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The Circular Economy and Textile Industry: Opportunities and Synergies for Reaching Sustainable Development Goals

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Abstract
Though the global textile industry contributes to economic growth and innovation, it creates several challenges in terms of environment and society, such as waste production, water contamination, and release of carbon, keeping major payoffs in the scales of India, especially Tamil Nadu, since it is one of the largest textile hubs. The purpose of this study is to examine how the Tamil Nadu textile industry has incorporated circular economy (CE) practices with regard to ecological consequences, identifying relevant CE tenets assessing the advantages of long-term viability analyzing public roles, and formulating policy proposals for accomplishing the UN Sustainable Development Goals (SDGs) in the industry. The study used quantitative research design and a structured survey conducted over 300 textile industry professionals in major hubs of Tamil Nadu to understand adoption of CE procedures in the declared extent linkage with sustainable development goals (SDGs). Data were analyzed using various statistical means descriptive and inferential statistics including multiple regression, ANOVA, SEM and factor analysis. The study found that technological innovations ($M = 4.19$, $t = 135.909$) and consumer awareness ($M = 4.18$, $t = 133.351$) were the most influential factors driving sustainability in Tamil Nadu's textile industry, while supply chain circularity ($M = 4.15$, $t = 135.440$) also played a key role. Statistical analysis confirmed that CE practices significantly enhance sustainability performance ($\beta = 0.478$, $p < 0.001$), with strong contributions from government policies ($\beta = 0.175$, $p < 0.001$), corporate sustainability strategies ($\beta = 0.384$, $p < 0.001$), consumer awareness ($\beta = 0.173$, $p = 0.003$), and technological advancements ($\beta = 0.131$, $p = 0.004$), while supply chain circularity mediated CE's impact on sustainability ($\beta = 0.132$, $p = 0.005$).

Keywords:
Circular economy, sustainability in textiles, environmental impact, quantitative analysis, textile industry in Tamilnadu, SEM.

1. Introduction
The backbone of today's economy stands firmly in globalized textile supply chains that filter through societies of different continents and cultures (Özdil & Konuralp, 2024). These chains, while stimulating economic growth, fashion innovation, and making the world flatter, have grown into harrowing environmental and social challenges. It is estimated that these industries are responsible for an enormous proportion (8-10%) of total global carbon emissions, greater than all of those caused by international aviation and shipping put together (Europarl, 2023; Leal Filho et al., 2022). Furthermore, the coloring and polishing methods used in textiles are responsible for roughly one fifth of the contamination of pure water worldwide (CNN, 2023).

In 2018, around 17 million tons of textile waste was generated by landfills, contributing 5.8% to the total generation of municipal solid waste (EPA, 2024). This reality brings to the forefront a most urgent and systemic requirement of the industry to lessen its environmental footprint.

One of the largest nations in the world's textile business, India, would also be significantly impacted by these issues (Atkar et al., 2021; Srivastava & Bandhu, 2022). In addition to contributing significantly to the nation's economy, the Indian textile industry uses a lot of water and electricity (Farhana et al., 2022). Dyeing and treatments in textiles account for 20% of industrial water pollution worldwide, India being a major contributor (Maheshwari et al., 2021). This has, over the years, compounded by the indiscriminate use of synthetic chemicals- about 8,000 types- that are utilized to convert raw materials into finished textiles, directly affecting the ecosystems and making health consequences suffered by local communities inevitable (Nikam, 2022). In Tamil Nadu, which is a leading textile manufacturing hub, such concentration has sparked critical concerns of water scarce regions, pollution questions, and waste management.

All these forces are set against the traditional linear model of textile production in the simple economy: 'take-make-dispose', resulting in the depletion and degradation of the world's resources (Radhakrishnan, 2021). This method is unsustainable as the growing world population would want even more of the textile demand to be increased by consumerism. The environmental consequences are deep-reaching, especially in terms of contributing to climate change, freshwater contamination, and the building-up of non-biodegradable waste in landfills. Multidimensional challenges require a shift in the paradigm of circular economies (CE) such as in the textile industry (Din et al., 2025). A CE approach is more focused on preventing contamination and waste, reusing resources and goods, and restoring ecological balance (Kara et al., 2022). CE practices would enable the textile industry to lessen its environmental impacts through recycling, up-cycling, or implementing closed-loop production systems. Such adoption would save resources further and relate to several UN SDGs, being accountable consumption and production (SDG 12) and climate action (SDG 13).

The adoption and use of CE practices in India's textile industry are notably low. Some of the constraints that limit the adoption of such practices would comprise a lack of awareness among various stakeholders, inadequate financial resources, technological incapacities, and inadequate policies in support of the shifts. The urgent need for such investigation is for creating a comprehensive framework of research identifying effective forms of integration of CE principles into the textile industry, especially for regions such as Tamil Nadu. The research should aim to unravel the synergies between CE adoption and achieving SDGs for a better roadmap toward sustainable transformation. This study attempts to investigate how circular economy practices could be integrated into Tamil Nadu's textile industry for the sake of sustainable development goals. The specific objectives include the following:

- Looking at the current environmental impact made by textile manufacturing processes in Tamil Nadu with respect to resource consumption and waste generation.
- Finding some of the most important circular economy principles that may be used in the textile industry in the area, such as reducing waste, product lifespan extension, and reuse of materials.
- Estimating how CE implementation might contribute towards improving sustainability measures, that is, reducing carbon emissions, water usage, and pollution.

