

RESEARCH ARTICLE

Sustainability Practices Impacts on Supplier Sustainability Risks and Sustainability Performance: An Empirical Study of Brazilian Companies

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ABSTRACT

This study explores the influence of sustainability practices on supplier sustainability risks and sustainability performance in Brazilian companies, offering key insights into how behavioral and technical practices impact these crucial areas. Data were collected from 152 Brazilian companies across various sectors. The theoretical framework was tested using partial least squares structural equation modeling. The research findings highlight that implementing behavioral sustainability practices has a positive effect on reducing supplier sustainability-related risks and improving overall sustainability performance in supply chains. These practices, focused on fostering sustainable behaviors within organizations and among suppliers, play a critical role in mitigating sustainability risks and enhancing long-term performance. Unexpectedly, the study did not confirm the predicted relationship between technical sustainability practices and improvements in supplier sustainability-related risks and performance. This surprising result challenges traditional assumptions about the effectiveness of technical practices in improving supply chain sustainability performance. By uncovering the distinct impact of behavioral versus technical sustainability practices, the study provides valuable insights for both researchers and practitioners. It emphasizes the importance of promoting behavioral change to achieve meaningful sustainability outcomes. The findings have practical implications for companies aiming to enhance their sustainability strategies and manage sustainability risks more effectively within their supply chains, making this research a significant contribution to sustainable management and supply chain theory.

1 | Introduction

The outsourcing of activities is increasingly common in companies; however, it raises issues that are widely discussed, such as the loss of control over outsourced activities and employees' working conditions. Concerns regarding climate change and the deterioration of human well-being have been heightened due to the manufacturing processes. It is a context that has

led to an increase in the impacts of human activities on the planet (Rauf et al. 2021). Supply chain management practices that focus on minimizing energy consumption, reducing pollution, and enhancing medium- and long-term sustainability can yield competitive advantages (Razzaq et al. 2020; Romano, Ferreira, and Caeiro 2023). Evidence indicates that adopting sustainability practices, including internal initiatives and collaborative approaches, can drive improvements in sustainability

performance. As a result, the implementation of these practices can offer significant competitive benefits (Yadav et al. 2023; Ahmadi-Gh and Bello-Pintado 2024).

To effectively implement sustainability practices, it is crucial to distinguish between technical and behavioral practices (Govindan, Khodaverdi, and Vafadarnikjoo 2015; Wang, Cheng, and Wang 2022; Romano, Ferreira, and Caeiro 2023). According to Ahmadi-Gh and Bello-Pintado (2024), both technical and behavioral practices play significant roles and have distinct effects on supplier sustainability performance. Sustainability practices, along with supply chain leadership, impact suppliers' sustainability competencies and performance. This highlights the importance of differentiating between these practices to enhance overall sustainability outcomes.

Technical practices relate to the application of sustainability tools, while behavioral practices involve engagement and relationships with partners (Chand and Tarei 2021; Jha et al. 2022; Huang, Surface, and Zhang 2022). Despite the lack of clarity regarding their dimensions and impact (Anuar et al. 2022), Yadav et al. (2023) found that both practices positively impact performance: Technical practices improve internal processes, while behavioral practices enhance social and environmental outcomes. The aim of this research is to investigate how these practices influence supplier sustainability risks and performance within supply chains.

Measuring and evaluating behavioral sustainability practices in supply chains presents challenges, encompassing dimensions like leadership, ethics, and values (Seuring and Müller 2008; Huang, Surface, and Zhang 2022; Romano, Ferreira, and Caeiro 2023). Moreover, there are few studies in Brazil that examine the implementation of sustainability practices and their influence on organizational performance or supplier sustainability risks (De Sousa Jabbour et al. 2017; Vanalle et al. 2017; Razzaq et al. 2020). Moreover, the adoption of sustainability practices by companies generates institutional pressure that impacts supplier performance, highlighting the need for more research in Brazil on the impact of these practices (Ahmadi-Gh and Bello-Pintado 2024). In developing nations, the focus usually revolves around the technical facets of sustainability and how they influence the overall effectiveness of organizations (Jabbour, Mauricio, and de Sousa Jabbour 2017).

In general, the analyses encompass studies conducted in North America, Europe, and Asia, highlighting that sustainability concerns have a global character. It is therefore relevant to investigate the role of culture and consider economic diversity, the sophistication of supply chain management, and governmental oversight in sustainable business practices (Golicic and Smith 2013). In this regard, exploring other contexts, such as those in Latin America, can be promising for expanding sustainability research due to its social, cultural, and economic characteristics (Aguinis et al. 2020).

Supplier sustainability risks stem from inadequate sustainability practices, leading to disruptions due to internal or external failures (Romano, Ferreira, and Caeiro 2021a; Öberg 2022).

Those risks can lead to adverse reactions from stakeholders, which can result in losses for the focal companies (Hofmann et al. 2014; Ahmadi and Jafari 2022; Khan et al. 2023). Social and environmental risks may emerge from direct and indirect suppliers, attributed to inadequate control within the supply chain (Busse et al. 2017; Tsetse et al. 2024).

An effective implementation of sustainability practices can lead to a decrease in supplier sustainability risks within supply chains and, subsequently, an improvement in sustainability performance. The research has shown that there is evidence that implementing sustainability practices can lead to benefits in performance across sustainability dimensions (Jabbour, Mauricio, and de Sousa Jabbour 2017; Dubey et al. 2017; Zhang et al. 2024). Nevertheless, it is crucial to institute various sustainability practices to effectively tackle the intricate challenges in supply chains, ensuring benefits for all companies embracing these approaches (Marshall et al. 2015). Although some companies may adopt sustainability practices spontaneously, research suggests that implementation is more likely to occur to reduce risks and improve sustainability performance (Dubey et al. 2017; Romano, Ferreira, and Caeiro 2023; Zhang et al. 2024). Therefore, further research is needed to examine the impact of implementing sustainability practices on supplier sustainability risks and sustainability performance within supply chains (Feng et al. 2018). According to Ahmadi-Gh and Bello-Pintado (2024), using structural equation modeling is an effective approach for examining the impact of sustainability practices. This aligns with the objective of studying how these practices influence supplier sustainability risks and sustainability performance.

