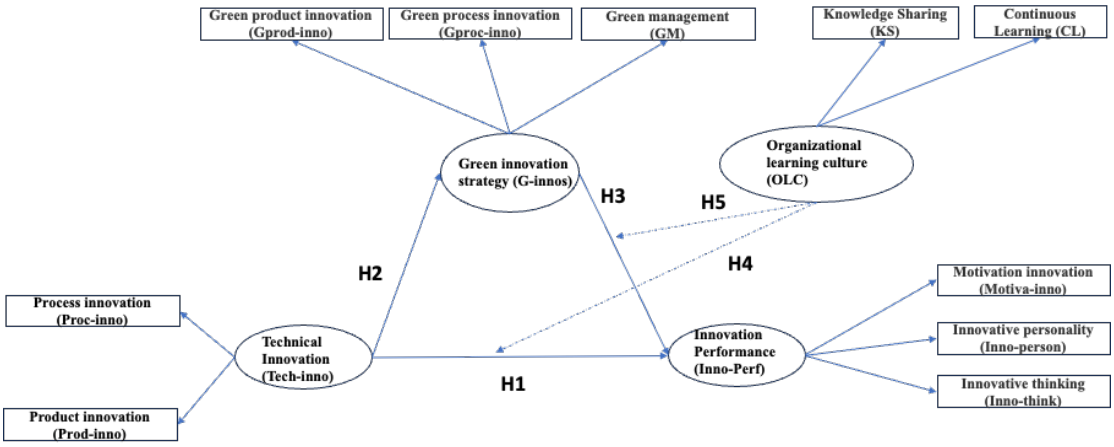


Figure 1: Overall Research Hypothesis Framework Diagram

## 3. Research Methodology

In order to test the study hypotheses and the suggested investigation strategy, a structured questionnaire was used to gather data (see Fig. 1). In the first semester of 2025, 400 questionnaires were sent to a convenience sample of Thai SMEs using data gathered from SME business associations. A key informant in each company was contacted and asked to complete the questionnaire, which was then delivered in-person using a snowball technique. Each respondent was requested to find three to five additional respondents and assist in contacting them until the full sample was obtained. Of them, 47% had between 21 and 50 employees, 23% had between 51 and 100 employees, 7% had between 101 and 200 employees, and 23% were from businesses with less than 20 employees. According to the legal constitution, private limited corporations accounted for 35%, limited partnerships for 46%, and single shareholder companies for 19%.

**Quantitative Phase**

In the quantitative phase, a structured questionnaire was developed based on established scales from prior literature. The survey instrument measured four principal constructs:

**Table 1: Definition of Constructs and Measurement Items**

| Construct (Abbreviation) | Observed Variables / Indicators |
|---|---|
| Technical Innovation (Tech-inno) | • Process innovation (Proc-inno)<br>• Product innovation (Prod-inno) |
| Green Innovation Strategy (G-inno) | • Green product innovation (Gprod-inno)<br>• Green process innovation (Gproc-inno)<br>• Green management (GM) |
| Organizational Learning Culture (OLC) | • Knowledge Sharing (KS)<br>• Continuous Learning (CL) |
| Innovation Performance (Inno-Perf) | • Motivation innovation (Motiva-inno)<br>• Innovative personality (Inno-person)<br>• Innovative thinking (Inno-think) |

The instrument used was a questionnaire with a measurement using a Likert scale of 1-5 used to measure each variable indicator. Statements were designed based on the dimensions and indicators of each variable. Before data collection, the instrument was tested through content validity involving experts using the confirmatory factor analysis (CFA) reliability test, which measured Cronbach's alpha and composite reliability.