- Examining how multiple stakeholders, such as governmental organizations, business executives, and the local population, could support or impede the shift to a cyclical textile sector.
- Development of policy recommendations and business models for effective implementation of CE practices, hence aiding the realization of relevant SDGs.

1.1 Theoretical Framework and Hypothesis Development

The textile industry is one of the most damaging and heavy on resources sectors, necessitating a shift from the conventional conventional economic model (take-make-dispose) to a model based on CE (reduce-reuse-recycle). Such transformation can be further understood theoretically in terms of organizational change, sustainability adoption, and technological diffusion. In doing so, this study employs the three most relevant theories, namely Diffusion of Innovations Theory (DIT) (Wejnert, 2002), Stakeholder Theory (Freeman, 2010), and the Resource-Based View (RBV) Theory (Barney, 2001), to build the theoretical basis for understanding the incorporation of CE practices in Tamil Nadu's textile sector and their import into sustainability performance.

The Diffusion of Innovations Theory describes how novel concepts, methods, and technology proliferate in a community or sector (Mbatha, 2024). Since it identified the elements that describe how and why businesses implement sustainability-driven innovations, it has a substantial bearing on the acceptance of CE principles by various textile sector participants (Todeschini et al., 2017). The companies in the textile industry in Tamil Nadu at varying levels of adoption of innovations may be leaders, followers, or laggards concerning the adoption of CE models. Companies that are some of the forerunners in applying recycling, upcycling, waste reduction, and eco-design will have a competitive advantage and will become less resource-dependent as well as more successful with their sustainability performance (Doranova et al., 2016). However, the adoption of the innovation diffusion is moderated by the factors perceived gain, compatibility with ongoing processes, complexity of application, testability, and observability--that is, the perceived value the user or customers see in adopting it (Huang et al., 2020).

H1: The adoption of CE practices has a significant positive impact on the sustainability performance of textile industries in Tamil Nadu.

One such important driver or enabler is that of government policies and regulations providing impetus and support toward such adoption by inspiring the spirit of sustainable production and waste management in their associated activities (Haldar, 2019). These regulatory measures provide, among others, tax benefits, compliance mandates as well as funding for green initiatives to add scale, efficiency, and innovative approaches to progress in the adoption of sustainable practices by a sector.

H2: Government policies and regulations positively influence the sustainability in Tamil Nadu’s textile industry.

Another dimension to the espousal of CE principles in the clothing sector is the Stakeholder Theory (Freeman, 2010), which argues that the business should consider the interests of different stakeholders, customers, investors, government agencies, and society at large when making decisions about strategy (Harrison & Wicks, 2013). Given that textile businesses are all intertwined, environmental impacts are incurred and affect several stakeholder groups.

In corporate sustainability, the ever-changing externality of perceptions among stakeholders would thus require for textile firms to integrate their business frameworks with what the stakeholders profess, hence going green with manufacture, ethical sourcing, and waste reduction (Matthes et al., 2021). Sustainability efforts that such companies engage in will achieve an even more pronounced image of the brand, increase consumers who are conscious of green products, and provide compliance with legislation. Stakeholder-focused sustainability involves employees, cooperation with suppliers, and public-private partnerships toward a more circular supply chain (Chabowski et al., 2022).

H3: The textile industry's sustainability ranking is directly improved by business environmental initiatives.
Consumer behavior has emerged as one of the major challenges in the successful application of CE principles (Shevchenko et al., 2023). They are at the core of raising demand for sustainable textiles and hence, will influence how companies react to sustainability pressures based on awareness, preferences, and purchasing decisions. Because they are actively seeking eco-, bio-, and ethically produced textiles, these consumers tend to tilt the market towards sustainable fashion and away from waste.

H4: Higher consumer awareness and preference for sustainable textiles drive the adoption of sustainable performance in Tamil Nadu.
The RBV theory clarifies how firms have a competitive advantage by unique, valuable, and inimitable resources (Brahma & Chakraborty, 2011). These resources would facilitate technology in making transitions than sustainable for textile firms during the embracing of the CE. Innovative textiles such as biodegradable fabrics, digital textile printing, AI-powered supply chain and tracing capabilities, and blockchain-based product authentication would all benefit a firm in achieving its sustainable goals from a strategic standpoint (Khan et al., 2024). In this way, the advanced textile manufacturing technology integration brings better waste minimization, improved energy efficiency, and material recovery.

