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Original Research

Stakeholder-Driven Sustainable Technology Application in Fashion Manufacturing Enterprises and Performance Impact

Yao Xiao[1*], Wei Li[2]**

[1]College of Economics, Shenzhen University, Shenzhen, China
[2]Shenzhen National Policy Information Service Co., Ltd., Shenzhen, China

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Abstract

This paper explores the role of multiple stakeholder-driven factors in promoting sustainable technology application in fashion manufacturing enterprises from the perspective of stakeholder theory and analyzes the impact of sustainable technology application on environmental, financial, and competitive performance. Through empirical analysis of survey data from 350 fashion manufacturing enterprises in Quanzhou City, the results reveal that customer pressure, management support, policy support, and competitive pressure significantly and positively influence sustainable technology application in enterprises, while the influence of regulatory pressure is not significant. Furthermore, sustainable technology application has a significant positive impact on the environmental, financial, and competitive performance of enterprises. The research findings provide theoretical insights for successful deployment and implementation of sustainable technology applications in fashion manufacturing enterprises, as well as for government optimization and adjustment of supportive policies.

Keywords: sustainable technology application, stakeholder-driven factors, performance, fashion manufacturing enterprises

Introduction

The fashion manufacturing industry has long been criticized for its environmental pollution and waste of resources [1]. According to the report released by the United Nations Environment Programme (UNEP), the fashion sector is one of the largest contributors to global climate and ecological crises. It accounts for 2-8% of global carbon emissions annually and 4% of global freshwater use, leading to the deforestation of 150 million trees, and is accompanied by unsafe working conditions, low wages, and other social issues [2]. Amplifying the application of sustainable technologies in the fashion manufacturing industry to reduce environmental pollution and resource wastage has become a consensus among the global fashion sector. Governments worldwide and renowned fashion brands have reinforced their social and environmental responsibility management for fashion manufacturing enterprises. The "UN Fashion Charter for Climate Action (UNFCCA)", led by the Intergovernmental Panel

* e-mail: xiaoyao_szu@163.com
** e-mail: leewei@sznpis.com;
Tel.: +86-13510111070;
Fax: +86-0755-86700907.

on Climate Change (IPCC), was launched in 2018, proposing a 30% reduction in carbon emissions by 2030 and carbon neutrality by 2050. However, in 2021, these goals were revised to include halving carbon emissions by 2030 and achieving carbon neutrality by 2050. The China National Textile and Apparel Council is one of the first signatories of the UNFCCA and has been actively promoting green and low-carbon development in the domestic fashion industry. It established the "China Green Carbon Foundation Fashion Climate Innovation Fund" and successively initiated projects like the "China Fashion Brand Climate Innovation Carbon Neutrality Acceleration Plan" and the "30·60 Carbon Neutrality Acceleration Plan". The attention and emphasis on ESG (Environment, Social, and Governance) are continuously growing, and the number of listed enterprises voluntarily disclosing ESG reports is rapidly increasing each year. International fashion giants such as LVMH, Prada, Richemont, OTB, Kering, H&M, and Patagonia have strengthened the application of digital technologies like blockchain and the Internet of Things in their supply chain management. They also actively implement sustainable supplier development programs, advocating for and promoting sustainable development in the fashion industry. Quanzhou's footwear and clothing fashion manufacturing industry enjoys global acclaim. Many internationally renowned brands rely on Quanzhou's design and supply chains. Local brands are also progressively moving towards a high-quality development path characterized by technological innovation, intelligent manufacturing, and green, low-carbon features. An increasing number of Quanzhou fashion manufacturing enterprises have received international factory and product certifications like LEED, BSCI, WRAP, SMETA, GOTS, TGI, OCS, and STeP, as well as domestic certifications such as Green Factory and China Environmental Labeling Product Certification. They are intensifying the application and investment in sustainable technologies to achieve green energy-saving and green manufacturing, leading and driving sustainable development in the industry.

Scholars have conducted extensive analyses of the circular business models, green supply chain systems, and environmental innovation practices of the fashion industry. However, the primary focus has been centered on retail, consumption, and recycling segments [3-5], with less attention given to the production and manufacturing processes. Additionally, scholars have analyzed the driving factors for the application of various sustainable technologies and their impacts on performance, touching upon both internal and external organizational driving elements, such as green technological capabilities, policy regulations, buyer demands, executive incentives, and market competition [6-9]. Yet, these studies predominantly concentrate on a macro perspective, encompassing regions and industries, and pay limited attention to the micro-level manufacturing processes of individual enterprises. Moreover, specialized research focusing on fashion manufacturing enterprises as subjects is considerably limited. Against the backdrop of high-quality industrial development, the depth and breadth of sustainable technology applications in the fashion manufacturing industry will continually expand, leading fashion manufacturing enterprises to frequently face decisions regarding the adoption of these sustainable technologies. Corporate managers must systematically consider the demands and influences of stakeholders. For instance, which stakeholders' demands are affected by the sustainable technology applications of fashion manufacturing enterprises? How do stakeholders like governments, customers, and competitors influence a company's application of sustainable technologies? Research on stakeholder-driven factors and performance impacts related to sustainable technology applications is still in its early stages among both domestic and international scholars. There is a noticeable lack of empirical research outcomes specifically targeting fashion manufacturing enterprises, underscoring the pressing need to enhance research in this area. Therefore, this study aims to categorize the types of sustainable technology applications during the production processes of fashion manufacturing enterprises. It will explore, from a stakeholder's perspective, the driving factors for the adoption of sustainable technologies by these enterprises, the impact of these applications on company performance, and be supported by empirical analysis.