Data analysis techniques This study uses Smart PLS version 4.1.0.9 (Hair et al., 2019), a statistical tool for testing data through PLS-SEM. The reason for choosing this analysis approach is based on data/sample features and moderation and mediation analysis. Data Analysis Techniques Using SEM-PLS (Hair et al., 2024) include three stages, namely: Measurement Model (Outer Model)

Evaluating the relationship between latent variables and their indicators. Testing includes Convergent Validity, which is seen from the outer value loading ($\geq 0.7$) and Average Variance Extracted (AVE) ($\geq 0.5$)—discriminant Validity Using Fornell-Larcker values Criterion. Construct Reliability Using Composite Values Reliability ($\geq 0.7$) and Cronbach's Alpha ($\geq 0.6$).

Responses were collected from a purposive sample of managers and executives in small and medium-sized enterprises (SMEs) across manufacturing and service sectors. Data were analyzed using Structural Equation Modeling (SEM) to test the hypothesized relationships, confirm measurement validity, and assess mediation and moderation effects. Specifically:

- Bootstrapping methods were applied to test the mediating role of green innovation strategy.
- Interaction analysis tested the moderating role of organizational learning culture.

## 4. Analysis and Results

Partial Least Squares Structural Equation Modeling (PLS-SEM), a reliable statistical method appropriate for analyzing complex models with latent constructs, especially when the data distribution is non-normal and the sample size is relatively moderate, was used to analyze the data using SmartPLS software version 4 (Subhaktiyasa, P.G.(2024). In order to manage several mediators and a moderator within a single-model framework, PLS-SEM was used due to its aptitude for predictive modeling. A non-parametric bootstrapping approach with 5000 resamples was carried out, as advised by (Hair et al., 2019), to guarantee the validity of the path coefficient estimations and significance testing. By producing bias-corrected confidence intervals for each model estimate, this method improves the statistical inference's resilience. Two phases of the analysis were carried out: a measurement model assessment to verify construct validity and reliability, and a structural model evaluation to examine the proposed links.

### 4.1 Measurement Model Assessment

The evaluation of the measurement model involves assessing reliability (indicator and internal consistency) and validity (convergent and discriminant).

Table 1: Measurement Model Results

| Construct | Items | Loadings | Cronbach's α | CR (rho_c) | AVE |
|---|---|---|---|---|---|
| Technical Innovation (TI) | 10 items | 0.796–0.853 | 0.957 | 0.957 | 0.691 |
| Green Innovation Strategy (GIS) | 15 items | 0.700–0.851 | 0.957 | 0.956 | 0.595 |
| Innovation Performance (IP) | 15 items | 0.458–0.870 | 0.964 | 0.966 | 0.655 |
| Organizational Learning Culture (OLC) | 10 items | 0.568–0.873 | 0.942 | 0.943 | 0.625 |

Interpretation: As shown in Table 1, all factor loadings exceed the threshold of 0.70, except for a few indicators in GIS which remain above 0.60 and were retained to ensure content validity. Internal consistency is established as both Cronbach's Alpha and Composite Reliability (CR) for all constructs are above 0.70. Furthermore, the Average Variance Extracted (AVE) for all constructs is greater than 0.50, confirming convergent validity.

Table 2: Discriminant Validity (HTMT Ratio)

| Construct | GIS | IP | OLC |
|---|---|---|---|
| GIS | 0 | | |
| IP | 0.702 | 0 | |
| OLC | 0.777 | 0.681 | 0 |
| TI | 0.692 | 0.993 | 0.666 |

Interpretation: Discriminant validity was assessed using the Heterotrait-Monotrait (HTMT) ratio. While most values are below the 0.85 threshold, the ratio between Technical Innovation and Innovation Performance (0.993) suggests a lack of discriminant validity between these two specific constructs in this sample, indicating they may share a high degree of conceptual overlap.

### 4.2 Structural Model and Hypothesis Testing

The structural model (inner model) was assessed in the second phase of the PLS-SEM analysis after the measurement model's validity and reliability had been established. This procedure evaluates the theoretical foundation and the potency of the proposed connections among the latent constructs.