H5: Technological innovation in textile production enhances circularity and improves sustainability outcomes.
A linear supply chain is concerned with resource extraction, production, consumption, and disposal; as for circular supply chains, materials will be reused, remanufactured, or reused when their existence cycle is over (De Angelis et al., 2018). The determinants of supply chain circularity in Tamil Nadu's textile industry include raw material sourcing, reverse logistics, recycling infrastructure, and interfacing across industries. That is, supply chain circularity has a mediating role in determining how the circular economy translates into sustainability performance. Companies in such conditions with a highly circular supply chain are more likely to manage waste reduction and carbon footprint minimization using efficient resource utilization. This adds to sustainability alignment with the SDGs.

H6: The association between sustainability outcomes and CE strategies in Tamil Nadu's textile industry is mediated by supply chain circularity.

1. Literature review

Research works on circular economy (CE) are vast in themselves, going into its potential impact, challenges, and strategies of implementation in the textile industry. Ortiz-de-Montellano et al. (2023) analyzed 27 circularity strategies and how they impacted the 17 SDGs.

Results showed that CE strategies considerably impacted SDGs 8, 12, and 13, whereas their contribution to SDGs 4, 5, 10, and 16 was relatively weaker. Though strategies in CE mostly pertain to products and materials, the SDGs have always focused on people and environmental well-being. Similar to this, Saha et al. (2022) surveyed 114 fabric and garment businesses in India, Vietnam, and Bangladesh to examine the opportunities and difficulties for CE. The major obstacles identified in their research were financing, technology, human resources, and overall slow reactions from management, coupled with consumer indifference. They emphasized the significance of a comprehensive strategy that includes industry involvement, tax breaks for purchasers, and consumer awareness of CE adoption. Further, the study found that sustainability performance in TC firms was related to CE fields of action, such as taking, making, distributing, using, and recovering materials.

The study Huang et al. conducted in 2021 investigated barriers for CE to the textile industry in Taiwan using an integrated approach of SEM, and six major barriers were identified, mainly low consumer demand for recycled textiles; lack of successful circular business models, collaborative innovation difficulty within supply chains; inadequate supply of excellent reuse components; and exorbitant expenses with little immediate financial gain. Noteworthy, these barriers made emphatic calls for Intervention and innovative, policy-targeted business strategies. Teixeira et al. (2023) aimed at incorporating CE principles into new product development (NPD) as part of the textile industry's processes, using Design Thinking (DT) as a method. Their research, coordinated with four textile companies, acknowledged that socio-environmental issues were part of product development, especially adoption facets, which were found to be significantly lacking. The proposed methodology was designed around DT and the cycle of consumption with an emphasis on creativity, user-centered design, and stakeholder integration to improve CE adoption.

A research framework employing the grey Analytical Network Process (ANP) was developed by Chowdhury et al. (2023) for the assessment of CE challenges and strategies related to the textile sector in Bangladesh. Their research findings indicated that waste recovery is one major step in a sustainable waste management system (SWMS) and emphasized that rigorous monitoring and control mechanisms were fundamentally essential. Similarly, Yadav and Majumdar (2024) found 18 interconnected obstacles to the application of CE in India's textile, apparel, and garment (TAC) sector. They identified a number of significant obstacles, including low customer awareness, insufficient financial rewards, insufficient legal direction, and an absence of confidence among those in the supply chain, using the weighted impact non-linear gauge system (WINGS) technique. Their study proposed mitigation strategies focusing on engagement from academia, government, industry, and society.

Challenges to the CE changeover in Dutch scientific and domestic textiles were examined by Hartley et al. in 2022. Their analysis identified high manufacturing and advertising costs along with poor buyer interest as the main obstacles, according to conversations with producers and merchants. The absence of circular delivery flows and a tendency regarding linear manufacturing norms further hindered the implementation of CE, while a lack of awareness of CE design alternatives raised prices. The study viewed these obstacles as a domino effect. Three CE barriers were also identified by Chen et al. (2021): low consumer awareness of recycled products, lack of effective business models, and little dialogue among stakeholders. Their study also emphasized managerial interventions to bridge these gaps.

John and Mishra (2023) proposed a sustainable circular three-layer supply chain model of the TC industry, integrating water purification, green technologies, and zero-waste techniques. They found that integrated CE models realized profits about 2% higher than those of traditional supply chains. Meanwhile, Saccani et al. (2023) used an instance on the Prato rejuvenated wool region in Italy to look into the difficulties in adopting CE in the fashion and textile sectors. By suggesting a circular supply chain orchestration method that integrates resource and supply management tactics, its findings also advanced CE knowledge. Altogether, these studies emphasize the diverse challenges and possibilities in CE adoption within the textile industry. While financial, technological, and consumer-related barriers persist, however, strategies emerging from digitalization, stakeholder collaboration, and developing circular supply chain models stand as pathways to sustainability.

