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Research Article

The Influence of Green Product Innovation, Green Process Innovation, and End-of-Line Management Innovation on Sustainability Performance Dimensions

Ehsan Masoudi[1*], Seyyed Amirhossein Emamiyan[2]

[1] Quality Management Research Group, University of Isfahan, Iran
[2] Operations Research, Tarbiat Modares University, Tehran, Iran
* Corresponding author: ehsanma74@yahoo.com

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Abstract

Purpose- Sustainability performance (SP) boosts competitive advantage and benefits the environment and society. The present study analyzes the impact of green technology innovation (GTI) dimensions, namely green product innovation (GPtI), green process innovation (GPsI), and end-of-line innovation management (ELIM), on SP dimensions, namely economic performance (EcP), environmental performance (EnP), and social performance (SoP).

Design/Methodology- A questionnaire instrument was developed and administered to a sample of 145 small and medium-sized enterprises (SMEs) located in the Tehran province of Iran. The data collected were analyzed using PLS-SEM.

Findings- The data analysis results showed that GPtI and GPsI significantly influence EcP, EnP, and SoP. Furthermore, the findings indicate that while ELIM positively impacts EnP and SoP, it does not exert any influence on EcP.

Practical Implications- This research highlights the significance of GTI in enhancing SP, providing practical implications for SMEs to adopt eco-friendly practices, thereby improving operational efficiency, reducing environmental impact, and fostering competitive advantage in the market.

Introduction

In the contemporary business landscape, sustainability performance (SP) has emerged as a critical focal point for small and medium-sized enterprises (SMEs), encompassing three fundamental dimensions: economic, environmental, and social performance (Mengistu & Panizzolo, 2023; Malesios et al., 2021). In an era marked by increasing environmental challenges and societal expectations, SMEs are uniquely positioned to drive sustainable practices that not only enhance their operational efficiency but also positively contribute to the broader community and ecosystem (Dey et al., 2018; Caldera et al., 2018). The economic dimension emphasizes the need for SMEs to adopt innovative business models that promote profitability while minimizing resource consumption and waste generation (Nosratabadi et al., 2019). Concurrently, the environmental aspect underscores the importance of reducing ecological footprints through the implementation of green technologies and sustainable resource management practices (Opoku-Mensah et al., 2024). Finally, the social dimension highlights the role of SMEs in fostering community engagement and ensuring fair labor practices, thereby enhancing their corporate social responsibility (CSR) initiatives (Ortiz-Avram et al., 2018; Inyang, 2013). Consequently, in recent years, many countries have become increasingly concerned about the challenges arising from inefficient production and consumption practices. In response to these significant issues, various nations have implemented measures, including the establishment of "sustainable development goals," aimed at addressing the negative impacts of unsustainable practices and promoting a balanced and responsible approach to development (Fatimah et al., 2023). As a result, organizations need to prioritize the assessment of SP rather than solely focusing on operational and financial metrics to enhance their sustainability indicators (Ali et al., 2023).

Various factors can potentially influence SP, with one significant factor being green technology innovation (GTI) (Mukhtar et al., 2024; Wang et al., 2022). GTI is particularly crucial for SMEs, as these companies are recognized as engines of economic growth and job creation (Peng et al., 2021). Innovation in this area encompasses three key dimensions: green product innovation, green process innovation, and end-of-line innovation management (Mukhtar et al., 2024; Wang et al., 2022). Green product innovation refers to the development of goods and services that have a lower environmental impact and meet sustainable consumer needs (Moshood et al., 2022; Sdrolia & Zarotiadis, 2019). In contrast, green process innovation involves improving production methods to reduce resource and energy consumption, which can lead to cost savings and enhanced efficiency (Xie et al., 2019). End-of-line innovation management focuses on applying new technologies to improve waste management efficiency, including wastewater, pollutant gases, and residues. This not only contributes to the development of sustainable products but also increases product lifespans by minimizing the need for raw materials and energy. Furthermore, it ensures compliance with pollutant discharge standards through effective waste processing technologies (Mukhtar et al., 2023). By embracing GTI, SMEs can contribute to environmental sustainability while enhancing their competitiveness and generating added value, ultimately achieving sustainable economic growth (Asad et al., 2023; Khan et al., 2023). In summary, GTI simultaneously impacts the economic, social, and environmental dimensions of SP, paving the way for sustainable development within organizations (Mukhtar et al., 2024; Mukhtar et al., 2023; Wang et al., 2022).

Very few studies have been conducted on the impact of GTI on SP. Mukhtar et al. (2024) and Mukhtar et al. (2023) demonstrated in their research that GTI can significantly affect SP. This study aims to explore the importance of SP among SMEs, particularly concerning their environmental impact. By investigating how these enterprises can integrate sustainable practices into their operations, the research seeks to provide insights into the potential benefits arising from such initiatives, including improved brand reputation, customer loyalty, and competitive advantage. This research is particularly significant in developing countries, where SMEs represent a substantial portion of the global economy and play a crucial role in job creation and economic growth. Developing countries face greater environmental and social challenges, making it essential to understand the impact of GTI on the SP of these enterprises. On one hand, green product innovation can enhance competitiveness and attract new customers. On the other hand, green process innovation contributes to cost reduction and resource optimization, both of which directly influence economic performance. Furthermore, end-of-line innovation management can help reduce waste and pollutants, thereby improving environmental and social performance. This research can assist policymakers and SMEs managers in developing countries in adopting more effective strategies for implementing green innovations. Additionally, the findings of this study could foster a culture of sustainability among companies and local communities, ultimately leading to the establishment of a more sustainable economy.

In the subsequent sections of this paper, we will begin by outlining and elucidating the theoretical frameworks that underpin our study. Following this, we will introduce the proposed research model along with its underlying hypotheses. The methodology employed for conducting the research will also be detailed. The practical application of the model will be examined through an empirical study, and ultimately, based on the findings derived from this investigation, we will engage in a comprehensive discussion and draw conclusions.

Literature Review

Sustainability Performance

The widely recognized perspective on SP encompasses three main dimensions: economic, social, and environmental (Jiang et al., 2018). Economic performance pertains to a production strategy that addresses both present and future demands. It reflects the ongoing profitability and financial viability of an organization, which is assessed based on long-term operational value, efficiency, output, return on investment, and market valuation (Romana & Gestoso, 2023). Social performance focuses on the interplay between societal issues, such as deprivation and environmental degradation. This concept posits that alleviating deprivation should not lead to unwarranted ecological harm or economic instability. It aims to reduce deprivation while ensuring alignment with a sustainable economic and environmental framework (Karia & Davadas Michael, 2022). Environmental performance involves the preservation of critical ecological functions, which necessitates maintaining the capacity of capital resources to deliver these functions. In essence, the effectiveness of an organization is evaluated through its environmental impact (Antwi-Boateng et al., 2023).