As shown in Table 3 of Figure 2, the results demonstrated that Technical Innovation (TI) was significantly and positively associated with Innovation Performance (IP) ($\beta = 0.954$, $t = 47.13$, $p = 0.000$), supporting H1. Additionally, Technical Innovation (TI) significantly enhanced Green Innovation Strategy (GIS) ($\beta = 0.695$, $t = 16.996$, $p = 0.000$), thus supporting H2. In turn, Green Innovation Strategy (GIS) was not significantly related to Innovation Performance (IP) ($\beta = 0.016$, $t = 0.654$, $p = 0.513$), no support for H3. Furthermore, Organizational Learning Culture (OLC) not significantly promoted Innovation Performance (IP) ($\beta = 0.023$, $t = 0.977$, $p = 0.329$), thus no support H4.

Table 3: Path Coefficients and Hypothesis Testing

| Hypothesis | Path | β | T-Statistic | P-Value | Result |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| H1 | TI → IP | 0.954 | 47.13 | 0.000*** | Supported |
| H2 | TI → GIS | 0.695 | 16.996 | 0.000*** | Supported |
| H3 | GIS → IP | 0.016 | 0.654 | 0.513 | Not Supported |
| H4 | OLC → IP | 0.023 | 0.977 | 0.329 | Not Supported |
| H5 (Mod) | OLC x TI → IP | -0.016 | 0.85 | 0.395 | Not Supported |
| H6 (Mod) | OLC x GIS → IP | -0.003 | 0.169 | 0.866 | Not Supported |

Note: *** p < 0.001 (Confidence Interval 95%)

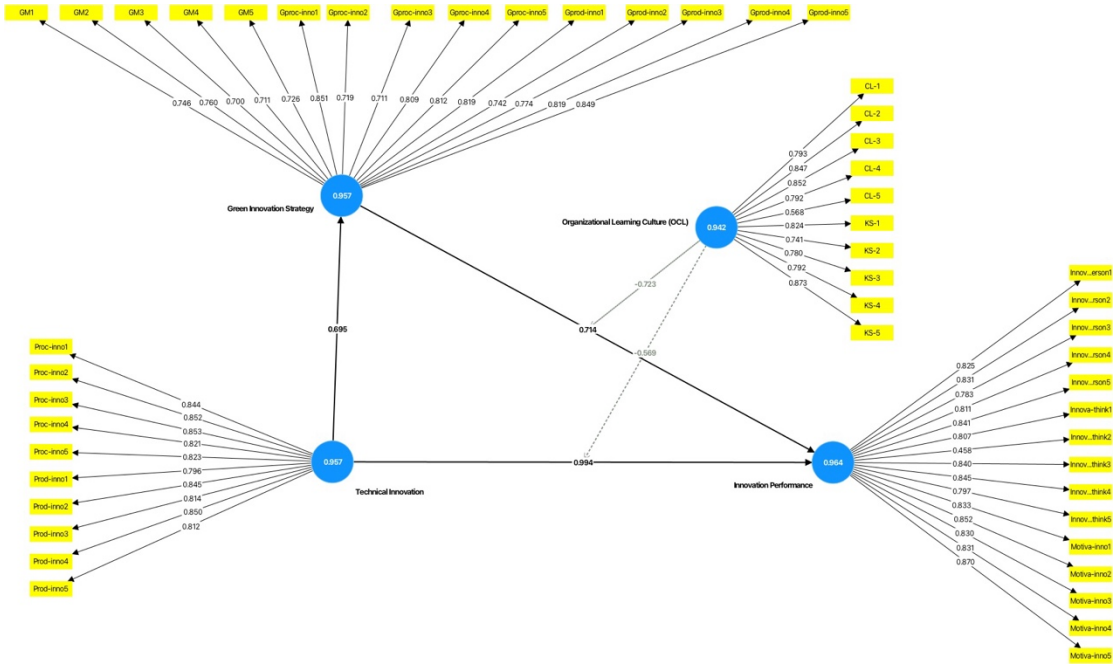


Figure 2: Structural model estimation. Note(s): Technical Innovation (TI), Green Innovation Strategy (GIS), Innovation Performance (IP), Organizational Learning Culture (OLC)