This investigation explores the inquiry outlined in the context of the research question (RQ):

(RQ): How are supplier sustainability risks in supply chains influenced by the adoption of sustainability practices, and how does this impact the sustainability performance?

This study tackles the research query by conducting a literature review on sustainability practices, supplier sustainability risks, and sustainability performance. Following the recommendations of Forza (2016), a survey involving Brazilian focal companies across several sectors examines the impact of sustainability practices on supplier sustainability risks and sustainability performance. The research contributes to supply chain sustainability theory, examining technical and behavioral practices through the resource-based view (RBV) and sociotechnical systems theory. It investigates the influence of these practices on supplier sustainability risks and sustainability performance.

The article encompasses a comprehensive exploration of existing literature, an elaboration of the theoretical framework, and the formulation of hypotheses in Section 2. Section 3 delves into the intricacies of the research methodology, with Section 4 unveiling the obtained results. Moving forward, Section 5 engages in a thorough discussion of the findings, while Section 6 encapsulates the conclusions drawn from the study.

2 | Theoretical Background and Hypothesis Development

2.1 | The Effect of Sustainability Practices on Supplier Sustainability Risks

Sustainability practices in supply chains are categorized into technical and behavioral practices (Nureen et al. 2022; Romano, Ferreira, and Caeiro 2023), grounded in sociotechnical systems theory (Govindan, Khodaverdi, and Vafadarnikjoo 2015). This theory emphasizes the integration of technical tools and methods with behavioral factors like leadership and engagement, which are crucial for effective implementation and performance (Laari et al. 2016; Jabbour, Mauricio, and de Sousa Jabbour 2017; Ahmadi-Gh and Bello-Pintado 2024). Arguments suggest that behavioral practices influence technical sustainability practices in supply chains and sustainability performance (De Sousa Jabbour et al. 2017; Dubey et al. 2017). Previous studies also explored the impact of behavioral practices on organizations' environmental performance (De Sousa Jabbour et al. 2017; Tsetse et al. 2024).

Results show that in the Brazilian context, organizations tend to prioritize customers over suppliers to improve their environmental performance (Tsetse et al. 2024). The study presents an original matrix that clarifies the roles of suppliers and customers in enhancing performance through sustainability practices. Additionally, other research evidence that behavioral sustainability practices in supply chains positively impact technical sustainability practices (Oyedijo et al. 2022; Satapathy 2022; Ahmadi-Gh and Bello-Pintado 2024).

However, the lack of implementation of sustainability practices can lead to significant risks in supply chains, affecting multiple dimensions and causing stakeholder backlash, reputational damage, and financial losses (Hofmann et al. 2014; Awasthi, Govindan, and Gold 2018). Supplier-related issues, such as environmental, social, or economic failures, can severely impact the focal company's performance and reputation (Ahmadi and Jafari 2022; Syed et al. 2019; Romano, Ferreira, and Caeiro 2021b).

Direct and indirect suppliers can influence a company's reputation through various unsustainable practices. These include inadequate waste management, labor rights violations, and fraudulent activities, which can lead to stakeholder criticism, reputational threats, and challenges in promoting sustainable products (Busse et al. 2017; Romano, Ferreira, and Caeiro 2021a). Therefore, it is crucial to manage these risks effectively to ensure a company's sustainable performance and maintain its operational legitimacy (Tsetse et al. 2024).

In this context, both technical and behavioral sustainability practices are crucial for managing and mitigating sustainability risks within supply chains. Research highlights that inadequate practices can lead to significant issues across social, environmental, and economic dimensions, negatively impacting a company's reputation and performance (Romano, Ferreira, and Caeiro 2021b; Giannakis and Papadopoulos 2016; Busse et al. 2017).

Considering the RBV theory (Barney 2001; Foerstl et al. 2010), which suggests that companies can leverage unique resources

to achieve superior performance, it is reasonable to assume that implementing both technical and behavioral sustainability practices can enhance the effectiveness of sustainability studies. Studies demonstrate that effective technical practices can reduce risks associated with suppliers, while behavioral practices can foster a more robust and integrated approach to sustainability (Hofmann et al. 2014; Awasthi, Govindan, and Gold 2018). Thus, Hypotheses H1 and H2 are formulated to assess the impact of these practices on supplier sustainability risks.

H1. *The implementation of technical sustainability practices positively influences supplier sustainability risks.*

H2. *The implementation of behavioral sustainability practices positively influences supplier sustainability risks.*

In summary, both technical and behavioral sustainability practices play a crucial role in managing and mitigating supplier sustainability risks, which, in turn, can enhance overall supply chain sustainability and performance.

2.2 | The Effect of Sustainability Practices on Sustainability Performance

The implementation of sustainability practices has proven to be crucial for improving the sustainable performance of companies, as evidenced in the literature. Esfahbodi et al. (2017), J. Liu et al. (2020), and Romano, Ferreira, and Caeiro (2021b) highlight that these practices are fundamental for enhancing sustainability performance. Hart and Dowell (2011) and Bag et al. (2021) reinforce that such practices not only promote sustainability but also serve as strategic assets that strengthen companies' competitiveness. Mani, Jabbour, and Mani (2020), Daft (2021), and Ahmadi-Gh and Bello-Pintado (2024) emphasize the importance of collaborating on sustainability projects with supply chain partners, which can create significant competitive advantages. Vanalle et al. (2017) and Romano, Ferreira, and Caeiro (2021b) advocate for an integrated approach that combines both technical and behavioral practices as essential for improving sustainability performance in supply chains.

Among sustainability practices, technical practices are especially important as they provide the tools, methods, and processes needed to implement concrete and measurable changes. The effectiveness of these practices can lead to substantial improvements in companies' holistic economic, environmental, and social performance. Well-implemented technical practices not only enable the realization of sustainability initiatives but also ensure that these initiatives are effective and measurable. This is crucial for effective sustainability management, as it facilitates the creation of practical solutions and the achievement of tangible results.

Based on the literature and the importance of technical practices for achieving sustainable outcomes, we propose the following hypotheses.

H3. *The implementation of technical sustainability practices positively influences economic sustainability performance.*

H4. *The implementation of technical sustainability practices positively influences environmental sustainability performance.*

H5. *The implementation of technical sustainability practices positively influences social sustainability performance.*

These hypotheses explore how technical sustainability practices impact performance, showing their role in improving sustainability and competitiveness in supply chains.