Literature Review

Sustainable Development Trends in the Fashion Manufacturing Industry and the Classification of Sustainable Technologies

Over the past decade, sustainable development has become a consensus in the industrial sector, with corporations increasingly focusing on environmental protection and social responsibility in their operations. These companies are incorporating eco-friendly and philanthropic philosophies into their business development strategies. The fashion industry, in particular, has been criticized for its environmental pollution and the extensive use of resources, leading to pollution and waste [10]. The notion that "fast fashion is destroying the planet" has been widely reported across various media outlets and published in renowned academic journals [11]. Influenced by regulatory pressures and societal consensus on sustainable development, core companies at the pinnacle of the fashion industry value chain have initiated sustainable supplier development programs. These programs set clear sustainability standards for their suppliers, with an increasing number of suppliers being required to provide sustainability certifications or disclose their sustainability practices [12, 13]. Numerous fashion manufacturing companies have proactively invested in the application of sustainable technologies to support the implementation of sustainability measures, such as reducing carbon footprints and improving working conditions [14, 15].

The definition of Sustainable Technology varies among environmental departments or organizations around the world. The United Nations Environment Programme (UNEP) defines sustainable technology as technology that exhibits optimal performance in social, economic, and environmental aspects, minimizing resource utilization and environmental impact throughout its life cycle [16]. The International Energy Agency (IEA) defines it as technology capable of meeting energy demands while minimizing adverse environmental impacts to the greatest extent, thereby ensuring the long-term sustainable development of the energy system [17]. The U.S. Environmental Protection Agency (EPA) defines sustainable technology as one that can meet both current and future demands while reducing environmental pollution and resource consumption [18]. These definitions underscore the extensive scope of sustainable technology, encompassing considerations from environmental, social, and economic dimensions, aiming to promote solutions and technological innovations in pursuit of sustainable development goals. Incorporating sustainable technology into the development of physical manufacturing can robustly support innovations in company products, processes, services, and business models. Such incorporation not only facilitates the transition towards industry-wide sustainable development but also enhances corporate compliance and competitiveness. Based on UNEP's classification, Fu et al. [6] suggested that sustainable technologies applicable to manufacturing enterprises can be divided into four categories: reduction of greenhouse gas emissions, substitution of materials or fuels, improvement in material or energy efficiency, and end-of-pipe recycling technologies. Hoque et al. [8] categorized sustainable technologies in the garment manufacturing sector into four classes: reducing energy consumption, pollution reduction, waste minimization, and digital technologies targeting green and low carbon objectives. In addition, the academic community has introduced other synonymous terminologies: clean technology focuses on reducing pollution and materials or energy consumption; energy-saving technology emphasizes improving energy efficiency; and environmental technology aims to reduce resource consumption while minimizing environmental damage [19]. Currently, the integration and application of digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), and blockchain, along with green and low-carbon technologies, have become standard practice [20]. Digital technologies and solutions are becoming a focal point for supporting the successful implementation of sustainable technology applications in manufacturing enterprises. For example, AI technology can be used for the intelligent management of production lines, enhancing production efficiency and product quality. IoT technology enables interconnectivity between devices, allowing for real-time monitoring and optimization of the production process, reducing energy consumption and emissions. Blockchain technology can facilitate the digital management of supply chains, enhancing their transparency and efficiency. Big data technology enables real-time monitoring and analysis of various segments of the supply chain, optimizing logistics and distribution strategies, and reducing transportation costs and carbon emissions. Combining the aforementioned perspectives, we can summarize the typical applications of sustainable technology involved in various production stages of fashion manufacturing enterprises, as illustrated in Fig. 1.

Stakeholder Theory and the Study of Sustainable Technology Application in Fashion Manufacturing Enterprises

According to stakeholder theory proposed by Freeman [21], stakeholders possess attributes of power, legitimacy, and urgency; hence, enterprises must address stakeholders' demands, allocating resources to achieve higher value creation [22, 23]. In many scenarios, significant strategic decisions of enterprises, including technology applications, are influenced by

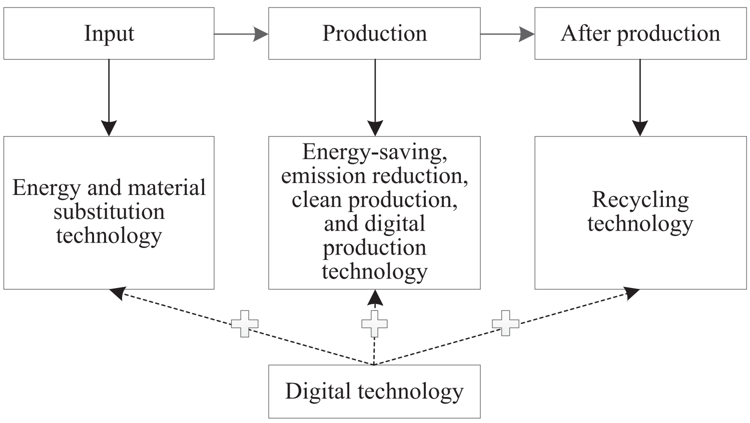

Fig. 1. Types of Sustainable Technology Applications in Fashion Manufacturing Enterprises.