### 4.3 Moderation Role Results of Organizational Learning Culture (OLC)

The moderating impacts of Organizational Learning Culture (OLC) on the connections between Innovation Performance (IP) and Green Innovation Strategy (GIS) were investigated in this study. Organizational Learning Culture (OLC) did not positively moderate the relationship between Technical Innovation (TI), Green Innovation Strategy (GIS), and Innovation Performance (IP) ($\beta = -0.016$, $t = 0.850$, $p = 0.395$) and ($\beta = -0.003$, $t = 0.169$, $p = 0.866$), according to the PLS-SEM results in Table 3 using the product indicator method. This did not support H5 and H6. This conclusion is depicted in Figure 2. A positive strengthening moderation pattern may be seen in the interaction plot. In particular, the slope corresponding to high OLC levels (+1 SD) is steeper than the slope corresponding to low levels (−1 SD). This suggests that the beneficial impact of green innovation strategy on innovation performance grows as organizational learning culture rises. While the incremental gains in innovation performance are significantly larger at high OLC levels, the increase in innovation performance across increasing GIS values is very modest at low OLC levels. This finding, illustrated in Figure 3 and Figure 4.

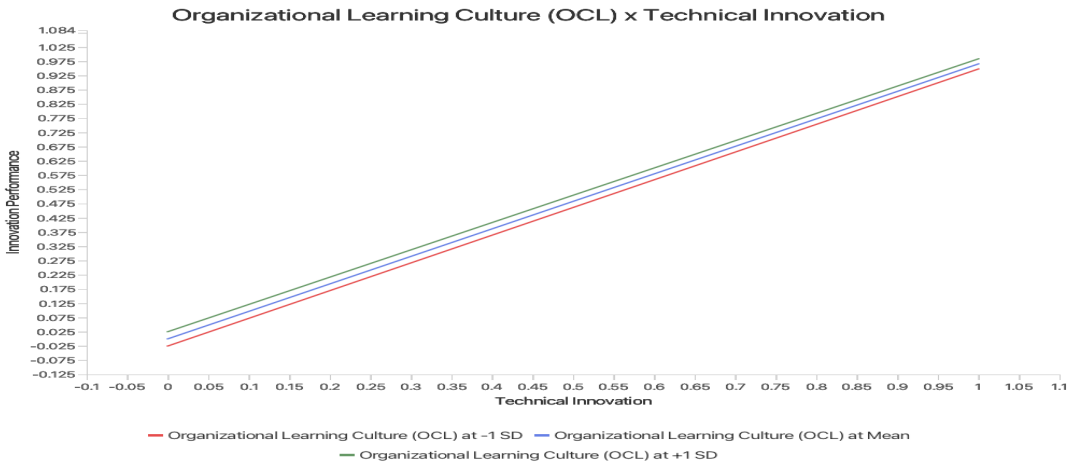


Figure 3. The interaction role of Organizational Learning Culture (OLC) in the relationship between Green Innovation Strategy (GIS) and Innovation Performance (IP).