Studies by Esfahbodi et al. (2017) and J. Liu et al. (2020) highlight that both technical and behavioral sustainability practices are essential for enhancing companies' sustainable performance. When effectively integrated into operations, these practices significantly contribute to efficiency and innovation while promoting greater competitiveness, as emphasized by Hart and Dowell (2011) and Bag et al. (2021).

The literature also underscores the importance of collaboration between companies and their supply chain partners on sustainability initiatives. Mani, Jabbour, and Mani (2020) and Daft (2021) stress that this collaboration can generate significant competitive advantages and improved performance outcomes. In this regard, the implementation of behavioral sustainability practices is seen as a critical factor for the success of supply chains, as it goes beyond operational efficiencies by fostering cultural transformations necessary for achieving sustainability goals.

Additionally, Vanalle et al. (2017) and Romano, Ferreira, and Caeiro (2021b) reinforce the need for an integrated approach that combines technical and behavioral practices to improve sustainable performance in supply chains. From this perspective, behavioral practices are particularly important because they address human and cultural aspects, which are often crucial in companies' and suppliers' adoption of sustainability practices.

Given this, we propose the following hypotheses.

H6. *The implementation of behavioral sustainability practices positively influences economic sustainability performance.*

H7. *The implementation of behavioral sustainability practices positively influences environmental sustainability performance.*

H8. *The implementation of behavioral sustainability practices positively influences social sustainability performance.*

These hypotheses help clarify how behavioral sustainability practices affect supply chain performance, guiding companies to implement more effective sustainability strategies that enhance economic, environmental, and social outcomes.

2.3 | The Effect of Supplier Risks on Sustainability Performance

In the context of supply chains, another relevant aspect is the study of supplier's sustainability risks effects on overall sustainability performance of companies. The literature highlights

the importance of managing these risks to ensure long-term sustainability and improve organizational performance across various dimensions (Kim, Wagner, and Colicchia 2019; Syed et al. 2019; Wang, Cheng, and Wang 2022). Nureen et al. (2022) point out that sustainability risks associated with suppliers can affect multiple dimensions of companies' sustainability performance, underscoring the urgent need for effective risk management strategies.

The relevance of studying sustainability risks lies in their ability to directly influence supply chain performance in economic, environmental, and social aspects. These risks can impact economic performance by affecting operational efficiency and cost structures. Similarly, they can adversely affect environmental performance by influencing resource utilization and waste management. Additionally, issues related to labor practices and community engagement can negatively impact social performance within supply chains.

Integrating sustainability practices into supply chain management is crucial for mitigating these risks and enhancing sustainability performance. Studies by Feng et al. (2018), Dubey et al. (2019), and Romano, Ferreira, and Caeiro (2021b) demonstrate that implementing sustainability practices plays a crucial role in improving overall performance. Further research by Baliga, Raut, and Kamble (2020), Roy, Schoenherr, and Charan (2020), J. Liu et al. (2020), and Nureen et al. (2022) emphasizes the critical importance of effective risk management to avoid adverse effects and enhance supply chain performance.

Therefore, studying supplier sustainability risks is essential for assessing and understanding their potential impact on sustainability performance. Based on this perspective, we propose the following hypotheses.

H9. *The effective management of supplier sustainability risks positively influences the economic sustainability performance.*

H10. *The effective management of supplier sustainability risks positively influences the environmental sustainability performance.*

H11. *The effective management of supplier sustainability risks positively influences the social sustainability performance.*

Understanding these impacts will help companies create better strategies to manage sustainability risks and improve performance in their supply chains.

Figure 1 displays the set of hypotheses.

3 | Methods

The empirical test of the theoretical framework and associated hypotheses employed a data collection instrument with items measured on a seven-point Likert scale, ensuring statistical variability. An exception was made for technical practices (AT9 to AT14), graded on a scale indicating stages of implementation, where (1) denotes *Never considered*, (2) *Already considered but*

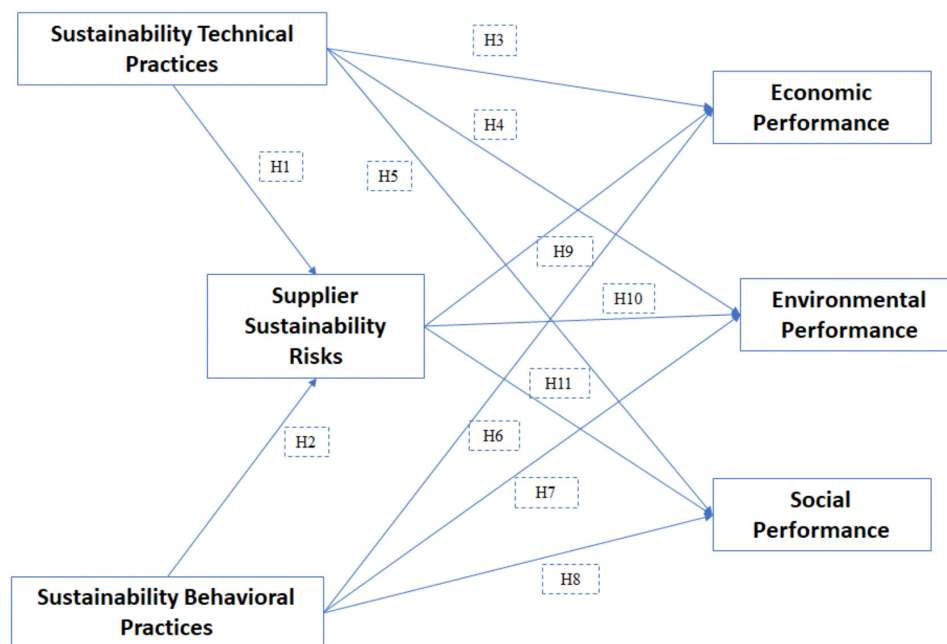


FIGURE 1 | Research model.

not planned, (3) *Is considering planning*, (4) *Is considering implementing*, (5) *Initiating implementation*, (6) *Successfully implemented*, and (7) *Successfully implemented with indicators*, with higher values indicating greater progress in sustainability technical tools implementation. Five experts participated in a pilot study to assess and validate the questionnaire's applicability within the context of sustainability in supply chains. Table 1 presents the questions used to evaluate supply chain sustainability practices.