stakeholders, including regulatory bodies, customers, industry associations, and the community. Scholars have investigated the impact of stakeholder demands on enterprises' sustainable technology application behaviors [8, 24]. Additionally, the theory of dynamic capabilities emphasizes the imperative for enterprises to continually renew their resource base to adapt to disruptive changes in the environment and sustain competitive advantages [25]. Through environmental insights from a stakeholder perspective, enterprises can timely perceive changes in environmental dynamics, establishing a knowledge foundation for crucial decisions aimed at aligning internal resources and capabilities with the external environment. However, due to the complexities of industry environment features and technology characteristics, internal stakeholders such as top executives, middle management, and employees perceive varying levels of pressure from customers, suppliers, competitors, and regulators. The prioritization of stakeholders also differs in each decision-making process. Consequently, research conclusions significantly vary depending on specific regional and industry contexts. For instance, Wagner's [26] research on German manufacturing enterprises indicates a positive correlation between stakeholder influence and corporate environmental innovation behavior, whereas Buysse & Verbeke's [27] research on Belgian manufacturing enterprises shows that stakeholder influence is unrelated to sustainable practices. Generally, governments exert the highest authority over corporate production behaviors through environmental policies and regulations, significantly promoting the application of sustainable technology in manufacturing enterprises [6]. However, in certain industries, the pressure from customers or the community might be more direct than regulatory forces, such as in fashion manufacturing enterprises. Meeting or even bypassing environmental policy and regulatory requirements still presents challenges when dealing with intricate and specific sustainable development standards posed by upstream brand merchants or traders. Hence, it's vital to discern the influence of various stakeholder-driven factors within the specific context of fashion manufacturing.

Currently, abundant academic research exists regarding the impact of sustainable technology applications on corporate performance. Most studies concur that the application of sustainable technology contributes to enhanced enterprise performance [28, 29]. Scholars have reached a consensus on mechanisms through which sustainable technology application enhances corporate performance, primarily encompassing pathways like promoting enterprise green innovation capabilities, invigorating human resources, alleviating agency issues, and easing corporate financing constraints [30]. Yet, existing research often adopts cross-industry data, predominantly examining the effects of sustainable technology application from a regional and industry macro perspective. Research focusing on micro-groups like fashion manufacturing enterprises remains scant. Furthermore, in discussions about environmental, financial, and competitive performance related to sustainable technology application, most focus lies on environmental and financial performance, with competitive performance often overlooked.

Research Hypotheses

Drawing from the research findings on stakeholder theory within the fashion manufacturing industry, the driving factors of various stakeholders in fashion manufacturing enterprises have been identified, primarily including top management support, customer pressure, policy support, regulatory pressure, and competitor pressure. Based on these factors, we have developed a theoretical model illustrating the relationships among stakeholder driving factors, the application of sustainable technologies, and corporate performance. The related research hypotheses are delineated as follows:

Stakeholder Drives for Sustainable Technology Application

The application of sustainable technology is often a significant decision-making topic for enterprises, involving substantial investments in terms of human, financial, and material resources. Owing to the characteristics of sustainable technology application, such as high costs, high risks, and dual externalities, opportunistic behaviors of executives within the company can hinder its promotion, leading to a lack of internal drive and execution [30]. The support from top management for the corporate culture and practices of sustainable development serves as an essential foundation for a company to actively fulfill its social responsibilities and prioritize environmentally-friendly innovations. It provides resource backing for the procurement and implementation of related technologies and aids in propelling the practice of sustainable technology application at the organizational level [7, 31]. For example, the operations, procurement, and production and design departments might propose the need for digital technology applications to enhance design and production efficiency, reduce waste, and shorten delivery cycles. Top management endorses and approves the purchase of software and hardware, deploys its use in the design and production stages, and provides resources and time for technical and operational training for employees. Thus, the following hypothesis is proposed:

H1: Top management support has a significant positive impact on sustainable technology application in fashion manufacturing enterprises.

A company's environmental management practices largely depend on the expectations and demands of its customers. However, the research findings regarding the influence of customer pressure on sustainable technology applications are inconsistent. For instance, Zhang et al. [32] found that customer pressure did not significantly influence the environmental management practices of logistics enterprises in China. On the other hand, a majority of studies, such as those by Adebanjo et al. [33] and Huq & Stevenson [34], indicate a significant positive influence of customer pressure on the implementation of sustainable technology. Such discrepancies may be related to industry structures. If the purchasing power of a product is dispersed, changes in buyer demands might not substantially impact the existing product market. Regarding the global value chain of the fashion industry, large brand retailers and wholesalers at the top have always held significant sway, enabling them to impose mandatory sustainability development standards on their supplier groups. Moreover, an increasing number of manufacturing suppliers are being asked to provide sustainability proofs or disclose sustainability practices. Abbate et al. [5] showed that the demand for supply chain transparency and the selection of certified suppliers by top brand customers led to fundamental changes in value proposition, product creation, and product delivery, spurring a wave of circular business model innovations and emerging digital technology applications. Therefore, the following hypothesis is proposed:

H2: Customer pressure has a significant positive impact on sustainable technology application in fashion manufacturing enterprises.

It's generally believed that incentive-based environmental regulatory policies, including financial subsidies, low-interest loans, government procurement, human resource training, and technical support, can either partially or fully offset the costs incurred by businesses in the R&D and implementation of sustainable technologies. Such policies can yield direct and indirect net benefits, resulting in cost compensation effects, talent attraction effects, and industry demonstration effects, thus motivating sustainable technology application by enterprises [30, 35, 36]. Nonetheless, a few studies have arrived at different conclusions. For example, Borghesi et al. [37] indicated that government subsidies had a significant positive impact on the diffusion of CO_2 reduction technology, but not on the proliferation of energy-saving technology. Hence, the following hypothesis is postulated:

H3: Policy support has a significant positive impact on sustainable technology application in fashion manufacturing enterprises.