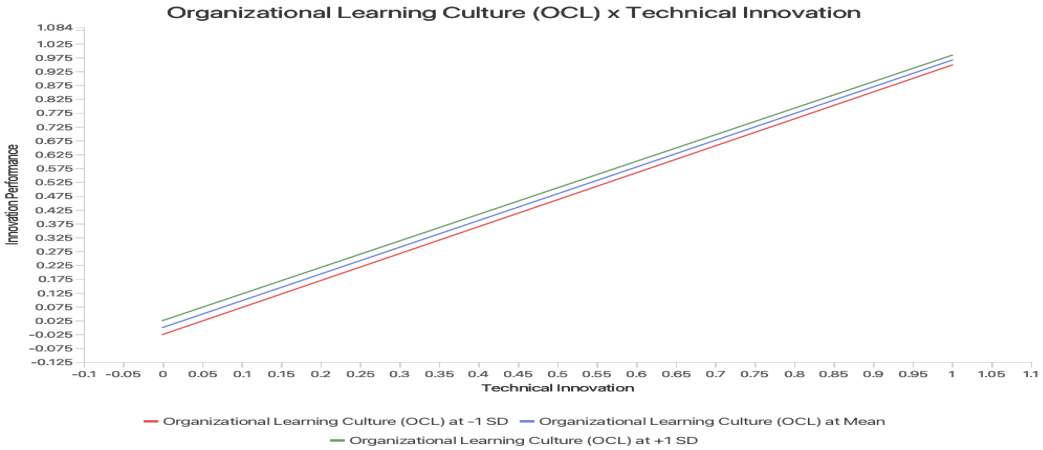


Figure 4. The interaction role of Organizational Learning Culture (OLC) in the relationship between Green Technical Innovation (TI) and Innovation Performance (IP).

## 5. Discussion and Conclusion

The empirical results of this study provide a nuanced understanding of the drivers of Innovation Performance (IP). While some hypotheses were strongly supported, the non-significance of others offers critical insights into the current state of organizational innovation within the sampled context.

### 5.1 Discussion

The most notable result is that Technical Innovation (TI) has a significant impact on Innovation Performance ($\beta = 0.954$, T 47.130, $p < 0.000$). This suggests that the major driver of organizational performance is still the technology core. Moreover, Tl significantly precedes Green Innovation Strategy (GIS) ($\beta = 0.695$, $T = 16.996$, $p < 0.000$), indicating that technical competence offers the framework required to embrace environmental projects. The high HTMT score (0.993) between Tl and IP, however, indicates that respondents view technical competence and performance as being almost interchangeable, which may call for additional conceptual development in subsequent research.

Remarkably, there were no discernible direct effects of Organizational Learning Culture (OLC) or Green Innovation Strategy (GIS) on Innovation Performance ($p = 0.329$ and 0.513, respectively). This lack of importance raises the possibility of a "decoupling" effect: whereas businesses may embrace learning cultures and green initiatives, these practices have not yet been successfully converted into quantifiable performance results. This can be because the "hard" technical execution needed for performance improvements and the "soft" strategic goals are not aligned.

The Moderation Analysis's findings (H5 and H6) further support the idea that OLC has no appreciable impact on the connection between performance and innovation drivers. The impact of TI on IP is unaffected by a learning culture's level of sophistication, as demonstrated by the Simple Slope Analysis (Figure 3 and 4). In a similar vein, the GIS-mediated mediation approach was disregarded because there was no significant correlation between GIS and IP, suggesting that technical innovation directly influences performance rather than via a green strategy.

5.2 **Conclusion**

By proving that technical resources continue to be the most important asset for performance, this study adds to the literature on innovation and the Resource-Based View (RBV). It also calls into question the widely held belief that "green" and "culture" factors inevitably improve performance. The strong discriminant validity problems (HTMT > 0.90) in the study indicate a possible measuring overlap between technical activity and performance outcomes.

The lesson is obvious for industry practitioners: give technical R&D top priority. Emphasis on Technical Core: Since technical innovation is the most accurate indicator of performance, managers should keep making significant investments in it. Operationalize Green Strategy: To close the existing performance gap, “Green Innovation” must be incorporated into technological workflows rather of being treated as a distinct strategy layer.Organizations should have a targeted culture that encourages technical and environmental problem-solving instead of a generic learning culture.