The sustainability risk measures were designed based on preliminary studies, which allowed the identification of supplier sustainability risks in supply chains (Busse et al. 2017). Table 2 presents the questions to be evaluated regarding supplier sustainability risks.

Regarding sustainability performance, previously developed scales were also used to evaluate performance in sustainability dimensions. The inquiries related to performance within the sustainability dimensions are outlined in Table 3.

This quantitative study examines supply chain sustainability in Brazilian companies, focusing on practices, risks, and performance. Data were collected from sustainability managers via a questionnaire administered through LimeSurvey. A sample from the Brazilian Sustainability Professionals Association database (www.abraps.org.br) was used, focusing on sustainability managers in supply chains. This approach provides key insights into organizational practices and strengthens the study's validity. A diverse sample of companies was chosen as detailed in Table 4. Out of 350 invited companies, 152 responded, yielding an effective response rate of 43.42%. This sample size aligns with the study's hypotheses (Hair et al. 2019). Statistical analyses were carried out using SMART PLS version 4. SMART PLS was selected for its flexibility with complex models, small sample sizes, and nonnormal data, making it ideal for exploring structural theories and

assessing intermediate constructs (Bhadra, Kamalanabhan, and Singh 2024; Ashraf et al. 2024).

To mitigate nonresponse bias, wave analysis (Armstrong and Overton 1977) was employed, dividing the sample by response date and testing for significant differences ($p < 0.05$) using the *t* statistic. This method, endorsed by Eckstein et al. (2015), confirmed the absence of nonresponse bias. A demographic data comparison between respondents and nonrespondents, following Fawcett et al.'s (2014) recommendation, further ensured data collection integrity.

To alleviate the influence of common method variance, as highlighted by Podsakoff et al. (2003), this study utilized multiple strategies (H. Liu et al. 2016). The marker variables MQ1 and MQ2 were included, not related to other constructs, as detailed in Tables 1 and 2.

In this study, Fornell and Larcker's (1981) criterion was employed for assessing average variance extracted (AVE), and the heterotrait-monotrait ratio matrix (HTMT) (Henseler, Ringle, and Sarstedt 2015) was utilized to evaluate discriminant validity. Pearson's R^2 coefficients were assessed by Cohen's (2013) classification. Model fit metrics ($NFI > 0.90$, $SRMR < 0.09$) adhered to Byrne's (2013) recommendations, while χ^2 , GFI, CFI, and RMSEA were irrelevant in partial least squares structural equation modeling (PLS-SEM) (Hair et al. 2019).

4 | Results

Survey data analyzed with SMART PLS 4 and SPSS 25 included frequency distribution, percentile metrics, and collinearity statistics. Reliability was assessed via Cronbach's alpha, and hypotheses were tested through the application of partial least squares in structural equation modeling (Hair et al. 2019).

TABLE 1 | Sustainability practice construct.

Item	COD	Description of the questions	Sources
Sustainability behavioral practices	BP1 ^a	Our company verifies the dedication of top management to the implementation of CSR.	Green et al. (2012); Luthra, Garg, and Haleem (2016); Jabbour, Mauricio, and de Sousa Jabbour (2017); Liu et al. (2020)
	BP2 ^a	Our company seeks understanding of CSR among departments and individuals.	
	BP3	Our company has an education and training program on environmental issues.	
	BP4	Our company has an education and training program on social issues.	
	BP5	There is coordination with customers for the use of environmental issues in design.	
	BP6 ^a	Our customers consider environmental considerations in choosing suppliers.	
	BP7 ^a	Our customers consider social considerations in choosing suppliers.	
	BP8 ^a	Our in providing technical assistance within the realms of environmental conservation and energy-saving initiatives.	
	BP9	Our company coordinates with our suppliers to achieve environmental objectives.	
	BP10 ^a	Our company coordinates with suppliers to achieve social objectives.	
	BP11	Our company considers environmental factors in the process of selecting and assessing suppliers.	
	BP12	Our company considers social factors in the process of selecting and assessing suppliers.	
	BP13	Our company provides necessary green technologies and training to suppliers.	
Sustainability technical practices	TP1 ^a	Our product design prioritizes minimal material and energy consumption.	Luthra, Garg, and Haleem (2016); Jabbour, Mauricio, and de Sousa Jabbour (2017); Liu et al. (2020)
	TP2 ^a	Our product design includes reusability and recycling of materials and/or components.	
	TP3 ^a	Our product design avoids or reduces the use of hazardous products in manufacturing.	
	TP4 ^a	Our company adopts reuse and/or recycling of materials or products.	
	TP5	Our company adopts remanufacturing of components or products.	
	TP6 ^a	Our company aims for implementing cleaner production.	
	TP7 ^a	Our company aims for implementing total quality environmental management.	
	TP8 ^a	Our company seeks continuous improvement of the process by reducing environmental impact.	
	TP9	Our company adopts an environmental management information system.	
	TP10	Our company adopts certification of environmental management standards (ISO 14001).	
	TP11	Our company conducts environmental audits to ensure compliance with environmental standards.	
	TP12	Our company adopts a social management information system.	
	TP13 ^a	Our company adopts certification of social management standards (SA 8000).	
	TP14	Our company conducts internal social audits to ensure compliance with social standards.	

^aThe items presented low factor loadings and were removed from the final model.

TABLE 2 | Presentation of supplier sustainability risk constructs.

Item	COD	Description of the questions	Sources
Sustainability risks	SR1 ^a	Our suppliers and their respective suppliers have never jeopardized our ability to market sustainable products.	Busse et al. (2017); Ahmadi and Jafari (2022); Wang, Cheng, and Wang (2022)
	SR2	Our stakeholders have never criticized us for working with our suppliers or their suppliers.	
	SR3	The relationship with our suppliers and their suppliers has never become a risk to our reputation.	
	SR4	Our business performance has never been threatened in any way by the social and environmental conditions of our suppliers and their suppliers.	
	SR5 ^a	The processes of our suppliers and their suppliers could never be considered socially or ecologically illegitimate.	