Environmental policy regulations and industry standards exert mandatory constraints on a company's environmental management behaviors [6]. Enterprises violating these regulations may face substantial fines, enforced rectifications, or even shutdowns. In China's fashion manufacturing industry, businesses mainly confront national environmental policy regulations and mandatory standards or requirements imposed by industry organizations such as the China National Textile and Apparel Council (CNTAC). For fashion manufacturers exporting products, besides adhering to domestic policies and regulations, they also need to comply with international environmental protection stipulations. Research by Yenipazarli [38] and Gu et al. [39] suggests that government regulatory mechanisms, such as carbon emission taxes and carbon trading rules, play a significant role in promoting the adoption of green technologies by businesses. Conversely, Scheiber [40] found in his study on Germany's textile and garment industry that pressures exerted by non-governmental entities, such as industry organizations and associations, serve as the primary driving force in propelling the industry's corporate social responsibility practices. Therefore, this study emphasizes the combination of government and industry association regulations. Based on the aforementioned views, the following hypothesis is postulated:

H4: Regulatory pressure has a significant positive impact on sustainable technology application in fashion manufacturing enterprises.

Gosh [41] posits that competitive pressure serves as a potent catalyst for enterprises to adopt green supply chain management. Pioneering firms that decisively act upon applying sustainable production methods not only reap considerable rewards in terms of market share and profits but also exert substantial pressure on industry laggards, compelling them to ramp up their technological investments. The domestic fashion manufacturing industry operates in an essentially fully competitive market. The rapid rise in labor costs coerces businesses to expedite their transition from human labor to machinery and the application of digital technologies to gain a competitive edge. Southeast Asian (e.g., Vietnam, Cambodia, Myanmar) and South Asian (e.g., Bangladesh) fashion industries might have the advantage of lower labor costs, but they are actively adopting energy-saving, material-saving, and automation technologies. Simultaneously, countries like Europe, America, and Japan, leveraging their high-tech materials and smart manufacturing capabilities, are causing a partial reshoring of the fashion manufacturing industry, presenting competitive challenges to China's fashion manufacturers. In a fiercely competitive market environment, applying sustainable technologies to reduce material and energy consumption in the manufacturing process can help reshape competition paradigms, redefine the rules of the game, and surpass competitors [29, 42]. Hence, the following hypothesis is proposed:

H5: Competitor pressure has a significant positive impact on sustainable technology application in fashion manufacturing enterprises.

Sustainable Technology Application and Enterprise Performance

While businesses may face increased operational costs when implementing sustainable technology

Table 1. Descriptive Statistics of the Sample.

Statistical Variable		Number	Percentage
Respondent Position	Medium level	124	35.43%
	Senior level	226	64.57%
Business Operating Duration	Up to 5 years (inclusive)	10	2.86%
	6 to 10 years (inclusive)	59	16.86%
	11 to 20 years (inclusive)	145	41.43%
	Over 20 years	136	38.86%
Annual Business Revenue (CNY)	20 to 50 million (inclusive)	96	27.43%
	50 million to 1 billion (inclusive)	140	40.00%
	1 to 10 billion (inclusive)	106	30.29%
	Over 10 billion	8	2.29%
Number of Employees	Up to 300 (inclusive)	55	15.71%
	301 to 1000 (inclusive)	82	23.43%
	1001 to 2000 (inclusive)	101	28.86%
	Over 2000	112	32.00%
Market Scope	Purely domestic	42	12.00%
	Purely international	120	34.29%
	Both domestic and international	188	53.71%

Table 2. Results of the Correlation Matrix.

	TMS	CP	PS	RP	CMP	STA	EP	FP	CTP
TMS	1								
CP	0.358**	1							
PS	0.364**	0.373**	1						
RP	0.387**	0.128*	0.481**	1					
CMP	0.311**	0.355**	0.338**	0.314**	1				
STA	0.463**	0.598**	0.417**	0.210**	0.406**	1			
EP	0.434**	0.492**	0.358**	0.230**	0.409**	0.565**	1		
FP	0.154*	0.502**	0.395**	0.020	0.281**	0.458**	0.342**	1	
CTP	0.449**	0.514**	0.362**	0.141*	0.346**	0.589**	0.614**	0.411**	1

Note: *p<0.05; ** p<0.01; ** *p<0.001

applications, they can surpass competitors in the market by raising product prices or expanding their market share, especially given the growing emphasis on sustainability [38]. In fact, over 90% of the Fortune 500 enterprises reported that they are intensifying their research and application of sustainable technologies to gain a competitive edge in their respective industries [43]. The essence of sustainable technology is to foster corporate growth through energy-saving, environmental protection, and green development technologies [1], reduce the consumption of natural resources, and minimize pollutant emissions. Environmental performance primarily involves reducing material use and waste emissions, enhancing energy efficiency, and increasing the use rate of recyclable materials [28], which aligns with the objectives of sustainable technology applications. Numerous studies have also demonstrated that the application of sustainable technology significantly bolsters the environmental performance levels of manufacturing enterprises [44]. Through the application of sustainable technologies, enterprises can increase their market share, penetrate new markets, achieve growth in profit margins, lessen financing constraints, and elevate corporate value, among other benefits [24, 39]. Moreover, the application of sustainable technology can also confer competitive advantages, such as boosting capacity utilization, enhancing corporate image and reputation, and elevating industry status [29, 33]. Based on the above, the following hypotheses are postulated:

H6: Sustainable technology application has a positive impact on the environmental performance of fashion manufacturing enterprises.

H7: Sustainable technology application has a positive impact on the financial performance of fashion manufacturing enterprises.

H8: Sustainable technology application has a positive impact on the competitive performance of fashion manufacturing enterprises.

Research Methodology

Scale Design

During the design of the scale, we adopted existing mature scales and made appropriate adjustments based on the specific context of our study to ensure accuracy and validity of measurement. We sought and incorporated the opinions of 6 experts from both the industry and academia, including 2 executives from footwear and clothing enterprises, 1 secretary-general from a textile and garment association, and 3 scholars specializing in environmental engineering and green manufacturing. Their insights played a pivotal role in refining measurement items, ensuring content validity, and enhancing comprehensibility. The final scale is presented in Table 3.