2. Research methodology

The adoption of CE practices in Tamil Nadu's textile sector and their relationship to the SDGs were examined in this investigation using a design of quantitative research. A structured survey method was used to collect data from professionals in the textile industries across major textile hubs such as Coimbatore, Tiruppur, Erode, and Karur. The study employed the stratified random sampling technique to obtain fair representation for employees across levels, industry sectors, and awareness levels with regard to CE practices. Stratification has been done with respect to job designation, organization size, and geographical location to enable the study to embrace variations in perception on CE implementation and related problems. The study targeted professionals in the Tamil Nadu textile industry engaged in production, supply chain management, sustainability, and quality control, as these functions directly link with CE practices.

The sample size for this study was decided at 300 respondents; sufficient representation of the workforce would be ensured while maintaining statistical reliability. The size of the sample has been determined based on previous studies in the textile sector that reflected on sustainability and CE practices, taking into account the variations in their responses, as well as the requirements for strong statistical analysis. Sampling involved employees from medium to large scale textile organizations, who are either practicing or piloting CE strategies. The inclusion criteria specified that study participants must have worked in the textile industry for at least a year to ensure their responses were influenced by practical exposure in the industry. Data collection took two months and was carried out using an online and offline structured questionnaire. The questionnaire was developed using a five-point Likert scale (1 = Strongly disagree to 5 = Strongly agree) measuring items such as awareness, challenges of implementation, sustainability impact, and organizational readiness toward CE.

The questionnaire includes sections on demographic factors, CE practices, barriers to CE implementation, and sustainability outcomes. The demographic section included the following aspects: age, gender, education, designation, experience, and size of the organization, while the core areas included CE adoption, barriers en route to CE implementation in terms of finances and technology, stakeholder engagement, and policy support. Afterward, a pilot study was conducted in which 30 respondents were enrolled in a pilot study to guarantee clarity and reliability of the survey instrument. Accordingly, some minor revisions were made to wording on questions and answers for increased clarity and accuracy.

The acquired data was analyzed using both inferential and descriptive statistical approaches. Descriptive statistics, namely mean, standard deviations, frequency distributions, skewness, and kurtosis, were used for the description of demographic characteristics and the response pattern. A foundational multiple regression analysis was performed with independent variables (organizational support, financial investment, technological readiness, policy awareness, and employee mindset) to examine their relationships with the dependent variable (CE implementation). With respect to this study, a mediating analysis via structural equation modeling (SEM) was performed to measure sustainability performance in its role of mediating between CE practices and long-term industry benefits. The questionnaire demonstrated reliability by virtue of Cronbach's alpha, which indicated internal consistency of measurement scales. Other vital tests imply validity, confirming that the constructs used in the study were indeed valid and that the principal factors impacting CE adoption in the textile industry were determined through factor analysis.

Significant insights were gathered into how organizational hierarchy and workforce characteristics influenced the CE practices. ANOVA (Analysis of variance) and t-tests were also used for analysis of adoption of CE across various demographic groups; experience levels, job roles, and organization sizes were variables considered. The study also attempted correlation analysis to analyze within some interdependencies among the variables such as financial constrains and technological readiness, which could potentially hinder CE adoption rates. The research findings were then elaborated upon via thematic analysis of open-ended responses to complement previously discussed methods and gain some qualitative insight into the industry professionals' views about CE-related challenges and opportunities. Strict adherence to ethical considerations was assured at every stage of this research project. The participants were made aware that their answers would be kept private and unidentified, and that being part of the study would be entirely optional. Respondents were able to discontinue participation at any point throughout the study, and their informed consent was obtained prior to data collection. The database generated from the study participants was safely kept and utilized exclusively for scholarly research. To make sure it complied with ethical guidelines for research involving human subjects, the study applied for clearance from many industry associations and pertinent institutional review boards.

3. Results

Table 1: Sociodemographic characteristics

Sociodemographic characteristics		Frequency %	Variance	Skewness	Kurtosis	t
Age	Below 25 years	6.0	.806	.711	.803	46.703
	25–34 years	40.0				
	35–44 years	42.4				
	45–54 years	6.0				
	55 years and above	5.6				
Gender	Male	66.4	.224	.699	-1.524	44.633
	Female	33.6				
Education	High school / Diploma	49.2	.418	.625	-.598	39.010

	Bachelor's degree (Textiles, Engineering, Business, etc.)	42.0				
	Master's degree or higher	8.8				
Designation	Supervisor / Team Lead	53.2	.250	.129	-1.999	46.424
	Manager (Production, Sustainability, Supply Chain)	46.8				
Experience	Less than 1 year	6.0	.408	-.225	-.326	60.334
	1–5 years	46.4				
	6–10 years	45.6				
	More than 10 years	2.0				
Organization size	Less than 50 employees	8.8	.612	.052	-.395	50.351
	51–200 employees	42.4				
	201–500 employees	39.6				
	More than 500 employees	9.2				
Awareness regarding CE practices	Somewhat aware	9.2	.413	-.470	-.679	57.801
	Aware but not implemented	46.8				
	Actively implementing CE practices	44.0				
Location	Coimbatore	22.4	1.216	-.123	-1.307	36.986
	Tirupur	23.2				
	Erode	28.4				
	Karur	26.0				