^aThe items presented low factor loadings and were removed from the final model.

TABLE 3 | Presentation of sustainability performance constructs.

Item	COD	Description of the questions	Sources
Economic	EC1 ^a	Our company registered a decrease in purchasing cost of materials per unit of product.	Luthra, Garg, and Haleem (2016); Feng et al. (2018); Liu et al. (2020)
	EC2	Our company registered a decrease in energy consumption cost per unit of product.	
	EC3	Our company registered a decrease in waste discharge rate per unit of product.	
	EC4	Our company registered a decrease in waste treatment rate per unit of product.	
	EC5 ^a	Our company registered a decrease in production costs in project (development/design).	
Environmental	EN1	Our company registered a decrease in atmospheric emissions, wastewater, solid waste per unit of product.	Yang et al. (2013); Luthra, Garg, and Haleem (2016); Feng et al. (2018); Liu et al. (2020)
	EN2	Our company registered a decrease in the consumption of hazardous/toxic materials per unit of product.	
	EN3	Our company registered a decrease in the frequency of environmental accidents.	
	EN4	Our company registered an improvement in the environmental situation of the company.	
	EN5	Our company registered a reduction of environmental damages.	
Social	SO1	Our company registered an improvement of the image as “A good place to work”.	Baliga, Raut, and Kamble (2020); Chowdhury et al. (2020)
	SO2	Our company registered an enhancement of corporate image as an ethical organization.	
	SO3	Our company registered an improvement of employee or community health and safety.	
	SO4	Our company registered an improvement of working conditions.	

^aThe items presented low factor loadings and were removed from the final model.

TABLE 4 | Sample characterization.

Variable definition		Quantity	Percentage
Company size (number of employees)	Over 301	86	56.60%
	From 101 up to 200	25	16.40%
	From 201 up to 300	24	15.80%
	51 to 100	12	7.90%
	Up to 50	5	3.30%
Company position in the chain (*)	Original equipment manufacturer	58	38.20%
	Direct supplier	56	36.80%
	Subsupplier	15	9.90%
	Indirect supplier	14	9.20%
	Raw material supplier	9	5.90%
Company's sector of activity	Mechanical metal	34	22.40%
	Food and drinks	18	11.80%
	Chemical	17	11.20%
	Household goods and personal care	14	9.20%
	Paper and cellulose	12	7.90%
	Automotive and parts	11	7.20%
	Building construction and building materials	9	5.90%
	Medical equipment	6	3.90%
	Oil and gas	5	3.30%
	Others	26	17.00%

Note: The asterisk (*) indicates the company's position in the supply chain, from raw materials (upstream) to the final product (downstream).

4.1 | Preliminary Univariate Analysis

This study involved the evaluation of a set of Brazilian companies ($n=152$), considering characteristics such as size and industry segment. Original equipment manufacturer represents 38.2%, direct supplier represents 36.8%, and mechanical metal dominates the sector at 22.4%. Regarding company size, the sample is made up of 56.6% of companies with more than 301 employees (Table 4).

A multicollinearity test was conducted to check for strong correlations among the independent variables, as such correlations can affect the model estimation results (Hasan et al. 2023). According to Hair et al. (2019), multicollinearity could be a potential issue if the variance inflation factor (VIF) surpasses 5 or if tolerance values fall below 0.1. In this study, the highest VIF observed was 1.214, well within acceptable limits. Additionally, tolerance values were within the permissible range (between 0.1 and 1), indicating that multicollinearity is not a concern in this dataset.

4.2 | Multivariate Statistical Analysis

4.2.1 | Measurement Model

The examination of the measurement model aims to uncover the connection between observed variables and a latent variable in a particular study (Hair et al. 2019; Hasan et al. 2023). Employing

SMART PLS 4.0, the proposed model underwent testing utilizing the PLS-SEM technique (Romano, Ferreira, and Caeiro 2021b; Ringle, Wende, and Becker 2022), requiring an evaluation of the reliability and validity of latent variables.

4.2.1.1 | Convergent Validity and Reliability. The results displayed in Table 5 disclosed that the construct reliability, evaluated using Cronbach's alpha and composite reliability values, surpassed 0.70 (Hair et al. 2019). It can be stated that convergent validity is established, based on factor loading (FL) values exceeding 0.70, and additionally, an AVE surpassing 0.50 (Hair et al. 2019), indicating satisfactory model performance.

Some items were excluded from the final model due to their limited factor impact, low factor loadings (FLs), and poor model fit. The items excluded include the following: behavioral practice items BP1, BP2, BP6, BP7, BP8, and BP10, technical practice items TP1, TP2, TP3, TP4, TP6, TP7, TP8, and TP13, economics sustainability performance items EC1 and EC5, and supplier sustainability risks SR1 and SR5. These items showed low FLs, indicating the need to remove them from the model (Ringle, Da Silva, and Bido 2014). Some items with FLs below 0.7 were maintained because there were no higher values in other constructs' rows and columns.

4.2.1.2 | Discriminant Validity. Discriminant validity, ensuring the distinctness of latent variables, was confirmed by comparing construct correlations with the square roots of AVE values. Following Fornell and Larcker (1981), in Table 6, bold

TABLE 5 | Cross-load values.

		BP	CA	CR	AVE
Behavioral practices (BP)	BP3	0.800	0.895	0.917	0.614
	BP4	0.762			
	BP5	0.771			
	BP9	0.819			
	BP11	0.784			
	BP12	0.739			
	BP13	0.807			
Technical practices (TP)	TP5	0.722	0.907	0.928	0.685
	TP9	0.914			
	TP10	0.781			
	TP11	0.897			
	TP12	0.857			
	TP14	0.778			
Economic performance (EC)	EC2	0.748	0.823	0.892	0.735
	EC3	0.915			
	EC4	0.899			
Environmental performance (EN)	EN1	0.707	0.862	0.901	0.646
	EN2	0.799			
	EN3	0.872			
	EN4	0.858			
	EN5	0.773			
Social performance (SO)	SO1	0.898	0.891	0.925	0.754
	SO2	0.869			
	SO3	0.858			
	SO4	0.848			
Sustainability risks (SR)	SR2	0.846	0.680	0.815	0.597
	SR3	0.716			
	SR4	0.749			

Abbreviations: AVE, average variance extracted; CA, Cronbach's alpha; CR, composite reliability.

diagonal elements (square roots of AVE) exceeded off-diagonal interconstruct correlation coefficients, confirming discriminant validity (Hair et al. 2019).