The integration of environmental, social, and economic objectives to enhance value and promote long-term growth within business operations is referred to as the sustainability function. Consequently, the effective utilization of environmental, social, and economic resources for immediate needs, while simultaneously safeguarding these resources for future generations, is termed SP (Rezaee, 2016). Among the dimensions of SP, environmental SP is crucial as it reflects a company's capability to mitigate its ecological footprint. Assessing environmental performance involves a comprehensive analysis of operational impacts on the environment to minimize harmful activities (Szennay et al., 2021). Economic SP constitutes a significant aspect of sustainability attributes aimed at increasing corporate market values. It encompasses financial gains and serves as a measure of a company's financial health and long-term viability (Wagner, 2010). Lastly, social SP pertains to various social dimensions, including enhancing employee productivity, ensuring health and safety, promoting social welfare, providing equal advancement opportunities, and supporting humanitarian efforts (Denu et al., 2023).

To evaluate SP, organizations utilize Key Performance Indicators (KPIs) that encompass environmental, economic, and social aspects, frequently grounded in the Triple Bottom Line (TBL) framework (Contini & Peruzzini, 2022). These KPIs enable companies to measure their sustainability achievements throughout the entire lifecycle and value chain. However, the application of these metrics can differ considerably due to cultural and legal contexts (López-Arceiz et al., 2020). Although sustainability KPIs are crucial, there is a notable absence of standardization in their implementation. This lack of uniformity can result in discrepancies in how SP is reported and assessed across various organizations (Contini & Peruzzini, 2022; López-Arceiz et al., 2020).

Green Technology Innovation

Innovation serves as a crucial driver of competitive advantage and has been extensively explored in numerous academic studies. Consequently, stakeholders place significant emphasis on innovation processes, viewing them as essential for achieving a strong competitive position in the market (Onileowo et al., 2021). The concept of technology in innovation was first introduced by Braun and Wield in 1994. GTI refers to the technologies and methodologies that enhance environmental quality while minimizing the consumption of natural resources (Zhou & Dai, 2023). This innovative approach focuses on fostering technological advancements in environmentally friendly processes or products and has been effectively applied in various areas, such as pollution prevention, waste management, resource recycling, and other practices aimed at improving environmental stewardship (Feng et al., 2021).

According to research by Mukhtar et al. (2023), GTI encompasses three key aspects: the innovation of eco-friendly products, innovation in green processes, and advancements in end-of-line management. Eco-friendly product innovation involves developing products that are environmentally sustainable by utilizing fewer non-toxic materials and ensuring their degradability. This form of innovation enhances the sustainability, longevity, and recyclability of products. Green process innovation focuses on improving the efficiency of manufacturing and recycling operations. It promotes the design and implementation of production methods that are more aligned with sustainable practices and the natural environment. Finally, end-of-line management innovation pertains to the adoption of technological advancements that enhance the effectiveness of managing three types of waste: wastewater, gaseous emissions, and solid waste. Such technologies play a crucial role in fostering sustainable products by minimizing the use of raw materials and energy while extending the product lifecycle.

The effectiveness of GTI can be affected by economic disparities across different regions. For example, in China, the eastern and western areas tend to gain more from environmental regulations due to their more robust economic structures when compared to the central region (Zuo, 2023). The success of GTI is often contingent upon various external elements, including governmental policies, international cooperation, and market dynamics. For instance, restrictions on digital trade can hinder innovation by limiting access to global technologies and collaborative opportunities (Wang et al., 2023). Although GTI is vital for promoting sustainability, its scalability and long-term sustainability are crucial considerations. Ongoing investment in research and development is essential to ensure that these technologies continue to be competitive and effective in mitigating environmental impacts (Zhang & Tang, 2022).

The Relationship between Green Technology Innovation and Sustainability Performance

Green technologies that focus on energy play a crucial role in mitigating the environmental issues that arose from the Industrial Revolution, achieving a significant reduction in carbon emissions of over 60%. Examples of GTI include pollution monitoring, waste management, and the implementation of clean technologies (Ye et al., 2022). GTI encompasses both the creation of novel technologies and the enhancement of existing ones, with the primary goals of minimizing carbon output, conserving natural resources, and reducing pollution to safeguard the health of workers and the general public. These technological advancements are specifically designed to lessen detrimental effects on the environment. Consequently, there is considerable scholarly interest in GTI, particularly regarding its contributions to sustainable development and its potential to provide a competitive edge in various industries (Mukhtar et al., 2023). Firstly, green product innovation can enhance demand and customer satisfaction by creating goods and services that reduce negative environmental impacts. These products typically feature unique characteristics that distinguish them from non-green competitors, ultimately resulting in an increased market share for the company (De Medeiros et al., 2022; Kam-Sing Wong, 2012). Secondly, green process innovation contributes to optimizing production methods and reducing resource consumption. Companies that employ innovative techniques and clean technologies can lower production costs while simultaneously decreasing their negative environmental footprint, thereby enhancing economic performance and fostering greater corporate social responsibility (Cheng et al., 2023; Xie et al., 2019). Finally, end-of-line innovation management focuses on reducing waste and pollutants, contributing to the achievement of social and environmental goals. These initiatives strengthen the public image of companies and enhance customer trust (Mukhtar et al., 2024; Mukhtar et al., 2023).

GTI plays a crucial role in promoting the sustainability of the green economy. It interacts with the digital economy to foster high-quality sustainability, indicating that the optimization of GTI and digital capabilities can enhance the sustainability of the green economy. The digital economy exhibits a dual threshold effect on the sustainability of the green economy through GTI. Beyond a specific threshold, the influence of GTI may decrease, implying that there are limits to the extent to which digitalization can improve sustainability (Wang et al., 2024). Initiatives such as the National E-commerce Demonstration Cities (NEDC) can support GTI through spatial spillover effects, benefiting both local and adjacent regions. Nevertheless, this also suggests that the effectiveness of GTI is contingent upon broader economic and policy frameworks (Yu et al., 2023). Based on this premise, we propose the following hypotheses:

H1: *Green product innovation impacts economic performance.*

H2: *Green product innovation impacts environmental performance.*

H3: *Green product innovation impacts social performance.*

H4: *Green process innovation impacts economic performance.*

H5: *Green process innovation impacts environmental performance.*

H6: *Green process innovation impacts social performance.*

H7: *End-of-line management innovation impacts economic performance.*

H8: *End-of-line management innovation impacts environmental performance.*

H9: *End-of-line management innovation impacts social performance.*

Research Methodology

Measurement Instrument

To assess the research variables, a structured questionnaire was employed. This instrument was divided into two sections: the first section gathered demographic details of the participants, comprising four questions (see Table 1). The subsequent section focused on the research variables, utilizing a five-point Likert scale for measurement, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). For the Green Technology Innovation variable, we used the questionnaire developed by Wang et al. (2022), which consists of 15 items categorized into three dimensions: green product innovation (5 items), green process innovation (5 items), and end-of-line management innovation (5 items). Similarly, for the Sustainability Performance variable, we utilized the questionnaire from Yang et al. (2023), which includes 14 items divided into three dimensions: economic performance (5 items), environmental performance (5 items), and social performance (4 items). To ensure content validity, the questionnaire was reviewed by two academic experts and two senior professionals from the industry.