Understanding the sociodemographic profiles of the respondents in the survey thus suggests their features relative to the working population in the state and among textile industries in Tamil Nadu about knowledge and awareness on CE practices (Table 1). The majority (42.4%) fell within the age category of 35–44 years, followed by 25–34 years (40.0%), whereas the other

young (below 25 years) and old (55 years and above) workers accounted for only small portions (6.0% and 5.6%, respectively). So, it took a trend that the gender is largely male-dominated in natural occurrence, as 66.4% of the respondents were male, and the other 33.6% were females, thus significantly disclosing the gender gap existing in the sector. About education, 49.2% of the respondents have reached either high school or a diploma qualification, while a bachelor degree in any course, be it textiles, engineering, or business, is achieved by only 42.0%. Only a meager 8.8% get hold of a master's degree or above, implying still limited higher education levels within the industry. The result for the respondents that stated most (53.2%) were supervisors or team leads, while 46.8% were managers of production, sustainability, and supply chain management activities. Most employees have worked between 1 and 5 years (46.4%), followed closely by those who have 6 to 10 years (45.6%). In contrast, very few employees have been working for less than a year (6.0%), and there are even fewer who've worked for over 10 years (2.0%). Size distribution thus indicates that most respondents occupy middle-sized organizations, with 42.4 percent in firms having employees numbering from 51-200 and 39.6 percent in firms employing a workforce numbering from 201-500 employees. Smaller organizations (having less than 50 employees) and larger organizations (more than 500 employees), on the other hand, comprise only 8.8% and 9.2%, respectively. Awareness on CE practices among respondents is quite high: more than four out of ten at 44 percent use CE, while 46.8 percent are aware but haven't adopted it, while 9.2 percent is just aware, indicating that it requires to be disseminated even more on CE education. The study further examined the location-wise distribution of respondents in which one found that they covered almost all the prominent textile hubs in Tamil Nadu such as Erode (28.4%), Karur (26.0%), Tiruppur (23.2%) and finally, Coimbatore (22.4%).The different variables have some variance, skewness, and kurtosis values, indicating slight deviations against the normal within some categories including gender and designation, yet the data overall seems to provide a complete picture of the workforce characteristics and CE awareness within Tamil Nadu's textile industry.

Table 2: Mean scores

Factors	N	t
Sustainability Performance	3.81 ± 0.89	67.084
Adoption of Circular Economy Practices	3.79 ± 0.89	67.575
Government Policies & Regulations	3.78 ± 0.89	67.154
Corporate Sustainability Strategies	3.80 ± 0.89	67.246
Consumer Awareness & Behavior	4.18 ± 0.49	133.351
Technological Innovation in Textile Production	4.19 ± 0.49	135.909
Supply Chain Circularity	4.15 ± 0.48	135.440

Table 2 outlines factors affecting the CE as well as sustainability performance in the textile industry and their mean values along with respective t-statistics. It was revealed that technological innovations in textiles production (M = 4.19, SD = 0.49, t = 135.909) and consumer awareness & behavior (M = 4.18, SD = 0.49, t = 133.351) are the two most influential factors, thus affirming the central role of technology and conscious consumerism in advancing sustainability in this sector. The circularity of the supply chain (M = 4.15, SD = 0.48, t = 135.440) would also emerge as a strong contributor, demonstrating the necessity of an effective continuously supply network to improve efficiency in the manufacturing of textiles. Moderate levels of engagement and excellence of the sustainability performance (M = 3.81, SD = 0.89, t

= 67.084), corporate sustainability strategies (M = 3.80, SD = 0.89, t = 67.246), and introduction of CE strategies (M = 3.79, SD = 0.89, t = 67.575) among the other factors reflect sustainability efforts engagement across the textile firms. The reason why lower mean scores were observed is that firms might acknowledge the importance of sustainability and CE adoption; however, there might be gaps in their implementation practice. On the other hand, government policies & regulations (M = 3.78, SD = 0.89, t = 67.154) were also seen to have a moderate influence, which indicates that while policy frameworks are vital, stronger enforcement or industry-specific incentives may be required for effective CE adoption. It would seem that while advances in technology and changes in consumer behavior have an impact on the extent of sustainability in the textile industry, research should look into the regulatory frameworks, corporate strategies regarding sustainability, and practical implementation of CE as it might warrant acceleration towards a fully circular economy.