In the scale, measurements for top management support, customer pressure, regulatory support, and policy support were referenced from the studies of Ghosh [41] and Lin & Ho [45], each containing 3 items. The measurement for competitor pressure was taken from Ghosh [41] and consists of 3 items. Measurements for sustainable technology application were derived from the studies of Ghosh [41] and Zhang et al. [46], which contained 3 items. Environmental performance measurement was based on Zhang et al. [46] and also comprises 3 items. Financial performance and competitive performance measurements were referenced from the studies of Zhang et al. [46] and Zhu et al. [47], which contained 3 and 4 items, respectively. All measurement items utilized a Likert 5-point scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Data Collection

A questionnaire survey was conducted targeting footwear and clothing fashion manufacturing enterprises in Quanzhou City, Fujian Province. In collaboration with the Textile and Garment Chamber of Commerce and the Footwear Chamber of Commerce of Quanzhou City, the research team reached out to 800 large-scale footwear and clothing fashion manufacturing enterprises between July and August 2023. We invited individuals such as the heads of production operations, factory directors, and directors of technical quality departments, as well as managers of production workshops and technical quality departments, encompassing both senior and middle management, to respond to the electronic questionnaire. In total, 360 questionnaires were collected. After eliminating 10 questionnaires due to missing responses or inconsistencies in the answers, we obtained 350 valid questionnaires.

Analytical Method

We employed the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, a variance-based method, for data analysis. The PLS-SEM method has advantages such as smaller sample size requirements and no stringent assumptions regarding data distribution normality. It provides robust parameter estimation results and is suitable for handling complex structural models, including those with numerous latent variables. This method is more fitting for exploratory and developmental theoretical endeavors without an excessive need for theoretical grounding [48]. For data analysis, we used the statistical software packages SPSS 26.0.0 and SmartPLS 3.3.9. The analysis covered descriptive statistics, assessment of common method bias, evaluation of measurement model reliability and validity, analysis of structural model path relationships, and hypothesis testing, among other aspects.

Research Results

Sample Structure Analysis

The basic statistical information of the respondents and the background of the enterprises they belong to are shown in Table 1. Among the valid samples, respondents in senior management positions accounted for over 60%. This provides a more accurate reflection of the true operational and technological application situations of the enterprises. In terms of years of operation, nearly 80% of the enterprises have been in operation for more than 10 years. In terms of average annual revenue, enterprises with revenue brackets of 20 million to 50 million and 50 million to 100 million account for over 70% of the sample. In terms of employee count, over 60% of the enterprises have a staff size ranging between 1,001 and 2,000 and more than 2,000. In terms of regional market scope, enterprises that cater to both domestic and international markets and those exclusively catering to international markets account for almost 90% of the sample. These statistical results are largely consistent with the overall developmental

Table 3. Analysis of Reliability and Convergent Validity.

Variables	Items	Loadings
Top Management Support (TMS) α = 0.882; CR = 0.913; Rho_A = 0.888; AVE = 0.795	TMS1 Top management in our company encourages sustainable technology application in all departments	0.803
	TMS2 Our top management pushes the implementation of sustainable supplier development plans	0.742
	TMS3 Our top management provides various resources to support sustainable development initiatives	0.846
Customer Pressure (CP) α = 0.826; CR = 0.886; Rho_A = 0.827; AVE = 0.746	CP1 The sustainability level of manufacturing processes and products is an important criterion for customers when selecting suppliers	0.839
	CP2 Our company frequently participates in sustainable technology training seminars organized by customers	0.761
	CP3 The number of green and environmentally friendly products in our product line, required by customers, is steadily increasing	0.817
Policy Support (PS) α = 0.873; CR = 0.918; Rho_A = 0.879; AVE = 0.781	PS1 The government offers financial rewards for our sustainable technology applications	0.827
	PS2 The government provides technical support for our sustainable technology applications	0.801
	PS3 The government offers personnel training support for our sustainable technology applications	0.749
Regulatory Pressure (RP) α = 0.861; CR = 0.890; Rho_A = 0.878; AVE = 0.760	RP1 The government enforces increasingly stringent environmental regulations	0.865
	RP2 Industry associations oversee our company's compliance with environmental regulations	0.811
	RP3 The government requires our company to produce more environmentally friendly products	0.729
Competitor Pressure (CMP) α = 0.890; CR = 0.907; Rho_A = 0.894; AVE = 0.713	CMP1 In our industry, the manufacturing process is increasingly focusing on sustainable technology applications	0.821
	CMP2 Our company introduces more environmentally friendly products to the market because our competitors are doing so	0.803
	CMP3 Our competitors receive government support due to their sustainable technology applications	0.764
Sustainable Technology Application (STA) α = 0.875; CR = 0.914; Rho_A = 0.877; AVE = 00.783	STA1 Our company applies technologies related to environmentally-friendly product innovation (e.g., eco-label certification, environmentally-friendly material alternatives, product degradation and remanufacturing techniques, etc.)	0.857
	STA2 Our company utilizes green manufacturing process innovation technologies (e.g., pollution/waste reduction, energy and material savings, recycling and remanufacturing techniques, etc.)	0.832
	STA3 Our company adopts sustainable management innovation technologies (e.g., smart manufacturing system applications, green supply chain systems, environmental audit/control systems, etc.)	0.771
Environmental Performance (EP) α = 0.897; CR = 0.928; Rho_A = 0.902; AVE = 00.806	EP1 Reduced energy and raw material consumption	0.846
	EP2 Reduced waste/pollutant emissions	0.839
	EP3 Reduced environmental impact over the product lifecycle	0.762
Financial Performance (FP) α = 0.837; CR = 0.878; Rho_A = 0.840; AVE = 00.770	FP1 Reduced energy and resource costs	0.822
	FP2 Increased market share	0.784
	FP3 Enhanced profitability	0.741
Competitive performance (CTP) α = 0.789; CR = 0.840; Rho_A = 0.791; AVE = 00.636	CTP1 Reduced operational/product costs	0.815
	CTP2 Improved product/service quality	0.802
	CTP3 Enhanced production capacity utilization	0.763
	CTP4 Elevated managerial efficiency	0.701