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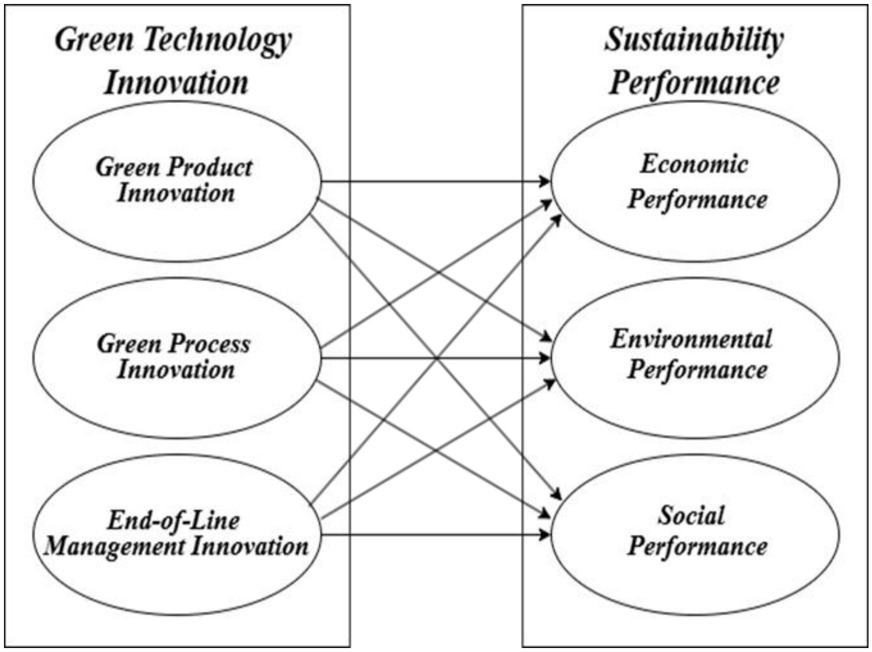

Figure 1 - Research model

Figure 1 illustrates the proposed conceptual model. The independent variables are green product innovation, green process innovation, and end-of-line management innovation, and the dependent variables are economic performance, environmental performance, and social performance.

Population, Sample Size and Respondents

The target population for this study comprises quality managers from SMEs located in Tehran Province. Tehran Province, which is also the capital of Iran, holds a significant position in entrepreneurship and job creation as the most populous province in the country. Numerous SMEs in this province have created employment opportunities for many people. As a result, environmental issues have become very important in Tehran Province. For this reason, SMEs in Tehran Province were studied. Data collection was conducted during the summer of 2024, employing a simple random sampling technique. To determine the necessary sample size for Partial Least Squares Structural Equation Modeling (PLS-SEM), G*Power software was utilized to perform a power analysis based on the model specifications outlined by Hair et al. (2014). The analysis indicated that a total of 145 responses were required to achieve an 80% statistical power level, enabling the detection of R^2 values of at least 0.1, with a 1% error margin as calculated by G*Power software.

Results

The analysis of the data revealed skewness and kurtosis values that fell outside the range of (-1, +1), indicating a deviation from normality in the distribution. Consequently, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed for the analytical process (Moradi & Miralmasi, 2020; Hair et al., 2014). SMART-PLS version 3 was then utilized to assess and model the relationships among the variables.

As noted by Chin (2010), the process of analyzing studies using PLS involves two key phases: evaluating the external model (measurement) and estimating the internal model (structural). Assessing the measurement model is crucial for verifying the validity and reliability of the constructs. Table 2 demonstrates that all factor loadings for the constructs exceed 0.7, indicating that the proposed model possesses validity (Moradi & Miralmasi, 2020; Hair et al., 2010; Chin, 1998). To evaluate the reliability of the external model, various metrics were employed, including Cronbach's alpha (C-α), composite reliability (CR), the Dijkstra-Hensler index (Rho_A), and average variance extracted (AVE). As shown in Table 2, both C-α and CR values are above 0.7, confirming the reliability of the constructs. Additionally, the AVE for all constructs is greater than 0.5, further validating their reliability (Moradi & Miralmasi, 2020; Hair et al., 2014). Furthermore, the CR values exceed the AVE, which supports the confirmation of composite reliability (Moradi & Miralmasi, 2020; Bagozzi & Yi, 1988). Table 2 also indicates that all Variance Inflation Factors (VIFs) are below 3.3, suggesting that the model is free from common method bias (Kock, 2015). The results for discriminant validity are presented in Tables 3 and 4. According to Table 4, all variables meet the criteria established by Fornell and Larcker (1981), as the squares of their AVEs exceed their correlations with other variables. Furthermore, Table 5 reveals that the HTMT indices are below 0.9, thereby confirming the establishment of discriminant validity (Henseler et al., 2015).

Table 1 - Demographic analysis of research

	Sample (%)		Sample (%)
Industry sector		***Duration of the company***	
Metals	13.07	<10 years	20.77
Chemical	8.46	10-20 years	54.61
Food	11.54	>20 years	24.62
Machine manufacturing	15.39		
Building Materials	25.39		
Plastics	20.00		
Others	6.15		
		No. of employees	
		<50	47.70
Respondent's work experience		50-100	24.62
<10 years	48.46	101-150	13.07
10-20 years	36.15	151-200	9.23
>20 years	15.39	>200	5.38

Table 2 - Measurement Model

Variable	Dimensions & Label	Factor Loading (Min-Max)	VIF (Min-Max)	C-α	Rho_A	CR	AVE
Green Technology Innovation (GTI)	Green Product Innovation (GPtI)	(0.731-0.871)	(1.657-2.840)	0.874	0.882	0.909	0.667
	Green Process Innovation (GPsI)	(0.724-0.839)	(1.602-2.132)	0.833	0.837	0.882	0.600
	End-of-Line Management Innovation (ELMI)	(0.710-0.865)	(1.523-2.916)	0.843	0.860	0.889	0.617
Sustainability Performance (SP)	Economic Performance (EcP)	(0.764-0.842)	(1.858-2.635)	0.858	0.862	0.898	0.639
	Environmental Performance (EnP)	(0.742-0.819)	(1.483-2.014)	0.866	0.875	0.902	0.650
	Social Performance (SoP)	(0.761-0.860)	(1.754-2.489)	0.777	0.786	0.856	0.599

In evaluating the structural model of the research, a three-phase method was employed, which involved assessing the R^2 value, the Q^2 model quality, and the significance of the path coefficients within the structural model (Moradi & Miralmasi, 2020; Aldás, 2016). The findings are detailed in Tables 5 and 6, as well as Figures 2 and 3.