Table 3: Pathway analysis

Pathway			Estimate	S.E.	C.R.	P
Supply Chain Circularity	<---	Adoption of Circular Economy Practices	0.163	0.051	2.187	0.003
	<---	Government Policies & Regulations	0.187	0.056	2.539	0.001
	<---	Corporate Sustainability Strategies	0.282	0.058	4.407	***
	<---	Technological Innovation in Textile Production	0.505	0.053	9.473	***
	<---	Consumer Awareness & Behavior	0.346	0.053	6.515	***
Sustainability Performance	<---	Supply Chain Circularity	0.132	0.068	1.945	0.005
	<---	Adoption of Circular Economy Practices	0.478	0.054	8.776	***
	<---	Government Policies & Regulations	0.175	0.06	2.248	***
	<---	Corporate Sustainability Strategies	0.384	0.062	6.15	***
	<---	Consumer Awareness & Behavior	0.173	0.061	2.143	0.003
	<---	Technological Innovation in Textile Production	0.131	0.066	2.82	0.004

According to the data analysis (Table 3), CE procedures significantly improve sustainability ratings compared to others ($\beta = 0.478$, $p < 0.001$), further evidence by H1. It means that firms adopting circularity practices over waste reduction, resource efficiency, recycling schemes, and the like will yield better sustainability performance. Moreover, government policies and regulations have a great deal of significant influence on sustainability performance ($\beta = 0.175$, $p < 0.001$), thus establishing H2. This means that the policy frameworks, incentives, and regulatory enforcement go a long way to driving sustainability in the textile sector of Tamil Nadu.

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The corporate sustainability strategy also confirms the positive effects on sustainability performance (β = 0.384, p < 0.001) to prove H3. This shows that firms with good sustainability policies including environmental goals, responsible sourcing, and green supply chain management have better sustainability outcomes. In similar speculation, consumer awareness and behavior also have significant impacts on sustainability performance (β = 0.173, p = 0.003), as such supporting H4. This makes clear that improved consumer preference for sustainable textiles and ethical sustainable production practices will cast a positive shadow on sustainability throughout the industry.

Technology advancements are also critical to making the magical wand of sustainable development, for in technological innovation in textile production, it has a high significant effect of supply chain circularity (β = 0.505, p < 0.001) and sustainability performance (β = 0.131, p = 0.004), thereby establishing H5. This means that employing investment in up-to-the-minute processes such as eco-dyes, biodegradable fabrics, and automatic recycling systems drives the improvements in long-term sustainability and circularity.

Moreover, supply chain circularity significantly mediated the nexus between CE practices and sustainability performance (β=0.132, p=0=0.005). Thus, it endorses H6. The favorable relation suggests that CE practices work better for sustainability when supply chains designed for circularity are put in place. Therefore, this signifies the importance of integrating waste management, resource recovery, and closed-loop production systems.

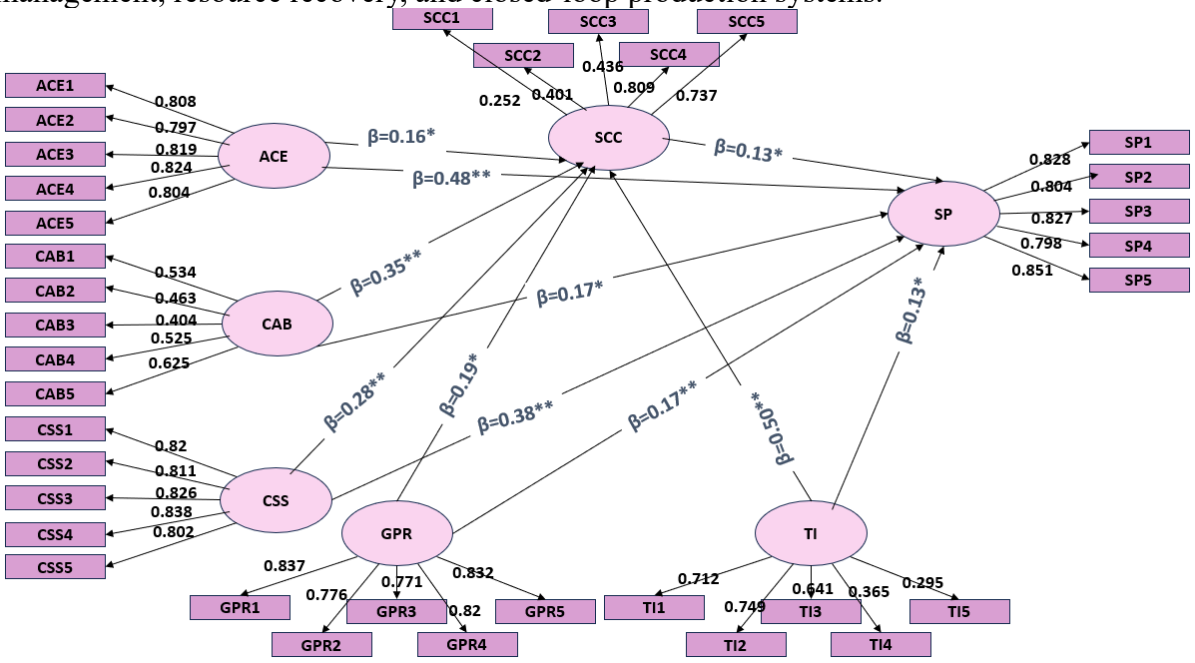

Figure 1: Pathway diagram with standardized coefficients of decomposed constructs