Note: α = Cronbach's α; AVE = Average Variance Extracted; CR = Composite Reliability; rho_A = Dijkstra-Henseler's rho.

characteristics of the fashion manufacturing industry in Quanzhou.

According to the results of Harman's single-factor test, the variance explained by the first common factor is 32.015%, which is below 40% [49]. As shown in Table 2, the correlation matrix indicates that the correlations between each variable are all below the 0.7 threshold [50]. To exclude the interference of multicollinearity, the Variance Inflation Factor (VIF) values were calculated. The VIF values range between 1.142 and 2.940, all of which are below the critical threshold of 3.3 [51]. This indicates that there is no multicollinearity issue. In summary, the adverse effects of common method bias in this study can be disregarded.

Assessment of the Measurement Model

The factor loadings of each variable's items are shown in Table 3. All the factor loadings of items are greater than 0.70, indicating a good correlation between each variable and its items. The reliability of the measurements is also shown in Table 3. All variables have a Cronbach's α value, CR value, and rho_A coefficient greater than 0.70 [52], indicating a high degree of correlation among items within the same variable, proving that the measurement model has good reliability. In terms of validity, the AVE values for all variables exceed the standard of 0.50 [53] (see Table 3). In the Fornell-Larcker Criterion, the square root of the AVE for each variable is smaller than the correlation coefficients between variables [53], and the HTMT values are all less than the 0.90 standard [54] (see Table 4). This demonstrates that the measurement model has good validity.

Evaluation of the Structural Model

Following the suggestions of Hair et al. [48], we used 5000 random subsamples for bootstrapping to verify if the research hypotheses held. The relationships between the variables are explained by the path coefficient and its significance. Firstly, the quality of the model structure is judged by R^2 value, Q^2 value, and f^2. The results of R^2 and Q^2 values are shown in Table 5, and the results of f^2 are presented in Table 6.

Table 5. Test Results for Model Explanatory Power and Predictive Relevance.

Variable	R^2	Q^2
STA	0.664	0.443
EP	0.605	0.365
FP	0.368	0.208
CTP	0.407	0.262

The explanatory power of the study model for sustainable technology application, environmental performance, financial performance, and competitive performance is moderate, with R^2 values of 0.664, 0.605, 0.407, and 0.368, respectively. This means they have a credibility of 66.4%, 60.5%, 40.7%, and 36.8%. The relatively lower R^2 value for financial performance may be due to the fact that the respondents to the sample questionnaire were mostly from the company's production and manufacturing, and technical quality department managers. They have a thorough understanding of the technical application operation, but they have less contact and communication with the financial department and are not familiar with the economic benefits brought to the enterprise by sustainable technology applications. The predictive relevance Q^2 value of this model is tested by the blindfolding algorithm. All Q^2 values are greater than 0, indicating that this model has predictive relevance. The impact degree between variables is tested by f^2. The impact of sustainable technology application on environmental performance and competitive

Table 4. Analysis of Discriminant Validity.

	TMS	CP	PS	RP	CMP	STA	EP	FP	CTP
TMS	0.892	0.585	0.705	0.445	0.404	0.388	0.172	0.693	0.541
CP	0.365	**0.864**	0.542	0.518	0.412	0.403	0.168	0.632	0.449
PS	0.318	0.360	**0.884**	0.358	0.375	0.458	0.230	0.655	0.539
RP	0.365	0.153	0.442	**0.872**	0.406	0.312	0.076	0.472	0.184
CMP	0.300	0.356	0.321	0.305	**0.844**	0.380	0.555	0.442	0.401
STA	0.448	0.586	0.388	0.210	0.385	**0.885**	0.347	0.425	0.378
EP	0.434	0.484	0.306	0.200	0.394	0.590	**0.898**	0.221	0.473
FP	0.155	0.468	0.348	0.033	0.282	0.440	0.293	**0.877**	0.566
CTP	0.434	0.512	0.334	0.145	0.334	0.634	0.578	0.513	**0.797**

Note: The bold numbers on the diagonal represent the square root of AVE; the values in the bottom-left region represent the Fornell-Larcker Criterion; the values in the upper-right region represent the HTMT indices.

Table 6. Path Analysis and Hypothesis Testing Results.