Table 3 - Fornell and Larcker coefficients

	EcP	ELMI	EnP	GPsI	GPtI	SoP
EcP	**0.799**					
ELMI	0.212	**0.785**				
EnP	0.521	0.306	**0.806**			
GPsI	0.374	0.209	0.448	**0.775**		
GPtI	0.407	0.264	0.452	0.363	**0.817**	
SoP	0.519	0.311	0.709	0.403	0.463	**0.774**

The R^2 values were categorized as low (0.25), medium (0.50), and high (0.75). The results revealed that the R^2 for EcP was low, while for EnP and SoP, it fell between low and medium levels (Hair et al., 2011; Henseler et al., 2009). Additionally, when considering redundancy indices categorized as low (0.02), medium (0.15), and high (0.35), the structural model exhibited a medium redundancy index for EcP, EnP, and SoP (Hair et al., 2014). The sharing index for these constructs was also found to be high. Lastly, the goodness of fit (GOF) test, based on thresholds of low (0.1), medium (0.25), and high (0.36) as suggested by Tenenhaus et al. (2005), indicated that the overall value of the research model was high, reflecting a strong fit.

Table 4 - HTMT criterion

	EcP	ELMI	EnP	GPsI	GPtI	SoP
EcP						
ELMI	0.237					
EnP	0.599	0.347				
GPsI	0.439	0.257	0.512			
GPtI	0.458	0.304	0.503	0.423		
SoP	0.631	0.377	0.861	0.493	0.555	

Table 5 - R^2, Cross validity redundancy and communality

Variables	R^2	ARS	Redundancy index	Communality index
Economic Performance	0.231	0.214	0.128	0.444
Environmental Performance	0.321	0.307	0.177	0.455
Social Performance	0.305	0.290	0.156	0.331

$$\text{GOF} = \sqrt{\overline{AVE}.\overline{R^2}} = 0.425$$

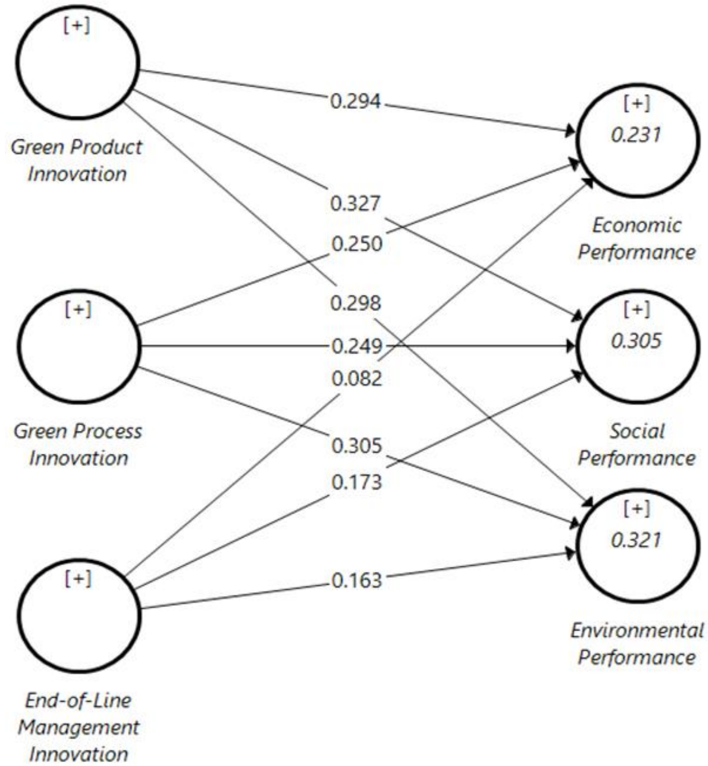

Figure 2 - Pls-Algorithm results

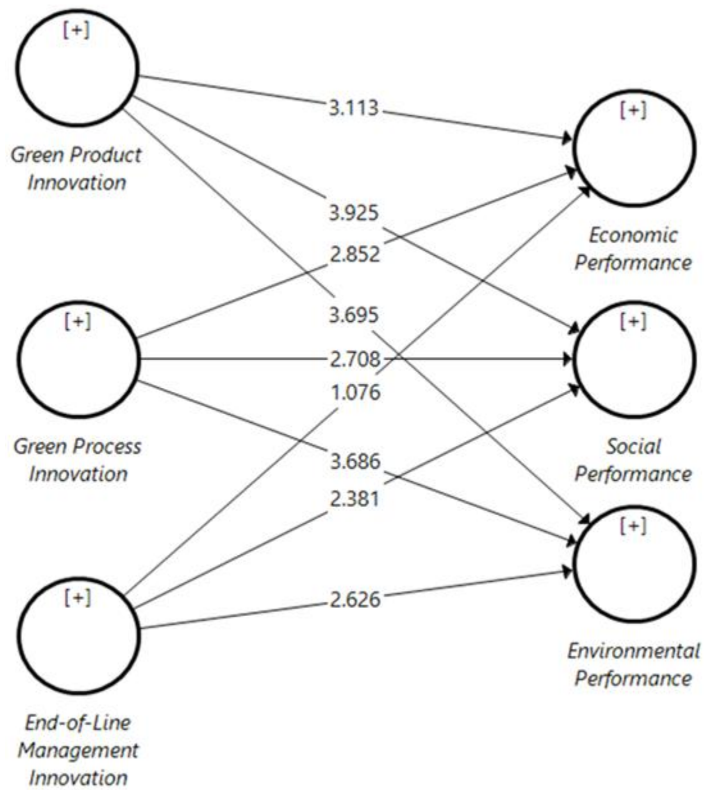

Figure 3 - Bootstrapping results

Table 6 - Hypotheses testing results

Hypothesis	Path coefficient	SE	t-value	p-value	Decision
Green Product Innovation → Economic Performance	0.294	0.095	3.113	0.002	Supported
Green Product Innovation → Environmental Performance	0.327	0.081	3.695	0.000	Supported
Green Product Innovation → Social Performance	0.298	0.083	3.925	0.000	Supported
Green Process Innovation → Economic Performance	0.250	0.088	2.852	0.005	Supported
Green Process Innovation → Environmental Performance	0.249	0.083	3.686	0.000	Supported
Green Process Innovation → Social Performance	0.305	0.092	2.708	0.007	Supported
End-of-Line Management Innovation → Economic Performance	0.082	0.076	1.076	0.282	Rejected
End-of-Line Management Innovation → Environmental Performance	0.173	0.062	2.626	0.009	Supported
End-of-Line Management Innovation → Social Performance	0.163	0.073	2.381	0.018	Supported