Table 4: Factor analysis

	ACE	CAB	CSS	GPR	SCC	SP	TI
ACE1	0.808						
ACE2	0.797						
ACE3	0.819						
ACE4	0.824						

ACE5	0.804						
CAB1		0.534					
CAB2		0.463					
CAB3		0.404					
CAB4		0.525					
CAB5		0.625					
CSS1			0.82				
CSS2			0.811				
CSS3			0.826				
CSS4			0.838				
CSS5			0.802				
GPR1				0.837			
GPR2				0.776			
GPR3				0.771			
GPR4				0.82			
GPR5				0.832			
SCC1					0.252		
SCC2					0.401		
SCC3					0.436		
SCC4					0.809		
SCC5					0.737		
SP1						0.828	
SP2						0.804	
SP3						0.827	
SP4						0.798	
SP5						0.851	
TI1							0.712
TI2							0.749
TI3							0.641
TI4							0.365
TI5							0.295

In our results (Table 4), most items exhibit to be very strongly loaded, which means good construct validity for the model. For Adoption of Circular Economy (ACE), all 5 items (ACE1-ACE5) are represented by high loadings from 0.797 to 0.824, indicating that the measurements represent the construct well whereby CE adoption in textile industries is concerned. Corporate Sustainability Strategies (CSS) also register high factor loadings of between 0.802 and 0.838, demonstrating the strong representation of these strategies by the items measuring sustainability-driven corporate initiatives. Factor loading for Government Policies & Regulations (GPR) remains relatively high (ranging from 0.771 to 0.837), thereby emphasizing the importance of regulatory framework support for sustainability and CE adoption. Sustainability performance (SP) is another construct that is well measured with loads ranging from 0.798 to 0.851, demonstrating the robustness of the measurement scale in determining the sustainability outcomes of textile firms.

On the contrary, Consumer Awareness and Behavior (CAB) achieved factor loadings of moderate value ranging from 0.404 to 0.625: This shows some variance in consumers'

perception and engagement in sustainable textile practice. Supply Chain Circularity (SCC) has a mix load range, where SCC4 and SCC5 are strongly loaded at 0.809 and 0.737, respectively, while SCC1-SCC3 score poorly (0.252 to 0.436), indicating that there may be some variability in how different aspects of circular supply chains contribute to the construct. On the whole, the techno-globalization factor shows the weakest load with values ranging from 0.295 to 0.749, whereas TI4 (0.365) and TI5 (0.295) characterized the lowest within the range. This indicates that some items may not adequately capture the construct, and thus, it might need to be revised or transformed in future studies.

4. Discussion

The current study adds to the growing corpus of information about the textile sector in Tamil Nadu's implementation of the CE and sustainability performance. The study accounts for technological innovations, consumer awareness, supply chain circularity, corporate sustainability strategies, and government policy as the major factors influencing sustainability performance. Yet, firms somewhat recognize the importance of applying CE practices, whereas there are significant gaps regarding implementation, regulatory enforcement, and consumer engagement, which need improvement. Possibilities and obstacles for long-term transformation have been identified by CE studies involving the textile industry. Ortiz-de-Montellano et al. (2023) also analyzed the interplay between CE strategies and SDGs and found that they strongly contribute to the achievement of responsible consumption (SDG 12), climate action (SDG 13), and economic growth (SGD 8). With regard to social dimensions, they noted that gender equality (SDG 5) and reducing inequalities (SDG 10) were less compelled by CE strategies. The current study sits comfortably in this position, asserting that technological innovation and supply chain circularity remain the paramount factors propelling sustainability performance. The study raises doubts, nonetheless, regarding the regulatory frameworks and implementation strategies that will need precise interventions for a successful transition into CE. Saha et al. (2022) similarly studied barriers to CE adoption in the textile and clothing industries in India, Bangladesh, and Vietnam. These authors found financial constraints, limited technological infrastructure, and lack of managerial commitment to be the key barriers, which resonate with this study's observation of a moderate level of CE adoption. Saha et al. stress the need for a holistic approach, which becomes clear in the Tamil Nadu textile sector in which government policies are positively affecting sustainable performance and stronger industry participation with consumer-driven demand is still needed.

One of the most notable findings from this study relates to technological innovation affecting both supply chain circularity and sustainability outcomes. This holds true, according to John and Mishra (2023), who proposed a three-layer circular supply chain model combining green technologies, water purification, and zero-waste techniques. They found in their research that CE-integrated supply chains would economically outperform the traditional ones, thus suggesting that technological investment is an environmental need and a strategic avenue for business. In a related study, Teixeira et al. (2023) speak about introducing innovation into product development for CE integration and leverage Design Thinking (DT) to attain that goal. The authors stress the importance of creativity and user-centered design in promoting sustainable textile production. This research strengthens the argument, stating that enterprises that embraced technological advancements in eco-friendly materials, automated recycling, and digital supply chain management achieve better circularity and overall sustainability performance. The role of consumer awareness in affecting sustainability outcomes has been a contested topic in the CE literature. Both studies by Chen et al. (2021) and Hartley et al. (2022)

stressed consumer reluctance as one of the major impediments to the CE transition. The Hartley et al. study identified that Dutch textile firms suffered a chain reaction that greatly impeded large-scale adoption of CE due to high production costs and weak market demand for circular products. Likewise, Yadav and Majumdar (2024) identified low consumer trust and awareness as two primary hindrances in the Indian textile sector. The present study corroborates this by indicating that whereas consumer awareness does positively intervene in sustainability performance, such awareness is a moderate driver compared to technology and policy interventions.