Hypothesis	Path	Coefficient	t-value	p-value	f^2	Test Result
H1	TMS→STA	0.226***	3.585	0.000	0.166	Supported
H2	CP→STA	0.399***	6.957	0.000	0.248	Supported
H3	PS→STA	0.170**	2.703	0.004	0.094	Supported
H4	RP→STA	0.078	1.083	0.315	0.018	Not
H5	CMP→STA	0.102*	1.713	0.053	0.052	Supported
H6	STA→EP	0.668***	16.117	0.000	0.686	Supported
H7	STA→FP	0.496***	10.580	0.000	0.335	Supported
H8	STA→CTP	0.528***	11.512	0.000	0.441	Supported

Note: * p<0.05; ** p<0.01; *** p<0.001

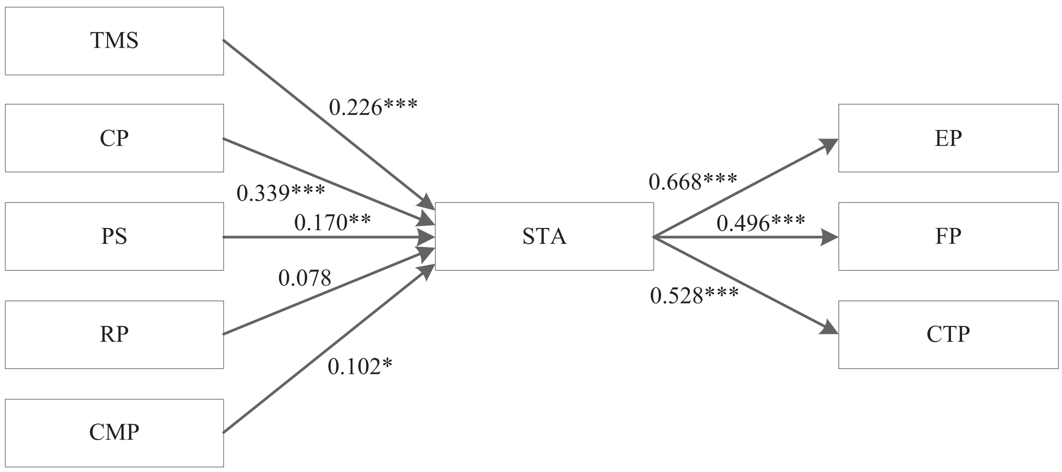

Fig. 2. Results of Path Analysis. Note: * p<0.05, ** p<0.01, *** p<0.001.

performance is high, the impact of top management support and customer pressure on sustainable technology application, and the influence of sustainable technology application on financial performance are all of medium effect. However, the impact of policy support, regulatory pressure, and competitor pressure on sustainable technology application is of low effect.

After evaluating the explanatory and predictive power of the model structure, a path analysis was conducted. The relationships between the variables were tested based on the β coefficient, the significance of the path coefficient (p-value), and the t-value. The results of the path analysis and hypothesis testing are shown in Fig. 2. and Table 6 as follows: Both top management support, customer pressure, policy support, and competitor pressure have a significant and positive predictive effect on the application of sustainable technology. This indicates that an increase in top management support, customer pressure, policy support, and competitor pressure will encourage enterprises to apply sustainable technologies more actively. Additionally, the application of sustainable technology has a significant and positive predictive effect on environmental performance, financial performance, and competitive performance. This suggests that by adopting sustainable technology applications, enterprises can improve their environmental, financial, and competitive performance. Thus, H1, H2, H3, H5, H6, H7, and H8 are supported. However, regulatory pressure did not show a significant predictive effect on sustainable technology application, so H4 is not supported.

Conclusions and Discussion

Conclusions

Based on the perspective of stakeholder theory, this study explored the driving factors for the application of sustainable technology in fashion manufacturing enterprises and analyzed the impact of sustainable technology applications on the environmental, financial, and competitive performance of enterprises. The conclusions are as follows:

Firstly, the impact of various stakeholder-driven factors on the sustainable technology application of fashion manufacturing enterprises varies. Customer pressure, top management support, policy support, and competitor pressure have a significant positive predictive effect on sustainable technology application, supporting the related research hypotheses. Particularly, customer pressure, as the strongest driving factor, aligns with the conclusions of Abbate et al. [5] and Hoque et al. [41] regarding buyer power in the apparel market as the primary driving force for corporate circular business models and social responsibility fulfillment. This is consistent with the global value chain structure of the fashion industry, where brand owners, whether for exports or domestic sales, are positioned at the top of the value chain, possessing significant bargaining power over manufacturing suppliers. Their emphasis on sustainable development requirements for manufacturing enterprises and fashion products, through the implementation of sustainable supplier development programs and actions, will promote the application of more sustainable technologies in the production and operation of supply chain enterprises. Against the backdrop of sustainable development becoming a collective choice for humanity to resolve crises and reshape the future, an increasing number of brand owners elevate sustainable development to a strategic corporate level. Sustainable supplier development programs can help establish a positive social image, enhancing consumer identification with and loyalty to the brand [13]. Only by increasing investment in the application of sustainable technologies can manufacturing enterprises secure more orders and win market share. Top management support is the second strongest driving factor, indicating that top management can advocate a corporate culture that values sustainable development, providing human, financial, and material resources and institutional guarantees during the implementation process of sustainable technology applications, and facilitating the practical application of sustainable technologies within enterprises. The innovative consciousness and risk preference of the top management team play a decisive role in the development strategy and business decisions of an enterprise [55]. Especially when enterprises adopt a centralized organizational structure, the top management team has more power to decide on technological development and may directly intervene or follow formal procedures less strictly in the decision-making process [56]. Executives determine the decision-making process and outcomes for the introduction and implementation of any new technology. The open innovation mindset of executives and their advocacy for the application of blockchain technology will facilitate the initiation of blockchain technology applications across organizational functions and beyond enterprise boundaries, providing resources and institutional guarantees during the implementation process. Policy support is also a crucial driver, indicating that government funding and technical and personnel training support for sustainable technology application can help guide the fashion manufacturing industry to accelerate the application of sustainable technology and speed up the transition to green manufacturing. Competitor pressure is also a positive driver, suggesting that technological upgrades by industry competitors increase the urgency for company technological innovation, compelling enterprises to re-evaluate their industry technology status and apply automation, digital technology, and green low-carbon technology to maintain or achieve a market-leading position. However, regulatory pressure did not significantly affect sustainable technology application behavior in fashion manufacturing enterprises. This might be because the new "Environmental Protection Law" has been in effect since 2015, and after undergoing environmental storms, Quanzhou's fashion manufacturing industry has steadily increased its sense of sustainability and level of intelligent manufacturing, transitioning from a passive response stage to an active action stage.