In conclusion, the evaluation of the structural model involved using path coefficient analysis in conjunction with the bootstrap method to assess the robustness of the relationships among the proposed research hypotheses. As illustrated in Figure 3 and detailed in Table 6, both GPtI and GPsI have a significant impact on EcP, EnP, and SoP. Furthermore, the findings indicate that while ELIM positively affects EnP and SoP, it does not influence EcP.

Discussion

Theoretical Implications

In the contemporary landscape, the pursuit of sustainable development and environmental conservation has emerged as a critical global concern. Innovations in green technology are increasingly viewed as essential strategies for addressing this challenge, encompassing various facets such as advancements in green products, processes, and management practices at the end of production lines. These elements significantly influence organizations' sustainability outcomes, including economic viability, environmental stewardship, and social responsibility. This study aims to analyze the effects of GTI on different dimensions of SP within SMEs. These enterprises, characterized by their adaptability and strong innovation capabilities, play a pivotal role in advancing sustainability goals. In light of ongoing environmental and societal issues, understanding how GTI correlates with SP can empower managers in these organizations to implement more effective strategies for reducing adverse environmental impacts and promoting social accountability. Consequently, this research thoroughly investigates these connections, with its results intended to inform managerial strategies aimed at fostering sustainable development.

The research findings indicate that all research hypotheses, except one, were confirmed. This suggests that GTI positively impacts SP. The results align with the findings of Mukhtar et al. (2024 and 2023), reinforcing the integral relationship between technological advancements and sustainable practices. Green product innovation, process innovation, and end-of-line innovation management collectively contribute to enhanced economic performance by reducing costs and increasing market competitiveness. Simultaneously, these innovations promote environmental performance through resource efficiency and waste reduction, leading to a smaller ecological footprint. Furthermore, social performance is strengthened as organizations adopt responsible practices that enhance community welfare and stakeholder engagement. This interplay suggests that SMEs can leverage green technology innovations not only to meet regulatory requirements but also to achieve competitive advantages while fulfilling their corporate social responsibilities. Thus, the findings underscore the necessity for SMEs to prioritize green technology innovations as a pathway to sustainable development.

The first, second, and third hypotheses of the study showed that green product innovation has an impact on economic performance, environmental performance, and social performance. The confirmation of the impact of green product innovation on economic, environmental, and social performance indicates a holistic approach to sustainability in business practices. Green product innovation contributes not only to the economic viability of organizations by reducing costs and enhancing competitiveness but also plays a crucial role in minimizing environmental impacts through resource efficiency and waste reduction. Furthermore, it fosters social responsibility by addressing consumer demands for sustainable products and improving community well-being. This interconnectedness highlights the importance of integrating green innovations into corporate strategies, as they can lead to enhanced overall SP.

The fourth, fifth, and sixth hypotheses of the study showed that green process innovation has an impact on economic performance, environmental performance, and social performance. The confirmation of the impact of green process innovation on economic, environmental, and social performance illustrates the multifaceted benefits of adopting sustainable practices in organizations. Green process innovation, which focuses on improving operational efficiencies and reducing waste, directly contributes to enhanced economic performance by lowering costs and increasing productivity. Simultaneously, it positively affects environmental performance through decreased resource consumption and waste generation, thereby minimizing ecological footprints. Furthermore, the social performance aspect highlights the importance of corporate responsibility and community engagement, as sustainable processes often lead to better working conditions and improved societal outcomes. This interconnectedness emphasizes the necessity for businesses to integrate green innovations into their operational strategies to achieve comprehensive sustainability goals.

The results of the seventh hypothesis indicated that end-of-line innovation management does not have a significant impact on economic performance. The lack of a confirmed effect of end-of-line innovation management on economic outcomes suggests several key insights. First, it may imply that while end-of-line innovation management contributes positively to other dimensions of sustainability, such as environmental and social performance, its direct influence on economic results is either minimal or potentially mediated by other factors. This finding suggests that organizations focusing exclusively on end-of-line innovation management might overlook critical elements that drive economic performance, such as market demand, cost efficiency, and operational effectiveness. Additionally, this raises questions about the effectiveness of current end-of-line innovation strategies in translating into tangible economic benefits. Furthermore, the absence of a confirmed relationship may indicate that the metrics used to evaluate economic performance about end-of-line innovation management need to be reassessed. It is possible that the indicators employed do not adequately capture the nuanced effects of these innovations on economic outcomes. On the other hand, this finding could have significant implications for policymakers and organizational managers. If end-of-line management innovation cannot directly influence economic performance, managers must seek ways to align this type of innovation with other economic and social dimensions of their business. In other words, organizations need to focus not only on environmental aspects but also adopt a comprehensive and integrated approach to assess and improve their economic and social performance.

The eighth and ninth hypotheses of the research showed that end-of-line management innovation has an impact on environmental performance and social performance. The confirmation of the impact of end-of-life management innovation on environmental and social performance highlights the critical role that sustainable practices play in achieving overall sustainability goals. End-of-life management encompasses strategies for the disposal, recycling, and repurposing of products at the end of their lifecycle. By implementing effective end-of-life management innovations, organizations can significantly reduce waste and pollution, thereby enhancing their environmental performance. Furthermore, these innovations often lead to improved social outcomes by fostering community engagement through recycling initiatives and creating job opportunities in the green economy. This relationship underscores the interconnectedness of GTI and SP, suggesting that organizations focusing on end-of-life management can achieve both ecological benefits and positive social impacts, ultimately contributing to a more sustainable future.

Managerial Implications

The affirmation of the impact of GTI on SP in SMEs necessitates actionable managerial strategies that can effectively guide these organizations in their sustainability journeys. First and foremost, SMEs must adopt an integrated approach that combines green product innovation, green process innovation, and end-of-line management. This can be achieved by establishing cross-functional teams that bring together diverse expertise from product development, operations, and sustainability departments. Such collaboration can facilitate the identification of synergies among the different types of innovations, ultimately leading to enhanced resource efficiency and reduced environmental impact. Furthermore, SMEs should prioritize the development of a sustainability roadmap that outlines specific, measurable goals for each dimension of GTI. This roadmap should be communicated clearly across the organization to ensure alignment and collective commitment towards sustainability objectives.