The HTMT is utilized to gauge the real correlations among components and functions as an indicator of discriminant validity in the PLS-SEM methodology (Hair et al. 2019). Discriminant validity is confirmed when the HTMT value is less than 0.90. In Table 7, it is evident that all HTMT values are below 0.90. These findings indicate that each latent variable possesses distinctiveness, thereby ensuring discriminant validity.

TABLE 6 | Discriminant and convergent analysis of the model under study.

	Fornell–Larcker criterion					
	BP	TP	EC	EN	SO	SR
BP	0.783					
TP	0.463	0.828				
EC	0.352	0.162	0.857			
EN	0.385	0.252	0.679	0.804		
SO	0.350	0.193	0.484	0.647	0.868	
SR	0.158	−0.141	0.282	0.188	0.195	0.772

Note: Reliability coefficients are displayed along the diagonal.

TABLE 7 | Results of discriminant validity.

	BP	TP	EC	EN	SO	SR
BP						
TP	0.491					
EC	0.392	0.187				
EN	0.428	0.278	0.794			
SO	0.380	0.208	0.563	0.738		
SR	0.193	0.176	0.316	0.236	0.253	

A single factor test and an exploratory factor analysis revealed that the first factor explains 47.44% of the variance. Bootstrap analysis confirmed significant differences from 1 in HTMT values, thus validating the distinction between constructs (Henseler, Ringle, and Sarstedt 2015; Hair et al. 2022).

4.2.2 | Analysis of the Structural Model

Figure 2 illustrates that behavioral practices have the most significant impact on environmental performance (0.296), social performance (0.285), and economic performance (0.282). This is followed by the impact of behavioral practices on supplier sustainability risks (0.283). Regarding the observable effect of technical practices on supplier sustainability risks, an unexpected result was found (−0.272). When including supplier sustainability risk, these practices explain 18.0%, 17.9%, and 14.8%, respectively, of the variance in sustainability performance in the economic dimension ($R^2=0.180$), environmental dimension ($R^2=0.179$), and social dimension ($R^2=0.148$).

The analysis of SEM involves assessing correlation and linear regression values and examining their significance ($p \leq 0.05$). Null hypotheses (H_0) for correlation ($r=0$) and regression (path coefficient = 0) are considered. A bootstrapping approach (Ringle, Wende, and Becker 2022) allowed us to estimate the structural model, presenting the path coefficient and significance level, as shown in Table 8.

In the context of the structural model, six hypotheses were validated, while five hypotheses were not supported. The hypothesis H1 revealed a statistically significant relationship between technical practices and the supplier sustainability risk, but contrary to what was initially expected, there exists a negative correlation in the relationship ($\beta = -0.272, p = 0.008$). This may occur for various reasons. There could be confounding variables, complex interactions among factors, or other factors not initially considered in the hypothesis. This unexpected finding may provide meaningful perspectives for future research and practices in the field of sustainability in supply chains.

H2 was supported ($\beta = 0.283, p = 0.001$), demonstrating a notable positive impact of behavioral practices on the supplier sustainability risk. This suggests that companies adopting sustainable behavioral practices may positively influence and mitigate risks in their supplier relationships.

The research revealed that the adoption of behavioral practices exerts a noteworthy positive impact on economic dimension of performance (H6: $\beta = 0.282, p = 0.006$) and on environmental performance (H7: $\beta = 0.296, p = 0.005$). Additionally, the study confirmed the positive influence of behavioral practices on social performance (H8: $\beta = 0.285, p = 0.005$). The findings suggest that the implementation of sustainability behavioral practices can have significant positive effects on a company's financial and nonfinancial outcomes, such as reputation, innovation, and competitive advantage.

Hypothesis H10 was also confirmed, that effective supplier sustainability risks have a significant impact on economic dimension (H9: $\beta = 0.247, p = 0.009$). The findings reveal that effective supplier sustainability risks significantly impact economic performance, with positive effects. Causes include operational impact, company reputation, regulatory compliance, additional

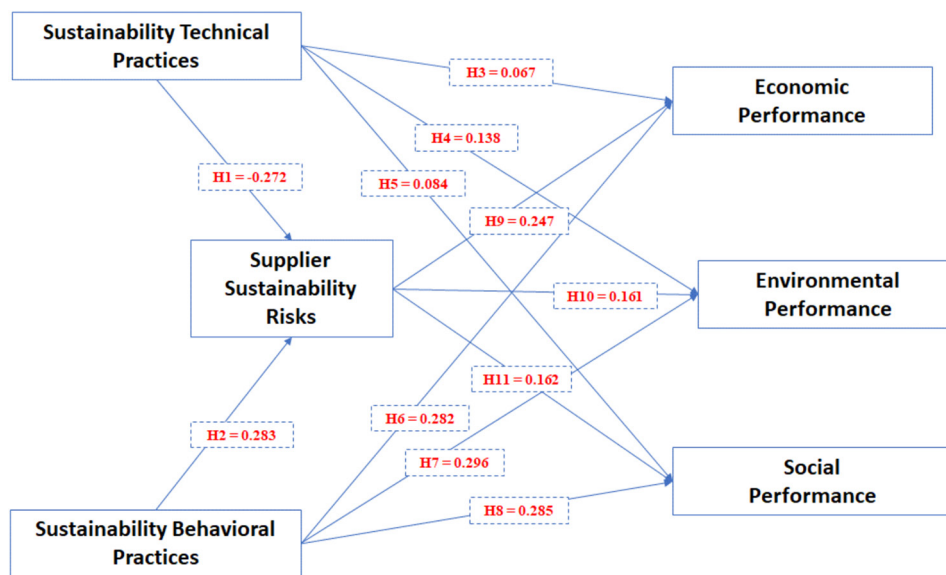


FIGURE 2 | Research model results.

TABLE 8 | Statistical tests for hypotheses.