The strong association between TI and IP, which could be the result of a common-method bias or conceptual redundancy in the indicators, is a significant study constraint. Since environmental investments can have a lagged influence on performance, future study should use longitudinal data to determine whether the impact of the Green Innovation Strategy develops over time. Furthermore, examining several performance categories (such as social versus financial) may uncover the hidden benefits of organizational learning culture.

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**References:**

**Aboelmaged, M. (2018).** Direct and indirect effects of eco-innovation, environmental orientation, and supplier collaboration on hotel performance: An empirical study. Journal of Cleaner Production, 184, 537–549. https://doi.org/10.1016/j.jclepro.2018.02.201

**Amabile, T. M. (1983).** The social psychology of creativity: A componential conceptualization. Journal of Personality and Social Psychology, 45(2), 357–376. https://doi.org/10.1037/0022-3514.45.2.357

**B. Li. (2021).** Exploration of Liuzhou City Image Propagation -- Taking Liuzhou snail noodle Successfully "out of the Circle" as an Example. *News Tribune, 35*(4), pp.72-75. https://kns.cnki.net/kcms/detail/detail.aspx?dbname=CJFD2021&filename=XWNT202104027&dbcode=CJFD. 10.19425/j.cnki.cn15-1019/g2.2021.04.025.

**Besemer, S. P., & O’Quin, K. (1987).** Creative product analysis: Testing a model by developing a judging instrument. Frontiers of Creativity Research: Beyond the Basics, 367–389.

**Bland, C. J., Center, B. A., Finstad, D. A., Risbey, K. R., & Staples, J. (2006)**. The impact of appointment type on the productivity and commitment of full-time faculty in research and doctoral institutions. The Journal of Higher Education, 77(1), 89–123.

**C. Xiao. (2018).** *Study on the Influencing Factors of Hotel Internal Service Quality*. [Master, Xiamen University]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1019012489.nh&DbName=CMFD2020.

**C.Z. Ma & Z.L. Gui. (2019).** Application of Balanced Scorecard in Government Budget Performance Evaluation and Index Design. *Journal of South China Normal University(social ScienceEdition),*(6),pp.102-112. https://kns.cnki.net/kcms/detail/detail.aspx?dbname=CJFD2019&filename=HNSB201906013&dbcode=CJFD.

Cheah, J.H.; Magno, F.; Cassia, F. Reviewing the SmartPLS 4 Software: The Latest Features and Enhancements. J. Mark. Anal.2024, 12, 97–107.[CrossRef]

**CHEN Y S, LAI S B, WEN C T.(2006).** The influence of green innovation performance on corporate advantage in Taiwan[J]. Journal of Business Ethics, 67(4): 331- 339.

**Chen, Y. S., Lai, S. B., & Wen, C. T. (2006).** The influence of green innovation performance on corporate advantage in Taiwan. Journal of Business Ethics, 67(4), 331–339. https://doi.org/10.1007/s10551-006-9025-5

**D.M. Miao. (2021).** *Research on the Influence of the Characteristics of Social Media Kol on Consumers' Impulsive Purchasing Behavior*. [Master, Nanjing University of Science and Technology]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1022536787.nh&DbName=CMFD2023.

**DAI J, CANTOR D E, MONTABON F L.(2017).** Examining corporate environmental proactivity and operational performance: A strategy-structure-capabilities performance perspective within a green context[J]. International Journal of Production Economics, 193:272-280.

**De Resende Ribeiro, OC, & Neto, PJS (2021).** Sustainable competitive advantage and green innovation: A review of joint scale propositions. Gestao e Producao, 28 (3), 1–20. https://doi.org/10.1590/1806-9649-2021V28E5669

**Eiadat, Y., Kelly, A., Roche, F., et al. (2008).** Green and competitive? An empirical test of the mediating role of environmental innovation strategy. Journal of World Business, 43(2), 131-145.