In addition to internal integration, stakeholder engagement is crucial for the successful implementation of green innovations. SMEs should actively involve various stakeholders, including employees, customers, suppliers, and local communities, in the innovation process. This participatory approach not only enriches the innovation process with diverse insights but also fosters a sense of ownership among stakeholders, thereby enhancing social performance. Moreover, SMEs must invest in training programs aimed at building the necessary skills and knowledge among employees to effectively implement green practices. By creating a culture of continuous learning and adaptation, organizations can empower their workforce to drive innovation forward. Lastly, establishing robust metrics for evaluating the economic, environmental, and social impacts of green innovations is essential. SMEs should develop a comprehensive framework for measuring these outcomes, which will enable them to identify strengths and weaknesses and demonstrate their commitment to sustainability to stakeholders.

Conclusion

This paper aims to analyze the impact of GTI dimensions on SP dimensions in SMEs. To achieve this, we first collected information from theoretical foundations and relevant literature, utilizing library resources, academic articles, and scientific databases. The results were then discussed and examined by testing the proposed model in SMEs located in Tehran province, Iran. The model assessing the impact of GTI on SMEs' SP offers several advantages. Firstly, it provides a holistic framework that integrates green product innovation, green process innovation, and end-of-line innovation management. This integration allows SMEs to comprehensively address sustainability challenges. By fostering synergies among different types of innovation, this approach enhances the potential for improved economic, environmental, and social performance. Secondly, the model emphasizes the importance of stakeholder engagement, which can yield richer insights and more effective innovation strategies. By involving various stakeholders, SMEs can tailor their innovations to meet market demands and societal expectations, thereby increasing their competitive advantage. Furthermore, this model encourages

SMEs to adopt a systematic evaluation of their SP across all three dimensions—economic, environmental, and social. Such structured assessments can help organizations identify their strengths and weaknesses, guiding future innovation efforts. Finally, the focus on GTI aligns with global sustainability goals, enabling SMEs to contribute positively to broader societal challenges while enhancing their reputation and brand value. Overall, this model serves as a strategic tool for SMEs aiming to achieve sustainable growth.

However, this study may encounter several challenges and drawbacks. One significant challenge is the potential lack of resources within SMEs, which can hinder their ability to invest in green innovations. Limited financial and human resources may restrict their capacity to implement comprehensive innovation strategies effectively. Additionally, SMEs often face difficulties in accessing relevant information and expertise regarding green technologies, which can impede their innovation efforts. The complexity of integrating multiple dimensions of SP—economic, environmental, and social—can also pose challenges, as SMEs may struggle to balance these often conflicting objectives. Moreover, measuring SP itself can be problematic. Defining appropriate metrics and benchmarks for evaluating performance across various dimensions is complex and may lead to inconsistencies in assessment. Lastly, resistance to change among employees or stakeholders can hinder the adoption of green innovations. Cultural and organizational inertia may prevent SMEs from fully embracing the innovative practices necessary for sustainability. Overall, while this study provides valuable insights, these challenges must be acknowledged to develop effective strategies for enhancing SP through GTI.

Limitations play a crucial role in academic research as they provide a framework for future scholars to build upon and confirm the findings. The importance of addressing potential biases during data collection cannot be overstated, as these biases can significantly impact the accuracy and reliability of the data, leading to flawed conclusions and decisions. By identifying and addressing biases during data collection to ensure the accuracy, fairness, and reliability of data-driven insights and decisions, potential biases for respondents were reduced. One significant constraint of this study is the relatively small sample size, which poses challenges in extrapolating the results to a broader statistical population. Furthermore, it is important to note that the study's focus on SMEs solely within the manufacturing sector may limit the generalizability of the results to other industries, such as services. Future research could enhance the applicability of these findings by including a more diverse range of sectors, thereby allowing for a comparative analysis that captures the unique challenges and opportunities associated with GTI across various contexts. This broader perspective would provide a more comprehensive understanding of how green technology impacts SP in different organizational settings. Based on the above, the following suggestions are recommended for future research:

First, it is essential to broaden the scope of research by including diverse sectors beyond manufacturing, such as services and agriculture. This approach will provide a comprehensive understanding of how GTI influences SP across various industries, thereby enriching the overall discourse on sustainability. Additionally, we advocate for longitudinal studies that examine the long-term effects of GTI on SP. Such studies will allow researchers to track trends and changes over time, offering valuable insights into the sustained impact of green innovations. Moreover, conducting in-depth case studies of specific SMEs that have successfully implemented GTI can reveal best practices and challenges encountered during the adoption process. These case studies will enhance our understanding of the nuanced relationship between green innovation and SP. Furthermore, exploring the perspectives of various stakeholders—including employees, customers, and suppliers—will provide a holistic view of how GTI affects SP from different angles. This stakeholder-centric approach can yield insights into collective engagement and its role in fostering sustainable practices. Another critical area for future research is the analysis of policy impacts. Investigating how governmental and organizational policies either facilitate or hinder GTI among SMEs can illuminate external factors that significantly influence SP. Cross-cultural comparisons are also vital; conducting comparative studies across different cultural and geographical contexts can reveal how cultural factors shape the adoption of green technologies and their subsequent effects on SP.

Finally, future research should consider various internal and external factors affecting the relationship between GTI and SP. These include organizational culture, stakeholder engagement, regulatory frameworks, and financial performance. Additionally, examining the interplay between sustainable supply chain practices and green innovations can provide deeper insights into how these elements collectively enhance sustainability goals. Understanding consumer behavior and preferences for sustainable products is also crucial, as it will inform market-driven strategies that drive innovation. By integrating these diverse variables into future research, we can achieve a comprehensive understanding of the multifaceted nature of SP in SMEs.

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References

Aldás, J. (2016). *Modelización Estructural con PLS-SEM: Constructos de Segundo Orden,* ADD Editorial, Madrid.