To overcome this challenge, firms should run awareness programs on environmental labeling and disclosure of sustainability reports to educate consumers on the relevance of circular products. The establishment of further government incentives would also help to boost consumers' willingness to change towards the sustainable purchase of textiles, thus bridging the gap between mere awareness and exercise of behavioral change. The findings suggest that government policies contribute positively albeit moderately to the sustainability performance, thus confirming previous work, including Huang et al. (2022), which also identified regulatory inconsistencies to be a significant hindrance to CE within the textile sector in Taiwan. Again, incorporating Fuzzy Delphi and structural modeling, the findings draw attention to the fact that ineffective policy frameworks and unavailability of high-quality recycling materials resulted in structural inefficiencies in textile circularity. By such a suggestion, the current study echoes that while government policies form a basis for sustainability performances, the effectiveness of these is largely dependent on how enforcement and clarity need to be aligned with the needs of the industry. Corporate sustainability strategies emerged as one major determinant of sustainability performance, a finding consistent with previous studies that emphasized internal business initiatives as necessary for adoption of CE. In their study on CE challenges and strategies in Bangladesh, Chowdhury et al. (2023) found that waste recovery and sustainable waste management systems served as key enablers of circularity. Essential elements of corporate sustainability were also found in monitoring and control mechanisms that their framework emphasized as relevant inputs into the process.

Similarly, John and Mishra (2023) proved that the integration of sustainability into corporate strategy leads to higher profitability, which contradicts the argument that CE initiatives are costly. Thus, the current study has confirmed this notion, showing that organizations implementing proactive sustainability such as responsible sourcing, environmental commitments, and closed-loop supply chain models have favorable results in terms of sustainability. Nevertheless, it does not seem feasible at a large scale since it requires investments and collaborations with the relevant industries to overcome financial and logistical barriers related to popularity. In such an environment, research proves that supply-chain circularity acts as a mediator between the two variables that are between CE adoption and sustainability performance, putting emphasis on closed-loop supply networks. This holds true with the work done by Saccani et al. (2023), which argues that resource and supply management strategies must be integrated for CE frameworks to yield their maximum potential. Other authors like Yadav and Majumdar (2024) have presented a quadruple helix framework for addressing supply-chain inefficiencies, with the emphasis on organized collaboration among academia, government, industry, and society. Going by the findings from this survey, which are made uniquely concerning Tamil Nadu's textile industry, this means that companies embrace CE practices and optimize supply chains towards circularity for better sustainability performance. The results emphasize perfect material recovery systems, a reliable recycling

infrastructure, and well-multisource collaborative links among manufacturers, suppliers, and policymakers.

5. Conclusion

This study places emphasis on the influence of CE practices on sustainability performance in the textile industry of Tamil Nadu along with related factors like technological innovation, awareness among consumers, sustainability initiatives undertaken by corporations, governmental policies, and circularity in supply chain instances. Findings verify significantly higher sustainability performance through CE practices, with technological advancement and supply chain circularity playing important roles in promoting circularity. Consumer awareness and government policies show positive influences on sustainability performance outcomes; however, they moderately do so, indicating a necessity for enforced legislation to make Engage consumers more. Corporate sustainability strategies enhance sustainability performance, stressing responsible sourcing, waste management, and closed-loop production. The novel contribution of this study is the holistic approach in examining the interrelationships between CE adoption, supply chain circularity, and sustainability performance within the Tamil Nadu textile industry. Past research has been expanded by empirically validating the mediating influence that supply chain circularity has in demonstrating how circular supply networks amplify the benefits of CE initiatives. The second contribution of the current study is to bridge the international literature on circular economy with the contextual issues facing the region, in practical terms providing an avenue for intervention for policymakers, industry leaders, and sustainability proponents interested in stimulating circular practices in emerging economies. Nevertheless, the study has limitations. It has focused on the textile industry in Tamil Nadu, making it difficult to generalize the findings in other regional or industrial contexts. Second, the study mainly relied on data collected by means of surveys, which may be affected by respondent bias. Future research could incorporate longitudinal survey data and case studies to evaluate any long-term trends regarding CE adoption. Moreover, evaluating the economic impact of CE implementation may shed light on the cost-benefit proposition for businesses. In conclusion, this study highlights the need for systemic integration of CE and provides practical advice for speeding up the process of sustainable transformation in the textile industry.

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