Hypotheses	Constructs			β	SE	R.C.	p-Value	Results
H1	TP	=>	SR	-0.272	0.103	2.640	0.008	Supported
H2	BP	=>	SR	0.283	0.089	3.202	0.001	Supported
H3	TP	=>	EC	0.067	0.106	0.631	0.528	Not
H4	TP	=>	EN	0.138	0.109	1.265	0.206	Not
H5	TP	=>	SO	0.084	0.102	0.828	0.408	Not
H6	BP	=>	EC	0.282	0.103	2.736	0.006	Supported
H7	BP	=>	EN	0.296	0.104	2.831	0.005	Supported
H8	BP	=>	SO	0.285	0.102	2.794	0.005	Supported
H9	SR	=>	EC	0.247	0.094	2.618	0.009	Supported
H10	SR	=>	EN	0.161	0.096	1.678	0.093	Not
H11	SR	=>	SO	0.162	0.093	1.744	0.081	Not

Note: Significance level (p-value). Bold formatting is used in the 'Results' column to highlight hypotheses that were statistically supported based on the analysis. Abbreviations: β , path coefficient; RC, regression coefficient; SE, standard error.

costs, and proactive corporate risk management. H11, which proposed that supplier sustainability risks influence environmental performance, was not supported with (H10: $\beta=0.161$, $p=0.093$), and H11, suggesting that effective supplier sustainability risks impact social performance, was also not supported, as the path coefficient (H11: $\beta=0.162$, $p=0.081$).

Hypothesis H3 was not also confirmed, i.e., the relationship that technical practices have a significantly favorable impact on economic performance (H3: $\beta=0.067$, $p=0.528$). Specifically, H5, which posited a significant influence of technical practices on environmental performance, did not receive support (H4: $\beta=0.138$ and $p=0.206$). Similarly, H5, which proposed that technical practices significantly influence social performance, was not substantiated (H5: $\beta=0.084$, $p=0.408$).

Confirmed hypotheses reveal behavioral practices significantly impact supplier sustainability risk, and sustainability performance. Technical practices only affect supplier sustainability risk, emphasizing behavioral practices' pivotal role in sustainability.

4.2.3 | The Assessment of Prediction

The predictability of the exogenous constructs is determined by different measures, such as the coefficient of determination, the magnitude of the effect size, cross-validated redundancy, and the significance and magnitudes of the path coefficients (Hair et al. 2019). These results are presented in Table 9.

The Q^2 coefficient (Hair et al. 2019) reveals a moderate predictive capacity for sustainability performance: environmental ($Q^2=0.369$), economic ($Q^2=0.333$), and social ($Q^2=0.277$) dimensions. Supplier sustainability risk shows weak predictability. R^2 values indicate varying effectiveness, while f^2 highlights medium impacts from TP to EC, with smaller effects elsewhere.

5 | Discussion of Results

The analysis of the study's results has provided significant insights into the effectiveness of sustainability practices within supply chains, revealing important implications for both theory and practice. The findings underscore the distinct and crucial roles of behavioral practices, technical practices, and supplier sustainability risk in enhancing sustainability performance. Detailed results are summarized in Table 10, which will be explained further in the text.

This study offers a detailed view of supply chain sustainability by exploring both behavioral and technical practices and their effects on supplier sustainability risks and performance. It underscores the importance of integrating diverse management practices, as supported by sociotechnical theory (Govindan, Khodaverdi, and Vafadarnikjoo 2015; Aarikka-Stenroos, Kokko, and Pohls 2023; Schünemann et al. 2024).

This research reveals that while supplier sustainability risks notably impact economic performance, they have limited immediate effects on environmental and social dimensions. This suggests that economic impacts are more immediate, whereas environmental and social effects may need longer observation or specific metrics, highlighting the need for further research.

Additionally, the study found a positive relationship between behavioral practices and supplier sustainability risks, emphasizing the importance of practices such as training and supplier evaluation based on environmental and social criteria. As Jabbour, Mauricio, and de Sousa Jabbour (2017) and Nureen et al. (2022) suggest, behavioral practices enhance the effectiveness of technical practices and overall organizational performance. These results confirm and extend previous research by showing how behavioral practices can mitigate supplier-related risks. In contrast, technical practices alone did not significantly impact sustainability performance, highlighting a critical gap in relying solely on technical measures for sustainability performance improvement.

TABLE 9 | Predictive power of the model.

Predictor	Outcomes	R^2		f^2		Q^2	
TP	SR	0.030	Weak	0.002	Small	0.007	Weak
BP				0.023	Medium		
TP	EC	0.384	Moderate	0.055	Medium	0.333	Moderate
SR				0.005	Small		
BP				0.410	Large		
TP	EN	0.400	Moderate	0.026	Medium	0.369	Moderate
SR				0.001	Small		
BP				0.522	Large		
TP	SO	0.301	Moderate	0.018	Small	0.277	Moderate
SR				0.000	Small		
BP				0.329	Large		

Note: Effect size (R^2), cross-validated redundancy (f^2), sizes and significance (Q^2).

TABLE 10 | Relationship between theory and results.