**F. Wang, H. Zhang & Z.B. Niu. (2015).** An Empirical Study on the Influences of Customer Engagement on User-library Relationship Quality. *Library and Information Knowledge,* (6), pp.48-60. https://kns.cnki.net/kcms/detail/detail.aspx?dbname=CJFD2015&filename=TSQC201506007&dbcode=CJFD. 10.13366/j.dik.2015.06.048.

**F.F. Jiang. (2021).** *Research on Social Marketing Reward and Offer Strategies Based on Consumer Sharing Behavior*. [Doctor, Southeast University]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1022776969.nh&DbName=CDFDTEMP.

**Freeman, C. (1973).** Success and failure in industrial innovation. National Institute Economic Review, 65(1), 45–62. https://doi.org/10.1177/002795017306500106

**G.P. Wu & R.L. Shi. (2022).** Research on the Influencing Factors of Online Doctor-patient Interaction on Doctor-patient Trust from the Perspective of Digital Empathy. *Chinese Journal of Health Policy,* *15*(11), pp.46-52. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=ZGWZ202211007&DbName=CJFQ2022.

**Ge, B., Yang, Y., Jiang, D., Gao, Y., Du, X., & Zhou, T. (2018).** An empirical study on green innovation strategy and sustainable competitive advantages: Path and boundary. Sustainability, 10(10), 3631.

**Gruber, H. E., & Wallace, D. B. (1999).** Handbook of creativity. Cambridge University Press.

**Gruber, H. E., & Wallace, D. B. (1999).** The Case Study Method and Evolving Systems Approach for Understanding. Handbook of Creativity, 93.

**H.Y. Shang, C.G. Zhang & F. Liu. (2017).** To Realize the Innovation Development Strategy of Small and Medium-sized Enterprises in China's Industry 4.0. *Teaching and Research,* (5), pp.42-47. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=JWDP201705006&DbName=CJFQ2017.

**Hadar, L. L., & Tirosh, M. (2019).** Creative thinking in mathematics curriculum: an analytic framework. Thinking Skills and Creativity, 33, 100585.

**Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019).** When to use and how to report the results of PLS-SEM. European Business Review, 31(1), 2–24. doi:10.1108/ebr-11-2018-0203

**Hair, J.F.; Sarstedt, M.; Ringle, C.M. Rethinking Some of the Rethinking of Partial Least Squares. Eur. J. Mark. 2019, 53, 566–584.[ https://doi.org/10.1108/EJM-10-2018-0665]**

**Huang, J., & Li, Y. (2018).** How resource alignment moderates the relationship between environmental innovation strategy and green innovation performance. The Journal of Business & Industrial Marketing, 33(3), 316-324.

**Jerez-Gómez, P., Céspedes-Lorente, J., & Valle-Cabrera, R. (2005).** Organizational learning and performance: a study of the interaction between organizational learning and human capital in Spanish manufacturing firms. International Journal of Human Resource Management, 16(10), 1640–1663.

**Jerez-Gómez, P., Céspedes-Lorente, J., & Valle-Cabrera, R. (2005).** Organizational learning and performance: The role of organizational learning capability. International Journal of Human Resource Management, 16(10), 1691–1710. https://doi.org/10.1080/09585190500239141

**L.J. Qiao. (2021)**. *Research on Technological Innovation, Product Heterogeneity and Upgrading of China's Equipment Manufacturing Industry*. [Doctor, Capital University of Economics and Business].

https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1022007120.nh&DbName=CDFD2023.

**L.Q. Zhang. (2019).** *Study on Service Quality Affecting Customer Satisfaction of Luxury Clothing Brands in Xi 'an Market*. [Master, Xi' an Polytechnic University]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1019954548.nh&DbName=CMFD2020.

**López-Muñoz, J. F., Escobar-Sánchez, M., & Bueno-Sánchez, J. C. (2022).** Green innovation strategy, environmental learning and firm performance: A mediating-moderating model. Journal of Cleaner Production, 336, 130398.