Secondly, sustainable technology application has a significant positive impact on the environmental, financial, and competitive performance of fashion manufacturing enterprises. The effects on environmental and competitive performance are the most pronounced, indicating that by applying sustainable technology, the urgent needs of fashion manufacturing enterprises for low-carbon ecological development and enhanced competitiveness can be met. However, the impact on financial performance is relatively small, possibly because the survey respondents are primarily from the production and operations departments, with limited awareness of financial performance. In reality, through the application of sustainable technology, fashion manufacturing enterprises can achieve energy-saving and emission reduction, resource conservation, and improved production efficiency, meeting the requirements of policies and customers, enhancing corporate image and industry recognition, and granting the company multiple competitive advantages. This also assists enterprises in increasing product prices and expanding market share. Thus, good environmental and competitive performance will bring higher financial performance for enterprises.

Theoretical and Practical Implications

Firstly, this study focuses on the issue of sustainable technology application in fashion manufacturing enterprises. It categorizes the types of sustainable technology applications used in the production process of fashion manufacturing enterprises, constructs a theoretical framework for driving factors and performance outcomes of sustainable technology applications in fashion manufacturing enterprises, and empirically tests this framework. This not only provides a new perspective and evidence for understanding the behavior of sustainable technology applications in fashion manufacturing enterprises, contributing to the application and development of stakeholder theory, but also enhances the understanding of the current situation of sustainable technology application behaviors in Chinese fashion manufacturing enterprises, helping to support research on traditional manufacturing enterprises in emerging economies achieving industrial transformation and upgrading through the application of sustainable technologies.

Secondly, the findings of this study can serve as a reference for fashion manufacturing enterprises to successfully deploy and implement sustainable technology applications and for the government to optimize and adjust support policies. The results indicate that the support or pressure from stakeholders such as customers, top management, the government, and competitors plays a positive role in elevating the level of sustainable technology application in fashion manufacturing enterprises. Promotions or assistance related to sustainable technology applications from customers and the government, as well as technological transformations by competitors, often provide opportunities for enterprises to achieve transformational development through the application of sustainable technology. Particularly, sustainable production standards and sustainable supplier development plans promoted by upstream brand merchants in the value chain can help fill the gaps in suppliers' reserves and application of sustainable innovation technologies, exerting the greatest promotional effect on manufacturers' application of sustainable technologies. Therefore, fashion manufacturing enterprises should actively respond to customer standards, participate in customer-promoted sustainable supplier development plans, and construct the necessary internal knowledge and resources for sustainable technology implementation through various approaches such as sustainable technology transfer and capacity training, joint R&D and collaborative adoption of sustainable technologies, supply chain information sharing and knowledge dissemination, as well as resource development and investment cooperation [57]. This will facilitate the application of sustainable technologies and achieve market advantages. The support from top management for sustainable technology applications reflects a company's developmental responsibility and enhances its image in terms of environmental and social responsibilities. Therefore, sustainable technology application projects should actively seek the support of the top management team, providing the necessary resources and decision-making momentum for concept validation, adoption, pilot testing, and implementation, thereby increasing the organizational feasibility and the likelihood of successful implementation of blockchain technology. The application of sustainable technology not only improves product quality but also reduces the unit manufacturing cost, assisting enterprises in overall improvements in environmental, financial, and competitive performance. This provides a solid reference for investors in the fashion manufacturing industry to further expand their investments in sustainable technology. Furthermore, compared to policy support, the impact of regulatory pressure is relatively low. This is because, under industry trends, environmental awareness has already integrated into corporate operations, and the independent consciousness of sustainable development has become mainstream. Therefore, the government should focus more on positive incentives, intensifying human, financial, and material support for the application of sustainable technology, and fostering a favorable environment and industry ecosystem conducive to the demonstration and diffusion of sustainable technology in the industry. Only in this way can the potential of sustainable technology application for high-quality development of the fashion manufacturing industry be maximized and a greater competitive advantage be achieved in the global fashion industry landscape.

Limitations

Firstly, some conclusions drawn in this study seem to differ somewhat from traditional views, such as the lack of statistical significance of regulatory pressure. Typically, regulatory pressure is considered a mandatory factor driving enterprises to adopt sustainable technologies. Future research can replicate this theoretical framework to compare the findings across regions at different stages of development (e.g., Henan Province in China, which is a domestic destination for footwear and clothing industry transfers, and Southeast Asian countries, which are international transfer destinations for the footwear and clothing industry). This would make the research findings more persuasive and generalizable. Secondly, this study's model does not take into account the role of technology suppliers or service providers as stakeholders. While traditional machinery and equipment suppliers have limited influence on fashion manufacturing enterprises, digital technology providers or service firms might play a crucial role in sustainable technology applications based on digital technology, such as green design development, service-oriented manufacturing, and product and energy traceability. Future studies could expand on this model by including the role of technology suppliers or service providers and testing it empirically. Lastly, due to challenges in obtaining financial data from sample enterprises and the exclusion of corporate financial managers from the survey, the assessment of financial performance relies solely on the views of non-financial staff from production and manufacturing departments. In future studies, it would be beneficial to include corporate financial managers in the survey and to seek additional channels to obtain both primary and secondary financial data from enterprises. This would provide a more accurate assessment of the impact of sustainable technology applications on financial performance.

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Conflict of Interest

The authors declare no conflict of interest.

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