Ali, S. S., Kaur, R. & Khan, S. (2023). Evaluating sustainability initiatives in warehouse for measuring sustainability performance: an emerging economy perspective. *Annals of Operations Research,* 324(1), 461-500. https://doi.org/10.1007/s10479-021-04454-w

Antwi-Boateng, C., Mensah, H. K. & Asumah, S. (2023). Eco-intellectual capital and sustainability performance of SMEs: The moderating effect of eco-dynamic capability. *Cogent Business & Management,* 10(3), 2258614. https://doi.org/10.1080/23311975.2023.2258614

Asad, M., Majali, T. E., Aledeinat, M., Abdelkarim Almajali, D., & Akhorshaideh, A. H. O. (2023). Green entrepreneurial orientation for enhancing SMEs financial and environmental performance: Synergetic moderation of green technology dynamism and knowledge transfer and integration. *Cogent Business & Management,* 10(3), 2278842. https://doi.org/10.1080/23311975.2023.2278842

Bagozzi, R. P. & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Science,* 16, 74-94. https://doi.org/10.1007/BF02723327

Braun, E., & Wield, D. (1994). Regulation as a means for the social control of technology. *Technology Analysis & Strategic Management,* 6(3), 259-272. https://doi.org/10.1080/09537329408524171

Caldera, H. T. S., Desha, C., & Dawes, L. (2018). Exploring the characteristics of sustainable business practice in small and medium-sized enterprises: Experiences from the Australian manufacturing industry. *Journal of Cleaner Production,* 177, 338-349. https://doi.org/10.1016/j.jclepro.2017.12.265

Cheng, C., Ahmad, S. F., Irshad, M., Alsanie, G., Khan, Y., Ahmad, A. Y. B., & Aleemi, A. R. (2023). Impact of green process innovation and productivity on sustainability: The moderating role of environmental awareness. *Sustainability,* 15(17), 12945. https://doi.org/10.3390/su151712945

Chin, W. W. (1998). *The partial least squares approach to structural equation modeling.* Modern methods for business research, 295(2), 295-336.

Chin, W. W. (2010). *How to write up and report PLS analyses. In Handbook of Partial Least Squares.* Springer, Berlin, Heidelberg, 655-690.

Contini, G., & Peruzzini, M. (2022). Sustainability and industry 4.0: definition of a set of key performance indicators for manufacturing companies. *Sustainability,* 14(17), 11004. https://doi.org/10.3390/su14171100

De Medeiros, J. F., Garlet, T. B., Ribeiro, J. L. D., & Cortimiglia, M. N. (2022). Success factors for environmentally sustainable product innovation: An updated review. *Journal of Cleaner Production,* 345, 131039. https://doi.org/10.1016/j.jclepro.2022.131039

Denu, M. K., Bentley, Y., & Duan, Y. (2023). Social sustainability performance: Developing and validating measures in the context of emerging African economies. *Journal of Cleaner Production,* 412, 137391. https://doi.org/10.1016/j.jclepro.2023.137391

Dey, P. K., Petridis, N. E., Petridis, K., Malesios, C., Nixon, J. D., & Ghosh, S. K. (2018). Environmental management and corporate social responsibility practices of small and medium-sized enterprises. *Journal of cleaner production,* 195, 687-702. https://doi.org/10.1016/j.jclepro.2018.05.201

Fatimah, Y. A., Kannan, D., Govindan, K. & Hasibuan, Z. A. (2023). Circular economy e-business model portfolio development for e-business applications: Impacts on ESG and sustainability performance. *Journal of Cleaner Production,* 415, 137528. https://doi.org/10.1016/j.jclepro.2023.137528

Feng, Y., Wang, X. & Liang, Z. (2021). How does environmental information disclosure affect economic development and haze pollution in Chinese cities? The mediating role of green technology innovation. *Science of the Total Environment,* 775, 145811. https://doi.org/10.1016/j.scitotenv.2021.145811

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research,* 18(1), 39-50. https://doi.org/10.1177/002224378101800104

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing theory and Practice,* 19(2), 139-152. https://doi.org/10.2753/MTP1069-6679190202

Hair, J.F., Anderson, R.E., Tatham,R. L., & Black, W. C. (2010). *Multivariate data analysis (7th ed).* New Jersey: Prentice Hall.

Hair, J.F., Hult, G.T.M., Ringle, C.M. & Sarstedt, M. (2014). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM),* Sage, Thousand Oaks, CA.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science,* 43, 115-135. https://doi.org/10.1007/s11747-014-0403-8

Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. *In New challenges to international marketing* (Vol. 20, pp. 277-319). Emerald Group Publishing Limited. https://doi.org/10.1108/S1474-7979(2009)0000020014

Inyang, B. J. (2013). Defining the role engagement of small and medium-sized enterprises (SMEs) in corporate social responsibility (CSR). *International business research,* 6(5), 123. http://dx.doi.org/10.5539/ibr.v6n5p123

Jiang, Q., Liu, Z., Liu, W., Li, T., Cong, W., Zhang, H., & Shi, J. (2018). A principal component analysis based three-dimensional sustainability assessment model to evaluate corporate sustainable performance. *Journal of Cleaner Production,* 187, 625-637. https://doi.org/10.1016/j.jclepro.2018.03.255

Kam-Sing Wong, S. (2012). The influence of green product competitiveness on the success of green product innovation: Empirical evidence from the Chinese electrical and electronics industry. *European Journal of Innovation Management,* 15(4), 468-490. https://doi.org/10.1108/14601061211272385

Karia, N., & Davadas Michael, R. C. (2022). Environmental Practices That Have Positive Impacts on Social Performance: An Empirical Study of Malaysian Firms. *Sustainability,* 14(7), 4032. https://doi.org/10.3390/su14074032

Khan, S. A. R., Ahmad, Z., Sheikh, A. A., & Yu, Z. (2023). Green technology adoption paving the way toward sustainable performance in circular economy: a case of Pakistani small and medium enterprises. *International Journal of Innovation Science,* (ahead-of-print). http://dx.doi.org/10.1108/IJIS-10-2022-0199

Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of e-Collaboration (ijec),* 11(4), 1-10. https://doi.org/10.4018/ijec.2015100101

López-Arceiz, F. J., Del Río, C., & Bellostas, A. J. (2020). Sustainability performance indicators: Definition, interaction, and influence of contextual characteristics. *Corporate Social Responsibility and Environmental Management,* 27(6), 2615-2630. https://doi.org/10.1002/csr.1986

Malesios, C., De, D., Moursellas, A., Dey, P. K., & Evangelinos, K. (2021). Sustainability performance analysis of small and medium sized enterprises: Criteria, methods and framework. *Socio-Economic Planning Sciences,* 75, 100993. https://doi.org/10.1016/j.seps.2020.100993

Mengistu, A. T., & Panizzolo, R. (2023). Metrics for measuring industrial sustainability performance in small and medium-sized enterprises. *International Journal of Productivity and Performance Management,* (ahead-of-print). https://doi.org/10.1108/IJPPM-04-2022-0200

Moradi, M., & Miralmasi, A. (2020). *Pragmatic research method. School of Quantitative and Qualitative Research.* Retrieved from https://analysisacademy.com

Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., AbdulGhani, A., & Kumar, S. (2022). Green product innovation: A means towards achieving global sustainable product within biodegradable plastic industry. *Journal of Cleaner Production,* 363, 132506. https://doi.org/10.1016/j.jclepro.2022.132506

Mukhtar, B., Shad, M. K. & Lai, F. W. (2024). Fostering sustainability performance in the Malaysian manufacturing companies: the role of green technology innovation and innovation capabilities. *Benchmarking: An International Journal.* https://doi.org/10.1108/BIJ-07-2023-0468

Mukhtar, B., Shad, M. K., Won, L. F., Waqas, A. & Mukhtar, Z. (2023). Role of green technology innovation to promote sustainability performance in Malaysian manufacturing solar PV industry: A conceptual framework. Platform: *A Journal of Management and Humanities,* 6(1), 36-46. https://doi.org/10.61762/pjmhvol6iss1art22890

Nosratabadi, S., Mosavi, A., Shamshirband, S., Zavadskas, E. K., Rakotonirainy, A., & Chau, K. W. (2019). Sustainable business models: A review. *Sustainability,* 11(6), 1663. https://doi.org/10.3390/su11061663

Onileowo, T. T., Muharam, F. M., Ramily, M. K., & Khatib, S. F. (2021). The Nexus between innovation and business competitive advantage: A conceptual study. *Universal Journal of Accounting and Finance,* 9(3), 352-361. https://doi.org/10.13189/ujaf.2021.090309

Opoku-Mensah, E., Chun, W., Ofori, E. K., Ampofo, S. A., Chen, W., & Appiah-Otoo, I. (2024). Revisiting the role of ICT and green institutional governance in environmental sustainability and proposing an ecological footprint mitigation pathway using a volatility-driven model. *Journal of Cleaner Production,* 434, 139824. https://doi.org/10.1016/j.jclepro.2023.139824

Ortiz-Avram, D., Domnanovich, J., Kronenberg, C., & Scholz, M. (2018). Exploring the integration of corporate social responsibility into the strategies of small-and medium-sized enterprises: A systematic literature review. *Journal of cleaner production,* 201, 254-271. https://doi.org/10.1016/j.jclepro.2018.08.011

Peng, Y., Fan, Y., & Liang, Y. (2021). A green technological innovation efficiency evaluation of technology-based smes based on the undesirable sbm and the malmquist index: A case of Hebei province in China. *Sustainability,* 13(19), 11079. https://doi.org/10.3390/su131911079

Rezaee, Z. (2016). Business sustainability research: A theoretical and integrated perspective. *Journal of Accounting literature,* 36(1), 48-64. https://doi.org/10.1016/j.acclit.2016.05.003

Romana, A. F., & Gestoso, C. (2023). Economic performance and the implementation of lean management model. *Economics and Finance,* 11(1), 13-23. http://hdl.handle.net/10400.5/30409

Sdrolia, E., & Zarotiadis, G. (2019). A comprehensive review for green product term: From definition to evaluation. *Journal of Economic Surveys,* 33(1), 150-178. https://doi.org/10.1111/joes.12268

Szennay, Á., Szigeti, C., Beke, J., & Radácsi, L. (2021). Ecological footprint as an indicator of corporate environmental performance—Empirical evidence from hungarian SMEs. *Sustainability,* 13(2), 1000. https://doi.org/10.3390/su13021000

Tenenhaus, M., Vinzi, V. E., Chatelin, Y. M. & Lauro, C. (2005). *PLS path modeling. Computational Statistics & Data Analysis*, 48(1)159-205. https://doi.org/10.1016/j.csda.2004.03.005

Wagner, M. (2010). The role of corporate sustainability performance for economic performance: A firm-level analysis of moderation effects. *Ecological economics,* 69(7), 1553-1560. https://doi.org/10.1016/j.ecolecon.2010.02.017

Wang, C., Du, D., Liu, T., Zhu, Y., Yang, D., Huang, Y., & Meng, F. (2024). Impact of Green Technology Innovation on Green Economy: Evidence from China. *Sustainability,* 16(19), 8557. https://doi.org/10.3390/su16198557

Wang, M., He, Y., Zhou, J. & Ren, K. (2022). Evaluating the effect of Chinese environmental regulation on corporate sustainability performance: the mediating role of green technology innovation. *International Journal of Environmental Research and Public Health,* 19(11), 6882. https://doi.org/10.3390/ijerph19116882

Wang, S., Wen, J., Yang, X., Deng, P., & Wang, N. (2023). Impacts of digital trade restrictiveness on green technology innovation: an empirical analysis. *Emerging Markets Finance and Trade,* 59(7), 2079-2101. https://doi.org/10.1080/1540496X.2023.2172321

Xie, X., Huo, J., & Zou, H. (2019). Green process innovation, green product innovation, and corporate financial performance: A content analysis method. *Journal of business research,* 101, 697-706. https://doi.org/10.1016/j.jbusres.2019.01.010

Xie, X., Zhu, Q., & Wang, R. (2019). Turning green subsidies into sustainability: How green process innovation improves firms' green image. *Business Strategy and the Environment,* 28(7), 1416-1433. https://doi.org/10.1002/bse.2323

Yang, Y., Jiang, Y., Chen, H. & Xu, Z. (2023). Linking relation-specific investments and sustainability performance: the mediating role of supply chain learning. *International Journal of Operations & Production Management,* 43(8), 1329-1356. https://doi.org/10.1108/IJOPM-07-2022-0463

Ye, M., Hao, F., Shahzad, M. & Kamran, H. W. (2022). How green organizational strategy and environmental CSR affect organizational sustainable performance through green technology innovation amid Covid-19. *Frontiers in Environmental Science,* 10, 959260. https://doi.org/10.3390/su16010277

Yu, Y., Hu, W., Dong, C., Gu, X., & Obrenovic, B. (2023). E-commerce development and green technology innovation: Impact mechanism and the spatial spillover effect. *Sustainability,* 15(17), 12988. https://doi.org/10.3390/su151712988

Zhang, X., & Tang, Z. (2022). Construction of computer model for enterprise green innovation by PSO-BPNN algorithm and its impact on economic performance. *Plos one,* 17(1), e0262963. https://doi.org/10.1371/journal.pone.0262963

Zhou, L. & Dai, Y. (2023). Green Production Management and Innovation Nexus: Evidence from Technology-Based SMEs of China. *Sustainability,* 15(6), 4710. https://doi.org/10.3390/su15064710

Zuo, G. (2023). The Influence and Mechanism Analysis of Environmental Regulation on Green Technology Innovation of Enterprises. *Frontiers in Business, Economics and Management,* 12(3), 229-234. https://doi.org/10.54097/8ryqz9ai