Hypotheses	Observed results	Relation to theory
H1: Technical practices reduce supplier sustainability risks.	Negative correlation: Isolated technical practices did not significantly reduce supplier risks, possibly due to an internal focus on operations.	Contradicts sociotechnical theory (Govindan, Khodaverdi, and Vafadarnikjoo 2015), which suggests that both technical and behavioral practices are essential. The lack of external collaboration with suppliers weakens the effectiveness of technical practices.
H2: Behavioral practices reduce supplier sustainability risks.	Positive impact: Behavioral practices such as training and evaluation based on socioenvironmental criteria reduce supplier risks.	Supports sociotechnical theory and aligns with studies (Jabbour, Mauricio, and de Sousa Jabbour 2017; Nureen et al. 2022) that show behavioral practices amplify the effectiveness of technical practices, reinforcing their importance in managing risks.
H3: Technical practices improve economic sustainability performance.	Positive effect: Significant improvement in economic performance due to technical practices like resource efficiency and waste management.	Supports resource-based view (RBV) theory (Barney 2001), where technical practices act as valuable resources, enhancing economic competitiveness. However, the focus on economic gains may overshadow broader sustainability goals.
H4: Technical practices improve environmental sustainability performance.	No significant effect: Environmental performance was not substantially improved through technical practices alone.	Challenges traditional expectations, suggesting that technical practices may need more extended implementation periods or better external alignment with environmental goals to show results.
H5: Technical practices improve social sustainability performance.	No significant effect: Limited impact on social sustainability outcomes through technical practices.	Contradicts expectations based on sociotechnical theory, implying that technical improvements do not directly address social dimensions, such as labor rights and community engagement.
H6: Behavioral practices improve economic sustainability performance.	Strong positive effect: Behavioral practices enhanced economic performance, mainly through better supplier engagement and reputation management.	Confirms RBV theory by showing that behavioral practices, as unique organizational capabilities, improve economic performance through enhanced relationships and collaboration with supply chain partners.
H7: Behavioral practices improve environmental sustainability performance.	Positive effect: Significant improvements in environmental performance due to behavioral practices prioritizing environmental criteria in supplier selection.	Supports existing literature (Giannakis and Papadopoulos 2016), affirming the key role of behavioral practices in driving environmental outcomes through better supplier engagement.
H8: Behavioral practices improve social sustainability performance.	Strong positive effect: Social sustainability improved through behavioral practices like training, social audits, and continuous engagement.	Aligns with sociotechnical theory, reinforcing those behavioral practices, such as supplier evaluation and training, directly address social issues within supply chains.
H9: Managing supplier risks improves economic performance.	Positive effect: Effective management of supplier risks improved economic outcomes by reducing operational disruptions and enhancing reputation.	Supports existing research, confirming that economic performance benefits the most from addressing supplier risks, as these risks often have immediate financial implications.

(Continues)

TABLE 10 | (Continued)

Hypotheses	Observed results	Relation to theory
H10: Managing supplier risks improves environmental performance.	No significant effect: Supplier risk management did not improve environmental performance.	Challenges expectations, suggesting that the environmental impacts of supplier risks are less immediate or harder to measure without long-term observation and specific metrics.
H11: Managing supplier sustainability risks improves social performance.	No significant effect: Limited impact on social performance despite efforts to manage supplier risks.	Contradicts sociotechnical theory, indicating that social performance improvements may require more direct, targeted interventions in supplier relationships beyond risk management.

An unexpected finding was the negative correlation between technical practices and supplier sustainability risks. This result, which may seem counterintuitive, can be attributed to an excessive emphasis on internal aspects of sustainability at the expense of crucial elements related to engagement with suppliers. Yadav et al. (2023) highlight that the implementation of sustainability practices should be accompanied by strong engagement with partners, as the lack of an integrated approach can lead to undesirable outcomes. This underscores the need to integrate technical practices with more robust engagement mechanisms to achieve a comprehensive and effective approach to sustainability risk management. Thus, it is suggested that internal improvements alone are insufficient without the development of solid external collaborations with suppliers, as emphasized in Yadav et al.'s (2023) research, which argues that collaboration and corporate social responsibility are key to the success of sustainability practices in the supply chain.

The study confirms that behavioral practices have a more significant impact on sustainability outcomes compared to technical practices, which is consistent with Giannakis and Papadopoulos (2016) and Romano and Ferreira (2023) findings. These practices influence internal dynamics and enhance resilience against reputational risks from supplier misconduct and unsustainable activities. This underscores the need for sustainability management systems to focus on fostering sustainability-oriented behaviors within both internal teams and supply chain partners.

From a RBV theory, behavioral sustainability practices build unique organizational capabilities that are valuable, rare, nonimitable, and nonsubstitutable (Andersén 2023). These capabilities enhance competitive advantage and foster long-term sustainability through knowledge exchange and innovation with supply chain partners (Bag et al. 2021), highlighting sustainability practices as strategic assets rather than mere compliance measures.

The findings highlight that while implementing technical practices like environmental management and ISO14001 standards is essential, they must be complemented by behavioral practices such as socioenvironmental criteria in supplier selection and ongoing sustainability training. Integrating both dimensions offers a comprehensive approach to enhancing supply chain sustainability, as noted by J. Liu et al. (2020).

In conclusion, committed top management and broad organizational involvement are crucial for successful sustainability initiatives. Engaging employees and supply chain partners, coupled with continuous education and collaboration, is essential for long-term performance. This study confirms and extends the existing literature on the synergistic impact of behavioral and technical practices in supply chain sustainability.

6 | Conclusions

This study investigated the impact of sustainability practices on supplier sustainability risks and on the sustainability performance in Brazilian companies. The results revealed that behavioral practices significantly positively impact both aspects. The

findings underscore the importance of prioritizing behavioral practices, such as engaging senior management and involving suppliers, to achieve sustainability goals. Encouraging suppliers to adopt social and environmental criteria and collaborate with customers is also crucial for enhancing overall sustainability performance.

An unexpected finding was the negative relationship between technical practices and supplier sustainability risks. This may be due to an excessive internal focus, which diverts attention from critical elements such as environmental and social management systems, certifications, and audits. This highlights the need for a careful balance between internal and external aspects of sustainability management.

Unlike traditional methods that focus solely on technical practices, this model provides a contextualized view specific to Brazilian supply chains, incorporating an understanding of behavioral practices and offering valuable insights for managing sustainability practices in supply chains.

The study also highlights the importance of collective responsibility in managing sustainability within supply chains, suggesting that focal companies should prioritize behavioral actions, such as senior management engagement, training programs, and supplier involvement. This approach broadens the scope of sustainability practices and fosters a collaborative environment with supply chain partners, contributing to the creation of a virtuous sustainability cycle.

The study's limitations include relying on single respondents per company, potentially narrowing insights. The multidisciplinary scope may have omitted some factors. Despite a representative sample, findings might not apply universally to all Brazilian companies.

It is essential to deepen the understanding of supplier sustainability risks, supply chain risk management, and sustainability practices. Future research on sustainability management in Brazilian supply chains should explore additional issues, such as the relationships between sustainability practices, risks, and performance, and investigate other samples and issues. Moreover, it is recommended to conduct comparative analyses across different markets and periods and diversify contexts and consider the impact of cultural factors.

These studies will contribute to a more comprehensive and widely applicable understanding of supply chain sustainability, advancing the field of study and sustainable management practices.

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