**M.M. Han. (2017).** *The Impact of Technological Innovation on Employment Growth*. [Master, Nanjing University of Information Science and Technology]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1017296014.nh&DbName=CMFD2018.

**Marcus, A. A., & Fremeth, A. R. (2009).** Green management matters regardless. [Journal name].

**Nonaka, I., & Takeuchi, H. (1995).** The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press.

**Paul, R., & Elder, L. (2019).** The nature and functions of critical & creative thinking. Rowman & Littlefield.

**Q. Yang. (2021).** *Research on Service Quality Evaluation of Academic Tourism Products Based on Servqual Improved Model*. [Master, Yanshan University]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1022785689.nh&DbName=CMFD2023.

**Qian G. (2008).** Science and technology innovation education in basic education (I) Science and technology education curriculum is an important guarantee for cultivating innovative talents. Internet Technology Times, 01, 30-33.Radcliffe, L. S. (2013). Qualitative diaries: Uncovering the complexities of work-life decision-making. Qualitative Research in Organizations and Management: An International Journal.

**R. Wang. (2018).** ***The Implementation Evaluation of Liuzhou Urban Landscape Plan(2006-2020)*.** [Master, South China University of Technology]. South China University of Technology. https://kns.cnki.net/kcms/detail/detail.aspx?dbname=CMFD2018&filename=1018871914.nh&dbcode=CMFD.

**R.X. Fang. (2018).** *The Influencing Factors of Consumer Trust in O2o Catering Takeout Under Mobile Internet Environment*. [Master, Yunnan University of Finance and Economics]. https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=1018097961.nh&DbName=CMFD2018.

**Schumpeter, J. A. (1934).** The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. Harvard University Press.

**Senge, P. M. (1990).** The Fifth Discipline: The Art and Practice of the Learning Organization. Doubleday/Currency.

**Senge, P. M. (1990).** The fifth discipline: The art and practice of the learning organization. Doubleday.

**Subhaktiyasa, P.G. PLS-SEM for Multivariate Analysis: A Practical Guide to Educational Research Using SmartPLS. EduLine J.Educ. Learn. Innov. 2024, 4, 353–365. [DOI: https://doi.org/10.35877/454RI.eduline2861]**

**Suwandej, N., Thongves, M., & Kleebbuabarn, N. (2024, November).** THE EFFECT OF TECHNICAL INNOVATION ON INNOVATION PERFORMANCE IN SMES: THE MEDIATING OF GREEN INNOVATION STRATEGY. In *International Conference" Actual economy: local solutions for global challenges"* (pp. 40-51).

**Suwandej, N., Thongves, M., & Kleebbuabarn, N. (2024).** Model of the mediating effect of Green innovation strategy between Technical innovation and Innovation performance. In International Conference on Management, Innovation, Economics and Social Sciences (Vol. 1, No. 1, pp. 77-88).

**Tomomi, T. (2010).** Environmental management strategy for small and medium-sized enterprises: Why do SMBs practice environmental management? Asian Business & Management, 9(2), 265-280.

**Y. Wu. (2021).** *The Influence of Consumers' Repeating Purchase in the E-commerce Live Broadcast Context*. [Master, Nanjing University of Finance and Economics]. Nanjing University of Finance and Economics. https://kns.cnki.net/kcms/detail/detail.aspx?dbname=CMFD2022&filename=1022401994.nh&dbcode=CMFD. 10.27705/d.cnki.gnjcj.2021.000246.

**Z.M. Yao. (2021).** Research on Inheritance and Innovation of Ningbo Time-honored Brands Based on Brand Culture. *Time-honored Brand Marketing,*(9), pp.7-9.

https://chn.oversea.cnki.net/kcms/detail/detail.aspx?FileName=LZHP202109004&DbName=CJFQ2021.

**Zhang Gang, Zhang Xiaojun. (2014).** The relationship between green innovation strategy and firm performance: taking employee participation as the mediating variable. Research of Finance and Trade, 24(04), 132-140.